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(54) **Title:** GRAPHITIC COMPOUNDS AND METHODS OF MAKING AND USE THEREOF

(57) **Abstract:** Disclosed are graphitic compounds, for example nanographenes and graphene nanoribbons, and precursors thereof. The compounds described can, for example, have a bandgap energy of from 0.5 eV to 2.5 eV. Also disclosed are methods of making the compounds described herein, for example by performing a Suzuki Miyaura coupling reaction between an aryl bromide and an aryl boronate ester, and/or by performing a cyclodehydrogenation. Also disclosed herein are devices comprising any of the compounds described herein.

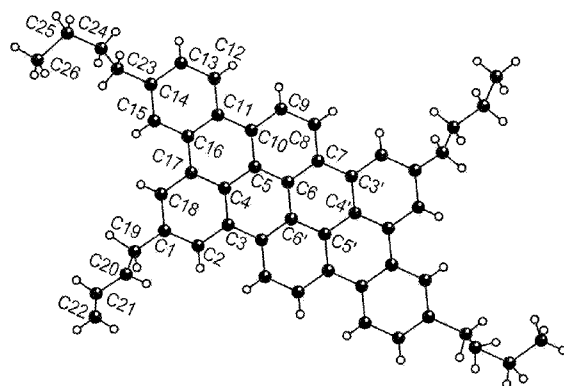


FIGURE 1



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GRAPHITIC COMPOUNDS AND METHODS OF MAKING AND USE THEREOF

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims the benefit of priority to U.S. Provisional Application No. 62/199,021, filed July 30, 2015, and U.S. Provisional Application No. 62/339,216, filed May 20, 2016, which are both hereby incorporated herein by reference in their entireties.

BACKGROUND

Graphene is a two-dimensional carbon material which possesses many attractive features, such as strong mechanical strength, and excellent electrical and thermal conductivity. However, the electronic applications of graphene are limited by its zero bandgap. Graphene nanoribbons are narrow strips of graphene (e.g., with width of 10 nm or less) and have a nonzero bandgap which can be tuned by both width and edge of their structures. The potential of graphene nanoribbons as highly promising candidates for the next generation electronic materials remains a topic of wide interest in both academic and industrial research. However, synthesis of graphene nanoribbons with precise length and edge structures remains challenging. The current syntheses have difficulties on either the efficiency of preparing these materials, or the length of the material that can be accessed. There is thus a need for new graphitic compounds and methods of making and using such materials. The compounds and methods disclosed herein address these and other needs.

SUMMARY

In accordance with the purposes of the disclosed methods, as embodied and broadly described herein, the disclosed subject matter relates to compositions and methods of making and using the compositions. More specifically, according to the aspects illustrated herein, there are provided graphitic compounds, for example nanographenes and graphene nanoribbons, and precursors thereof. As used herein, the term “graphene” and other forms of the word, such as “graphitic,” is meant to refer to multiple fused hexagonal carbon rings. In some examples, the nanographenes and graphene nanoribbons described herein can have tunable width and functionalized edge structures. Methods of making and using these graphitic compounds are also disclosed.

Additional advantages of the disclosed compositions and methods will be set forth in part in the description which follows, and in part will be obvious from the description. The advantages of the disclosed compositions will be realized and attained by means of the elements

and combinations particularly pointed out in the appended claims. It is to be understood that both the foregoing general description and the following detailed description are exemplary and explanatory only and are not restrictive of the disclosed compositions, as claimed.

The details of one or more embodiments of the invention are set forth in the accompanying drawings and the description below. Other features, objects, and advantages of the invention will be apparent from the description and drawings, and from the claims.

BRIEF DESCRIPTION OF THE FIGURES

The accompanying figures, which are incorporated in and constitute a part of this specification, illustrate several aspects described below.

Figure 1 displays the X-ray crystal structure of a nanographene dimer.

Figure 2 displays the MALDI-ToF-MS spectrum of a nanographene dimer (linear mode, matrix TCNQ).

Figure 3 displays the X-ray crystal structure of a nanographene trimer.

Figure 4 displays the MALDI-ToF-MS spectrum of a nanographene trimer (linear mode, matrix TCDB).

Figure 5 displays a gel permeation chromatography spectrum of a polymer precursor.

Figure 6 displays a ^1H NMR spectrum of a polymer precursor (CD_2Cl_2 , 400 MHz, 25°C).

Figure 7 displays a ^{13}C NMR spectrum of a polymer precursor (CD_2Cl_2 , 101 MHz, 25°C).

Figure 8A displays the FTIR spectra of a polymer precursor (top curve) and its respective graphene nanoribbon (bottom curve) at wavenumbers $4200\text{-}3150\text{ cm}^{-1}$.

Figure 8B displays the FTIR spectra of a polymer precursor (top curve) and its respective graphene nanoribbon (bottom curve) at wavenumbers $2200\text{-}2600\text{ cm}^{-1}$.

Figure 8C displays the FTIR spectra of a polymer precursor (top curve) and its respective graphene nanoribbon (bottom curve) at wavenumbers $1650\text{-}700\text{ cm}^{-1}$.

Figure 9 displays a representative Raman spectrum of a graphene nanoribbon.

Figure 10 displays the normalized UV-vis absorption spectra of a graphene nanoribbon formed from an oligomer precursor (GNR G1) and a graphene nanoribbon formed from a polymer precursor (GNR G1s).

Figure 11 shows the matrix-assisted laser desorption/ionization time-of-flight (MALDI-TOF) mass spectrum of the compound of Formula III-b-2 (linear mode, matrix: DCTB).

Figure 12 shows the X-ray structure of the compound of Formula III-b-2.

Figure 13 shows the ^1H NMR spectrum (400 MHz, CDCl_3 , 25°C) of the compound of Formula XIII-b-1.

Figure 14 shows the ^{13}C NMR (400 MHz, CDCl_3 , 25°C) spectrum of the compound of Formula XIII-b-1.

5 Figure 15 shows the Raman spectrum of the compound of Formula XIII-b-1.

Figure 16 shows the Raman spectrum of the compound of Formula VI-b-1.

Figure 17 shows the FTIR spectra of the compounds of Formula XIII-b-1 and Formula VI-b-1.

DETAILED DESCRIPTION

10 The compounds, compositions, and methods described herein may be understood more readily by reference to the following detailed description of specific aspects of the disclosed subject matter and the Examples included therein.

Before the present compounds, compositions, and methods are disclosed and described, it is to be understood that the aspects described below are not limited to specific synthetic methods
15 or specific reagents, as such may, of course, vary. It is also to be understood that the terminology used herein is for the purpose of describing particular aspects only and is not intended to be limiting.

Also, throughout this specification, various publications are referenced. The disclosures of these publications in their entireties are hereby incorporated by reference into this application
20 in order to more fully describe the state of the art to which the disclosed matter pertains. The references disclosed are also individually and specifically incorporated by reference herein for the material contained in them that is discussed in the sentence in which the reference is relied upon.

General Definitions

25 In this specification and in the claims that follow, reference will be made to a number of terms, which shall be defined to have the following meanings.

Throughout the description and claims of this specification the word “comprise” and other forms of the word, such as “comprising” and “comprises,” means including but not limited to, and is not intended to exclude, for example, other additives, components, integers, or steps.

30 As used in the description and the appended claims, the singular forms “a,” “an,” and “the” include plural referents unless the context clearly dictates otherwise. Thus, for example, reference to “a composition” includes mixtures of two or more such compositions, reference to “an agent” includes mixtures of two or more such agents, reference to “the component” includes

mixtures of two or more such components, and the like.

“Optional” or “optionally” means that the subsequently described event or circumstance can or cannot occur, and that the description includes instances where the event or circumstance occurs and instances where it does not.

5 Ranges can be expressed herein as from “about” one particular value, and/or to “about” another particular value. By “about” is meant within 5% of the value, e.g., within 4, 3, 2, or 1% of the value. When such a range is expressed, another aspect includes from the one particular value and/or to the other particular value. Similarly, when values are expressed as approximations, by use of the antecedent “about,” it will be understood that the particular value
10 forms another aspect. It will be further understood that the endpoints of each of the ranges are significant both in relation to the other endpoint, and independently of the other endpoint.

It is understood that throughout this specification the identifiers “first” and “second” are used solely to aid in distinguishing the various components and steps of the disclosed subject matter. The identifiers “first” and “second” are not intended to imply any particular order,
15 amount, preference, or importance to the components or steps modified by these terms.

Chemical Definitions

Terms used herein will have their customary meaning in the art unless specified otherwise. The organic moieties mentioned when defining variable positions within the general formulae described herein (e.g., the term “halogen”) are collective terms for the individual
20 substituents encompassed by the organic moiety. The prefix C_n-C_m preceding a group or moiety indicates, in each case, the possible number of carbon atoms in the group or moiety that follows.

As used herein, the term “substituted” is contemplated to include all permissible substituents of organic compounds. In a broad aspect, the permissible substituents include acyclic and cyclic, branched and unbranched, carbocyclic and heterocyclic, and aromatic and
25 nonaromatic substituents of organic compounds. Illustrative substituents include, for example, those described below. The permissible substituents can be one or more and the same or different for appropriate organic compounds. For purposes of this disclosure, heteroatoms present in a compound or moiety, such as nitrogen, can have hydrogen substituents and/or any permissible substituents of organic compounds described herein which satisfy the valency of the
30 heteroatom. This disclosure is not intended to be limited in any manner by the permissible substituents of organic compounds. Also, the terms “substitution” or “substituted with” include the implicit proviso that such substitution is in accordance with permitted valence of the substituted atom and the substituent, and that the substitution results in a stable compound (e.g.,

a compound that does not spontaneously undergo transformation such as by rearrangement, cyclization, elimination, etc.

“Z¹,” “Z²,” “Z³,” and “Z⁴” are used herein as generic symbols to represent various specific substituents. These symbols can be any substituent, not limited to those disclosed herein, and when they are defined to be certain substituents in one instance, they can, in another instance, be defined as some other substituents.

As used herein, the term “alkyl” refers to saturated, straight-chained or branched saturated hydrocarbon moieties. Unless otherwise specified, C₁-C₅₀ (e.g., C₁-C₄₅, C₁-C₄₀, C₁-C₃₅, C₁-C₃₀, C₁-C₂₅, C₁-C₂₀, C₁-C₁₈, C₁-C₁₆, C₁-C₁₄, C₁-C₁₂, C₁-C₁₀, C₁-C₈, C₁-C₆, or C₁-C₄) alkyl groups are intended. Examples of alkyl groups include methyl, ethyl, propyl, 1-methyl-ethyl, butyl, 1-methyl-propyl, 2-methyl-propyl, 1,1-dimethyl-ethyl, pentyl, 1-methyl-butyl, 2-methyl-butyl, 3-methyl-butyl, 2,2-dimethyl-propyl, 1-ethyl-propyl, hexyl, 1,1-dimethyl-propyl, 1,2-dimethyl-propyl, 1-methyl-pentyl, 2-methyl-pentyl, 3-methyl-pentyl, 4-methyl-pentyl, 1,1-dimethyl-butyl, 1,2-dimethyl-butyl, 1,3-dimethyl-butyl, 2,2-dimethyl-butyl, 2,3-dimethyl-butyl, 3,3-dimethyl-butyl, 1-ethyl-butyl, 2-ethyl-butyl, 1,1,2-trimethyl-propyl, 1,2,2-trimethyl-propyl, 1-ethyl-1-methyl-propyl, and 1-ethyl-2-methyl-propyl. Alkyl substituents may be unsubstituted or substituted with one or more chemical moieties. The alkyl group can be substituted with one or more groups including, but not limited to, hydroxy, halogen, acyl, alkyl, alkoxy, alkenyl, alkynyl, aryl, heteroaryl, aldehyde, amino, cyano, carboxylic acid, ester, ether, ketone, nitro, phosphonyl, silyl, sulfo-oxo, sulfonyl, sulfone, sulfoxide, or thiol, as described below, provided that the substituents are sterically compatible and the rules of chemical bonding and strain energy are satisfied.

Throughout the specification “alkyl” is generally used to refer to both unsubstituted alkyl groups and substituted alkyl groups; however, substituted alkyl groups are also specifically referred to herein by identifying the specific substituent(s) on the alkyl group. For example, the term “halogenated alkyl” specifically refers to an alkyl group that is substituted with one or more halides (halogens; e.g., fluorine, chlorine, bromine, or iodine). The term “alkoxyalkyl” specifically refers to an alkyl group that is substituted with one or more alkoxy groups, as described below. The term “alkylamino” specifically refers to an alkyl group that is substituted with one or more amino groups, as described below, and the like. When “alkyl” is used in one instance and a specific term such as “alkylalcohol” is used in another, it is not meant to imply that the term “alkyl” does not also refer to specific terms such as “alkylalcohol” and the like.

This practice is also used for other groups described herein. That is, while a term such as

“cycloalkyl” refers to both unsubstituted and substituted cycloalkyl moieties, the substituted moieties can, in addition, be specifically identified herein; for example, a particular substituted cycloalkyl can be referred to as, *e.g.*, an “alkylcycloalkyl.” Similarly, a substituted alkoxy can be specifically referred to as, *e.g.*, a “halogenated alkoxy,” a particular substituted alkenyl can be, *e.g.*, an “alkenylalcohol,” and the like. Again, the practice of using a general term, such as “cycloalkyl,” and a specific term, such as “alkylcycloalkyl,” is not meant to imply that the general term does not also include the specific term.

As used herein, the term “alkenyl” refers to unsaturated, straight-chained, or branched hydrocarbon moieties containing a double bond. Unless otherwise specified, C₂-C₅₀ (*e.g.*, C₂-C₄₅, C₂-C₄₀, C₂-C₃₅, C₂-C₃₀, C₂-C₂₅, C₂-C₂₀, C₂-C₁₈, C₂-C₁₆, C₂-C₁₄, C₂-C₁₂, C₂-C₁₀, C₂-C₈, C₂-C₆, or C₂-C₄) alkenyl groups are intended. Alkenyl groups may contain more than one unsaturated bond. Examples include ethenyl, 1-propenyl, 2-propenyl, 1-methylethenyl, 1-butenyl, 2-butenyl, 3-butenyl, 1-methyl-1-propenyl, 2-methyl-1-propenyl, 1-methyl-2-propenyl, 2-methyl-2-propenyl, 1-pentenyl, 2-pentenyl, 3-pentenyl, 4-pentenyl, 1-methyl-1-butenyl, 2-methyl-1-butenyl, 3-methyl-1-butenyl, 1-methyl-2-butenyl, 2-methyl-2-butenyl, 3-methyl-2-butenyl, 1-methyl-3-butenyl, 2-methyl-3-butenyl, 3-methyl-3-butenyl, 1,1-dimethyl-2-propenyl, 1,2-dimethyl-1-propenyl, 1,2-dimethyl-2-propenyl, 1-ethyl-1-propenyl, 1-ethyl-2-propenyl, 1-hexenyl, 2-hexenyl, 3-hexenyl, 4-hexenyl, 5-hexenyl, 1-methyl-1-pentenyl, 2-methyl-1-pentenyl, 3-methyl-1-pentenyl, 4-methyl-1-pentenyl, 1-methyl-2-pentenyl, 2-methyl-2-pentenyl, 3-methyl-2-pentenyl, 4-methyl-2-pentenyl, 1-methyl-3-pentenyl, 2-methyl-3-pentenyl, 3-methyl-3-pentenyl, 4-methyl-3-pentenyl, 1-methyl-4-pentenyl, 2-methyl-4-pentenyl, 3-methyl-4-pentenyl, 4-methyl-4-pentenyl, 1,1-dimethyl-2-butenyl, 1,1-dimethyl-3-butenyl, 1,2-dimethyl-1-butenyl, 1,2-dimethyl-2-butenyl, 1,2-dimethyl-3-butenyl, 1,3-dimethyl-1-butenyl, 1,3-dimethyl-2-butenyl, 1,3-dimethyl-3-butenyl, 2,2-dimethyl-3-butenyl, 2,3-dimethyl-1-butenyl, 2,3-dimethyl-2-butenyl, 2,3-dimethyl-3-butenyl, 3,3-dimethyl-1-butenyl, 3,3-dimethyl-2-butenyl, 1-ethyl-1-butenyl, 1-ethyl-2-butenyl, 1-ethyl-3-butenyl, 2-ethyl-1-butenyl, 2-ethyl-2-butenyl, 2-ethyl-3-butenyl, 1,1,2-trimethyl-2-propenyl, 1-ethyl-1-methyl-2-propenyl, 1-ethyl-2-methyl-1-propenyl, and 1-ethyl-2-methyl-2-propenyl. The term “vinyl” refers to a group having the structure –CH=CH₂; 1-propenyl refers to a group with the structure –CH=CH-CH₃; and 2-propenyl refers to a group with the structure –CH₂-CH=CH₂. Asymmetric structures such as (Z¹Z²)C=C(Z³Z⁴) are intended to include both the *E* and *Z* isomers. This can be presumed in structural formulae herein wherein an asymmetric alkene is present, or it can be explicitly indicated by the bond symbol C=C. Alkenyl substituents may be unsubstituted or substituted with one or more

chemical moieties. Examples of suitable substituents include, for example, alkyl, halogenated alkyl, alkoxy, alkenyl, alkynyl, aryl, heteroaryl, acyl, aldehyde, amino, cyano, carboxylic acid, ester, ether, halide, hydroxy, ketone, nitro, phosphonyl, silyl, sulfo-oxo, sulfonyl, sulfone, sulfoxide, or thiol, as described below, provided that the substituents are sterically compatible and the rules of chemical bonding and strain energy are satisfied.

As used herein, the term “alkynyl” represents straight-chained or branched hydrocarbon moieties containing a triple bond. Unless otherwise specified, C₂-C₅₀ (e.g., C₂-C₄₅, C₂-C₄₀, C₂-C₃₅, C₂-C₃₀, C₂-C₂₅, C₂-C₂₀, C₂-C₁₈, C₂-C₁₆, C₂-C₁₄, C₂-C₁₂, C₂-C₁₀, C₂-C₈, C₂-C₆, or C₂-C₄) alkynyl groups are intended. Alkynyl groups may contain more than one unsaturated bond.

Examples include C₂-C₆-alkynyl, such as ethynyl, 1-propynyl, 2-propynyl (or propargyl), 1-butynyl, 2-butynyl, 3-butynyl, 1-methyl-2-propynyl, 1-pentynyl, 2-pentynyl, 3-pentynyl, 4-pentynyl, 3-methyl-1-butynyl, 1-methyl-2-butynyl, 1-methyl-3-butynyl, 2-methyl-3-butynyl, 1,1-dimethyl-2-propynyl, 1-ethyl-2-propynyl, 1-hexynyl, 2-hexynyl, 3-hexynyl, 4-hexynyl, 5-hexynyl, 3-methyl-1-pentynyl, 4-methyl-1-pentynyl, 1-methyl-2-pentynyl, 4-methyl-2-pentynyl, 1-methyl-3-pentynyl, 2-methyl-3-pentynyl, 1-methyl-4-pentynyl, 2-methyl-4-pentynyl, 3-methyl-4-pentynyl, 1,1-dimethyl-2-butynyl, 1,1-dimethyl-3-butynyl, 1,2-dimethyl-3-butynyl, 2,2-dimethyl-3-butynyl, 3,3-dimethyl-1-butynyl, 1-ethyl-2-butynyl, 1-ethyl-3-butynyl, 2-ethyl-3-butynyl, and 1-ethyl-1-methyl-2-propynyl. Alkynyl substituents may be unsubstituted or substituted with one or more chemical moieties. Examples of suitable substituents include, for example, alkyl, halogenated alkyl, alkoxy, alkenyl, alkynyl, aryl, heteroaryl, acyl, aldehyde, amino, cyano, carboxylic acid, ester, ether, halide, hydroxy, ketone, nitro, phosphonyl, silyl, sulfo-oxo, sulfonyl, sulfone, sulfoxide, or thiol, as described below.

As used herein, the term “aryl,” as well as derivative terms such as aryloxy, refers to groups that include a monovalent aromatic carbocyclic group of from 3 to 50 carbon atoms.

Aryl groups can include a single ring or multiple condensed rings. In some embodiments, aryl groups include C₆-C₁₀ aryl groups. Examples of aryl groups include, but are not limited to, phenyl, biphenyl, naphthyl, tetrahydronaphthyl, phenylcyclopropyl, and indanyl. In some embodiments, the aryl group can be a phenyl, indanyl or naphthyl group. The term “heteroaryl” is defined as a group that contains an aromatic group that has at least one heteroatom incorporated within the ring of the aromatic group. Examples of heteroatoms include, but are not limited to, nitrogen, oxygen, sulfur, and phosphorus. The term “non-heteroaryl,” which is included in the term “aryl,” defines a group that contains an aromatic group that does not contain a heteroatom. The aryl or heteroaryl substituents may be unsubstituted or substituted with one or

more chemical moieties. Examples of suitable substituents include, for example, alkyl, halogenated alkyl, alkoxy, alkenyl, alkynyl, aryl, heteroaryl, acyl, aldehyde, amino, cyano, carboxylic acid, ester, ether, halide, hydroxy, ketone, nitro, phosphonyl, silyl, sulfo-oxo, sulfonyl, sulfone, sulfoxide, or thiol as described herein. The term “biaryl” is a specific type of aryl group and is included in the definition of aryl. Biaryl refers to two aryl groups that are bound together *via* a fused ring structure, as in naphthalene, or are attached *via* one or more carbon-carbon bonds, as in biphenyl.

The term “cycloalkyl” as used herein is a non-aromatic carbon-based ring composed of at least three carbon atoms. Examples of cycloalkyl groups include, but are not limited to, cyclopropyl, cyclobutyl, cyclopentyl, cyclohexyl, etc. The term “heterocycloalkyl” is a cycloalkyl group as defined above where at least one of the carbon atoms of the ring is substituted with a heteroatom such as, but not limited to, nitrogen, oxygen, sulfur, or phosphorus. The cycloalkyl group and heterocycloalkyl group can be substituted or unsubstituted. The cycloalkyl group and heterocycloalkyl group can be substituted with one or more groups including, but not limited to, alkyl, alkoxy, alkenyl, alkynyl, aryl, heteroaryl, acyl, aldehyde, amino, cyano, carboxylic acid, ester, ether, halide, hydroxy, ketone, nitro, phosphonyl, silyl, sulfo-oxo, sulfonyl, sulfone, sulfoxide, or thiol as described herein.

The term “cycloalkenyl” as used herein is a non-aromatic carbon-based ring composed of at least three carbon atoms and containing at least one double bond, *i.e.*, C=C. Examples of cycloalkenyl groups include, but are not limited to, cyclopropenyl, cyclobutenyl, cyclopentenyl, cyclopentadienyl, cyclohexenyl, cyclohexadienyl, and the like. The term “heterocycloalkenyl” is a type of cycloalkenyl group as defined above, and is included within the meaning of the term “cycloalkenyl,” where at least one of the carbon atoms of the ring is substituted with a heteroatom such as, but not limited to, nitrogen, oxygen, sulfur, or phosphorus. The cycloalkenyl group and heterocycloalkenyl group can be substituted or unsubstituted. The cycloalkenyl group and heterocycloalkenyl group can be substituted with one or more groups including, but not limited to, alkyl, alkoxy, alkenyl, alkynyl, aryl, heteroaryl, acyl, aldehyde, amino, cyano, carboxylic acid, ester, ether, halide, hydroxy, ketone, nitro, phosphonyl, silyl, sulfo-oxo, sulfonyl, sulfone, sulfoxide, or thiol as described herein.

The term “cyclic group” is used herein to refer to either aryl groups, non-aryl groups (*i.e.*, cycloalkyl, heterocycloalkyl, cycloalkenyl, and heterocycloalkenyl groups), or both. Cyclic groups have one or more ring systems that can be substituted or unsubstituted. A cyclic group can contain one or more aryl groups, one or more non-aryl groups, or one or more aryl groups

and one or more non-aryl groups.

The term “acyl” as used herein is represented by the formula $-\text{C}(\text{O})\text{Z}^1$ where Z^1 can be a hydrogen, hydroxyl, alkoxy, alkyl, halogenated alkyl, alkenyl, alkynyl, aryl, heteroaryl, cycloalkyl, cycloalkenyl, heterocycloalkyl, or heterocycloalkenyl group described above. As
 5 used herein, the term “acyl” can be used interchangeably with “carbonyl.” Throughout this specification “C(O)” or “CO” is a short hand notation for $\text{C}=\text{O}$.

As used herein, the term “alkoxy” refers to a group of the formula $\text{Z}^1-\text{O}-$, where Z^1 is unsubstituted or substituted alkyl as defined above. Unless otherwise specified, alkoxy groups wherein Z^1 is a C_1 - C_{50} (e.g., C_1 - C_{45} , C_1 - C_{40} , C_1 - C_{35} , C_1 - C_{30} , C_1 - C_{25} , C_1 - C_{20} , C_1 - C_{18} , C_1 - C_{16} , C_1 -
 10 C_{14} , C_1 - C_{12} , C_1 - C_{10} , C_1 - C_8 , C_1 - C_6 , C_1 - C_4) alkyl group are intended. Examples include methoxy, ethoxy, propoxy, 1-methyl-ethoxy, butoxy, 1-methyl-propoxy, 2-methyl-propoxy, 1,1-dimethyl-ethoxy, pentoxy, 1-methyl-butyloxy, 2-methyl-butoxy, 3-methyl-butoxy, 2,2-di-methyl-propoxy, 1-ethyl-propoxy, hexoxy, 1,1-dimethyl-propoxy, 1,2-dimethyl-propoxy, 1-methyl-pentoxy, 2-methyl-pentoxy, 3-methyl-pentoxy, 4-methyl-pentoxy, 1,1-dimethyl-butoxy, 1,2-dimethyl-
 15 butoxy, 1,3-dimethyl-butoxy, 2,2-dimethyl-butoxy, 2,3-dimethyl-butoxy, 3,3-dimethyl-butoxy, 1-ethyl-butoxy, 2-ethylbutoxy, 1,1,2-trimethyl-propoxy, 1,2,2-trimethyl-propoxy, 1-ethyl-1-methyl-propoxy, and 1-ethyl-2-methyl-propoxy.

The term “aldehyde” as used herein is represented by the formula $-\text{C}(\text{O})\text{H}$.

The terms “amine” or “amino” as used herein are represented by the formula $-\text{NZ}^1\text{Z}^2$,
 20 where Z^1 and Z^2 can each be substitution group as described herein, such as hydrogen, an alkyl, halogenated alkyl, alkenyl, alkynyl, aryl, heteroaryl, cycloalkyl, cycloalkenyl, heterocycloalkyl, or heterocycloalkenyl group described above. “Amido” is $-\text{C}(\text{O})\text{NZ}^1\text{Z}^2$.

The term “carboxylic acid” as used herein is represented by the formula $-\text{C}(\text{O})\text{OH}$. A
 25 “carboxylate” or “carboxyl” group as used herein is represented by the formula $-\text{C}(\text{O})\text{O}^-$.

The term “cyano” as used herein is represented by the formula $-\text{CN}$.

The term “ester” as used herein is represented by the formula $-\text{OC}(\text{O})\text{Z}^1$ or $-\text{C}(\text{O})\text{OZ}^1$, where Z^1 can be an alkyl, halogenated alkyl, alkenyl, alkynyl, aryl, heteroaryl,
 30 cycloalkyl, cycloalkenyl, heterocycloalkyl, or heterocycloalkenyl group described above.

The term “ether” as used herein is represented by the formula Z^1OZ^2 , where Z^1 and Z^2 can be, independently, an alkyl, halogenated alkyl, alkenyl, alkynyl, aryl, heteroaryl, cycloalkyl, cycloalkenyl, heterocycloalkyl, or heterocycloalkenyl group described above.

The term “ketone” as used herein is represented by the formula $Z^1C(O)Z^2$, where Z^1 and Z^2 can be, independently, an alkyl, halogenated alkyl, alkenyl, alkynyl, aryl, heteroaryl, cycloalkyl, cycloalkenyl, heterocycloalkyl, or heterocycloalkenyl group described above.

The term “halide” or “halogen” or “halo” as used herein refers to fluorine, chlorine,
5 bromine, and iodine.

The term “hydroxyl” as used herein is represented by the formula $—OH$.

The term “nitro” as used herein is represented by the formula $—NO_2$.

The term “phosphonyl” is used herein to refer to the phospho-oxo group represented by the formula $—P(O)(OZ^1)_2$, where Z^1 can be hydrogen, an alkyl, halogenated alkyl, alkenyl,
10 alkynyl, aryl, heteroaryl, cycloalkyl, cycloalkenyl, heterocycloalkyl, or heterocycloalkenyl group described above.

The term “silyl” as used herein is represented by the formula $—SiZ^1Z^2Z^3$, where Z^1 , Z^2 , and Z^3 can be, independently, hydrogen, alkyl, halogenated alkyl, alkoxy, alkenyl, alkynyl, aryl, heteroaryl, cycloalkyl, cycloalkenyl, heterocycloalkyl, or heterocycloalkenyl group described
15 above.

The term “sulfonyl” is used herein to refer to the sulfo-oxo group represented by the formula $—S(O)_2Z^1$, where Z^1 can be hydrogen, an alkyl, halogenated alkyl, alkenyl, alkynyl, aryl, heteroaryl, cycloalkyl, cycloalkenyl, heterocycloalkyl, or heterocycloalkenyl group described above.

The term “sulfonylamino” or “sulfonamide” as used herein is represented by the formula $—S(O)_2NH—$.
20

The term “thiol” as used herein is represented by the formula $—SH$.

The term “sulfide” as used herein is comprises the formula $—S—$.

As used herein, Me refers to a methyl group; OMe refers to a methoxy group; and *i*-Pr
25 refers to an isopropyl group.

“ R^1 ,” “ R^2 ,” “ R^3 ,” “ R^n ,” etc., where n is some integer, as used herein can, independently, possess one or more of the groups listed above. For example, if R^1 is a straight chain alkyl group, one of the hydrogen atoms of the alkyl group can optionally be substituted with a hydroxyl group, an alkoxy group, an amine group, an alkyl group, a halide, and the like.

Depending upon the groups that are selected, a first group can be incorporated within second group or, alternatively, the first group can be pendant (i.e., attached) to the second group. For example, with the phrase “an alkyl group comprising an amino group,” the amino group can be
30 incorporated within the backbone of the alkyl group. Alternatively, the amino group can be

attached to the backbone of the alkyl group. The nature of the group(s) that is (are) selected will determine if the first group is embedded or attached to the second group.

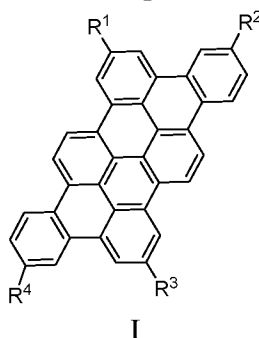
Unless stated to the contrary, a formula with chemical bonds shown only as solid lines and not as wedges or dashed lines contemplates each possible stereoisomer or mixture of stereoisomer (e.g., each enantiomer, each diastereomer, each meso compound, a racemic mixture, or scalemic mixture).

Reference will now be made in detail to specific aspects of the disclosed materials, compounds, compositions, articles, and methods, examples of which are illustrated in the accompanying Examples and Figures.

Compounds

Disclosed herein are graphitic compounds, for example nanographenes and graphene nanoribbons, and precursors thereof. As used herein, the term “graphene” and other forms of the word, such as “graphitic,” is meant to refer to multiple fused hexagonal carbon rings.

In certain examples, disclosed herein are compounds defined by Formula I:



wherein

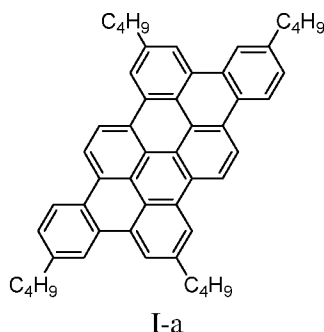
R^1 , R^2 , R^3 , and R^4 are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C_1 - C_{40} alkyl, substituted or unsubstituted C_2 - C_{40} alkenyl, substituted or unsubstituted C_2 - C_{40} alkynyl, substituted or unsubstituted C_3 - C_{40} aryl, substituted or unsubstituted C_3 - C_{40} cycloalkyl, substituted or unsubstituted C_3 - C_{40} cycloalkenyl, substituted or unsubstituted C_1 - C_{40} acyl, substituted or unsubstituted C_1 - C_{40} alkoxy, $P(O)(OR^a)_2$, SR^a , $S(O)_2R^a$, $SiR^aR^bR^c$, or NR^aR^b ; and

R^a , R^b , and R^c are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C_1 - C_{40} alkyl, substituted or unsubstituted C_2 - C_{40} alkenyl, substituted or unsubstituted C_2 - C_{40} alkynyl, substituted or unsubstituted C_3 - C_{40} aryl, substituted or unsubstituted C_3 - C_{40} cycloalkyl, substituted or unsubstituted C_3 - C_{40} cycloalkenyl,

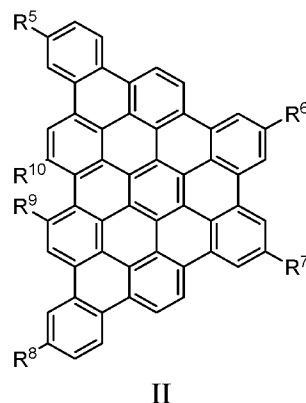
substituted or unsubstituted C₁-C₄₀ acyl, or substituted or unsubstituted C₁-C₄₀ alkoxy.

In some examples of Formula I, R¹, R², R³, and R⁴ are independently substituted or unsubstituted C₁-C₂₀ alkyl. In some examples of Formula I, R¹, R², R³, and R⁴ are independently
 5 unsubstituted C₁-C₁₀ alkyl. In some examples of Formula I, R¹, R², R³, and R⁴ are the same.

In some examples of Formula I, the compound can be defined by Formula I-a.



Also disclosed herein are compounds defined by Formula II:



wherein

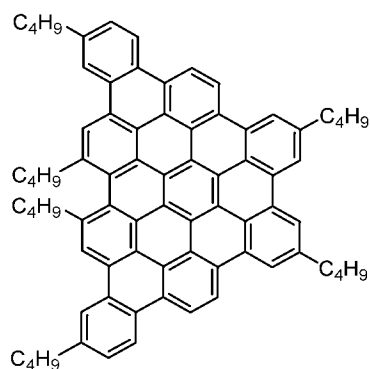
R⁵, R⁶, R⁷, R⁸, R⁹, and R¹⁰ are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C₁-C₄₀ alkyl, substituted or unsubstituted C₂-C₄₀ alkenyl,
 15 substituted or unsubstituted C₂-C₄₀ alkynyl, substituted or unsubstituted C₃-C₄₀ aryl, substituted or unsubstituted C₃-C₄₀ cycloalkyl, substituted or unsubstituted C₃-C₄₀ cycloalkenyl, substituted or unsubstituted C₁-C₄₀ acyl, substituted or unsubstituted C₁-C₄₀ alkoxy, P(O)(OR^a)₂, SR^a, S(O)₂R^a, SiR^aR^bR^c, or NR^aR^b; and

R^a, R^b, and R^c are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted
 20 or unsubstituted C₁-C₄₀ alkyl, substituted or unsubstituted C₂-C₄₀ alkenyl, substituted or unsubstituted C₂-C₄₀ alkynyl, substituted or unsubstituted C₃-C₄₀ aryl, substituted or unsubstituted C₃-C₄₀ cycloalkyl, substituted or unsubstituted C₃-C₄₀ cycloalkenyl,

substituted or unsubstituted C₁-C₄₀ acyl, or substituted or unsubstituted C₁-C₄₀ alkoxy.

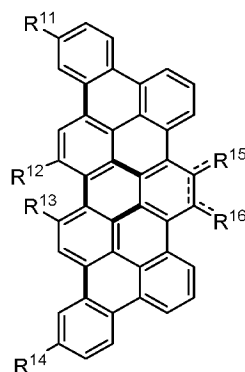
In some examples of Formula II, R⁵, R⁶, R⁷, R⁸, R⁹, and R¹⁰ are independently substituted or unsubstituted C₁-C₂₀ alkyl. In some examples of Formula II, R⁵, R⁶, R⁷, R⁸, R⁹, and R¹⁰ are independently unsubstituted C₁-C₁₀ alkyl. In some examples of Formula II, R⁵, R⁶, R⁷, R⁸, R⁹, and R¹⁰ are the same.

In some examples of Formula II, the compound can be defined by Formula II-a.



II-a

Also disclosed herein are compounds defined by Formula III:



III

wherein

the dotted lines to R¹⁵, R¹⁶, and between the carbons within the ring to which R¹⁵ and R¹⁶ are bonded independently indicate that the bond can be a single bond or a double bond, as valence permits;

R¹¹, R¹², R¹³, R¹⁴, R¹⁵, and R¹⁶ are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C₁-C₄₀ alkyl, substituted or unsubstituted C₂-C₄₀ alkenyl, substituted or unsubstituted C₂-C₄₀ alkynyl, substituted or unsubstituted C₃-C₄₀ aryl, substituted or unsubstituted C₃-C₄₀ cycloalkyl, substituted or unsubstituted C₃-C₄₀ cycloalkenyl, substituted or unsubstituted C₁-C₄₀ acyl, substituted or

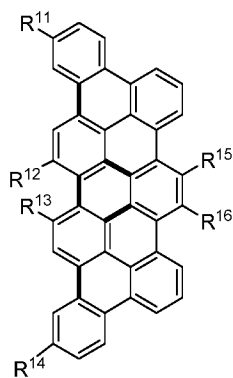
unsubstituted C₁-C₄₀ alkoxy, P(O)(OR^a)₂, SR^a, S(O)₂R^a, SiR^aR^bR^c, or NR^aR^b, or wherein, as valence permits, R¹⁵ and R¹⁶, together with the atoms to which they are attached, form a 3-10 membered substituted or unsubstituted cyclic moiety optionally including from 1 to 3 heteroatoms; and

R^a, R^b, and R^c are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C₁-C₄₀ alkyl, substituted or unsubstituted C₂-C₄₀ alkenyl, substituted or unsubstituted C₂-C₄₀ alkynyl, substituted or unsubstituted C₃-C₄₀ aryl, substituted or unsubstituted C₃-C₄₀ cycloalkyl, substituted or unsubstituted C₃-C₄₀ cycloalkenyl, substituted or unsubstituted C₁-C₄₀ acyl, or substituted or unsubstituted C₁-C₄₀ alkoxy.

In some examples of Formula III, R¹¹, R¹², R¹³, and R¹⁴ are independently substituted or unsubstituted C₁-C₂₀ alkyl. In some examples of Formula III, R¹¹, R¹², R¹³, and R¹⁴ are independently unsubstituted C₁-C₁₀ alkyl. In some examples of Formula III, R¹¹, R¹², R¹³, and R¹⁴ are the same.

In some examples of Formula III, R¹⁵ and R¹⁶ are independently hydrogen, halogen, hydroxyl, substituted or unsubstituted C₁-C₂₀ alkyl, substituted or unsubstituted C₁-C₂₀ acyl, or wherein, as valence permits, R¹⁵ and R¹⁶, together with the atoms to which they are attached, form a 3-10 membered substituted or unsubstituted cyclic moiety optionally including from 1 to 3 heteroatoms. In some examples of Formula III, R¹⁵ and R¹⁶ are independently hydrogen or unsubstituted C₁-C₅ acyl. In some examples of Formula III, R¹⁵ and R¹⁶ are the same. In some examples of Formula III, R¹⁵ and R¹⁶ together with the atoms to which they are attached, form a 5-10 membered substituted or unsubstituted cyclic moiety optionally including from 1 to 3 heteroatoms.

In some examples of Formula III, the compounds can be defined by Formula III-a:



III-a

wherein

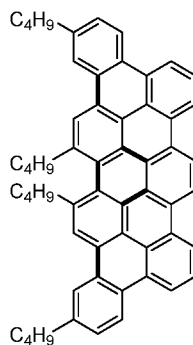
R^{11} , R^{12} , R^{13} , R^{14} , R^{15} , and R^{16} are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C_1 - C_{40} alkyl, substituted or unsubstituted C_2 - C_{40} alkenyl, substituted or unsubstituted C_2 - C_{40} alkynyl, substituted or unsubstituted C_3 - C_{40} aryl, substituted or unsubstituted C_3 - C_{40} cycloalkyl, substituted or unsubstituted C_3 - C_{40} cycloalkenyl, substituted or unsubstituted C_1 - C_{40} acyl, substituted or unsubstituted C_1 - C_{40} alkoxy, $P(O)(OR^a)_2$, SR^a , $S(O)_2R^a$, $SiR^aR^bR^c$, or NR^aR^b , or wherein, as valence permits, R^{15} and R^{16} , together with the atoms to which they are attached, form a 3-10 membered substituted or unsubstituted cyclic moiety optionally including from 1 to 3 heteroatoms; and

R^a , R^b , and R^c are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C_1 - C_{40} alkyl, substituted or unsubstituted C_2 - C_{40} alkenyl, substituted or unsubstituted C_2 - C_{40} alkynyl, substituted or unsubstituted C_3 - C_{40} aryl, substituted or unsubstituted C_3 - C_{40} cycloalkyl, substituted or unsubstituted C_3 - C_{40} cycloalkenyl, substituted or unsubstituted C_1 - C_{40} acyl, or substituted or unsubstituted C_1 - C_{40} alkoxy.

In some examples of Formula III-a, R^{11} , R^{12} , R^{13} , and R^{14} are independently substituted or unsubstituted C_1 - C_{20} alkyl. In some examples of Formula III-a, R^{11} , R^{12} , R^{13} , and R^{14} are independently unsubstituted C_1 - C_{10} alkyl. In some examples of Formula III-a, R^{11} , R^{12} , R^{13} , and R^{14} are the same.

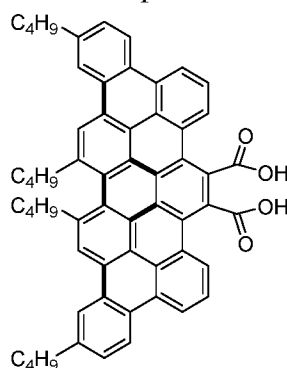
In some examples of Formula III-a, R^{15} and R^{16} are independently hydrogen, halogen, hydroxyl, substituted or unsubstituted C_1 - C_{20} alkyl, substituted or unsubstituted C_1 - C_{20} acyl, or wherein, as valence permits, R^{15} and R^{16} , together with the atoms to which they are attached, form a 3-10 membered substituted or unsubstituted cyclic moiety optionally including from 1 to 3 heteroatoms. In some examples of Formula III-a, R^{15} and R^{16} are independently hydrogen or unsubstituted C_1 - C_5 acyl. In some examples of Formula III-a, R^{15} and R^{16} are the same. In some examples of Formula III-a, R^{15} and R^{16} together with the atoms to which they are attached, form a 5-10 membered substituted or unsubstituted cyclic moiety optionally including from 1 to 3 heteroatoms.

In some examples of Formula III-a, the compounds can be defined by Formula III-a-1:



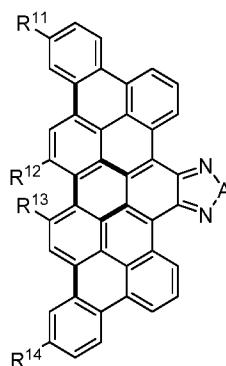
III-a-1

In some examples of Formula III-a, the compounds can be defined by Formula III-a-2:



III-a-2

In some examples of Formula III, the compounds can be defined by Formula III-b:



III-b

wherein

R^{11} , R^{12} , R^{13} , and R^{14} are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C_1 - C_{40} alkyl, substituted or unsubstituted C_2 - C_{40} alkenyl, substituted or unsubstituted C_2 - C_{40} alkynyl, substituted or unsubstituted C_3 - C_{40} aryl, substituted or unsubstituted C_3 - C_{40} cycloalkyl, substituted or unsubstituted C_3 - C_{40} cycloalkenyl, substituted or unsubstituted C_1 - C_{40} acyl, substituted or unsubstituted C_1 - C_{40} alkoxy, $P(O)(OR^a)_2$, SR^a , $S(O)_2R^a$, $SiR^aR^bR^c$, or NR^aR^b ;

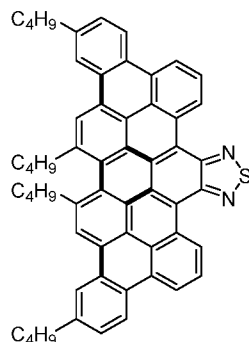
A is O, S, Se, Te, or NR^a; and

R^a, R^b, and R^c are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C₁-C₄₀ alkyl, substituted or unsubstituted C₂-C₄₀ alkenyl, substituted or unsubstituted C₂-C₄₀ alkynyl, substituted or unsubstituted C₃-C₄₀ aryl, substituted or unsubstituted C₃-C₄₀ cycloalkyl, substituted or unsubstituted C₃-C₄₀ cycloalkenyl, substituted or unsubstituted C₁-C₄₀ acyl, or substituted or unsubstituted C₁-C₄₀ alkoxy.

In some examples of Formula III-b, R¹¹, R¹², R¹³, and R¹⁴ are independently substituted or unsubstituted C₁-C₂₀ alkyl. In some examples of Formula III-b, R¹¹, R¹², R¹³, and R¹⁴ are independently unsubstituted C₁-C₁₀ alkyl. In some examples of Formula III-b, R¹¹, R¹², R¹³, and R¹⁴ are the same.

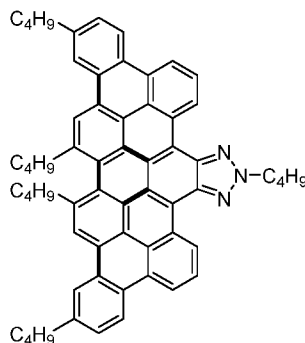
In some examples of Formula III-b, A is S or NR^a. In some examples of Formula III-b, A is NR^a and R^a is a substituted or unsubstituted C₁-C₂₀ alkyl. In some examples of Formula III-b, A is NR^a and R^a is an unsubstituted C₁₋₁₀ alkyl.

In some examples of Formula III-b, the compounds can be defined by Formula III-b-1:



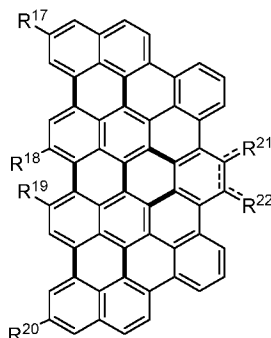
III-b-1

In some examples of Formula III-b, the compounds can be defined by Formula III-b-2:



III-b-2

Also disclosed herein are compounds defined by Formula IV:



IV

wherein

the dotted lines to R^{21} , R^{22} , and between the carbons within the ring to which R^{21} and R^{22} are bonded, independently indicate that the bond can be a single bond or a double bond, as valence permits;

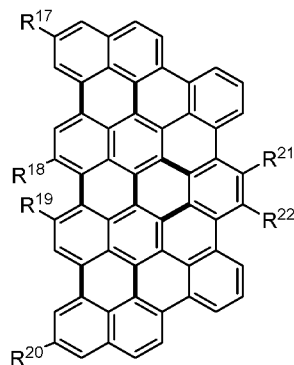
R^{17} , R^{18} , R^{19} , R^{20} , R^{21} , and R^{22} are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C_1 - C_{40} alkyl, substituted or unsubstituted C_2 - C_{40} alkenyl, substituted or unsubstituted C_2 - C_{40} alkynyl, substituted or unsubstituted C_3 - C_{40} aryl, substituted or unsubstituted C_3 - C_{40} cycloalkyl, substituted or unsubstituted C_3 - C_{40} cycloalkenyl, substituted or unsubstituted C_1 - C_{40} acyl, substituted or unsubstituted C_1 - C_{40} alkoxy, $P(O)(OR^a)_2$, SR^a , $S(O)_2R^a$, $SiR^aR^bR^c$, or NR^aR^b , or wherein, as valence permits, R^{21} and R^{22} , together with the atoms to which they are attached, form a 3-10 membered substituted or unsubstituted cyclic moiety optionally including from 1 to 3 heteroatoms; and

R^a , R^b , and R^c are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C_1 - C_{40} alkyl, substituted or unsubstituted C_2 - C_{40} alkenyl, substituted or unsubstituted C_2 - C_{40} alkynyl, substituted or unsubstituted C_3 - C_{40} aryl, substituted or unsubstituted C_3 - C_{40} cycloalkyl, substituted or unsubstituted C_3 - C_{40} cycloalkenyl, substituted or unsubstituted C_1 - C_{40} acyl, or substituted or unsubstituted C_1 - C_{40} alkoxy.

In some examples of Formula IV, R^{17} , R^{18} , R^{19} , and R^{20} are independently substituted or unsubstituted C_1 - C_{20} alkyl. In some examples of Formula IV, R^{17} , R^{18} , R^{19} , and R^{20} are independently unsubstituted C_1 - C_{10} alkyl. In some examples of Formula IV, R^{17} , R^{18} , R^{19} , and R^{20} are the same.

In some examples of Formula IV, R^{21} and R^{22} are independently hydrogen, halogen, hydroxyl, substituted or unsubstituted C_1 - C_{20} alkyl, substituted or unsubstituted C_1 - C_{20} acyl, or wherein, as valence permits, R^{21} and R^{22} , together with the atoms to which they are attached, form a 3-10 membered substituted or unsubstituted cyclic moiety optionally including from 1 to 3 heteroatoms. In some examples of Formula IV, R^{21} and R^{22} are independently hydrogen or unsubstituted C_1 - C_5 acyl. In some examples of Formula IV, R^{21} and R^{22} are the same. In some examples of Formula IV, R^{21} and R^{22} together with the atoms to which they are attached, form a 5-10 membered substituted or unsubstituted cyclic moiety optionally including from 1 to 3 heteroatoms.

In some examples of Formula IV, the compounds can be defined by Formula IV-a:



IV-a

wherein

R^{17} , R^{18} , R^{19} , R^{20} , R^{21} , and R^{22} are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C_1 - C_{40} alkyl, substituted or unsubstituted C_2 - C_{40} alkenyl, substituted or unsubstituted C_2 - C_{40} alkynyl, substituted or unsubstituted C_3 - C_{40} aryl, substituted or unsubstituted C_3 - C_{40} cycloalkyl, substituted or unsubstituted C_3 - C_{40} cycloalkenyl, substituted or unsubstituted C_1 - C_{40} acyl, substituted or unsubstituted C_1 - C_{40} alkoxy, $P(O)(OR^a)_2$, SR^a , $S(O)_2R^a$, $SiR^aR^bR^c$, or NR^aR^b , or wherein, as valence permits, R^{21} and R^{22} , together with the atoms to which they are attached, form a 3-10 membered substituted or unsubstituted cyclic moiety optionally including from 1 to 3 heteroatoms; and

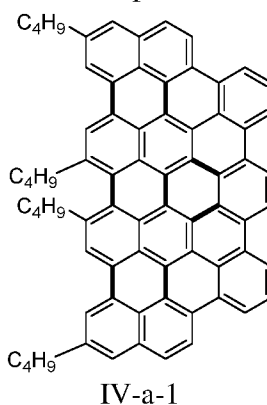
R^a , R^b , and R^c are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C_1 - C_{40} alkyl, substituted or unsubstituted C_2 - C_{40} alkenyl, substituted or unsubstituted C_2 - C_{40} alkynyl, substituted or unsubstituted C_3 - C_{40} aryl, substituted or unsubstituted C_3 - C_{40} cycloalkyl, substituted or unsubstituted C_3 - C_{40} cycloalkenyl,

substituted or unsubstituted C₁-C₄₀ acyl, or substituted or unsubstituted C₁-C₄₀ alkoxy.

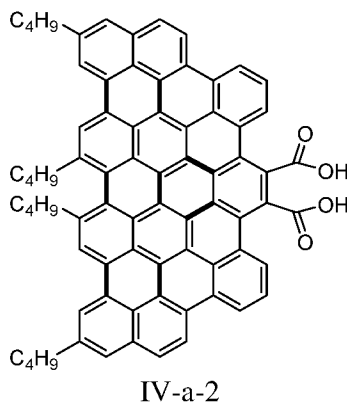
In some examples of Formula IV-a, R¹⁷, R¹⁸, R¹⁹, and R²⁰ are independently substituted or unsubstituted C₁-C₂₀ alkyl. In some examples of Formula IV-a, R¹⁷, R¹⁸, R¹⁹, and R²⁰ are
 5 independently unsubstituted C₁-C₁₀ alkyl. In some examples of Formula IV-a, R¹⁷, R¹⁸, R¹⁹, and R²⁰ are the same.

In some examples of Formula IV-a, R²¹ and R²² are independently hydrogen, halogen, hydroxyl, substituted or unsubstituted C₁-C₂₀ alkyl, substituted or unsubstituted C₁-C₂₀ acyl, or wherein, as valence permits, R²¹ and R²², together with the atoms to which they are attached,
 10 form a 3-10 membered substituted or unsubstituted cyclic moiety optionally including from 1 to 3 heteroatoms. In some examples of Formula IV-a, R²¹ and R²² are independently hydrogen or unsubstituted C₁-C₅ acyl. In some examples of Formula IV-a, R²¹ and R²² are the same. In some examples of Formula IV-a, R²¹ and R²² together with the atoms to which they are attached, form
 15 a 5-10 membered substituted or unsubstituted cyclic moiety optionally including from 1 to 3 heteroatoms.

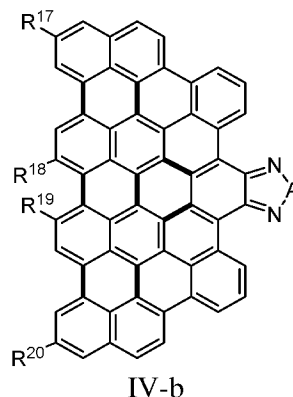
In some examples of Formula IV-a, the compounds can be defined by Formula IV-a-1.



In some examples of Formula IV-a, the compounds can be defined by Formula IV-a-2.



In some examples of Formula IV, the compounds can be defined by Formula IV-b:



wherein

R^{17} , R^{18} , R^{19} , and R^{20} are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C_1 - C_{40} alkyl, substituted or unsubstituted C_2 - C_{40} alkenyl, substituted or unsubstituted C_2 - C_{40} alkynyl, substituted or unsubstituted C_3 - C_{40} aryl, substituted or unsubstituted C_3 - C_{40} cycloalkyl, substituted or unsubstituted C_3 - C_{40} cycloalkenyl, substituted or unsubstituted C_1 - C_{40} acyl, substituted or unsubstituted C_1 - C_{40} alkoxy, $P(O)(OR^a)_2$, SR^a , $S(O)_2R^a$, $SiR^aR^bR^c$, or NR^aR^b ;

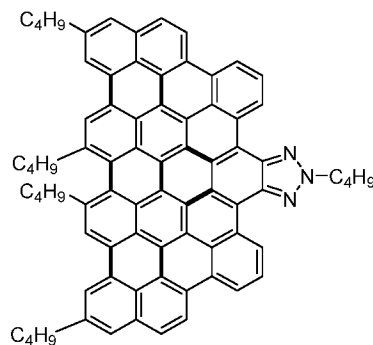
A is O, S, Se, Te, or NR^a ; and

R^a , R^b , and R^c are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C_1 - C_{40} alkyl, substituted or unsubstituted C_2 - C_{40} alkenyl, substituted or unsubstituted C_2 - C_{40} alkynyl, substituted or unsubstituted C_3 - C_{40} aryl, substituted or unsubstituted C_3 - C_{40} cycloalkyl, substituted or unsubstituted C_3 - C_{40} cycloalkenyl, substituted or unsubstituted C_1 - C_{40} acyl, or substituted or unsubstituted C_1 - C_{40} alkoxy.

In some examples of Formula IV-b, R^{17} , R^{18} , R^{19} , and R^{20} are independently substituted or unsubstituted C_1 - C_{20} alkyl. In some examples of Formula IV-b, R^{17} , R^{18} , R^{19} , and R^{20} are independently unsubstituted C_1 - C_{10} alkyl. In some examples of Formula IV-b, R^{17} , R^{18} , R^{19} , and R^{20} are the same.

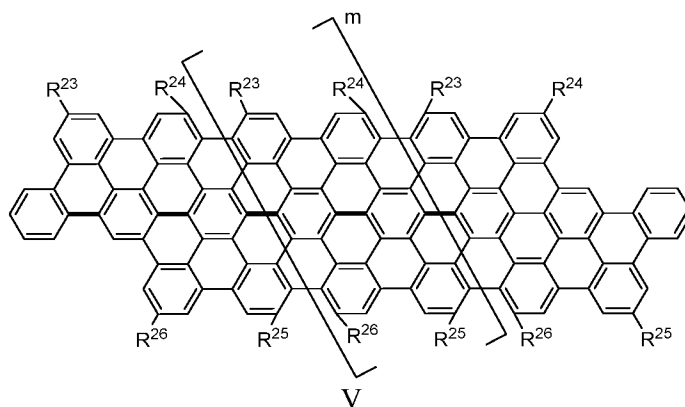
In some examples of Formula IV-b, A is S or NR^a . In some examples of Formula IV-b, A is NR^a and R^a is a substituted or unsubstituted C_1 - C_{20} alkyl. In some examples of Formula IV-b, A is NR^a and R^a is an unsubstituted C_{1-10} alkyl.

In some examples of Formula IV-b, the compounds can be defined by Formula IV-b-1.



IV-b-1

Also disclosed herein are compounds defined by Formula V:



wherein

m is from 1 to 1000;

R^{23} , R^{24} , R^{25} , and R^{26} are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C_1 - C_{40} alkyl, substituted or unsubstituted C_2 - C_{40} alkenyl, substituted or unsubstituted C_2 - C_{40} alkynyl, substituted or unsubstituted C_3 - C_{40} aryl, substituted or unsubstituted C_3 - C_{40} cycloalkyl, substituted or unsubstituted C_3 - C_{40} cycloalkenyl, substituted or unsubstituted C_1 - C_{40} acyl, substituted or unsubstituted C_1 - C_{40} alkoxy, $P(O)(OR^a)_2$, SR^a , $S(O)_2R^a$, $SiR^aR^bR^c$, or NR^aR^b ; and

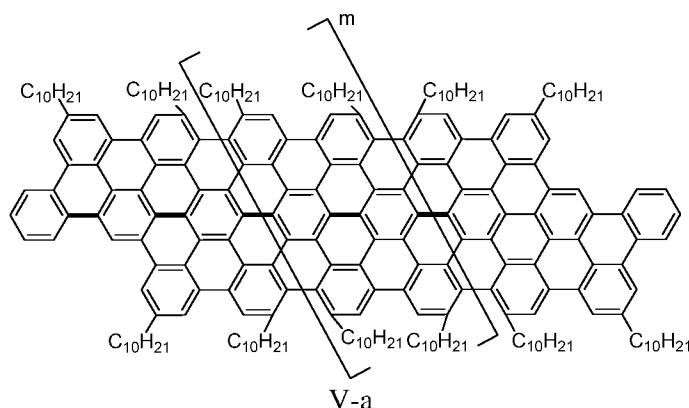
R^a , R^b , and R^c are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C_1 - C_{40} alkyl, substituted or unsubstituted C_2 - C_{40} alkenyl, substituted or unsubstituted C_2 - C_{40} alkynyl, substituted or unsubstituted C_3 - C_{40} aryl, substituted or unsubstituted C_3 - C_{40} cycloalkyl, substituted or unsubstituted C_3 - C_{40} cycloalkenyl, substituted or unsubstituted C_1 - C_{40} acyl, or substituted or unsubstituted C_1 - C_{40} alkoxy.

In some examples of Formula V, R^{23} , R^{24} , R^{25} , and R^{26} are independently substituted or unsubstituted C_1 - C_{20} alkyl. In some examples of Formula V, R^{23} , R^{24} , R^{25} , and R^{26} are

independently unsubstituted C₂-C₁₅ alkyl. In some examples of Formula V, R²³, R²⁴, R²⁵, and R²⁶ are the same.

In some examples of Formula V, m is from 1 to 500. In some examples of Formula V, m is from 1 to 100. In some examples of Formula V, m is from 1 to 50.

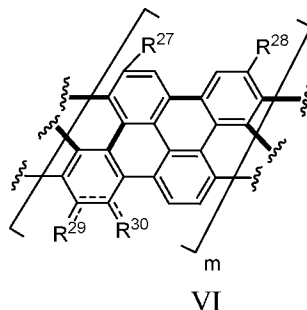
5 In some examples of Formula V, the compounds can be defined by Formula V-a:



wherein m is from 1 to 1000.

10 In some examples of Formula V-a, m is from 1 to 500. In some examples of Formula V-a, m is from 1 to 100. In some examples of Formula V-a, m is from 1 to 50.

Also disclosed herein are compounds defined by Formula VI:



wherein

15 m is from 1 to 1000;

the dotted lines to R²⁹, R³⁰, and between the carbons within the ring to which R²⁹ and R³⁰ are bonded, independently indicate that the bond can be a single bond or a double bond, as valence permits;

20 R²⁷, R²⁸, R²⁹, and R³⁰ are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C₁-C₄₀ alkyl, substituted or unsubstituted C₂-C₄₀ alkenyl, substituted or unsubstituted C₂-C₄₀ alkynyl, substituted or unsubstituted C₃-C₄₀ aryl, substituted or unsubstituted C₃-C₄₀ cycloalkyl, substituted or unsubstituted C₃-C₄₀ cycloalkenyl, substituted or unsubstituted C₁-C₄₀ acyl, substituted or unsubstituted

C₁-C₄₀ alkoxy, P(O)(OR^a)₂, SR^a, S(O)₂R^a, SiR^aR^bR^c, or NR^aR^b, or wherein, as valence permits, R²⁹ and R³⁰, together with the atoms to which they are attached, form a 3-10 membered substituted or unsubstituted cyclic moiety optionally including from 1 to 3 heteroatoms; and

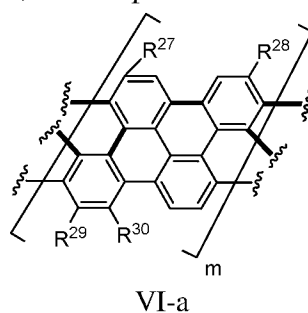
R^a, R^b, and R^c are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C₁-C₄₀ alkyl, substituted or unsubstituted C₂-C₄₀ alkenyl, substituted or unsubstituted C₂-C₄₀ alkynyl, substituted or unsubstituted C₃-C₄₀ aryl, substituted or unsubstituted C₃-C₄₀ cycloalkyl, substituted or unsubstituted C₃-C₄₀ cycloalkenyl, substituted or unsubstituted C₁-C₄₀ acyl, or substituted or unsubstituted C₁-C₄₀ alkoxy.

In some examples of Formula VI, R²⁷ and R²⁸ are independently substituted or unsubstituted C₁-C₂₀ alkyl. In some examples of Formula VI, R²⁷ and R²⁸ are independently unsubstituted C₂-C₁₅ alkyl. In some examples of Formula VI, R²⁷ and R²⁸ are the same.

In some examples of Formula VI, R²⁹ and R³⁰ are independently hydrogen, halogen, hydroxyl, substituted or unsubstituted C₁-C₂₀ alkyl, substituted or unsubstituted C₁-C₂₀ acyl, or wherein, as valence permits, R²⁹ and R³⁰, together with the atoms to which they are attached, form a 3-10 membered substituted or unsubstituted cyclic moiety optionally including from 1 to 3 heteroatoms. In some examples of Formula VI, R²⁹ and R³⁰ are independently hydrogen or unsubstituted C₁-C₅ acyl. In some examples of Formula VI, R²⁹ and R³⁰ are the same. In some examples of Formula VI, R²⁹ and R³⁰ together with the atoms to which they are attached, form a 5-10 membered substituted or unsubstituted cyclic moiety optionally including from 1 to 3 heteroatoms.

In some examples of Formula VI, m is from 1 to 500. In some examples of Formula VI, m is from 1 to 100. In some examples of Formula VI, m is from 1 to 50.

In some examples of Formula VI, the compounds can be defined by Formula VI-a:



wherein

m is from 1 to 1000;

R^{27} , R^{28} , R^{29} , and R^{30} are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C_1 - C_{40} alkyl, substituted or unsubstituted C_2 - C_{40} alkenyl, substituted or unsubstituted C_2 - C_{40} alkynyl, substituted or unsubstituted C_3 - C_{40} aryl, substituted or unsubstituted C_3 - C_{40} cycloalkyl, substituted or unsubstituted C_3 - C_{40} cycloalkenyl, substituted or unsubstituted C_1 - C_{40} acyl, substituted or unsubstituted C_1 - C_{40} alkoxy, $P(O)(OR^a)_2$, SR^a , $S(O)_2R^a$, $SiR^aR^bR^c$, or NR^aR^b , or wherein, as valence permits, R^{29} and R^{30} , together with the atoms to which they are attached, form a 3-10 membered substituted or unsubstituted cyclic moiety optionally including from 1 to 3 heteroatoms; and

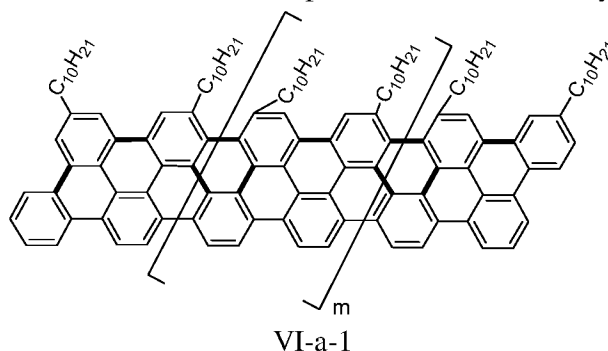
R^a , R^b , and R^c are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C_1 - C_{40} alkyl, substituted or unsubstituted C_2 - C_{40} alkenyl, substituted or unsubstituted C_2 - C_{40} alkynyl, substituted or unsubstituted C_3 - C_{40} aryl, substituted or unsubstituted C_3 - C_{40} cycloalkyl, substituted or unsubstituted C_3 - C_{40} cycloalkenyl, substituted or unsubstituted C_1 - C_{40} acyl, or substituted or unsubstituted C_1 - C_{40} alkoxy.

In some examples of Formula VI-a, R^{27} and R^{28} are independently substituted or unsubstituted C_1 - C_{20} alkyl. In some examples of Formula VI-a, R^{27} and R^{28} are independently unsubstituted C_2 - C_{15} alkyl. In some examples of Formula VI-a, R^{27} and R^{28} are the same.

In some examples of Formula VI-a, R^{29} and R^{30} are independently hydrogen, halogen, hydroxyl, substituted or unsubstituted C_1 - C_{20} alkyl, substituted or unsubstituted C_1 - C_{20} acyl, or wherein, as valence permits, R^{29} and R^{30} , together with the atoms to which they are attached, form a 3-10 membered substituted or unsubstituted cyclic moiety optionally including from 1 to 3 heteroatoms. In some examples of Formula VI-a, R^{29} and R^{30} are independently hydrogen or unsubstituted C_1 - C_5 acyl. In some examples of Formula VI-a, R^{29} and R^{30} are the same. In some examples of Formula VI-a, R^{29} and R^{30} together with the atoms to which they are attached, form a 5-10 membered substituted or unsubstituted cyclic moiety optionally including from 1 to 3 heteroatoms.

In some examples of Formula VI-a, m is from 1 to 500. In some examples of Formula VI-a, m is from 1 to 100. In some examples of Formula VI-a, m is from 1 to 50.

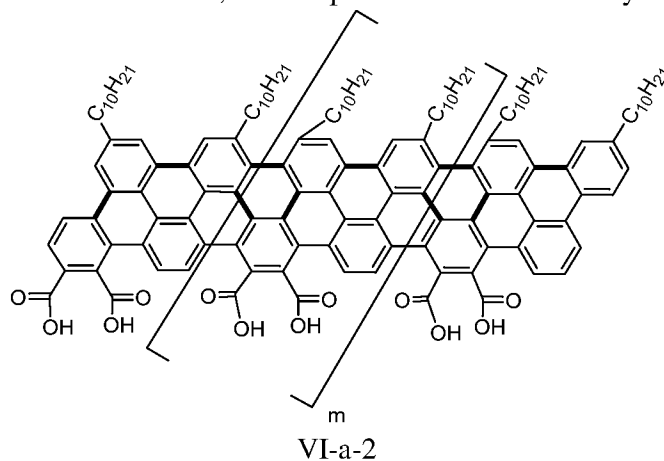
In some examples of Formula VI-a, the compounds can be defined by Formula VI-a-1:



wherein m is from 1 to 1000.

- 5 In some examples of Formula VI-a-1, m is from 1 to 500. In some examples of Formula VI-a-1, m is from 1 to 100. In some examples of Formula VI-a-1, m is from 1 to 50.

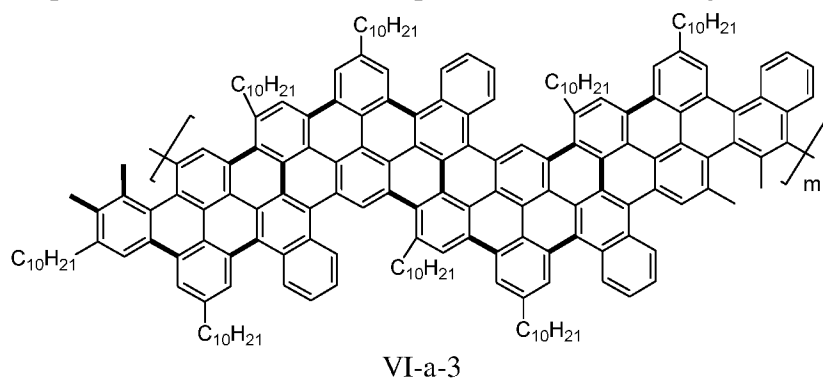
In some examples of Formula VI-a, the compounds can be defined by Formula VI-a-2



- 10 wherein m is from 1 to 1000.

In some examples of Formula VI-a-2, m is from 1 to 500. In some examples of Formula VI-a-2, m is from 1 to 100. In some examples of Formula VI-a-2, m is from 1 to 50.

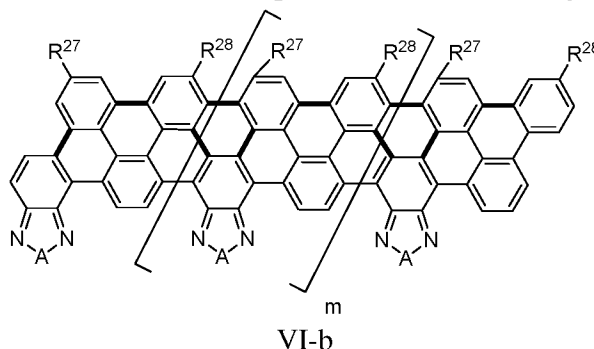
In some examples of Formula VI-a, the compounds can be defined by Formula VI-a-3:



- 15 wherein m is from 1 to 1000.

In some examples of Formula VI-a-3, m is from 1 to 500. In some examples of Formula VI-a-3, m is from 1 to 100. In some examples of Formula VI-a-3, m is from 1 to 50.

In some examples of Formula VI, the compounds can be defined by Formula VI-b:



wherein

m is from 1 to 1000;

R^{27} and R^{28} are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C_1 - C_{40} alkyl, substituted or unsubstituted C_2 - C_{40} alkenyl, substituted or unsubstituted C_2 - C_{40} alkynyl, substituted or unsubstituted C_3 - C_{40} aryl, substituted or unsubstituted C_3 - C_{40} cycloalkyl, substituted or unsubstituted C_3 - C_{40} cycloalkenyl, substituted or unsubstituted C_1 - C_{40} acyl, substituted or unsubstituted C_1 - C_{40} alkoxy, $P(O)(OR^a)_2$, SR^a , $S(O)_2R^a$, $SiR^aR^bR^c$, or NR^aR^b ;

A is O, S, Se, Te, or NR^a ; and

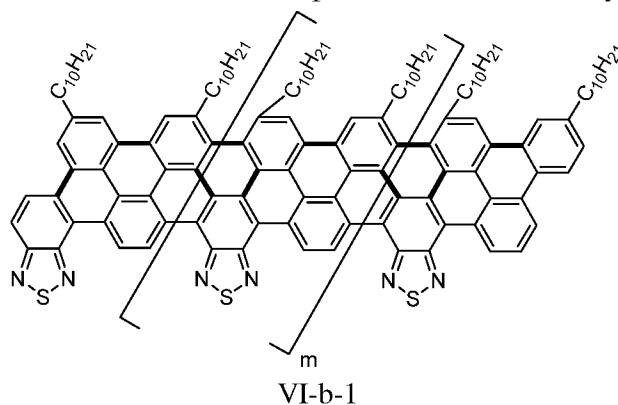
R^a , R^b , and R^c are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C_1 - C_{40} alkyl, substituted or unsubstituted C_2 - C_{40} alkenyl, substituted or unsubstituted C_2 - C_{40} alkynyl, substituted or unsubstituted C_3 - C_{40} aryl, substituted or unsubstituted C_3 - C_{40} cycloalkyl, substituted or unsubstituted C_3 - C_{40} cycloalkenyl, substituted or unsubstituted C_1 - C_{40} acyl, or substituted or unsubstituted C_1 - C_{40} alkoxy.

In some examples of Formula VI-b, R^{27} and R^{28} are independently substituted or unsubstituted C_1 - C_{20} alkyl. In some examples of Formula VI-b, R^{27} and R^{28} are independently unsubstituted C_2 - C_{15} alkyl. In some examples of Formula VI-b, R^{27} and R^{28} are the same.

In some examples of Formula VI-b, A is S or NR^a . In some examples of Formula VI-b, A is NR^a and R^a is a substituted or unsubstituted C_1 - C_{20} alkyl. In some examples of Formula VI-b, A is NR^a and R^a is an unsubstituted C_{1-10} alkyl.

In some examples of Formula VI-b, m is from 1 to 500. In some examples of Formula VI-b, m is from 1 to 100. In some examples of Formula VI-b, m is from 1 to 50.

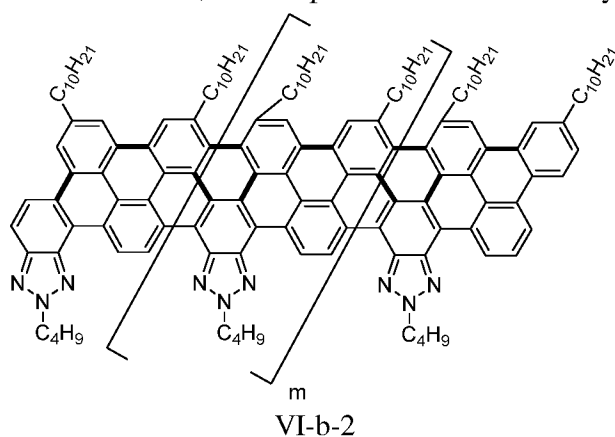
In some examples of Formula VI-b, the compounds can be defined by Formula VI-b-1:



wherein m is from 1 to 1000.

- 5 In some examples of Formula VI-b-1, m is from 1 to 500. In some examples of Formula VI-b-1, m is from 1 to 100. In some examples of Formula VI-b-1, m is from 1 to 50.

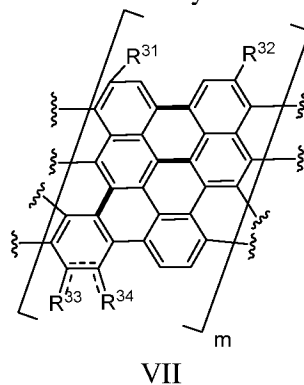
In some examples of Formula VI-b, the compounds can be defined by Formula VI-b-2:



- 10 wherein m is from 1 to 1000.

In some examples of Formula VI-b-2, m is from 1 to 500. In some examples of Formula VI-b-2, m is from 1 to 100. In some examples of Formula VI-b-2, m is from 1 to 50.

Also disclosed herein are compounds defined by Formula VII:



wherein

m is from 1 to 1000;

the dotted lines to R³³, R³⁴, and between the carbons within the ring to which R³³ and R³⁴ are bonded, independently indicate that the bond can be a single bond or a double bond, as valence permits;

R³¹, R³², R³³, and R³⁴ are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C₁-C₄₀ alkyl, substituted or unsubstituted C₂-C₄₀ alkenyl, substituted or unsubstituted C₂-C₄₀ alkynyl, substituted or unsubstituted C₃-C₄₀ aryl, substituted or unsubstituted C₃-C₄₀ cycloalkyl, substituted or unsubstituted C₃-C₄₀ cycloalkenyl, substituted or unsubstituted C₁-C₄₀ acyl, substituted or unsubstituted C₁-C₄₀ alkoxy, P(O)(OR^a)₂, SR^a, S(O)₂R^a, SiR^aR^bR^c, or NR^aR^b, or wherein, as valence permits, R³³ and R³⁴, together with the atoms to which they are attached, form a 3-10 membered substituted or unsubstituted cyclic moiety optionally including from 1 to 3 heteroatoms; and

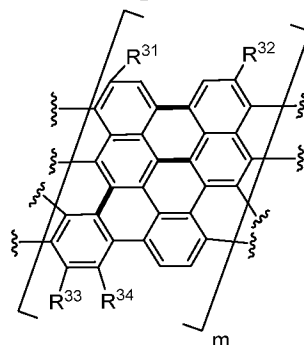
R^a, R^b, and R^c are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C₁-C₄₀ alkyl, substituted or unsubstituted C₂-C₄₀ alkenyl, substituted or unsubstituted C₂-C₄₀ alkynyl, substituted or unsubstituted C₃-C₄₀ aryl, substituted or unsubstituted C₃-C₄₀ cycloalkyl, substituted or unsubstituted C₃-C₄₀ cycloalkenyl, substituted or unsubstituted C₁-C₄₀ acyl, or substituted or unsubstituted C₁-C₄₀ alkoxy.

In some examples of Formula VII, R³¹ and R³² are independently substituted or unsubstituted C₁-C₂₀ alkyl. In some examples of Formula VII, R³¹ and R³² are independently unsubstituted C₂-C₁₅ alkyl. In some examples of Formula VII, R³¹ and R³² are the same.

In some examples of Formula VII, R³³ and R³⁴ are independently hydrogen, halogen, hydroxyl, substituted or unsubstituted C₁-C₂₀ alkyl, substituted or unsubstituted C₁-C₂₀ acyl, or wherein, as valence permits, R³³ and R³⁴, together with the atoms to which they are attached, form a 3-10 membered substituted or unsubstituted cyclic moiety optionally including from 1 to 3 heteroatoms. In some examples of Formula VII, R³³ and R³⁴ are independently hydrogen or unsubstituted C₁-C₅ acyl. In some examples of Formula VII, R³³ and R³⁴ are the same. In some examples of Formula VII, R³³ and R³⁴ together with the atoms to which they are attached, form a 5-10 membered substituted or unsubstituted cyclic moiety optionally including from 1 to 3 heteroatoms.

In some examples of Formula VII, m is from 1 to 500. In some examples of Formula VII, m is from 1 to 100. In some examples of Formula VII, m is from 1 to 50.

In some examples of Formula VII, the compounds can be defined by formula VII-a:



VII-a

wherein

m is from 1 to 1000;

R^{31} , R^{32} , R^{33} , and R^{34} are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C_1 - C_{40} alkyl, substituted or unsubstituted C_2 - C_{40} alkenyl, substituted or unsubstituted C_2 - C_{40} alkynyl, substituted or unsubstituted C_3 - C_{40} aryl, substituted or unsubstituted C_3 - C_{40} cycloalkyl, substituted or unsubstituted C_3 - C_{40} cycloalkenyl, substituted or unsubstituted C_1 - C_{40} acyl, substituted or unsubstituted C_1 - C_{40} alkoxy, $P(O)(OR^a)_2$, SR^a , $S(O)_2R^a$, $SiR^aR^bR^c$, or NR^aR^b , or wherein, as valence permits, R^{33} and R^{34} , together with the atoms to which they are attached, form a 3-10 membered substituted or unsubstituted cyclic moiety optionally including from 1 to 3 heteroatoms; and

R^a , R^b , and R^c are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C_1 - C_{40} alkyl, substituted or unsubstituted C_2 - C_{40} alkenyl, substituted or unsubstituted C_2 - C_{40} alkynyl, substituted or unsubstituted C_3 - C_{40} aryl, substituted or unsubstituted C_3 - C_{40} cycloalkyl, substituted or unsubstituted C_3 - C_{40} cycloalkenyl, substituted or unsubstituted C_1 - C_{40} acyl, or substituted or unsubstituted C_1 - C_{40} alkoxy.

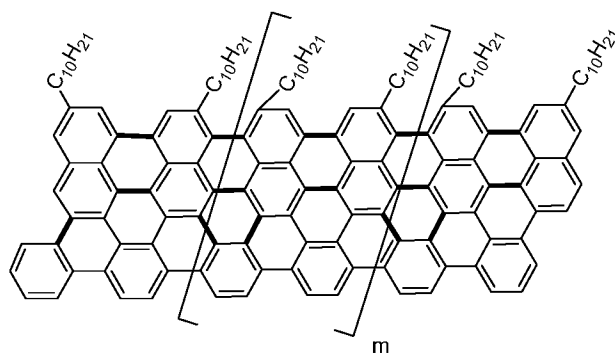
In some examples of Formula VII-a, R^{31} and R^{32} are independently substituted or unsubstituted C_1 - C_{20} alkyl. In some examples of Formula VII-a, R^{31} and R^{32} are independently unsubstituted C_2 - C_{15} alkyl. In some examples of Formula VII-a, R^{31} and R^{32} are the same.

In some examples of Formula VII-a, R^{33} and R^{34} are independently hydrogen, halogen, hydroxyl, substituted or unsubstituted C_1 - C_{20} alkyl, substituted or unsubstituted C_1 - C_{20} acyl, or

wherein, as valence permits, R^{33} and R^{34} , together with the atoms to which they are attached, form a 3-10 membered substituted or unsubstituted cyclic moiety optionally including from 1 to 3 heteroatoms. In some examples of Formula VII-a, R^{33} and R^{34} are independently hydrogen or unsubstituted C_1 - C_5 acyl. In some examples of Formula VII-a, R^{33} and R^{34} are the same. In some examples of Formula VII-a, R^{33} and R^{34} together with the atoms to which they are attached, form a 5-10 membered substituted or unsubstituted cyclic moiety optionally including from 1 to 3 heteroatoms.

In some examples of Formula VII-a, m is from 1 to 500. In some examples of Formula VII-a, m is from 1 to 100. In some examples of Formula VII-a, m is from 1 to 50.

In some examples of Formula VII-a, the compounds can be defined by Formula VII-a-1:

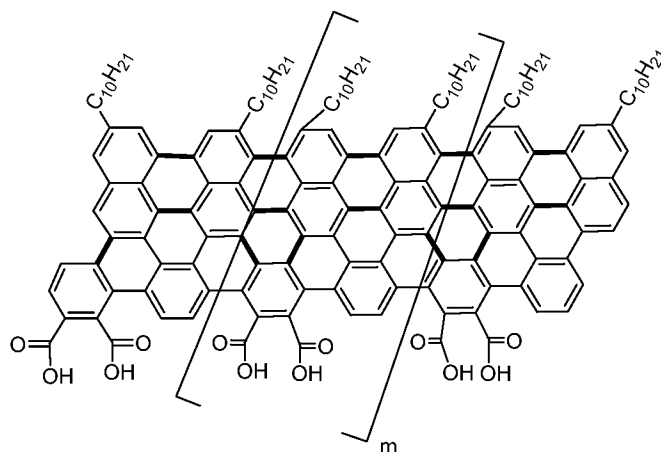


VII-a-1

wherein m is from 1 to 1000.

In some examples of Formula VII-a-1, m is from 1 to 500. In some examples of Formula VII-a-1, m is from 1 to 100. In some examples of Formula VII-a-1, m is from 1 to 50.

In some examples of Formula VII-a, the compounds can be defined by Formula VII-a-2:

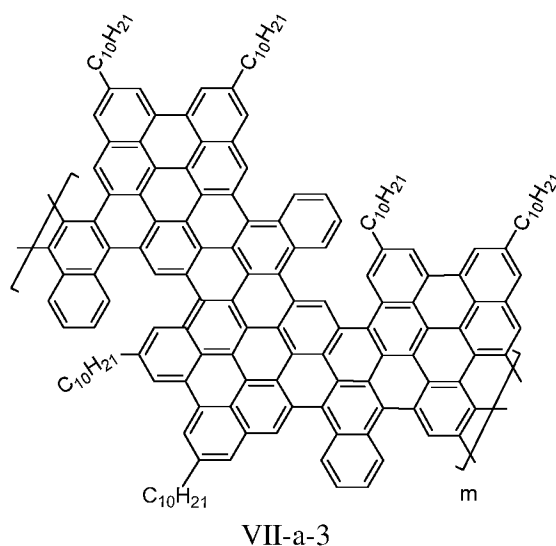


VII-a-2

wherein m is from 1 to 1000.

In some examples of Formula VII-a-2, m is from 1 to 500. In some examples of Formula VII-a-2, m is from 1 to 100. In some examples of Formula VII-a-2, m is from 1 to 50.

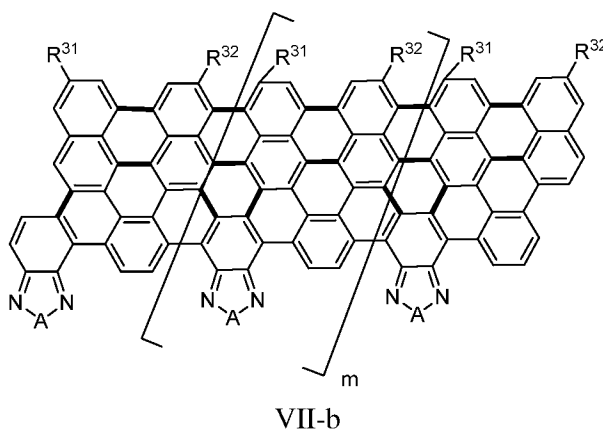
In some examples of Formula VII-a, the compounds can be defined by Formula VII-a-3:



wherein m is from 1 to 1000.

In some examples of Formula VII-a-3, m is from 1 to 500. In some examples of Formula VII-a-3, m is from 1 to 100. In some examples of Formula VII-a-3, m is from 1 to 50.

In some examples of Formula VII, the compounds can be defined by Formula VII-b:



wherein

m is from 1 to 1000;

R^{31} and R^{32} are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C_1 - C_{40} alkyl, substituted or unsubstituted C_2 - C_{40} alkenyl, substituted or unsubstituted C_2 - C_{40} alkynyl, substituted or unsubstituted C_3 - C_{40} aryl, substituted or unsubstituted C_3 - C_{40} cycloalkyl, substituted or unsubstituted C_3 - C_{40} cycloalkenyl,

substituted or unsubstituted C₁-C₄₀ acyl, substituted or unsubstituted C₁-C₄₀ alkoxy, P(O)(OR^a)₂, SR^a, S(O)₂R^a, SiR^aR^bR^c, or NR^aR^b;

A is O, S, Se, Te, or NR^a; and

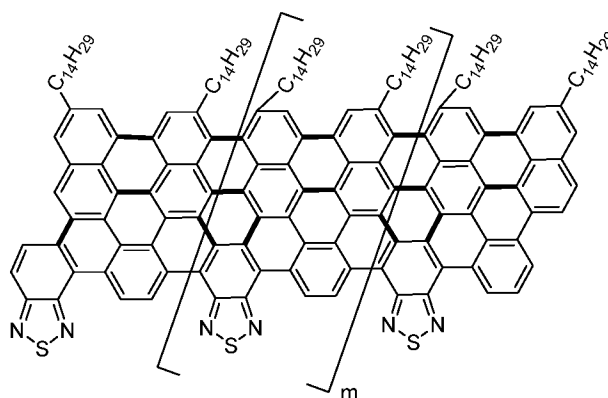
R^a, R^b, and R^c are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C₁-C₄₀ alkyl, substituted or unsubstituted C₂-C₄₀ alkenyl, substituted or unsubstituted C₂-C₄₀ alkynyl, substituted or unsubstituted C₃-C₄₀ aryl, substituted or unsubstituted C₃-C₄₀ cycloalkyl, substituted or unsubstituted C₃-C₄₀ cycloalkenyl, substituted or unsubstituted C₁-C₄₀ acyl, or substituted or unsubstituted C₁-C₄₀ alkoxy.

In some examples of Formula VII-b, R³¹ and R³² are independently substituted or unsubstituted C₁-C₂₀ alkyl. In some examples of Formula VII-b, R³¹ and R³² are independently unsubstituted C₂-C₁₅ alkyl. In some examples of Formula VII-b, R³¹ and R³² are the same.

In some examples of Formula VII-b, A is S or NR^a. In some examples of Formula VII-b, A is NR^a and R^a is a substituted or unsubstituted C₁-C₂₀ alkyl. In some examples of Formula VII-b, A is NR^a and R^a is an unsubstituted C₁₋₁₀ alkyl.

In some examples of Formula VII-b, m is from 1 to 500. In some examples of Formula VII-b, m is from 1 to 100. In some examples of Formula VII-b, m is from 1 to 50.

In some examples of Formula VII-b, the compounds can be defined by Formula VII-b-1:

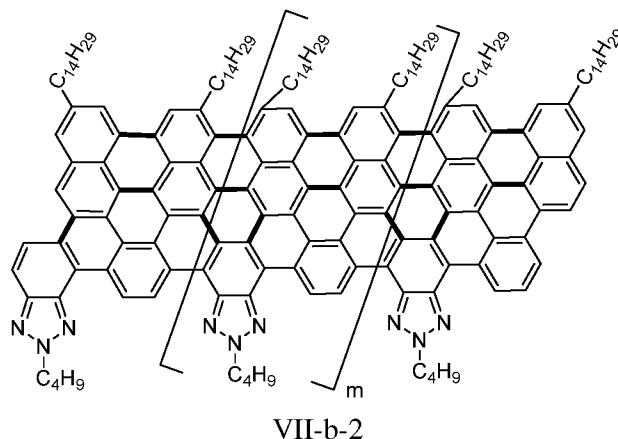


VII-b-1

wherein m is from 1 to 1000.

In some examples of Formula VII-b-1, m is from 1 to 500. In some examples of Formula VII-b-1, m is from 1 to 100. In some examples of Formula VII-b-1, m is from 1 to 50.

In some examples of Formula VII-b, the compounds can be defined by Formula VII-b-2:



wherein m is from 1 to 1000.

5 In some examples of Formula VII-b-2, m is from 1 to 500. In some examples of Formula VII-b-2, m is from 1 to 100. In some examples of Formula VII-b-2, m is from 1 to 50.

In some examples, the compounds of Formulas I-VII can have an average maximum dimension (e.g., length) of 1000 nm or less (e.g., 900 nm or less, 800 nm or less, 700 nm or less, 600 nm or less, 500 nm or less, 450 nm or less, 400 nm or less, 350 nm or less, 300 nm or less, 250 nm or less, 200 nm or less, 150 nm or less, 100 nm or less, 90 nm or less, 80 nm or less, 70 nm or less, 60 nm or less, 50 nm or less, 45 nm or less, 40 nm or less, 35 nm or less, 30 nm or less, 25 nm or less, 20 nm or less, 19 nm or less, 18 nm or less, 17 nm or less, 16 nm or less, 15 nm or less, 14 nm or less, 13 nm or less, 12 nm or less, 11 nm or less, 10 nm or less, 9 nm or less, 8 nm or less, 7 nm or less, 6 nm or less, 5 nm or less, 4 nm or less, 3 nm or less, or 2 nm or less). In some examples, the compounds of Formulas I-VII can have an average maximum dimension (e.g., length) of 1 nm or more (e.g., 2 nm or more, 3 nm or more, 4 nm or more, 5 nm or more, 6 nm or more, 7 nm or more, 8 nm or more, 9 nm or more, 10 nm or more, 11 nm or more, 12 nm or more, 13 nm or more, 14 nm or more, 15 nm or more, 16 nm or more, 17 nm or more, 18 nm or more, 19 nm or more, 20 nm or more, 25 nm or more, 30 nm or more, 35 nm or more, 40 nm or more, 45 nm or more, 50 nm or more, 60 nm or more, 70 nm or more, 80 nm or more, 90 nm or more, 100 nm or more, 150 nm or more, 200 nm or more, 250 nm or more, 300 nm or more, 350 nm or more, 400 nm or more, 450 nm or more, 500 nm or more, 600 nm or more, 700 nm or more, 800 nm or more, or 900 nm or more).

The average maximum dimension of the compounds of Formulas I-VII can range from any of the minimum values described above to any of the maximum values described above. For example, the compounds of Formulas I-VII can have an average maximum dimension of from 1

nm to 1000 nm (e.g., from 1 nm to 500 nm, from 500 nm to 1000 nm, from 1 nm to 200 nm, from 200 nm to 400 nm, from 400 nm to 600 nm, from 600 nm to 800 nm, from 800 nm to 1000 nm, from 1 nm to 100 nm, or from 1 nm to 20 nm).

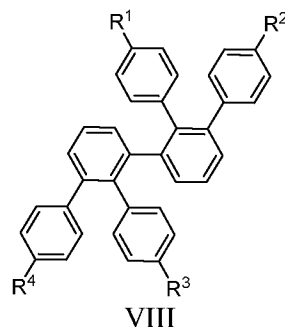
In some examples, the compounds of Formulas I-VII, can have a bandgap energy of 0.5 eV or more (e.g., 0.55 eV or more, 0.6 eV or more, 0.65 eV or more, 0.7 eV or more, 0.75 eV or more, 0.8 eV or more, 0.85 eV or more, 0.9 eV or more, 0.95 eV or more, 1.0 eV or more, 1.05 eV or more, 1.1 eV or more, 1.15 eV or more, 1.2 eV or more, 1.25 eV or more, 1.3 eV or more, 1.35 eV or more, 1.4 eV or more, 1.45 eV or more, 1.5 eV or more, 1.55 eV or more, 1.6 eV or more, 1.65 eV or more, 1.7 eV or more, 1.75 eV or more, 1.8 eV or more, 1.85 eV or more, 1.9 eV or more, 1.95 eV or more, 2.0 eV or more, 2.05 eV or more, 2.1 eV or more, 2.15 eV or more, 2.2 eV or more, 2.25 eV or more, 2.3 eV or more, 2.35 eV or more, 2.4 eV or more, or 2.45 eV or more).

In some examples, the compounds of Formulas I-VII, can have a bandgap energy of 2.5 eV or less (e.g., 2.45 eV or less, 2.4 eV or less, 2.35 eV or less, 2.3 eV or less, 2.25 eV or less, 2.2 eV or less, 2.15 eV or less, 2.1 eV or less, 2.05 eV or less, 2.0 eV or less, 1.95 eV or less, 1.9 eV or less, 1.85 eV or less, 1.8 eV or less, 1.75 eV or less, 1.7 eV or less, 1.65 eV or less, 1.6 eV or less, 1.55 eV or less, 1.5 eV or less, 1.45 eV or less, 1.4 eV or less, 1.35 eV or less, 1.3 eV or less, 1.25 eV or less, 1.2 eV or less, 1.15 eV or less, 1.1 eV or less, 1.05 eV or less, 1.0 eV or less, 0.95 eV or less, 0.9 eV or less, 0.85 eV or less, 0.8 eV or less, 0.75 eV or less, 0.7 eV or less, 0.65 eV or less, 0.6 eV or less, or 0.55 eV or less).

The bandgap energy of the compounds of Formulas I-VII can range from any of the minimum values described above to any of the maximum values described above. For example, the compounds of Formulas I-VII can have a bandgap energy of from 0.5 eV to 2.5 eV (e.g., from 0.5 eV to 1.5 eV, from 1.5 eV to 2.5 eV, from 0.5 eV to 0.75 eV, from 0.75 eV to 1 eV, from 1 eV to 1.25 eV, from 1.25 eV to 1.5 eV, from 1.5 eV to 1.75 eV, from 1.75 eV to 2.0 eV, from 2.0 eV to 2.25 eV, from 2.25 eV to 2.5 eV, or from 0.75 eV to 2 eV).

Also disclosed herein are precursors of the compounds of Formulas I-VII. In some examples, the compounds of Formulas I-VII can be made from their respective precursors by cyclodehydrogenation.

Also disclosed herein are compounds defined by Formula VIII:



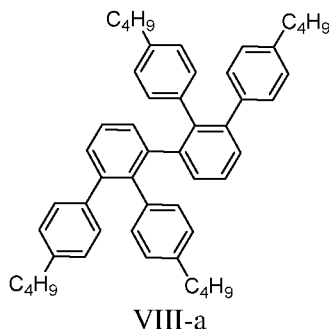
wherein

R^1 , R^2 , R^3 , and R^4 are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C_1 - C_{40} alkyl, substituted or unsubstituted C_2 - C_{40} alkenyl, substituted or unsubstituted C_2 - C_{40} alkynyl, substituted or unsubstituted C_3 - C_{40} aryl, substituted or unsubstituted C_3 - C_{40} cycloalkyl, substituted or unsubstituted C_3 - C_{40} cycloalkenyl, substituted or unsubstituted C_1 - C_{40} acyl, substituted or unsubstituted C_1 - C_{40} alkoxy, $P(O)(OR^a)_2$, SR^a , $S(O)_2R^a$, $SiR^aR^bR^c$, or NR^aR^b ; and

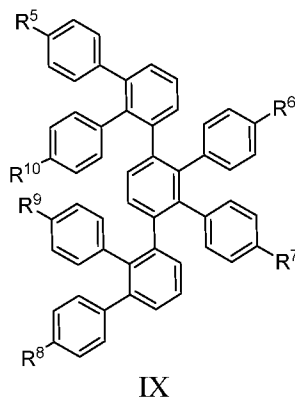
R^a , R^b , and R^c are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C_1 - C_{40} alkyl, substituted or unsubstituted C_2 - C_{40} alkenyl, substituted or unsubstituted C_2 - C_{40} alkynyl, substituted or unsubstituted C_3 - C_{40} aryl, substituted or unsubstituted C_3 - C_{40} cycloalkyl, substituted or unsubstituted C_3 - C_{40} cycloalkenyl, substituted or unsubstituted C_1 - C_{40} acyl, or substituted or unsubstituted C_1 - C_{40} alkoxy.

In some examples of Formula VIII, R^1 , R^2 , R^3 , and R^4 are independently substituted or unsubstituted C_1 - C_{20} alkyl. In some examples of Formula VIII, R^1 , R^2 , R^3 , and R^4 are independently unsubstituted C_1 - C_{10} alkyl. In some examples of Formula VIII, R^1 , R^2 , R^3 , and R^4 are the same.

In some examples of Formula VIII, the compound can be defined by Formula VIII-a.



Also disclosed herein are compounds defined by Formula IX:



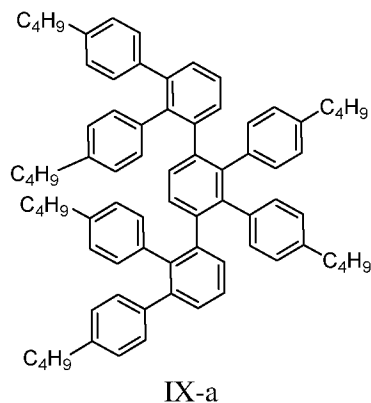
wherein

R^5 , R^6 , R^7 , R^8 , R^9 , and R^{10} are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C_1 - C_{40} alkyl, substituted or unsubstituted C_2 - C_{40} alkenyl, substituted or unsubstituted C_2 - C_{40} alkynyl, substituted or unsubstituted C_3 - C_{40} aryl, substituted or unsubstituted C_3 - C_{40} cycloalkyl, substituted or unsubstituted C_3 - C_{40} cycloalkenyl, substituted or unsubstituted C_1 - C_{40} acyl, substituted or unsubstituted C_1 - C_{40} alkoxy, $P(O)(OR^a)_2$, SR^a , $S(O)_2R^a$, $SiR^aR^bR^c$, or NR^aR^b ; and

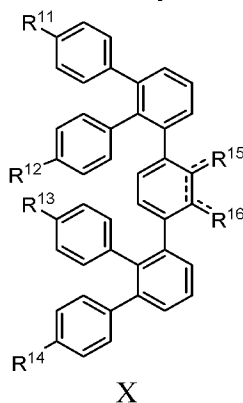
R^a , R^b , and R^c are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C_1 - C_{40} alkyl, substituted or unsubstituted C_2 - C_{40} alkenyl, substituted or unsubstituted C_2 - C_{40} alkynyl, substituted or unsubstituted C_3 - C_{40} aryl, substituted or unsubstituted C_3 - C_{40} cycloalkyl, substituted or unsubstituted C_3 - C_{40} cycloalkenyl, substituted or unsubstituted C_1 - C_{40} acyl, or substituted or unsubstituted C_1 - C_{40} alkoxy.

In some example of Formula IX, R^5 , R^6 , R^7 , R^8 , R^9 , and R^{10} are independently substituted or unsubstituted C_1 - C_{20} alkyl. In some example of Formula IX, R^5 , R^6 , R^7 , R^8 , R^9 , and R^{10} are independently unsubstituted C_1 - C_{10} alkyl. In some example of Formula IX, R^5 , R^6 , R^7 , R^8 , R^9 , and R^{10} are the same.

In some example of Formula IX, the compound can be defined by Formula IX-a.



Also disclosed herein are compounds defined by Formula X:



wherein

the dotted lines to R¹⁵, R¹⁶, and between the carbons within the ring to which R¹⁵ and R¹⁶ are bonded, independently indicate that the bond can be a single bond or a double bond, as valence permits;

R¹¹, R¹², R¹³, R¹⁴, R¹⁵, and R¹⁶ are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C₁-C₄₀ alkyl, substituted or unsubstituted C₂-C₄₀ alkenyl, substituted or unsubstituted C₂-C₄₀ alkynyl, substituted or unsubstituted C₃-C₄₀ aryl, substituted or unsubstituted C₃-C₄₀ cycloalkyl, substituted or unsubstituted C₃-C₄₀ cycloalkenyl, substituted or unsubstituted C₁-C₄₀ acyl, substituted or unsubstituted C₁-C₄₀ alkoxy, P(O)(OR^a)₂, SR^a, S(O)₂R^a, SiR^aR^bR^c, or NR^aR^b, or wherein, as valence permits, R¹⁵ and R¹⁶, together with the atoms to which they are attached, form a 3-10 membered substituted or unsubstituted cyclic moiety optionally including from 1 to 3 heteroatoms; and

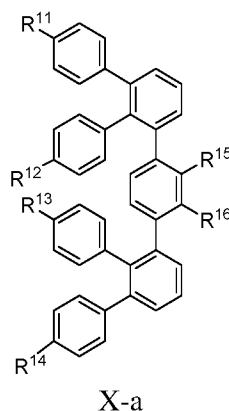
R^a, R^b, and R^c are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C₁-C₄₀ alkyl, substituted or unsubstituted C₂-C₄₀ alkenyl, substituted

or unsubstituted C₂-C₄₀ alkynyl, substituted or unsubstituted C₃-C₄₀ aryl, substituted or unsubstituted C₃-C₄₀ cycloalkyl, substituted or unsubstituted C₃-C₄₀ cycloalkenyl, substituted or unsubstituted C₁-C₄₀ acyl, or substituted or unsubstituted C₁-C₄₀ alkoxy.

5 In some examples of Formula X, R¹¹, R¹², R¹³, and R¹⁴ are independently substituted or unsubstituted C₁-C₂₀ alkyl. In some examples of Formula X, R¹¹, R¹², R¹³, and R¹⁴ are independently unsubstituted C₁-C₁₀ alkyl. In some examples of Formula X, R¹¹, R¹², R¹³, and R¹⁴ are the same.

10 In some examples of Formula X, R¹⁵ and R¹⁶ are independently hydrogen, halogen, hydroxyl, substituted or unsubstituted C₁-C₂₀ alkyl, substituted or unsubstituted C₁-C₂₀ acyl, or wherein, as valence permits, R¹⁵ and R¹⁶, together with the atoms to which they are attached, form a 3-10 membered substituted or unsubstituted cyclic moiety optionally including from 1 to 3 heteroatoms. In some examples of Formula X, R¹⁵ and R¹⁶ are independently hydrogen or unsubstituted C₁-C₅ acyl. In some examples of Formula X, R¹⁵ and R¹⁶ are the same. In some
15 examples of Formula X, R¹⁵ and R¹⁶ together with the atoms to which they are attached, form a 5-10 membered substituted or unsubstituted cyclic moiety optionally including from 1 to 3 heteroatoms.

In some examples of Formula X, the compounds can be defined by Formula X-a:



wherein

R¹¹, R¹², R¹³, R¹⁴, R¹⁵, and R¹⁶ are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C₁-C₄₀ alkyl, substituted or unsubstituted C₂-C₄₀ alkenyl, substituted or unsubstituted C₂-C₄₀ alkynyl, substituted or unsubstituted C₃-C₄₀ aryl, substituted or unsubstituted C₃-C₄₀ cycloalkyl, substituted or unsubstituted C₃-C₄₀ cycloalkenyl, substituted or unsubstituted C₁-C₄₀ acyl, substituted or unsubstituted C₁-C₄₀ alkoxy, P(O)(OR^a)₂, SR^a, S(O)₂R^a, SiR^aR^bR^c, or NR^aR^b, or

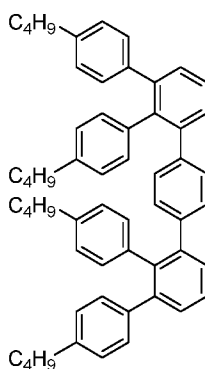
wherein, as valence permits, R^{15} and R^{16} , together with the atoms to which they are attached, form a 3-10 membered substituted or unsubstituted cyclic moiety optionally including from 1 to 3 heteroatoms; and

R^a , R^b , and R^c are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C_1 - C_{40} alkyl, substituted or unsubstituted C_2 - C_{40} alkenyl, substituted or unsubstituted C_2 - C_{40} alkynyl, substituted or unsubstituted C_3 - C_{40} aryl, substituted or unsubstituted C_3 - C_{40} cycloalkyl, substituted or unsubstituted C_3 - C_{40} cycloalkenyl, substituted or unsubstituted C_1 - C_{40} acyl, or substituted or unsubstituted C_1 - C_{40} alkoxy.

In some examples of Formula X-a, R^{11} , R^{12} , R^{13} , and R^{14} are independently substituted or unsubstituted C_1 - C_{20} alkyl. In some examples of Formula X-a, R^{11} , R^{12} , R^{13} , and R^{14} are independently unsubstituted C_1 - C_{10} alkyl. In some examples of Formula X-a, R^{11} , R^{12} , R^{13} , and R^{14} are the same.

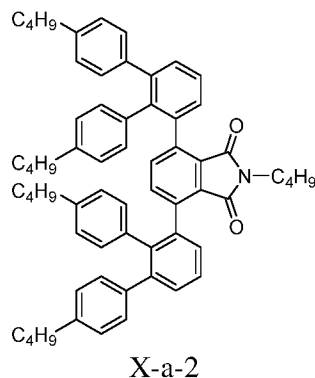
In some examples of Formula X-a, R^{15} and R^{16} are independently hydrogen, halogen, hydroxyl, substituted or unsubstituted C_1 - C_{20} alkyl, substituted or unsubstituted C_1 - C_{20} acyl, or wherein, as valence permits, R^{15} and R^{16} , together with the atoms to which they are attached, form a 3-10 membered substituted or unsubstituted cyclic moiety optionally including from 1 to 3 heteroatoms. In some examples of Formula X-a, R^{15} and R^{16} are independently hydrogen or unsubstituted C_1 - C_5 acyl. In some examples of Formula X-a, R^{15} and R^{16} are the same. In some examples of Formula X-a, R^{15} and R^{16} together with the atoms to which they are attached, form a 5-10 membered substituted or unsubstituted cyclic moiety optionally including from 1 to 3 heteroatoms.

In some examples of Formula X-a, the compounds can be defined by Formula X-a-1:

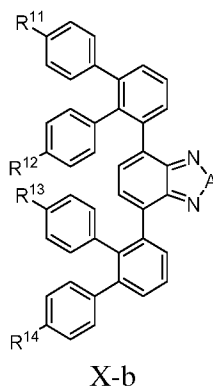


X-a-1

In some examples of Formula X-a, the compounds can be defined by Formula X-a-2:



In some examples of Formula X, the compounds can be defined by Formula X-b:



wherein

R^{11} , R^{12} , R^{13} , and R^{14} are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C_1 - C_{40} alkyl, substituted or unsubstituted C_2 - C_{40} alkenyl, substituted or unsubstituted C_2 - C_{40} alkynyl, substituted or unsubstituted C_3 - C_{40} aryl, substituted or unsubstituted C_3 - C_{40} cycloalkyl, substituted or unsubstituted C_3 - C_{40} cycloalkenyl, substituted or unsubstituted C_1 - C_{40} acyl, substituted or unsubstituted C_1 - C_{40} alkoxy, $P(O)(OR^a)_2$, SR^a , $S(O)_2R^a$, $SiR^aR^bR^c$, or NR^aR^b ;

A is O, S, Se, Te, or NR^a ; and

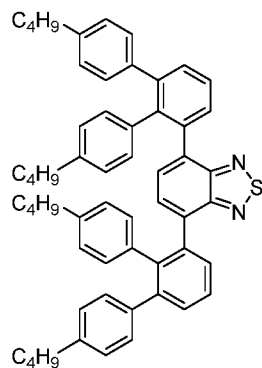
R^a , R^b , and R^c are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C_1 - C_{40} alkyl, substituted or unsubstituted C_2 - C_{40} alkenyl, substituted or unsubstituted C_2 - C_{40} alkynyl, substituted or unsubstituted C_3 - C_{40} aryl, substituted or unsubstituted C_3 - C_{40} cycloalkyl, substituted or unsubstituted C_3 - C_{40} cycloalkenyl, substituted or unsubstituted C_1 - C_{40} acyl, or substituted or unsubstituted C_1 - C_{40} alkoxy.

In some examples of Formula X-b, R^{11} , R^{12} , R^{13} , and R^{14} are independently substituted or unsubstituted C_1 - C_{20} alkyl. In some examples of Formula X-b, R^{11} , R^{12} , R^{13} , and R^{14} are

independently unsubstituted C₁-C₁₀ alkyl. In some examples of Formula X-b, R¹¹, R¹², R¹³, and R¹⁴ are the same.

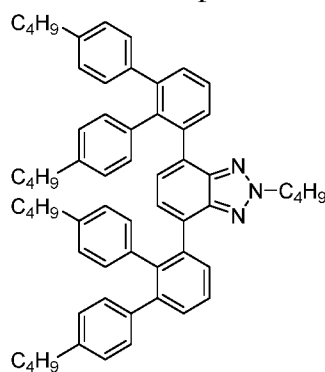
In some examples of Formula X-b, A is S or NR^a. In some examples of Formula X-b, A is NR^a and R^a is a substituted or unsubstituted C₁-C₂₀ alkyl. In some examples of Formula X-b,
5 A is NR^a and R^a is an unsubstituted C₁₋₁₀ alkyl.

In some examples of Formula X-b, the compounds can be defined by Formula X-b-1:



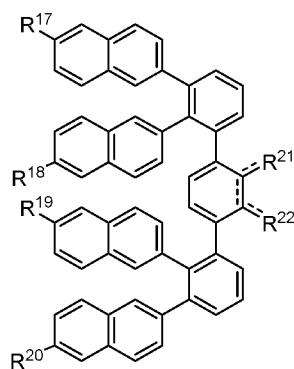
X-b-1

In some examples of Formula X-b, the compounds can be defined by Formula X-b-2:



X-b-2

Also disclosed herein are compounds defined by Formula XI:



XI

wherein

the dotted lines to R²¹, R²², and between the carbons within the ring to which R²¹ and R²² are bonded, independently indicate that the bond can be a single bond or a double bond, as valence permits;

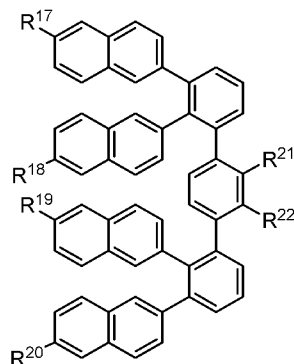
R¹⁷, R¹⁸, R¹⁹, R²⁰, R²¹, and R²² are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C₁-C₄₀ alkyl, substituted or unsubstituted C₂-C₄₀ alkenyl, substituted or unsubstituted C₂-C₄₀ alkynyl, substituted or unsubstituted C₃-C₄₀ aryl, substituted or unsubstituted C₃-C₄₀ cycloalkyl, substituted or unsubstituted C₃-C₄₀ cycloalkenyl, substituted or unsubstituted C₁-C₄₀ acyl, substituted or unsubstituted C₁-C₄₀ alkoxy, P(O)(OR^a)₂, SR^a, S(O)₂R^a, SiR^aR^bR^c, or NR^aR^b, or wherein, as valence permits, R²¹ and R²², together with the atoms to which they are attached, form a 3-10 membered substituted or unsubstituted cyclic moiety optionally including from 1 to 3 heteroatoms; and

R^a, R^b, and R^c are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C₁-C₄₀ alkyl, substituted or unsubstituted C₂-C₄₀ alkenyl, substituted or unsubstituted C₂-C₄₀ alkynyl, substituted or unsubstituted C₃-C₄₀ aryl, substituted or unsubstituted C₃-C₄₀ cycloalkyl, substituted or unsubstituted C₃-C₄₀ cycloalkenyl, substituted or unsubstituted C₁-C₄₀ acyl, or substituted or unsubstituted C₁-C₄₀ alkoxy.

In some examples of Formula XI, R¹⁷, R¹⁸, R¹⁹, and R²⁰ are independently substituted or unsubstituted C₁-C₂₀ alkyl. In some examples of Formula XI, R¹⁷, R¹⁸, R¹⁹, and R²⁰ are independently unsubstituted C₁-C₁₀ alkyl. In some examples of Formula XI, R¹⁷, R¹⁸, R¹⁹, and R²⁰ are the same.

In some examples of Formula XI, R²¹ and R²² are independently hydrogen, halogen, hydroxyl, substituted or unsubstituted C₁-C₂₀ alkyl, substituted or unsubstituted C₁-C₂₀ acyl, or wherein, as valence permits, R²¹ and R²², together with the atoms to which they are attached, form a 3-10 membered substituted or unsubstituted cyclic moiety optionally including from 1 to 3 heteroatoms. In some examples of Formula XI, R²¹ and R²² are independently hydrogen or unsubstituted C₁-C₅ acyl. In some examples of Formula XI, R²¹ and R²² are the same. In some examples of Formula XI, R²¹ and R²² together with the atoms to which they are attached, form a 5-10 membered substituted or unsubstituted cyclic moiety optionally including from 1 to 3 heteroatoms.

In some examples of Formula XI, the compounds can be defined by Formula XI-a:



XI-a

wherein

R^{17} , R^{18} , R^{19} , R^{20} , R^{21} , and R^{22} are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C_1 - C_{40} alkyl, substituted or unsubstituted C_2 - C_{40} alkenyl, substituted or unsubstituted C_2 - C_{40} alkynyl, substituted or unsubstituted C_3 - C_{40} aryl, substituted or unsubstituted C_3 - C_{40} cycloalkyl, substituted or unsubstituted C_3 - C_{40} cycloalkenyl, substituted or unsubstituted C_1 - C_{40} acyl, substituted or unsubstituted C_1 - C_{40} alkoxy, $P(O)(OR^a)_2$, SR^a , $S(O)_2R^a$, $SiR^aR^bR^c$, or NR^aR^b , or wherein, as valence permits, R^{21} and R^{22} , together with the atoms to which they are attached, form a 3-10 membered substituted or unsubstituted cyclic moiety optionally including from 1 to 3 heteroatoms; and

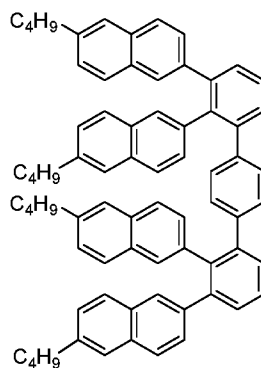
R^a , R^b , and R^c are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C_1 - C_{40} alkyl, substituted or unsubstituted C_2 - C_{40} alkenyl, substituted or unsubstituted C_2 - C_{40} alkynyl, substituted or unsubstituted C_3 - C_{40} aryl, substituted or unsubstituted C_3 - C_{40} cycloalkyl, substituted or unsubstituted C_3 - C_{40} cycloalkenyl, substituted or unsubstituted C_1 - C_{40} acyl, or substituted or unsubstituted C_1 - C_{40} alkoxy.

In some examples of Formula XI-a, R^{17} , R^{18} , R^{19} , and R^{20} are independently substituted or unsubstituted C_1 - C_{20} alkyl. In some examples of Formula XI-a, R^{17} , R^{18} , R^{19} , and R^{20} are independently unsubstituted C_1 - C_{10} alkyl. In some examples of Formula XI-a, R^{17} , R^{18} , R^{19} , and R^{20} are the same.

In some examples of Formula XI-a, R^{21} and R^{22} are independently hydrogen, halogen, hydroxyl, substituted or unsubstituted C_1 - C_{20} alkyl, substituted or unsubstituted C_1 - C_{20} acyl, or wherein, as valence permits, R^{21} and R^{22} , together with the atoms to which they are attached, form a 3-10 membered substituted or unsubstituted cyclic moiety optionally including from 1 to

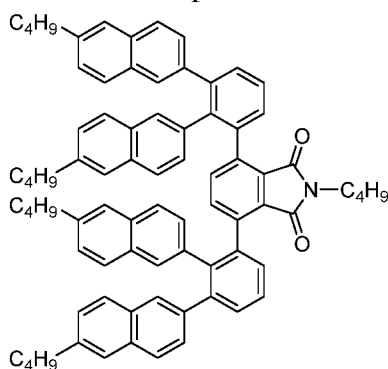
3 heteroatoms. In some examples of Formula XI-a, R^{21} and R^{22} are independently hydrogen or unsubstituted C_1 - C_5 acyl. In some examples of Formula XI-a, R^{21} and R^{22} are the same. In some examples of Formula XI-a, R^{21} and R^{22} together with the atoms to which they are attached, form a 5-10 membered substituted or unsubstituted cyclic moiety optionally including from 1 to 3 heteroatoms.

In some examples of Formula XI-a, the compounds can be defined by Formula XI-a-1.



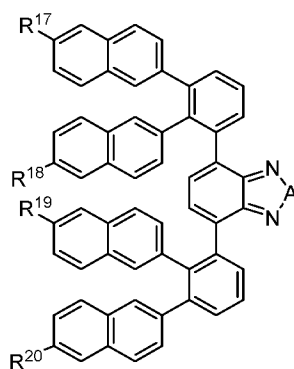
XI-a-1

In some examples of Formula XI-a, the compounds can be defined by Formula XI-a-2.



XI-a-2

In some examples of Formula XI, the compounds can be defined by Formula XI-b:



XI-b

wherein

R^{17} , R^{18} , R^{19} , and R^{20} are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C_1 - C_{40} alkyl, substituted or unsubstituted C_2 - C_{40} alkenyl, substituted or unsubstituted C_2 - C_{40} alkynyl, substituted or unsubstituted C_3 - C_{40} aryl, substituted or unsubstituted C_3 - C_{40} cycloalkyl, substituted or unsubstituted C_3 - C_{40} cycloalkenyl, substituted or unsubstituted C_1 - C_{40} acyl, substituted or unsubstituted C_1 - C_{40} alkoxy, $P(O)(OR^a)_2$, SR^a , $S(O)_2R^a$, $SiR^aR^bR^c$, or NR^aR^b ;

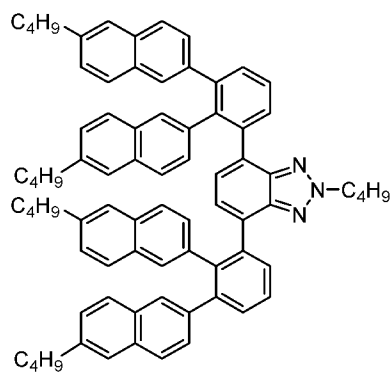
A is O, S, Se, Te, or NR^a ; and

R^a , R^b , and R^c are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C_1 - C_{40} alkyl, substituted or unsubstituted C_2 - C_{40} alkenyl, substituted or unsubstituted C_2 - C_{40} alkynyl, substituted or unsubstituted C_3 - C_{40} aryl, substituted or unsubstituted C_3 - C_{40} cycloalkyl, substituted or unsubstituted C_3 - C_{40} cycloalkenyl, substituted or unsubstituted C_1 - C_{40} acyl, or substituted or unsubstituted C_1 - C_{40} alkoxy.

In some examples of Formula XI-b, R^{17} , R^{18} , R^{19} , and R^{20} are independently substituted or unsubstituted C_1 - C_{20} alkyl. In some examples of Formula XI-b, R^{17} , R^{18} , R^{19} , and R^{20} are independently unsubstituted C_1 - C_{10} alkyl. In some examples of Formula XI-b, R^{17} , R^{18} , R^{19} , and R^{20} are the same.

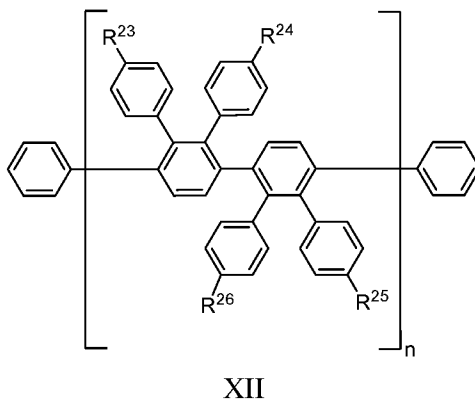
In some examples of Formula XI-b, A is S or NR^a . In some examples of Formula XI-b, A is NR^a and R^a is a substituted or unsubstituted C_1 - C_{20} alkyl. In some examples of Formula XI-b, A is NR^a and R^a is an unsubstituted C_{1-10} alkyl.

In some examples of Formula XI-b, the compounds can be defined by Formula XI-b-1.



XI-b-1

Also disclosed herein are compounds defined by Formula XII:



wherein

n is from 3 to 1000;

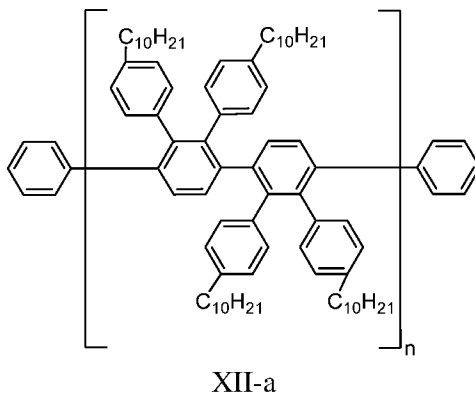
R^{23} , R^{24} , R^{25} , and R^{26} are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C_1 - C_{40} alkyl, substituted or unsubstituted C_2 - C_{40} alkenyl, substituted or unsubstituted C_2 - C_{40} alkynyl, substituted or unsubstituted C_3 - C_{40} aryl, substituted or unsubstituted C_3 - C_{40} cycloalkyl, substituted or unsubstituted C_3 - C_{40} cycloalkenyl, substituted or unsubstituted C_1 - C_{40} acyl, substituted or unsubstituted C_1 - C_{40} alkoxy, $P(O)(OR^a)_2$, SR^a , $S(O)_2R^a$, $SiR^aR^bR^c$, or NR^aR^b ; and

R^a , R^b , and R^c are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C_1 - C_{40} alkyl, substituted or unsubstituted C_2 - C_{40} alkenyl, substituted or unsubstituted C_2 - C_{40} alkynyl, substituted or unsubstituted C_3 - C_{40} aryl, substituted or unsubstituted C_3 - C_{40} cycloalkyl, substituted or unsubstituted C_3 - C_{40} cycloalkenyl, substituted or unsubstituted C_1 - C_{40} acyl, or substituted or unsubstituted C_1 - C_{40} alkoxy.

In some examples of Formula XII, R^{23} , R^{24} , R^{25} , and R^{26} are independently substituted or unsubstituted C_1 - C_{20} alkyl. In some examples of Formula XII, R^{23} , R^{24} , R^{25} , and R^{26} are independently unsubstituted C_2 - C_{15} alkyl. In some examples of Formula XII, R^{23} , R^{24} , R^{25} , and R^{26} are the same.

In some examples of Formula XII, n is from 3 to 500. In some examples of Formula XII, n is from 3 to 100. In some examples of Formula XII, n is from 3 to 50.

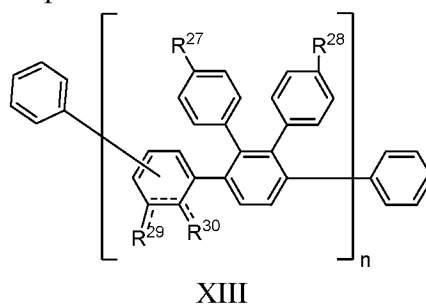
In some examples of Formula XII, the compound can be defined by Formula XII-a:



wherein n is from 3 to 1000.

5 In some examples of Formula XII-a, n is from 3 to 500. In some examples of Formula XII-a, n is from 3 to 100. In some examples of Formula XII-a, n is from 3 to 50.

Also disclosed herein are compounds of Formula XIII:



10 wherein
n is from 3 to 1000;
the dotted lines to R²⁹, R³⁰, and between the carbons within the ring to which R²⁹ and R³⁰
are bonded, independently indicate that the bond can be a single bond or a double
bond, as valence permits;
15 R²⁷, R²⁸, R²⁹, and R³⁰ are independently hydrogen, halogen, hydroxyl, cyano, nitro,
substituted or unsubstituted C₁-C₄₀ alkyl, substituted or unsubstituted C₂-C₄₀ alkenyl,
substituted or unsubstituted C₂-C₄₀ alkynyl, substituted or unsubstituted C₃-C₄₀ aryl,
substituted or unsubstituted C₃-C₄₀ cycloalkyl, substituted or unsubstituted C₃-C₄₀
cycloalkenyl, substituted or unsubstituted C₁-C₄₀ acyl, substituted or unsubstituted
20 C₁-C₄₀ alkoxy, P(O)(OR^a)₂, SR^a, S(O)₂R^a, SiR^aR^bR^c, or NR^aR^b, or wherein, as
valence permits, R²⁹ and R³⁰, together with the atoms to which they are attached,
form a 3-10 membered substituted or unsubstituted cyclic moiety optionally
including from 1 to 3 heteroatoms; and

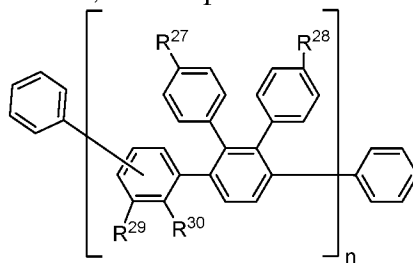
R^a , R^b , and R^c are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C_1 - C_{40} alkyl, substituted or unsubstituted C_2 - C_{40} alkenyl, substituted or unsubstituted C_2 - C_{40} alkynyl, substituted or unsubstituted C_3 - C_{40} aryl, substituted or unsubstituted C_3 - C_{40} cycloalkyl, substituted or unsubstituted C_3 - C_{40} cycloalkenyl, substituted or unsubstituted C_1 - C_{40} acyl, or substituted or unsubstituted C_1 - C_{40} alkoxy.

In some examples of Formula XIII, R^{27} and R^{28} are independently substituted or unsubstituted C_1 - C_{20} alkyl. In some examples of Formula XIII, R^{27} and R^{28} are independently unsubstituted C_2 - C_{15} alkyl. In some examples of Formula XIII, R^{27} and R^{28} are the same.

In some examples of Formula XIII, R^{29} and R^{30} are independently hydrogen, halogen, hydroxyl, substituted or unsubstituted C_1 - C_{20} alkyl, substituted or unsubstituted C_1 - C_{20} acyl, or wherein, as valence permits, R^{29} and R^{30} , together with the atoms to which they are attached, form a 3-10 membered substituted or unsubstituted cyclic moiety optionally including from 1 to 3 heteroatoms. In some examples of Formula XIII, R^{29} and R^{30} are independently hydrogen or unsubstituted C_1 - C_5 acyl. In some examples of Formula XIII, R^{29} and R^{30} are the same. In some examples of Formula XIII, R^{29} and R^{30} together with the atoms to which they are attached, form a 5-10 membered substituted or unsubstituted cyclic moiety optionally including from 1 to 3 heteroatoms.

In some examples of Formula XIII, n is from 3 to 500. In some examples of Formula XIII, n is from 3 to 100. In some examples of Formula XIII, n is from 3 to 50.

In some examples of Formula XIII, the compounds can be defined by Formula XIII-a:



XIII-a

wherein

n is from 3 to 1000;

R^{27} , R^{28} , R^{29} , and R^{30} are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C_1 - C_{40} alkyl, substituted or unsubstituted C_2 - C_{40} alkenyl, substituted or unsubstituted C_2 - C_{40} alkynyl, substituted or unsubstituted C_3 - C_{40} aryl, substituted or unsubstituted C_3 - C_{40} cycloalkyl, substituted or unsubstituted C_3 - C_{40}

cycloalkenyl, substituted or unsubstituted C₁-C₄₀ acyl, substituted or unsubstituted C₁-C₄₀ alkoxy, P(O)(OR^a)₂, SR^a, S(O)₂R^a, SiR^aR^bR^c, or NR^aR^b, or wherein, as valence permits, R²⁹ and R³⁰, together with the atoms to which they are attached, form a 3-10 membered substituted or unsubstituted cyclic moiety optionally including from 1 to 3 heteroatoms; and

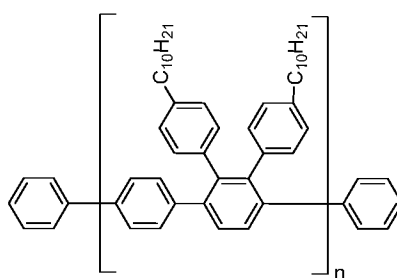
R^a, R^b, and R^c are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C₁-C₄₀ alkyl, substituted or unsubstituted C₂-C₄₀ alkenyl, substituted or unsubstituted C₂-C₄₀ alkynyl, substituted or unsubstituted C₃-C₄₀ aryl, substituted or unsubstituted C₃-C₄₀ cycloalkyl, substituted or unsubstituted C₃-C₄₀ cycloalkenyl, substituted or unsubstituted C₁-C₄₀ acyl, or substituted or unsubstituted C₁-C₄₀ alkoxy.

In some examples of Formula XIII-a, R²⁷ and R²⁸ are independently substituted or unsubstituted C₁-C₂₀ alkyl. In some examples of Formula XIII-a, R²⁷ and R²⁸ are independently unsubstituted C₂-C₁₅ alkyl. In some examples of Formula XIII-a, R²⁷ and R²⁸ are the same.

In some examples of Formula XIII-a, R²⁹ and R³⁰ are independently hydrogen, halogen, hydroxyl, substituted or unsubstituted C₁-C₂₀ alkyl, substituted or unsubstituted C₁-C₂₀ acyl, or wherein, as valence permits, R²⁹ and R³⁰, together with the atoms to which they are attached, form a 3-10 membered substituted or unsubstituted cyclic moiety optionally including from 1 to 3 heteroatoms. In some examples of Formula XIII-a, R²⁹ and R³⁰ are independently hydrogen or unsubstituted C₁-C₅ acyl. In some examples of Formula XIII-a, R²⁹ and R³⁰ are the same. In some examples of Formula XIII-a, R²⁹ and R³⁰ together with the atoms to which they are attached, form a 5-10 membered substituted or unsubstituted cyclic moiety optionally including from 1 to 3 heteroatoms.

In some examples of Formula XIII-a, n is from 3 to 500. In some examples of Formula XIII-a, n is from 3 to 100. In some examples of Formula XIII-a, n is from 3 to 50.

In some examples of Formula XIII-a, the compounds can be defined by Formula XIII-a-1:

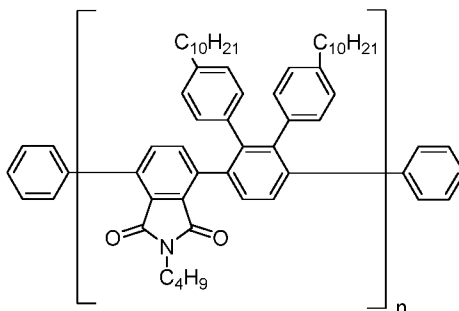


XIII-a-1

wherein n is from 3 to 1000.

In some examples of Formula XIII-a-1, n is from 3 to 500. In some examples of Formula XIII-a-1, n is from 3 to 100. In some examples of Formula XIII-a-1, n is from 3 to 50.

In some examples of Formula XIII-a, the compounds can be defined by Formula XIII-a-2:

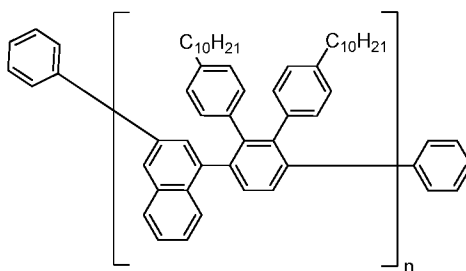


XIII-a-2

wherein n is from 3 to 1000.

In some examples of Formula XIII-a-2, n is from 3 to 500. In some examples of Formula XIII-a-2, n is from 3 to 100. In some examples of Formula XIII-a-2, n is from 3 to 50.

In some examples of Formula XIII-a, the compounds can be defined by Formula XIII-a-3:

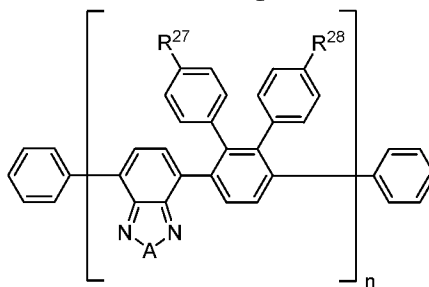


XIII-a-3

wherein n is from 3 to 1000.

In some examples of Formula XIII-a-3, n is from 3 to 500. In some examples of Formula XIII-a-3, n is from 3 to 100. In some examples of Formula XIII-a-3, n is from 3 to 50.

In some examples of Formula XIII, the compounds can be defined by Formula XIII-b:



XIII-b

wherein

n is from 3 to 1000;

R^{27} and R^{28} are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C_1 - C_{40} alkyl, substituted or unsubstituted C_2 - C_{40} alkenyl, substituted or unsubstituted C_2 - C_{40} alkynyl, substituted or unsubstituted C_3 - C_{40} aryl, substituted or unsubstituted C_3 - C_{40} cycloalkyl, substituted or unsubstituted C_3 - C_{40} cycloalkenyl, substituted or unsubstituted C_1 - C_{40} acyl, substituted or unsubstituted C_1 - C_{40} alkoxy, $P(O)(OR^a)_2$, SR^a , $S(O)_2R^a$, $SiR^aR^bR^c$, or NR^aR^b ;

A is O, S, Se, Te, or NR^a ; and

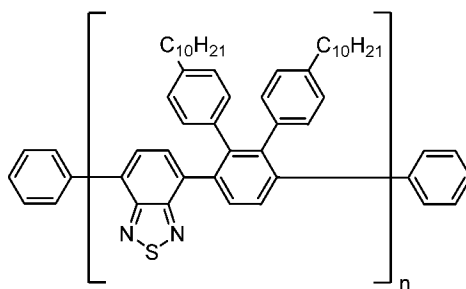
R^a , R^b , and R^c are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C_1 - C_{40} alkyl, substituted or unsubstituted C_2 - C_{40} alkenyl, substituted or unsubstituted C_2 - C_{40} alkynyl, substituted or unsubstituted C_3 - C_{40} aryl, substituted or unsubstituted C_3 - C_{40} cycloalkyl, substituted or unsubstituted C_3 - C_{40} cycloalkenyl, substituted or unsubstituted C_1 - C_{40} acyl, or substituted or unsubstituted C_1 - C_{40} alkoxy.

In some examples of Formula XIII-b, R^{27} and R^{28} are independently substituted or unsubstituted C_1 - C_{20} alkyl. In some examples of Formula XIII-b, R^{27} and R^{28} are independently unsubstituted C_2 - C_{15} alkyl. In some examples of Formula XIII-b, R^{27} and R^{28} are the same.

In some examples of Formula XIII-b, A is S or NR^a . In some examples of Formula XIII-b, A is NR^a and R^a is a substituted or unsubstituted C_1 - C_{20} alkyl. In some examples of Formula XIII-b, A is NR^a and R^a is an unsubstituted C_{1-10} alkyl.

In some examples of Formula XIII-b, n is from 3 to 500. In some examples of Formula XIII-b, n is from 3 to 100. In some examples of Formula XIII-b, n is from 3 to 50.

In some examples of Formula XIII-b, the compounds can be defined by Formula XIII-b-1:

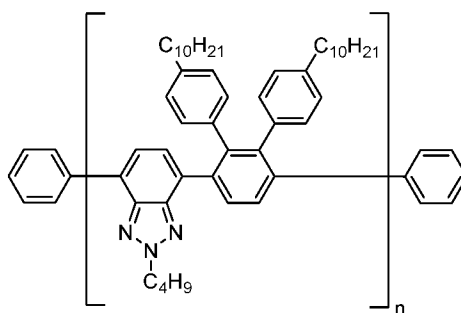


XIII-b-1

wherein n is from 3 to 1000.

In some examples of Formula XIII-b-1, n is from 3 to 500. In some examples of Formula XIII-b-1, n is from 3 to 100. In some examples of Formula XIII-b-1, n is from 3 to 50.

In some examples of Formula XIII-b, the compounds can be defined by Formula XIII-b-2:

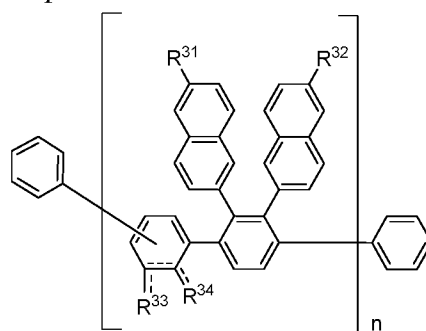


XIII-b-2

wherein n is from 3 to 1000.

In some examples of Formula XIII-b-2, n is from 3 to 500. In some examples of Formula XIII-b-2, n is from 3 to 100. In some examples of Formula XIII-b-2, n is from 3 to 50.

Also disclosed herein are compounds of Formula XIV



XIV

wherein

n is from 3 to 1000;

the dotted lines to R^{33} , R^{34} , and between the carbons within the ring to which R^{33} and R^{34} are bonded, independently indicate that the bond can be a single bond or a double bond, as valence permits;

R^{31} , R^{32} , R^{33} , and R^{34} are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C_1 - C_{40} alkyl, substituted or unsubstituted C_2 - C_{40} alkenyl, substituted or unsubstituted C_2 - C_{40} alkynyl, substituted or unsubstituted C_3 - C_{40} aryl, substituted or unsubstituted C_3 - C_{40} cycloalkyl, substituted or unsubstituted C_3 - C_{40} cycloalkenyl, substituted or unsubstituted C_1 - C_{40} acyl, substituted or unsubstituted C_1 - C_{40} alkoxy, $P(O)(OR^a)_2$, SR^a , $S(O)_2R^a$, $SiR^aR^bR^c$, or NR^aR^b , or wherein, as

valence permits, R^{33} and R^{34} , together with the atoms to which they are attached, form a 3-10 membered substituted or unsubstituted cyclic moiety optionally including from 1 to 3 heteroatoms; and

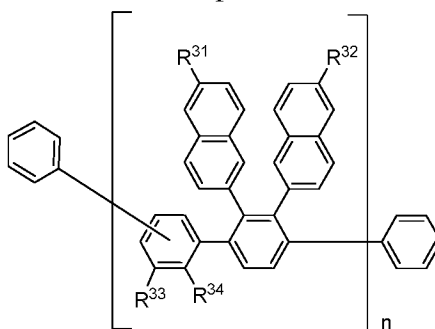
R^a , R^b , and R^c are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C_1 - C_{40} alkyl, substituted or unsubstituted C_2 - C_{40} alkenyl, substituted or unsubstituted C_2 - C_{40} alkynyl, substituted or unsubstituted C_3 - C_{40} aryl, substituted or unsubstituted C_3 - C_{40} cycloalkyl, substituted or unsubstituted C_3 - C_{40} cycloalkenyl, substituted or unsubstituted C_1 - C_{40} acyl, or substituted or unsubstituted C_1 - C_{40} alkoxy.

In some examples of Formula XIV, R^{31} and R^{32} are independently substituted or unsubstituted C_1 - C_{20} alkyl. In some examples of Formula XIV, R^{31} and R^{32} are independently unsubstituted C_2 - C_{15} alkyl. In some examples of Formula XIV, R^{31} and R^{32} are the same.

In some examples of Formula XIV, R^{33} and R^{34} are independently hydrogen, halogen, hydroxyl, substituted or unsubstituted C_1 - C_{20} alkyl, substituted or unsubstituted C_1 - C_{20} acyl, or wherein, as valence permits, R^{33} and R^{34} , together with the atoms to which they are attached, form a 3-10 membered substituted or unsubstituted cyclic moiety optionally including from 1 to 3 heteroatoms. In some examples of Formula XIV, R^{33} and R^{34} are independently hydrogen or unsubstituted C_1 - C_5 acyl. In some examples of Formula XIV, R^{33} and R^{34} are the same. In some examples of Formula XIV, R^{33} and R^{34} together with the atoms to which they are attached, form a 5-10 membered substituted or unsubstituted cyclic moiety optionally including from 1 to 3 heteroatoms.

In some examples of Formula XIV, n is from 3 to 500. In some examples of Formula XIV, n is from 3 to 100. In some examples of Formula XIV, n is from 3 to 50.

In some examples of Formula XIV, the compounds can be defined by Formula XIV-a:



XIV-a

wherein

n is from 3 to 1000;

R^{31} , R^{32} , R^{33} , and R^{34} are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C_1 - C_{40} alkyl, substituted or unsubstituted C_2 - C_{40} alkenyl, substituted or unsubstituted C_2 - C_{40} alkynyl, substituted or unsubstituted C_3 - C_{40} aryl, substituted or unsubstituted C_3 - C_{40} cycloalkyl, substituted or unsubstituted C_3 - C_{40} cycloalkenyl, substituted or unsubstituted C_1 - C_{40} acyl, substituted or unsubstituted C_1 - C_{40} alkoxy, $P(O)(OR^a)_2$, SR^a , $S(O)_2R^a$, $SiR^aR^bR^c$, or NR^aR^b , or wherein, as valence permits, R^{33} and R^{34} , together with the atoms to which they are attached, form a 3-10 membered substituted or unsubstituted cyclic moiety optionally including from 1 to 3 heteroatoms; and

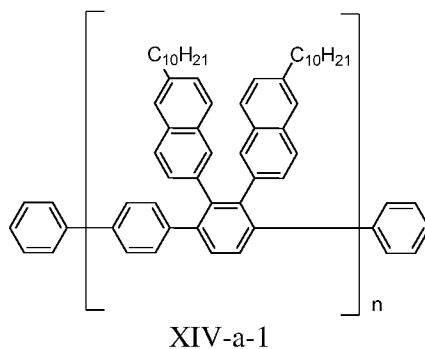
R^a , R^b , and R^c are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C_1 - C_{40} alkyl, substituted or unsubstituted C_2 - C_{40} alkenyl, substituted or unsubstituted C_2 - C_{40} alkynyl, substituted or unsubstituted C_3 - C_{40} aryl, substituted or unsubstituted C_3 - C_{40} cycloalkyl, substituted or unsubstituted C_3 - C_{40} cycloalkenyl, substituted or unsubstituted C_1 - C_{40} acyl, or substituted or unsubstituted C_1 - C_{40} alkoxy.

In some examples of Formula XIV-a, R^{31} and R^{32} are independently substituted or unsubstituted C_1 - C_{20} alkyl. In some examples of Formula XIV-a, R^{31} and R^{32} are independently unsubstituted C_2 - C_{15} alkyl. In some examples of Formula XIV-a, R^{31} and R^{32} are the same.

In some examples of Formula XIV-a, R^{33} and R^{34} are independently hydrogen, halogen, hydroxyl, substituted or unsubstituted C_1 - C_{20} alkyl, substituted or unsubstituted C_1 - C_{20} acyl, or wherein, as valence permits, R^{33} and R^{34} , together with the atoms to which they are attached, form a 3-10 membered substituted or unsubstituted cyclic moiety optionally including from 1 to 3 heteroatoms. In some examples of Formula XIV-a, R^{33} and R^{34} are independently hydrogen or unsubstituted C_1 - C_5 acyl. In some examples of Formula XIV-a, R^{33} and R^{34} are the same. In some examples of Formula XIV-a, R^{33} and R^{34} together with the atoms to which they are attached, form a 5-10 membered substituted or unsubstituted cyclic moiety optionally including from 1 to 3 heteroatoms.

In some examples of Formula XIV-a, n is from 3 to 500. In some examples of Formula XIV-a, n is from 3 to 100. In some examples of Formula XIV-a, n is from 3 to 50.

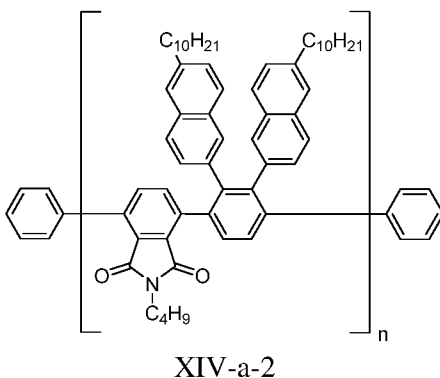
In some examples of Formula XIV-a, the compounds can be defined by Formula XIV-a-1:



wherein n is from 3 to 1000;

In some examples of Formula XIV-a-1, n is from 3 to 500. In some examples of Formula XIV-a-1, n is from 3 to 100. In some examples of Formula XIV-a-1, n is from 3 to 50.

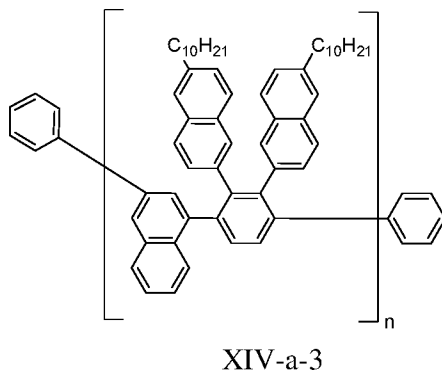
In some examples of Formula XIV-a, the compounds can be defined by Formula XIV-a-2:



wherein n is from 3 to 1000.

In some examples of Formula XIV-a-2, n is from 3 to 500. In some examples of Formula XIV-a-2, n is from 3 to 100. In some examples of Formula XIV-a-2, n is from 3 to 50.

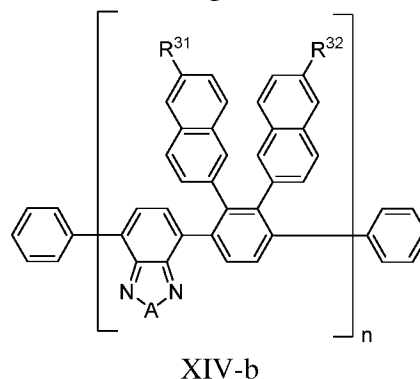
In some examples of Formula XIV-a, the compounds can be defined by Formula XIV-a-3:



wherein n is from 3 to 1000.

In some examples of Formula XIV-a-3, n is from 3 to 500. In some examples of Formula XIV-a-3, n is from 3 to 100. In some examples of Formula XIV-a-3, n is from 3 to 50.

In some examples of Formula XIV, the compounds can be defined by Formula XIV-b:



wherein

n is from 3 to 1000;

R^{31} and R^{32} are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C_1 - C_{40} alkyl, substituted or unsubstituted C_2 - C_{40} alkenyl, substituted or unsubstituted C_2 - C_{40} alkynyl, substituted or unsubstituted C_3 - C_{40} aryl, substituted or unsubstituted C_3 - C_{40} cycloalkyl, substituted or unsubstituted C_3 - C_{40} cycloalkenyl, substituted or unsubstituted C_1 - C_{40} acyl, substituted or unsubstituted C_1 - C_{40} alkoxy, $P(O)(OR^a)_2$, SR^a , $S(O)_2R^a$, $SiR^aR^bR^c$, or NR^aR^b ;

A is O, S, Se, Te, or NR^a ; and

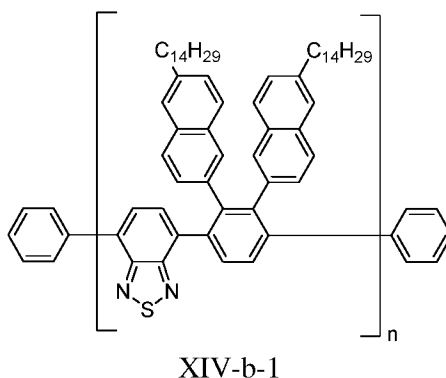
R^a , R^b , and R^c are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C_1 - C_{40} alkyl, substituted or unsubstituted C_2 - C_{40} alkenyl, substituted or unsubstituted C_2 - C_{40} alkynyl, substituted or unsubstituted C_3 - C_{40} aryl, substituted or unsubstituted C_3 - C_{40} cycloalkyl, substituted or unsubstituted C_3 - C_{40} cycloalkenyl, substituted or unsubstituted C_1 - C_{40} acyl, or substituted or unsubstituted C_1 - C_{40} alkoxy.

In some examples of Formula XIV-b, R^{31} and R^{32} are independently substituted or unsubstituted C_1 - C_{20} alkyl. In some examples of Formula XIV-b, R^{31} and R^{32} are independently unsubstituted C_2 - C_{15} alkyl. In some examples of Formula XIV-b, R^{31} and R^{32} are the same.

In some examples of Formula XIV-b, A is S or NR^a . In some examples of Formula XIV-b, A is NR^a and R^a is a substituted or unsubstituted C_1 - C_{20} alkyl. In some examples of Formula XIV-b, A is NR^a and R^a is an unsubstituted C_{1-10} alkyl.

In some examples of Formula XIV-b, n is from 3 to 500. In some examples of Formula XIV-b, n is from 3 to 100. In some examples of Formula XIV-b, n is from 3 to 50.

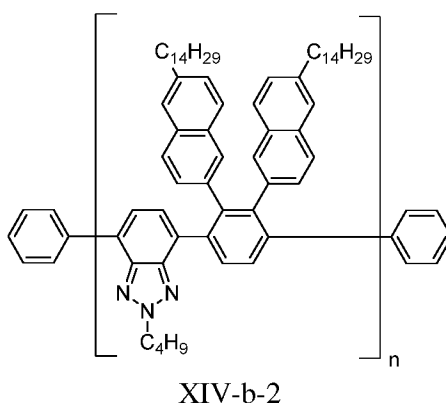
In some examples of Formula XIV-b, the compounds can be defined by Formula XIV-b-1:



wherein n is from 3 to 1000.

In some examples of Formula XIV-b-1, n is from 3 to 500. In some examples of Formula XIV-b-1, n is from 3 to 100. In some examples of Formula XIV-b-1, n is from 3 to 50.

In some examples of Formula XIV-b, the compounds can be defined by Formula XIV-b-2:



wherein n is from 3 to 1000.

In some examples of Formula XIV-b-2, n is from 3 to 500. In some examples of Formula XIV-b-2, n is from 3 to 100. In some examples of Formula XIV-b-2, n is from 3 to 50.

Methods of Making

The compounds described herein can be prepared in a variety of ways known to one skilled in the art of organic synthesis or variations thereon as appreciated by those skilled in the art. The compounds described herein can be prepared from readily available starting materials. Optimum reaction conditions can vary with the particular reactants or solvents used, but such conditions can be determined by one skilled in the art.

Variations on the compounds described herein include the addition, subtraction, or movement of the various constituents as described for each compound. Similarly, when one or more chiral centers are present in a molecule, the chirality of the molecule can be changed. Additionally, compound synthesis can involve the protection and deprotection of various chemical groups. The use of protection and deprotection, and the selection of appropriate protecting groups can be determined by one skilled in the art. The chemistry of protecting groups can be found, for example, in Wuts and Greene, *Protective Groups in Organic Synthesis*, 4th Ed., Wiley & Sons, 2006, which is incorporated herein by reference in its entirety.

The starting materials and reagents used in preparing the disclosed compounds and compositions are either available from commercial suppliers such as Aldrich Chemical Co., (Milwaukee, WI), Acros Organics (Morris Plains, NJ), Fisher Scientific (Pittsburgh, PA), Sigma (St. Louis, MO), Pfizer (New York, NY), GlaxoSmithKline (Raleigh, NC), Merck (Whitehouse Station, NJ), Johnson & Johnson (New Brunswick, NJ), Aventis (Bridgewater, NJ), AstraZeneca (Wilmington, DE), Novartis (Basel, Switzerland), Wyeth (Madison, NJ), Bristol-Myers-Squibb (New York, NY), Roche (Basel, Switzerland), Lilly (Indianapolis, IN), Abbott (Abbott Park, IL), Schering Plough (Kenilworth, NJ), or Boehringer Ingelheim (Ingelheim, Germany), or are prepared by methods known to those skilled in the art following procedures set forth in references such as Fieser and Fieser's *Reagents for Organic Synthesis*, Volumes 1-17 (John Wiley and Sons, 1991); Rodd's *Chemistry of Carbon Compounds*, Volumes 1-5 and Supplementals (Elsevier Science Publishers, 1989); *Organic Reactions*, Volumes 1-40 (John Wiley and Sons, 1991); March's *Advanced Organic Chemistry*, (John Wiley and Sons, 4th Edition); and Larock's *Comprehensive Organic Transformations* (VCH Publishers Inc., 1989). Other materials, such as the pharmaceutical carriers disclosed herein can be obtained from commercial sources.

Reactions to produce the compounds described herein can be carried out in solvents, which can be selected by one of skill in the art of organic synthesis. Solvents can be substantially nonreactive with the starting materials (reactants), the intermediates, or products under the conditions at which the reactions are carried out, *i.e.*, temperature and pressure. Reactions can be carried out in one solvent or a mixture of more than one solvent. Product or intermediate formation can be monitored according to any suitable method known in the art. For example, product formation can be monitored by spectroscopic means, such as nuclear magnetic resonance spectroscopy (*e.g.*, ^1H or ^{13}C) infrared spectroscopy, spectrophotometry (*e.g.*, UV-visible), or mass spectrometry, or by chromatography such as high performance liquid

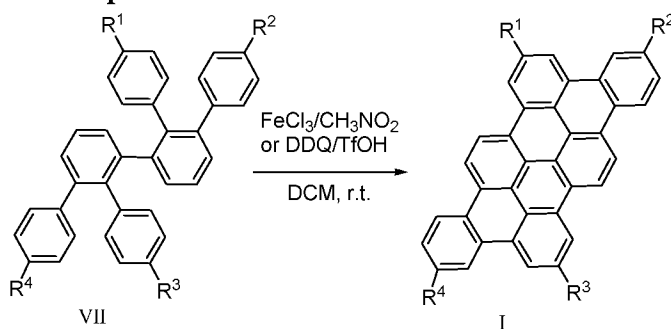
chromatography (HPLC) or thin layer chromatography.

Described herein are methods of making nanographenes (e.g., graphene with dimensions on the nanometer scale) and graphene nanoribbons. In some examples, the methods described herein can provide control over parameters such as the length, width, and/or edge structure of the compounds described herein. The electronic state of the graphitic compounds described herein can, for example, depend on the edge structure (e.g., armchair, zigzag, etc.). The methods described herein can, in some example, be used to make compounds with a certain edge structure.

Also disclosed herein are methods of making the compounds of Formulas I-VII. In some example, the methods of making the compounds of Formulas I-VII can comprise cyclodehydrogenating the compounds of Formulas VIII-XIV. In some examples, the cyclodehydrogenation can comprise, for example, contacting the compound with a Lewis acid and an oxidant, such as FeCl_3 and CH_3NO_2 . In some examples, the cyclodehydrogenation comprises contacting the compound with 2,3-dichloro-5,6-dicyano-1,4-benzoquinone and $\text{CF}_3\text{SO}_3\text{H}$.

In some examples, the method of making the compounds of Formula I can comprise cyclodehydrogenating a compound of Formula VIII, for example as shown in Scheme 1. In some examples, the method of making the compound of Formula I-a can comprise cyclodehydrogenating a compound of Formula VIII-a, for example as shown in Scheme 1 when R^1 , R^2 , R^3 and R^4 are each C_4H_9 .

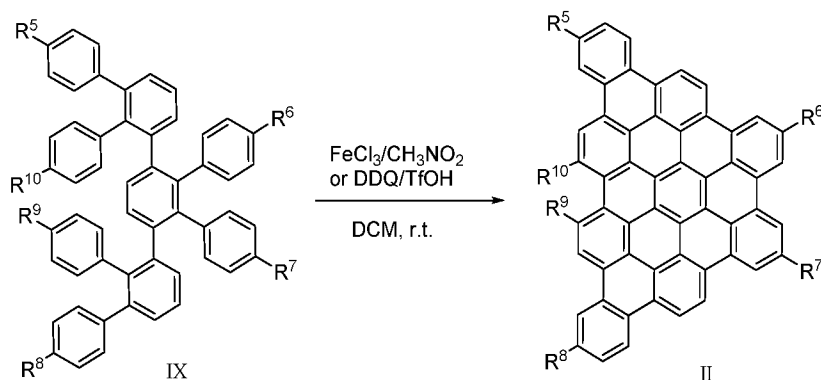
Scheme 1. Synthesis of compounds of Formula I.



In some examples, the method of making the compounds of Formula II can comprise cyclodehydrogenating a compound of Formula IX, for example as shown in Scheme 2. In some examples, the method of making the compound of Formula II-a can comprise

cyclodehydrogenating a compound of Formula IX-a, for example as shown in Scheme 2 when R^5 , R^6 , R^7 , R^8 , R^9 , and R^{10} are each C_4H_9 .

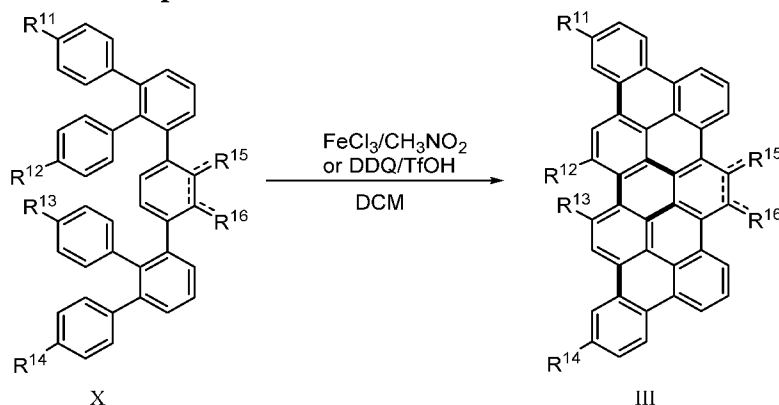
Scheme 2. Synthesis of compounds of Formula II.



In some examples, the method of making the compounds of Formula III can comprise cyclodehydrogenating a compound of Formula X, for example as shown in Scheme 3. In some examples, the method of making the compounds of Formula III-a can comprise cyclodehydrogenating a compound of Formula X-a, for example as shown in Scheme 3 when the dashed bonds to R^{15} and R^{16} are both single bonds, and the dashed bond within the ring is a double bond. In some examples, the method of making the compounds of Formula III-a-1 can comprise cyclodehydrogenating a compound of Formula X-a-1, for example as shown in Scheme 3 when each of R^{11} , R^{12} , R^{13} and R^{14} are C_4H_9 ; the dashed bonds to R^{15} and R^{16} are both single bonds; R^{15} and R^{16} are both hydrogen; and the dashed bond within the ring is a double bond. In some examples, the method of making the compounds of Formula III-b can comprise cyclodehydrogenating a compound of Formula X-b, for example as shown in Scheme 3 when the dashed bonds to R^{15} and R^{16} are both double bonds, the dashed bond within the ring is a single bond, and R^{15} and R^{16} together with the atoms to which they are attached form a 5 membered cyclic moiety with a N-A-N bridging group, wherein A is O, S, Se, Te, or NR^a . In some examples, the method of making the compounds of Formula III-b-1 can comprise cyclodehydrogenating a compound of Formula X-b-1, for example as shown in Scheme 3 when each of R^{11} , R^{12} , R^{13} and R^{14} are C_4H_9 ; the dashed bonds to R^{15} and R^{16} are both double bonds; the dashed bond within the ring is a single bond; and R^{15} and R^{16} together with the atoms to which they are attached form a 1,2,5-thiadiazole group. In some examples, the method of making the compounds of Formula III-b-2 can comprise cyclodehydrogenating a compound of Formula X-b-2, for example as shown in Scheme 3 when each of R^{11} , R^{12} , R^{13} and R^{14} are C_4H_9 ;

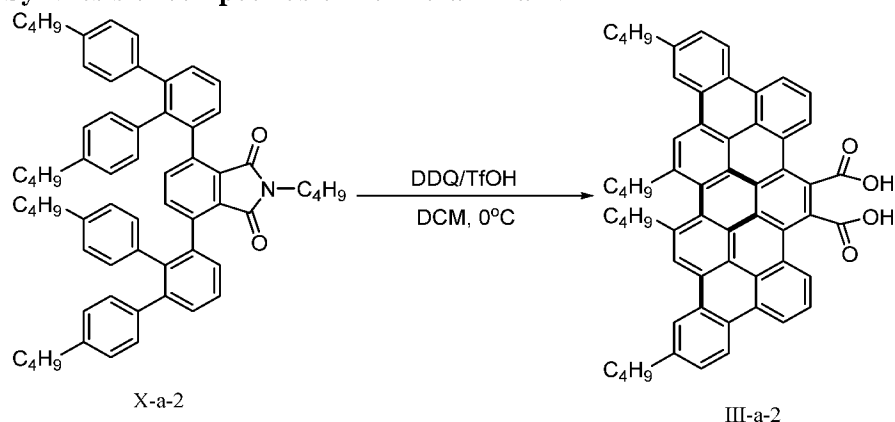
the dashed bonds to R¹⁵ and R¹⁶ are both double bonds; the dashed bond within the ring is a single bond; and R¹⁵ and R¹⁶ together with the atoms to which they are attached form a 2-butyl-2H-1,2,3-triazole group.

5 Scheme 3. Synthesis of compounds of Formula III.



In some examples, the method of making the compounds of Formula III-a-2 can comprise cyclodehydrogenating a compound of Formula X-a-2, for example as shown in Scheme 4.

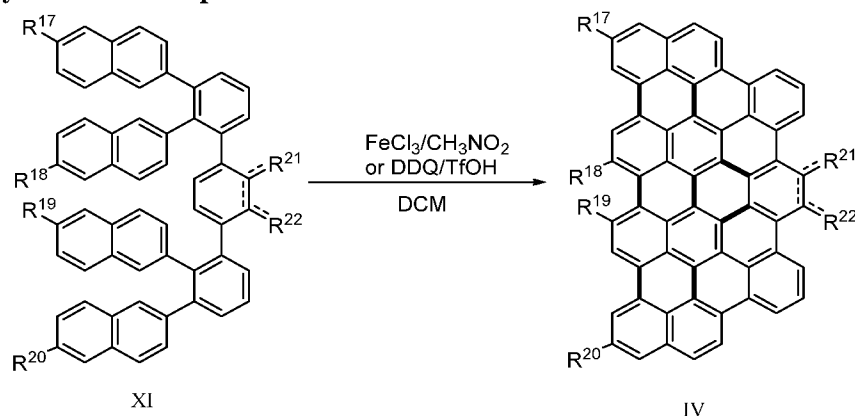
10 Scheme 4. Synthesis of compounds of Formula III-a-2.



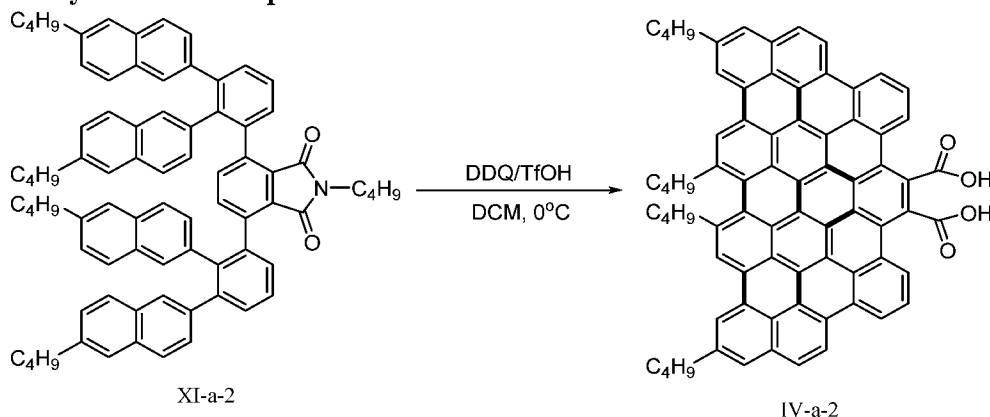
In some examples, the method of making the compounds of Formula IV can comprise cyclodehydrogenating a compound of Formula XI, for example as shown in Scheme 5. In some examples, the method of making the compounds of Formula IV-a can comprise cyclodehydrogenating a compound of Formula XI-a, for example as shown in Scheme 5 when the dashed bonds to R²¹ and R²² are both single bonds, and the dashed bond within the ring is a double bond. In some examples, the method of making the compounds of Formula IV-a-1 can

comprise cyclodehydrogenating a compound of Formula XI-a-1, for example as shown in Scheme 5 when each of R¹⁷, R¹⁸, R¹⁹ and R²⁰ are C₄H₉; the dashed bonds to R²¹ and R²² are both single bonds; R²¹ and R²² are both hydrogen; and the dashed bond within the ring is a double bond. In some examples, the method of making the compounds of Formula IV-b can comprise cyclodehydrogenating a compound of Formula XI-b, for example as shown in Scheme 5 when the dashed bonds to R²¹ and R²² are both double bonds, the dashed bond within the ring is a single bond, and R²¹ and R²² together with the atoms to which they are attached form a 5 membered cyclic moiety with a N-A-N bridging group, wherein A is O, S, Se, Te, or NR^a. In some examples, the method of making the compounds of Formula IV-b-1 can comprise cyclodehydrogenating a compound of Formula XI-b-1, for example as shown in Scheme 5 when each of R¹⁷, R¹⁸, R¹⁹ and R²⁰ are C₄H₉; the dashed bonds to R²¹ and R²² are both double bonds; the dashed bond within the ring is a single bond; and R²¹ and R²² together with the atoms to which they are attached form a 2-butyl-2*H*-1,2,3-triazole group.

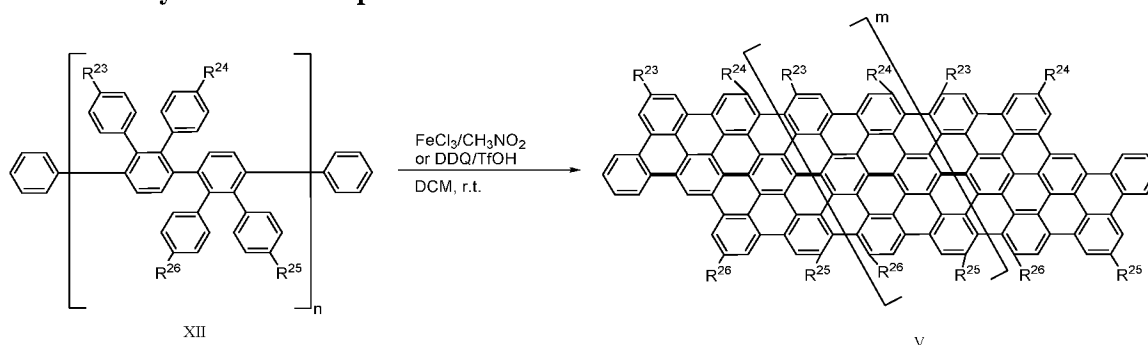
Scheme 5. Synthesis of compounds of Formula IV.



In some examples, the method of making the compounds of Formula IV-a-2 can comprise cyclodehydrogenating a compound of Formula XI-a-2, for example as shown in Scheme 6.

Scheme 6. Synthesis of compounds of Formula IV-a-2.

In some examples, the method of making the compounds of Formula V can comprise cyclodehydrogenating a compound of Formula XII, for example as shown in Scheme 7. In some examples, the method of making the compounds of Formula V-a, can comprise cyclodehydrogenating a compound of Formula XII-a, for example as shown in Scheme 7 when R^{23} , R^{24} , R^{25} and R^{26} are each $C_{10}H_{21}$.

Scheme 7. Synthesis of compounds of Formula V.

In some examples, the method of making the compounds of Formula VI can comprise cyclodehydrogenating a compound of Formula XIII, for example as shown in Scheme 8. In some examples, the method of making the compounds of Formula VI-a can comprise cyclodehydrogenating a compound of Formula XIII-a, for example as shown in Scheme 8 when the dashed bonds to R^{29} and R^{30} are both single bonds, and the dashed bond within the ring is a double bond. In some examples, the method of making the compounds of Formula VI-a-1 can comprise cyclodehydrogenating a compound of Formula XIII-a-1, for example as shown in Scheme 8 when R^{27} and R^{28} are $C_{10}H_{21}$; the dashed bonds to R^{29} and R^{30} are both single bonds; R^{29} and R^{30} are both hydrogen; and the dashed bond within the ring is a double bond. In some examples, the method of making the compounds of Formula VI-a-3 can comprise

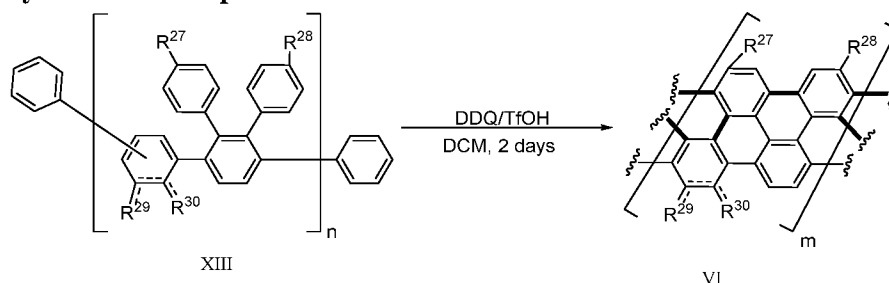
cyclodehydrogenating a compound of Formula XIII-a-3, for example as shown in Scheme 8 when R^{27} and R^{28} are $C_{10}H_{21}$; and R^{29} and R^{30} together with the atoms to which they are attached form a benzene ring. In some examples, the method of making the compounds of Formula VI-b can comprise cyclodehydrogenating a compound of Formula XIII-b, for example as shown in

5 Scheme 8 when the dashed bonds to R^{29} and R^{30} are both double bonds, the dashed bond within the ring is a single bond, and R^{29} and R^{30} together with the atoms to which they are attached form a 5 membered ring with a N-A-N bridging group, wherein A is O, S, Se, Te, or NR^a . In some examples, the method of making the compounds of Formula VI-b-1 can comprise cyclodehydrogenating a compound of Formula XIII-b-1, for example as shown in Scheme 8

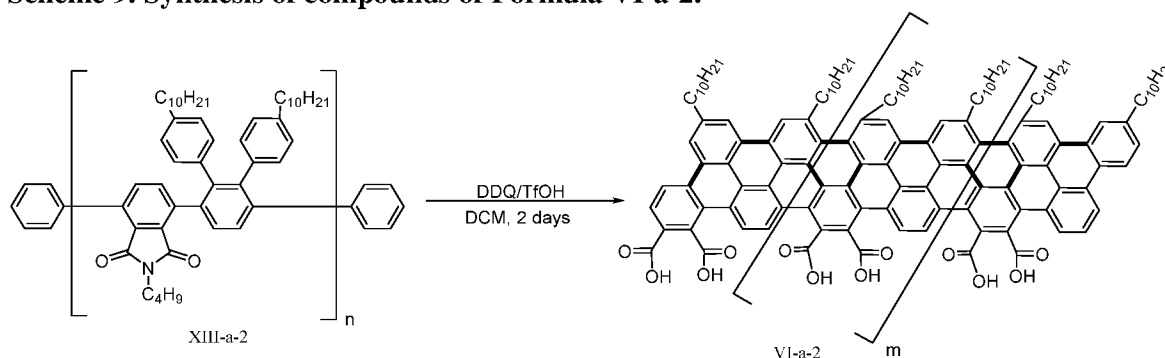
10 when R^{27} and R^{28} $C_{10}H_{21}$; the dashed bonds to R^{29} and R^{30} are both double bonds; the dashed bond within the ring is a single bond; and R^{29} and R^{30} together with the atoms to which they are attached form a 1,2,5-thiadiazole group. In some examples, the method of making the compounds of Formula VI-b-2 can comprise cyclodehydrogenating a compound of Formula XIII-b-2, for example as shown in Scheme 8 when each of R^{27} and R^{28} are $C_{10}H_{21}$; the dashed

15 bonds to R^{29} and R^{30} are both double bonds; the dashed bond within the ring is a single bond; and R^{29} and R^{30} together with the atoms to which they are attached form a 2-butyl-2*H*-1,2,3-triazole group.

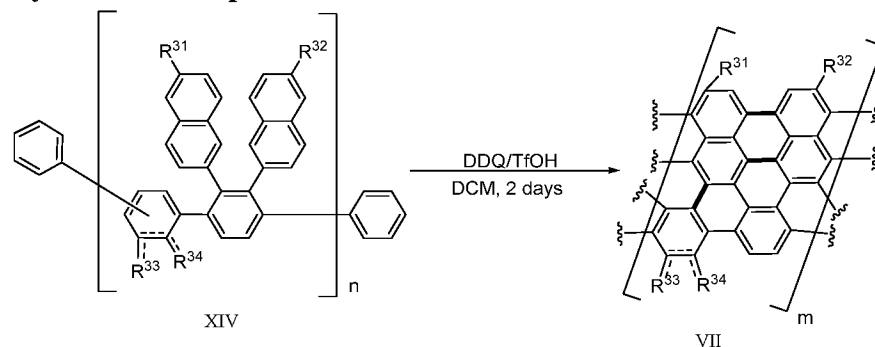
Scheme 8. Synthesis of compounds of Formula VI.



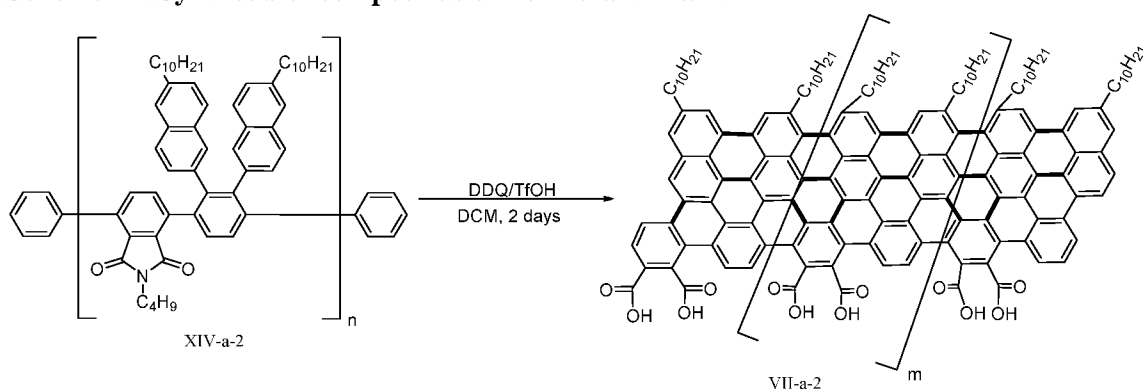
In some examples, the method of making the compounds of Formula VI-a-2 can comprise cyclodehydrogenating a compound of Formula XIII-a-2, for example as shown in Scheme 9.

Scheme 9. Synthesis of compounds of Formula VI-a-2.

In some examples, the method of making the compounds of Formula VII can comprise cyclodehydrogenating a compound of Formula XIV, for example as shown in Scheme 10. In some examples, the method of making the compounds of Formula VII-a can comprise cyclodehydrogenating a compound of Formula XIV-a, for example as shown in Scheme 10 when the dashed bonds to R^{33} and R^{34} are both single bonds, and the dashed bond within the ring is a double bond. In some examples, the method of making the compounds of Formula VII-a-1 can comprise cyclodehydrogenating a compound of Formula XIV-a-1, for example as shown in Scheme 10 when R^{31} and R^{32} are $C_{10}H_{21}$; the dashed bonds to R^{33} and R^{34} are both single bonds; R^{33} and R^{34} are both hydrogen; and the dashed bond within the ring is a double bond. In some examples, the method of making the compounds of Formula VII-a-3 can comprise cyclodehydrogenating a compound of Formula XIV-a-3, for example as shown in Scheme 10 when R^{31} and R^{32} are $C_{10}H_{21}$; and R^{33} and R^{34} together with the atoms to which they are attached form a benzene ring. In some examples, the method of making the compounds of Formula VII-b can comprise cyclodehydrogenating a compound of Formula XIV-b, for example as shown in Scheme 10 when the dashed bonds to R^{33} and R^{34} are both double bonds, the dashed bond within the ring is a single bond, and R^{33} and R^{34} together with the atoms to which they are attached form a 5 membered ring with a N-A-N bridging group, wherein A is O, S, Se, Te, or NR^a . In some examples, the method of making the compounds of Formula VII-b-1 can comprise cyclodehydrogenating a compound of Formula XIV-b-1, for example as shown in Scheme 10 when R^{31} and R^{32} are $C_{14}H_{29}$; the dashed bonds to R^{33} and R^{34} are both double bonds; the dashed bond within the ring is a single bond; and R^{33} and R^{34} together with the atoms to which they are attached form a 1,2,5-thiadiazole group.

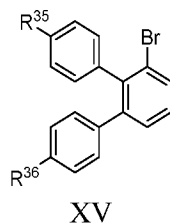
Scheme 10. Synthesis of compounds of Formula VII.

In some examples, the method of making the compounds of Formula VII-a-2 can comprise cyclodehydrogenating a compound of Formula XIV-a-2, for example as shown in Scheme 11.

Scheme 11. Synthesis of compounds of Formula VII-a-2.

Also disclosed herein are methods of making the compounds of Formulas VIII-XIV. The methods of making the compounds of Formulas VIII-XIV can comprise, for example, performing a polycondensation reaction between an aryl bromide and an aryl boronate ester. The polycondensation reaction can comprise, for example, a Suzuki-Miyaura cross coupling reaction.

In some examples, the aryl bromide can comprise a compound of Formula XV:



wherein

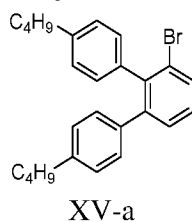
R^{35} and R^{36} are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C_1 - C_{40} alkyl, substituted or unsubstituted C_2 - C_{40} alkenyl, substituted or

unsubstituted C₂-C₄₀ alkynyl, substituted or unsubstituted C₃-C₄₀ aryl, substituted or unsubstituted C₃-C₄₀ cycloalkyl, substituted or unsubstituted C₃-C₄₀ cycloalkenyl, substituted or unsubstituted C₁-C₄₀ acyl, substituted or unsubstituted C₁-C₄₀ alkoxy, P(O)(OR^a)₂, SR^a, S(O)₂R^a, SiR^aR^bR^c, or NR^aR^b; and

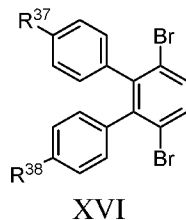
R^a, R^b, and R^c are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C₁-C₄₀ alkyl, substituted or unsubstituted C₂-C₄₀ alkenyl, substituted or unsubstituted C₂-C₄₀ alkynyl, substituted or unsubstituted C₃-C₄₀ aryl, substituted or unsubstituted C₃-C₄₀ cycloalkyl, substituted or unsubstituted C₃-C₄₀ cycloalkenyl, substituted or unsubstituted C₁-C₄₀ acyl, or substituted or unsubstituted C₁-C₄₀ alkoxy.

In some examples of Formula XV, R³⁵ and R³⁶ are independently substituted or unsubstituted C₁-C₂₀ alkyl. In some examples of Formula XV, R³⁵ and R³⁶ are the same.

In some examples of Formula XV, the aryl bromide can be defined by Formula XV-a.



In some examples, the aryl bromide can comprise a compound of Formula XVI:



wherein

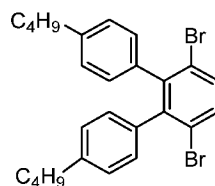
R³⁷ and R³⁸ are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C₁-C₄₀ alkyl, substituted or unsubstituted C₂-C₄₀ alkenyl, substituted or unsubstituted C₂-C₄₀ alkynyl, substituted or unsubstituted C₃-C₄₀ aryl, substituted or unsubstituted C₃-C₄₀ cycloalkyl, substituted or unsubstituted C₃-C₄₀ cycloalkenyl, substituted or unsubstituted C₁-C₄₀ acyl, substituted or unsubstituted C₁-C₄₀ alkoxy, P(O)(OR^a)₂, SR^a, S(O)₂R^a, SiR^aR^bR^c, or NR^aR^b; and

R^a, R^b, and R^c are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C₁-C₄₀ alkyl, substituted or unsubstituted C₂-C₄₀ alkenyl, substituted or unsubstituted C₂-C₄₀ alkynyl, substituted or unsubstituted C₃-C₄₀ aryl, substituted

or unsubstituted C₃-C₄₀ cycloalkyl, substituted or unsubstituted C₃-C₄₀ cycloalkenyl, substituted or unsubstituted C₁-C₄₀ acyl, or substituted or unsubstituted C₁-C₄₀ alkoxy.

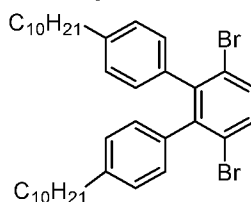
In some examples of Formula XVI, R³⁷ and R³⁸ are independently substituted or unsubstituted C₁-C₂₀ alkyl. In some examples of Formula XVI, R³⁷ and R³⁸ are the same.

In some examples of Formula XVI, the aryl bromide can be defined by Formula XVI-a.



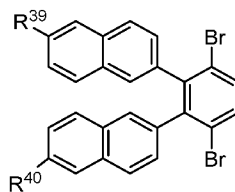
XVI-a

In some examples of Formula XVI, the aryl bromide can be defined by Formula XVI-b.



XVI-b

In some examples, the aryl bromide can comprise a compound of Formula XVII:



XVII

wherein

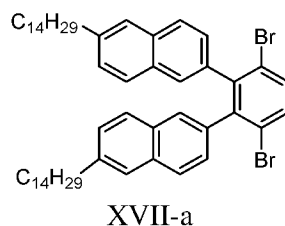
R³⁹ and R⁴⁰ are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C₁-C₄₀ alkyl, substituted or unsubstituted C₂-C₄₀ alkenyl, substituted or unsubstituted C₂-C₄₀ alkynyl, substituted or unsubstituted C₃-C₄₀ aryl, substituted or unsubstituted C₃-C₄₀ cycloalkyl, substituted or unsubstituted C₃-C₄₀ cycloalkenyl, substituted or unsubstituted C₁-C₄₀ acyl, substituted or unsubstituted C₁-C₄₀ alkoxy, P(O)(OR^a)₂, SR^a, S(O)₂R^a, SiR^aR^bR^c, or NR^aR^b; and

R^a, R^b, and R^c are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C₁-C₄₀ alkyl, substituted or unsubstituted C₂-C₄₀ alkenyl, substituted or unsubstituted C₂-C₄₀ alkynyl, substituted or unsubstituted C₃-C₄₀ aryl, substituted or unsubstituted C₃-C₄₀ cycloalkyl, substituted or unsubstituted C₃-C₄₀ cycloalkenyl,

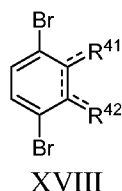
substituted or unsubstituted C₁-C₄₀ acyl, or substituted or unsubstituted C₁-C₄₀ alkoxy.

In some examples of Formula XVII, R³⁹ and R⁴⁰ are independently substituted or unsubstituted C₁-C₂₀ alkyl. In some examples of Formula XVII, R³⁹ and R⁴⁰ are the same.

5 In some examples of Formula XVII, the aryl bromide can comprise a compound of Formula XVII-a.



In some examples, the aryl bromide can comprise a compound of Formula XVIII:



wherein

the dotted lines to R⁴¹, R⁴², and between the carbons within the ring to which R⁴¹ and R⁴² are bonded, independently indicate that the bond can be a single bond or a double bond, as valence permits;

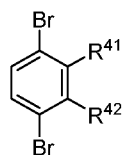
15 R⁴¹ and R⁴² are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C₁-C₄₀ alkyl, substituted or unsubstituted C₂-C₄₀ alkenyl, substituted or unsubstituted C₂-C₄₀ alkynyl, substituted or unsubstituted C₃-C₄₀ aryl, substituted or unsubstituted C₃-C₄₀ cycloalkyl, substituted or unsubstituted C₃-C₄₀ cycloalkenyl, substituted or unsubstituted C₁-C₄₀ acyl, substituted or unsubstituted C₁-C₄₀ alkoxy, P(O)(OR^a)₂, SR^a, S(O)₂R^a, SiR^aR^bR^c, or NR^aR^b, or wherein, as valence permits, R⁴¹ and R⁴², together with the atoms to which they are attached, form a 3-10 membered substituted or unsubstituted cyclic moiety optionally including from 1 to 3 heteroatoms; and

25 R^a, R^b, and R^c are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C₁-C₄₀ alkyl, substituted or unsubstituted C₂-C₄₀ alkenyl, substituted or unsubstituted C₂-C₄₀ alkynyl, substituted or unsubstituted C₃-C₄₀ aryl, substituted or unsubstituted C₃-C₄₀ cycloalkyl, substituted or unsubstituted C₃-C₄₀ cycloalkenyl,

substituted or unsubstituted C₁-C₄₀ acyl, or substituted or unsubstituted C₁-C₄₀ alkoxy.

In some examples of Formula XVIII, R⁴¹ and R⁴² are independently hydrogen, halogen, hydroxyl, substituted or unsubstituted C₁-C₂₀ alkyl, substituted or unsubstituted C₁-C₂₀ acyl, or
 5 wherein, as valence permits, R⁴¹ and R⁴², together with the atoms to which they are attached, form a 3-10 membered substituted or unsubstituted cyclic moiety optionally including from 1 to 3 heteroatoms. In some examples of Formula XVIII, R⁴¹ and R⁴² are independently hydrogen or unsubstituted C₁-C₅ acyl. In some examples of Formula XVIII, R⁴¹ and R⁴² are the same. In some examples of Formula XVIII, R⁴¹ and R⁴² together with the atoms to which they are
 10 attached, form a 5-10 membered substituted or unsubstituted cyclic moiety optionally including from 1 to 3 heteroatoms.

In some examples of Formula XVIII, the aryl bromide can comprise a compound of Formula XVIII-a:



XVIII-a

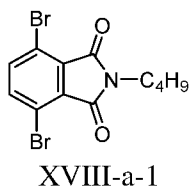
wherein

R⁴¹ and R⁴² are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C₁-C₄₀ alkyl, substituted or unsubstituted C₂-C₄₀ alkenyl, substituted or unsubstituted C₂-C₄₀ alkynyl, substituted or unsubstituted C₃-C₄₀ aryl, substituted or
 20 unsubstituted C₃-C₄₀ cycloalkyl, substituted or unsubstituted C₃-C₄₀ cycloalkenyl, substituted or unsubstituted C₁-C₄₀ acyl, substituted or unsubstituted C₁-C₄₀ alkoxy, P(O)(OR^a)₂, SR^a, S(O)₂R^a, SiR^aR^bR^c, or NR^aR^b, or wherein, as valence permits, R⁴¹ and R⁴², together with the atoms to which they are attached, form a 3-10 membered substituted or unsubstituted cyclic moiety optionally including from 1 to 3
 25 heteroatoms; and

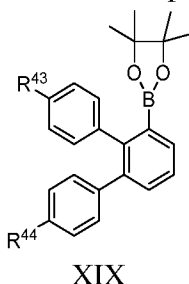
R^a, R^b, and R^c are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C₁-C₄₀ alkyl, substituted or unsubstituted C₂-C₄₀ alkenyl, substituted or unsubstituted C₂-C₄₀ alkynyl, substituted or unsubstituted C₃-C₄₀ aryl, substituted or unsubstituted C₃-C₄₀ cycloalkyl, substituted or unsubstituted C₃-C₄₀ cycloalkenyl,
 30 substituted or unsubstituted C₁-C₄₀ acyl, or substituted or unsubstituted C₁-C₄₀ alkoxy.

In some examples of Formula XVIII-a, R^{41} and R^{42} are independently hydrogen, halogen, hydroxyl, substituted or unsubstituted C_1 - C_{20} alkyl, substituted or unsubstituted C_1 - C_{20} acyl, or wherein, as valence permits, R^{41} and R^{42} , together with the atoms to which they are attached, form a 3-10 membered substituted or unsubstituted cyclic moiety optionally including from 1 to 3 heteroatoms. In some examples of Formula XVIII-a, R^{41} and R^{42} are independently hydrogen or unsubstituted C_1 - C_5 acyl. In some examples of Formula XVIII-a, R^{41} and R^{42} are the same. In some examples of Formula XVIII-a, R^{41} and R^{42} together with the atoms to which they are attached, form a 5-10 membered substituted or unsubstituted cyclic moiety optionally including from 1 to 3 heteroatoms.

In some examples of Formula XVIII-a, the aryl bromide can comprise a compound of Formula XVIII-a-1.



In some examples, the aryl boronate ester can comprise a compound of Formula XIX:



wherein

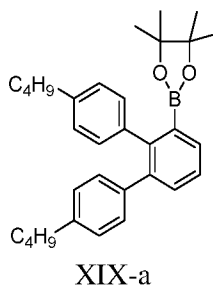
R^{43} and R^{44} are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C_1 - C_{40} alkyl, substituted or unsubstituted C_2 - C_{40} alkenyl, substituted or unsubstituted C_2 - C_{40} alkynyl, substituted or unsubstituted C_3 - C_{40} aryl, substituted or unsubstituted C_3 - C_{40} cycloalkyl, substituted or unsubstituted C_3 - C_{40} cycloalkenyl, substituted or unsubstituted C_1 - C_{40} acyl, substituted or unsubstituted C_1 - C_{40} alkoxy, $P(O)(OR^a)_2$, SR^a , $S(O)_2R^a$, $SiR^aR^bR^c$, or NR^aR^b ; and

R^a , R^b , and R^c are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C_1 - C_{40} alkyl, substituted or unsubstituted C_2 - C_{40} alkenyl, substituted or unsubstituted C_2 - C_{40} alkynyl, substituted or unsubstituted C_3 - C_{40} aryl, substituted or unsubstituted C_3 - C_{40} cycloalkyl, substituted or unsubstituted C_3 - C_{40} cycloalkenyl,

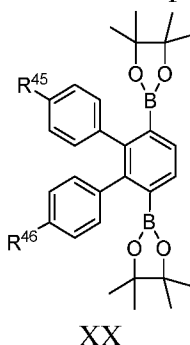
substituted or unsubstituted C₁-C₄₀ acyl, or substituted or unsubstituted C₁-C₄₀ alkoxy.

In some examples of Formula XIX, R⁴³ and R⁴⁴ are independently substituted or unsubstituted C₁-C₂₀ alkyl. In some examples of Formula XIX, R⁴³ and R⁴⁴ are the same.

5 In some examples of Formula XIX, the aryl boronate ester can be defined by Formula XIX-a.



In some examples, the aryl boronate ester can comprise a compound of Formula XX:



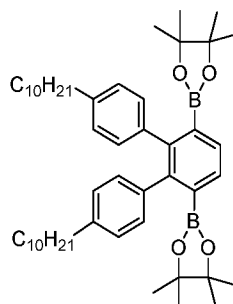
wherein

R⁴⁵ and R⁴⁶ are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C₁-C₄₀ alkyl, substituted or unsubstituted C₂-C₄₀ alkenyl, substituted or unsubstituted C₂-C₄₀ alkynyl, substituted or unsubstituted C₃-C₄₀ aryl, substituted or unsubstituted C₃-C₄₀ cycloalkyl, substituted or unsubstituted C₃-C₄₀ cycloalkenyl, substituted or unsubstituted C₁-C₄₀ acyl, substituted or unsubstituted C₁-C₄₀ alkoxy, P(O)(OR^a)₂, SR^a, S(O)₂R^a, SiR^aR^bR^c, or NR^aR^b; and

R^a, R^b, and R^c are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C₁-C₄₀ alkyl, substituted or unsubstituted C₂-C₄₀ alkenyl, substituted or unsubstituted C₂-C₄₀ alkynyl, substituted or unsubstituted C₃-C₄₀ aryl, substituted or unsubstituted C₃-C₄₀ cycloalkyl, substituted or unsubstituted C₃-C₄₀ cycloalkenyl, substituted or unsubstituted C₁-C₄₀ acyl, or substituted or unsubstituted C₁-C₄₀ alkoxy.

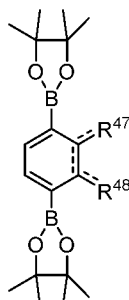
In some examples of Formula XX, R⁴⁵ and R⁴⁶ are independently substituted or unsubstituted C₁-C₂₀ alkyl. In some examples of Formula XX, R⁴⁵ and R⁴⁶ are the same.

In some examples of Formula XX, the aryl boronate ester can comprise a compound of Formula XX-a.



XX-a

In some examples, the aryl boronate ester can comprise a compound of Formula XXI:



XXI

wherein

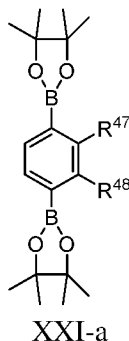
the dotted lines to R⁴⁷, R⁴⁸, and between the carbons within the ring to which R⁴⁷ and R⁴⁸ are bonded, independently indicate that the bond can be a single bond or a double bond, as valence permits;

R⁴⁷ and R⁴⁸ are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C₁-C₄₀ alkyl, substituted or unsubstituted C₂-C₄₀ alkenyl, substituted or unsubstituted C₂-C₄₀ alkynyl, substituted or unsubstituted C₃-C₄₀ aryl, substituted or unsubstituted C₃-C₄₀ cycloalkyl, substituted or unsubstituted C₃-C₄₀ cycloalkenyl, substituted or unsubstituted C₁-C₄₀ acyl, substituted or unsubstituted C₁-C₄₀ alkoxy, P(O)(OR^a)₂, SR^a, S(O)₂R^a, SiR^aR^bR^c, or NR^aR^b, or wherein, as valence permits, R⁴⁷ and R⁴⁸, together with the atoms to which they are attached, form a 3-10 membered substituted or unsubstituted cyclic moiety optionally including from 1 to 3 heteroatoms; and

R^a , R^b , and R^c are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C_1 - C_{40} alkyl, substituted or unsubstituted C_2 - C_{40} alkenyl, substituted or unsubstituted C_2 - C_{40} alkynyl, substituted or unsubstituted C_3 - C_{40} aryl, substituted or unsubstituted C_3 - C_{40} cycloalkyl, substituted or unsubstituted C_3 - C_{40} cycloalkenyl, substituted or unsubstituted C_1 - C_{40} acyl, or substituted or unsubstituted C_1 - C_{40} alkoxy.

In some examples of Formula XXI, R^{47} and R^{48} are independently hydrogen, halogen, hydroxyl, substituted or unsubstituted C_1 - C_{20} alkyl, substituted or unsubstituted C_1 - C_{20} acyl, or wherein, as valence permits, R^{47} and R^{48} , together with the atoms to which they are attached, form a 3-10 membered substituted or unsubstituted cyclic moiety optionally including from 1 to 3 heteroatoms. In some examples of Formula XXI, R^{47} and R^{48} are independently hydrogen or unsubstituted C_1 - C_5 acyl. In some examples of Formula XXI, R^{47} and R^{48} are the same. In some examples of Formula XXI, R^{47} and R^{48} together with the atoms to which they are attached, form a 5-10 membered substituted or unsubstituted cyclic moiety optionally including from 1 to 3 heteroatoms.

In some examples of Formula XXI, the aryl boronate ester can comprise a compound of Formula XXI-a:



wherein

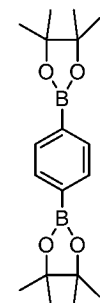
R^{47} and R^{48} are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C_1 - C_{40} alkyl, substituted or unsubstituted C_2 - C_{40} alkenyl, substituted or unsubstituted C_2 - C_{40} alkynyl, substituted or unsubstituted C_3 - C_{40} aryl, substituted or unsubstituted C_3 - C_{40} cycloalkyl, substituted or unsubstituted C_3 - C_{40} cycloalkenyl, substituted or unsubstituted C_1 - C_{40} acyl, substituted or unsubstituted C_1 - C_{40} alkoxy, $P(O)(OR^a)_2$, SR^a , $S(O)_2R^a$, $SiR^aR^bR^c$, or NR^aR^b , or wherein, as valence permits, R^{47} and R^{48} , together with the atoms to which they are attached, form a 3-10 membered

substituted or unsubstituted cyclic moiety optionally including from 1 to 3 heteroatoms; and

R^a , R^b , and R^c are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C_1 - C_{40} alkyl, substituted or unsubstituted C_2 - C_{40} alkenyl, substituted or unsubstituted C_2 - C_{40} alkynyl, substituted or unsubstituted C_3 - C_{40} aryl, substituted or unsubstituted C_3 - C_{40} cycloalkyl, substituted or unsubstituted C_3 - C_{40} cycloalkenyl, substituted or unsubstituted C_1 - C_{40} acyl, or substituted or unsubstituted C_1 - C_{40} alkoxy.

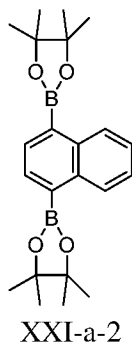
In some examples of Formula XXI-a, R^{47} and R^{48} are independently hydrogen, halogen, hydroxyl, substituted or unsubstituted C_1 - C_{20} alkyl, substituted or unsubstituted C_1 - C_{20} acyl, or wherein, as valence permits, R^{47} and R^{48} , together with the atoms to which they are attached, form a 3-10 membered substituted or unsubstituted cyclic moiety optionally including from 1 to 3 heteroatoms. In some examples of Formula XXI-a, R^{47} and R^{48} are independently hydrogen or unsubstituted C_1 - C_5 acyl. In some examples of Formula XXI-a, R^{47} and R^{48} are the same. In some examples of Formula XXI-a, R^{47} and R^{48} together with the atoms to which they are attached, form a 5-10 membered substituted or unsubstituted cyclic moiety optionally including from 1 to 3 heteroatoms.

In some examples of Formula XXI-a, the aryl boronate ester can comprise a compound of Formula XXI-a-1.

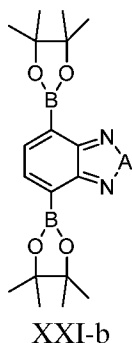


XXI-a-1

In some examples of Formula XXI-a, the aryl boronate ester can comprise a compound of Formula XXI-a-2.



5 In some examples of Formula XXI, the aryl boronate ester can comprise a compound of Formula XXI-b:



wherein

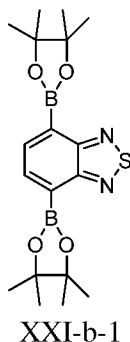
10 A is O, S, Se, Te, or NR^a; and

R^a, R^b, and R^c are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C₁-C₄₀ alkyl, substituted or unsubstituted C₂-C₄₀ alkenyl, substituted or unsubstituted C₂-C₄₀ alkynyl, substituted or unsubstituted C₃-C₄₀ aryl, substituted or unsubstituted C₃-C₄₀ cycloalkyl, substituted or unsubstituted C₃-C₄₀ cycloalkenyl, substituted or unsubstituted C₁-C₄₀ acyl, or substituted or unsubstituted C₁-C₄₀ alkoxy.

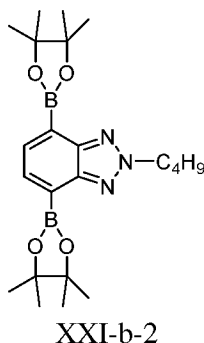
15

In some examples of Formula XXI-b, A is S or NR^a. In some examples of Formula XXI-b, A is NR^a and R^a is a substituted or unsubstituted C₁-C₂₀ alkyl. In some examples of Formula XXI-b, A is NR^a and R^a is an unsubstituted C₁₋₁₀ alkyl.

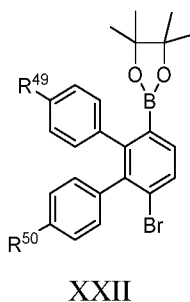
In some examples of Formula XXI-b, the aryl boronate ester can comprise a compound of Formula XXI-b-1.



5 In some examples of Formula XXI-b, the aryl boronate ester can comprise a compound of Formula XXI-b-2.



10 In some examples, the polycondensation reaction between an aryl bromide and an aryl boronate ester can comprise a polycondensation reaction of a compound an aryl compound with both a bromide and a boronate ester group. For example, the aryl bromide and aryl boronate ester can comprise a single compound. In some examples, the aryl bromide and the aryl boronate ester can comprise a compound of Formula XXII:



15 wherein

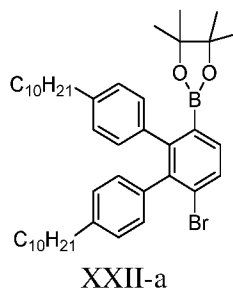
R^{49} and R^{50} are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C_1 - C_{40} alkyl, substituted or unsubstituted C_2 - C_{40} alkenyl, substituted or unsubstituted C_2 - C_{40} alkynyl, substituted or unsubstituted C_3 - C_{40} aryl, substituted or

unsubstituted C₃-C₄₀ cycloalkyl, substituted or unsubstituted C₃-C₄₀ cycloalkenyl, substituted or unsubstituted C₁-C₄₀ acyl, substituted or unsubstituted C₁-C₄₀ alkoxy, P(O)(OR^a)₂, SR^a, S(O)₂R^a, SiR^aR^bR^c, or NR^aR^b; and

R^a, R^b, and R^c are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C₁-C₄₀ alkyl, substituted or unsubstituted C₂-C₄₀ alkenyl, substituted or unsubstituted C₂-C₄₀ alkynyl, substituted or unsubstituted C₃-C₄₀ aryl, substituted or unsubstituted C₃-C₄₀ cycloalkyl, substituted or unsubstituted C₃-C₄₀ cycloalkenyl, substituted or unsubstituted C₁-C₄₀ acyl, or substituted or unsubstituted C₁-C₄₀ alkoxy.

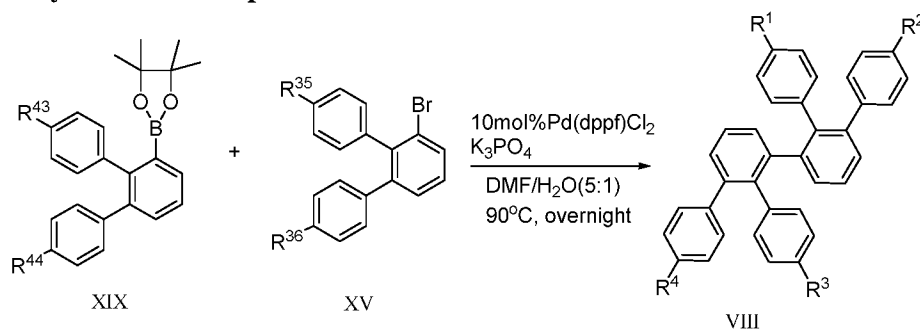
In some examples of Formula XXII, R⁴⁹ and R⁵⁰ are independently substituted or unsubstituted C₁-C₂₀ alkyl. In some examples of Formula XXII, R⁴⁹ and R⁵⁰ are the same.

In some examples of Formula XXII, the compound can be defined by Formula XXII-a.



In some examples, the methods of making the compounds of Formula VIII can comprise performing a Suzuki-Miyaura cross coupling reaction between an aryl bromide of Formula XV and an aryl boronate ester of Formula XIX, for example as shown in in Scheme 12.

Scheme 12. Synthesis of compounds of Formula VIII.

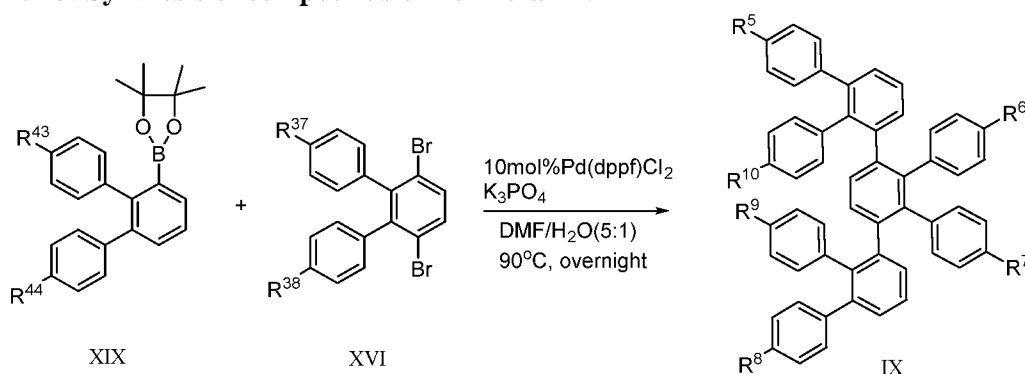


In some examples, R¹, R², R³, R⁴, R³⁵, R³⁶, R⁴³ and R⁴⁴ are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C₁-C₄₀ alkyl, substituted or unsubstituted C₂-C₄₀ alkenyl, substituted or unsubstituted C₂-C₄₀ alkynyl, substituted or

unsubstituted C₃-C₄₀ aryl, substituted or unsubstituted C₃-C₄₀ cycloalkyl, substituted or unsubstituted C₃-C₄₀ cycloalkenyl, substituted or unsubstituted C₁-C₄₀ acyl, substituted or unsubstituted C₁-C₄₀ alkoxy, P(O)(OR^a)₂, SR^a, S(O)₂R^a, SiR^aR^bR^c, or NR^aR^b; and R^a, R^b, and R^c, are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C₁-C₄₀ alkyl, substituted or unsubstituted C₂-C₄₀ alkenyl, substituted or unsubstituted C₂-C₄₀ alkynyl, substituted or unsubstituted C₃-C₄₀ aryl, substituted or unsubstituted C₃-C₄₀ cycloalkyl, substituted or unsubstituted C₃-C₄₀ cycloalkenyl, substituted or unsubstituted C₁-C₄₀ acyl, or substituted or unsubstituted C₁-C₄₀ alkoxy. In some examples, R¹, R², R³, R⁴, R³⁵, R³⁶, R⁴³ and R⁴⁴ are independently substituted or unsubstituted C₁-C₂₀ alkyl. In some examples, R¹, R², R³, R⁴, R³⁵, R³⁶, R⁴³ and R⁴⁴ are independently unsubstituted C₁-C₁₀ alkyl. In some examples, R¹, R², R³, R⁴, R³⁵, R³⁶, R⁴³ and R⁴⁴ are the same. In some examples, R¹, R², R³, R⁴, R³⁵, R³⁶, R⁴³ and R⁴⁴ are each C₄H₉.

In some examples, the method of making the compound of Formula IX can comprise performing a Suzuki-Miyaura cross coupling reaction between an aryl bromide of Formula XVI and an aryl boronate ester of Formula XIX, for example as shown in Scheme 13.

Scheme 13. Synthesis of compounds of Formula IX.

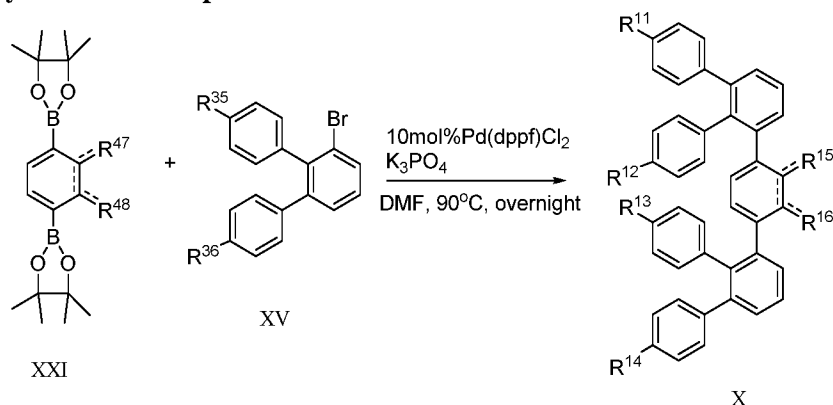


In some examples, R⁵, R⁶, R⁷, R⁸, R⁹, R¹⁰, R³⁷, R³⁸, R⁴³ and R⁴⁴ are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C₁-C₄₀ alkyl, substituted or unsubstituted C₂-C₄₀ alkenyl, substituted or unsubstituted C₂-C₄₀ alkynyl, substituted or unsubstituted C₃-C₄₀ aryl, substituted or unsubstituted C₃-C₄₀ cycloalkyl, substituted or unsubstituted C₃-C₄₀ cycloalkenyl, substituted or unsubstituted C₁-C₄₀ acyl, substituted or unsubstituted C₁-C₄₀ alkoxy, P(O)(OR^a)₂, SR^a, S(O)₂R^a, SiR^aR^bR^c, or NR^aR^b; and R^a, R^b, and R^c, are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C₁-C₄₀ alkyl, substituted or unsubstituted C₂-C₄₀ alkenyl, substituted or unsubstituted C₂-C₄₀ alkynyl,

substituted or unsubstituted C₃-C₄₀ aryl, substituted or unsubstituted C₃-C₄₀ cycloalkyl, substituted or unsubstituted C₃-C₄₀ cycloalkenyl, substituted or unsubstituted C₁-C₄₀ acyl, or substituted or unsubstituted C₁-C₄₀ alkoxy. In some examples, R⁵, R⁶, R⁷, R⁸, R⁹, R¹⁰, R³⁷, R³⁸, R⁴³ and R⁴⁴ are independently substituted or unsubstituted C₁-C₂₀ alkyl. In some examples, R⁵, R⁶, R⁷, R⁸, R⁹, R¹⁰, R³⁷, R³⁸, R⁴³ and R⁴⁴ are independently unsubstituted C₁-C₁₀ alkyl. In some examples, R⁵, R⁶, R⁷, R⁸, R⁹, R¹⁰, R³⁷, R³⁸, R⁴³ and R⁴⁴ are the same. In some examples, R⁵, R⁶, R⁷, R⁸, R⁹, R¹⁰, R³⁷, R³⁸, R⁴³ and R⁴⁴ are each C₄H₉.

In some examples, the methods of making the compound of Formula X can comprise performing a Suzuki-Miyaura cross coupling reaction between an aryl bromide of Formula XV and an aryl boronate ester of Formula XXI, for example as shown in Scheme 14.

Scheme 14. Synthesis of compounds of Formula X.

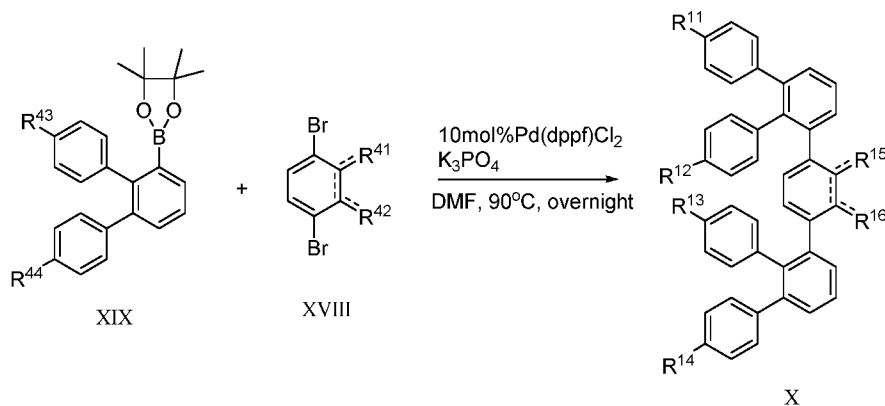


In some examples, the dotted lines to R¹⁵, R¹⁶, R⁴⁷, R⁴⁸, between the carbons within the ring to which R¹⁵ and R¹⁶ are bonded, and between the carbons within the ring to which R⁴⁷ and R⁴⁸ are bonded, independently indicate that the bond can be a single bond or a double bond, as valence permits; R¹¹, R¹², R¹³, R¹⁴, R¹⁵, R¹⁶, R³⁵, R³⁶, R⁴⁷, and R⁴⁸ are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C₁-C₄₀ alkyl, substituted or unsubstituted C₂-C₄₀ alkenyl, substituted or unsubstituted C₂-C₄₀ alkynyl, substituted or unsubstituted C₃-C₄₀ aryl, substituted or unsubstituted C₃-C₄₀ cycloalkyl, substituted or unsubstituted C₃-C₄₀ cycloalkenyl, substituted or unsubstituted C₁-C₄₀ acyl, substituted or unsubstituted C₁-C₄₀ alkoxy, P(O)(OR^a)₂, SR^a, S(O)₂R^a, SiR^aR^bR^c, or NR^aR^b, or wherein, as valence permits, R⁴⁷ and R⁴⁸, and/or R¹⁵ and R¹⁶, together with the atoms to which they are attached, form a 3-10 membered substituted or unsubstituted cyclic moiety optionally including from 1 to 3 heteroatoms; and R^a, R^b, and R^c are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C₁-C₄₀ alkyl, substituted or unsubstituted C₂-C₄₀

alkenyl, substituted or unsubstituted C₂-C₄₀ alkynyl, substituted or unsubstituted C₃-C₄₀ aryl, substituted or unsubstituted C₃-C₄₀ cycloalkyl, substituted or unsubstituted C₃-C₄₀ cycloalkenyl, substituted or unsubstituted C₁-C₄₀ acyl, or substituted or unsubstituted C₁-C₄₀ alkoxy. In some examples, R¹¹, R¹², R¹³, R¹⁴, R³⁵, and R³⁶ are independently substituted or unsubstituted C₁-C₂₀ alkyl. In some examples, R¹¹, R¹², R¹³, R¹⁴, R³⁵ and R³⁶ are the same. In some examples, R¹⁵, R¹⁶, R⁴⁷, and R⁴⁸ are independently hydrogen, halogen, hydroxyl, substituted or unsubstituted C₁-C₂₀ alkyl, substituted or unsubstituted C₁-C₂₀ acyl, or wherein, as valence permits, R¹⁵ and R¹⁶, and/or R⁴⁷, and R⁴⁸, together with the atoms to which they are attached, form a 3-10 membered substituted or unsubstituted cyclic moiety optionally including from 1 to 3 heteroatoms. In some examples, R¹⁵, R¹⁶, R⁴⁷, and R⁴⁸ are independently hydrogen or unsubstituted C₁-C₅ acyl. In some examples of, R¹⁵, R¹⁶, R⁴⁷, and R⁴⁸ are the same. In some examples, R¹⁵ and R¹⁶, and/or R⁴⁷, and R⁴⁸ together with the atoms to which they are attached, form a 5-10 membered substituted or unsubstituted cyclic moiety optionally including from 1 to 3 heteroatoms.

In some examples, the methods of making the compound of Formula X can comprise performing a Suzuki-Miyaura cross coupling reaction between an aryl bromide of Formula XVIII and an aryl boronate ester of Formula XIX, for example as shown in Scheme 15.

Scheme 15. Synthesis of compounds of Formula X.

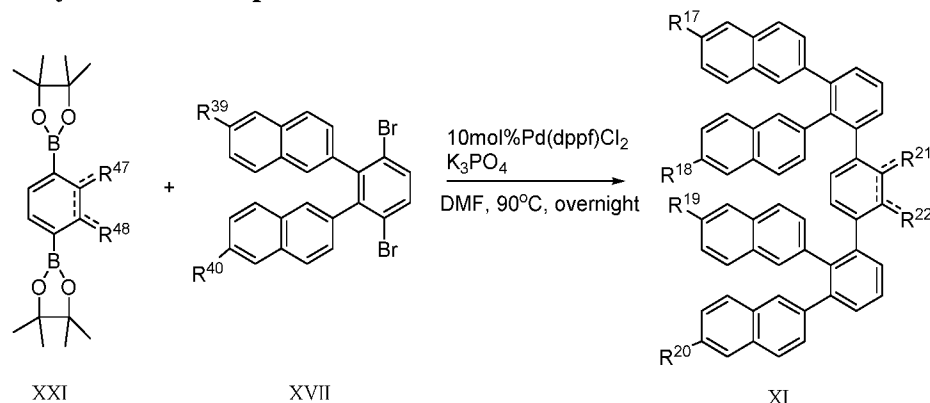


In some examples, the dotted lines to R¹⁵, R¹⁶, R⁴¹, R⁴², between the carbons within the ring to which R¹⁵ and R¹⁶ are bonded, and between the carbons within the ring to which R⁴¹ and R⁴² are bonded, independently indicate that the bond can be a single bond or a double bond, as valence permits; R¹¹, R¹², R¹³, R¹⁴, R¹⁵, R¹⁶, R⁴¹, R⁴², R⁴³, and R⁴⁴ are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C₁-C₄₀ alkyl, substituted or

unsubstituted C₂-C₄₀ alkenyl, substituted or unsubstituted C₂-C₄₀ alkynyl, substituted or unsubstituted C₃-C₄₀ aryl, substituted or unsubstituted C₃-C₄₀ cycloalkyl, substituted or unsubstituted C₃-C₄₀ cycloalkenyl, substituted or unsubstituted C₁-C₄₀ acyl, substituted or unsubstituted C₁-C₄₀ alkoxy, P(O)(OR^a)₂, SR^a, S(O)₂R^a, SiR^aR^bR^c, or NR^aR^b, or wherein, as valence permits, R¹⁵ and R¹⁶ and/or R⁴¹ and R⁴², together with the atoms to which they are attached, form a 3-10 membered substituted or unsubstituted cyclic moiety optionally including from 1 to 3 heteroatoms; and R^a, R^b, and R^c are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C₁-C₄₀ alkyl, substituted or unsubstituted C₂-C₄₀ alkenyl, substituted or unsubstituted C₂-C₄₀ alkynyl, substituted or unsubstituted C₃-C₄₀ aryl, substituted or unsubstituted C₃-C₄₀ cycloalkyl, substituted or unsubstituted C₃-C₄₀ cycloalkenyl, substituted or unsubstituted C₁-C₄₀ acyl, or substituted or unsubstituted C₁-C₄₀ alkoxy. In some examples, R¹¹, R¹², R¹³, R¹⁴, R⁴³, and R⁴⁴ are independently substituted or unsubstituted C₁-C₂₀ alkyl. In some examples, R¹¹, R¹², R¹³, R¹⁴, R⁴³ and R⁴⁴ are the same. In some examples, R¹⁵, R¹⁶, R⁴¹, and R⁴² are independently hydrogen, halogen, hydroxyl, substituted or unsubstituted C₁-C₂₀ alkyl, substituted or unsubstituted C₁-C₂₀ acyl, or wherein, as valence permits, R¹⁵ and R¹⁶, and/or R⁴¹, and R⁴², together with the atoms to which they are attached, form a 3-10 membered substituted or unsubstituted cyclic moiety optionally including from 1 to 3 heteroatoms. In some examples, R¹⁵, R¹⁶, R⁴¹, and R⁴² are independently hydrogen or unsubstituted C₁-C₅ acyl. In some examples of, R¹⁵, R¹⁶, R⁴¹, and R⁴² are the same. In some examples, R¹⁵ and R¹⁶, and/or R⁴¹, and R⁴² together with the atoms to which they are attached, form a 5-10 membered substituted or unsubstituted cyclic moiety optionally including from 1 to 3 heteroatoms.

In some examples, the methods of making the compound of Formula XI can comprise performing a Suzuki-Miyaura cross coupling reaction between an aryl bromide of Formula XVII and an aryl boronate ester of Formula XXI, for example as shown in Scheme 16.

Scheme 16. Synthesis of compounds of Formula XI.

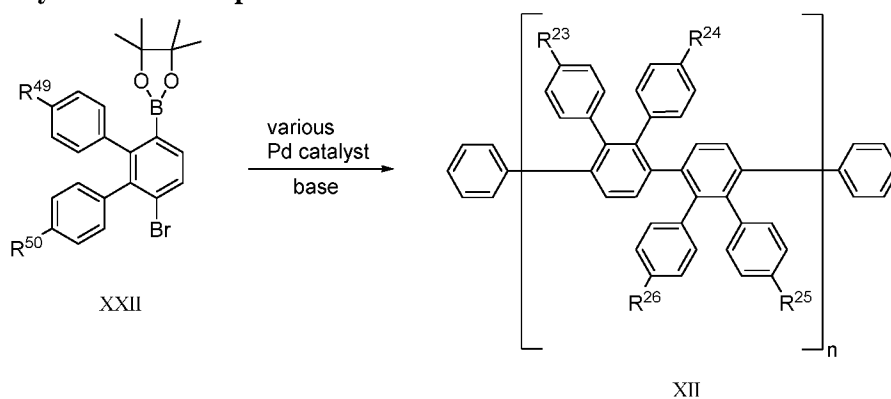


In some examples, the dotted lines to R²¹, R²², R⁴⁷, R⁴⁸, between the carbons within the ring to which R²¹ and R²² are bonded, and between the carbons within the ring to which R⁴⁷ and R⁴⁸ are bonded, independently indicate that the bond can be a single bond or a double bond, as valence permits; R¹⁷, R¹⁸, R¹⁹, R²⁰, R²¹, R²², R³⁹, R⁴⁰, R⁴⁷, and R⁴⁸ are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C₁-C₄₀ alkyl, substituted or unsubstituted C₂-C₄₀ alkenyl, substituted or unsubstituted C₂-C₄₀ alkynyl, substituted or unsubstituted C₃-C₄₀ aryl, substituted or unsubstituted C₃-C₄₀ cycloalkyl, substituted or unsubstituted C₃-C₄₀ cycloalkenyl, substituted or unsubstituted C₁-C₄₀ acyl, substituted or unsubstituted C₁-C₄₀ alkoxy, P(O)(OR^a)₂, SR^a, S(O)₂R^a, SiR^aR^bR^c, or NR^aR^b, or wherein, as valence permits, R²¹ and R²² and/or R⁴⁷ and R⁴⁸, together with the atoms to which they are attached, form a 3-10 membered substituted or unsubstituted cyclic moiety optionally including from 1 to 3 heteroatoms; and R^a, R^b, and R^c are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C₁-C₄₀ alkyl, substituted or unsubstituted C₂-C₄₀ alkenyl, substituted or unsubstituted C₂-C₄₀ alkynyl, substituted or unsubstituted C₃-C₄₀ aryl, substituted or unsubstituted C₃-C₄₀ cycloalkyl, substituted or unsubstituted C₃-C₄₀ cycloalkenyl, substituted or unsubstituted C₁-C₄₀ acyl, or substituted or unsubstituted C₁-C₄₀ alkoxy. In some examples, R¹⁷, R¹⁸, R¹⁹, R²⁰, R³⁹, and R⁴⁰ are independently substituted or unsubstituted C₁-C₂₀ alkyl. In some examples, R¹⁷, R¹⁸, R¹⁹, R²⁰, R³⁹, and R⁴⁰ are the same. In some examples, R²¹, R²², R⁴⁷, and R⁴⁸ are independently hydrogen, halogen, hydroxyl, substituted or unsubstituted C₁-C₂₀ alkyl, substituted or unsubstituted C₁-C₂₀ acyl, or wherein, as valence permits, R²¹ and R²² and/or R⁴⁷ and R⁴⁸, together with the atoms to which they are attached, form a 3-10 membered substituted or unsubstituted cyclic moiety optionally including from 1 to 3 heteroatoms. In some examples, R²¹, R²², R⁴⁷, and R⁴⁸ are independently hydrogen or

unsubstituted C₁-C₅ acyl. In some examples, R²¹, R²², R⁴⁷, and R⁴⁸ are the same. In some examples, R²¹ and R²² and/or R⁴⁷ and R⁴⁸ together with the atoms to which they are attached, form a 5-10 membered substituted or unsubstituted cyclic moiety optionally including from 1 to 3 heteroatoms.

In some examples, the methods of making the compound of Formula XII can comprise performing a Suzuki-Miyaura cross coupling reaction between bromide compound of Formula XXII and itself, as the compound of Formula XXII is both an aryl bromide and an aryl boronate ester, for example as shown in Scheme 17.

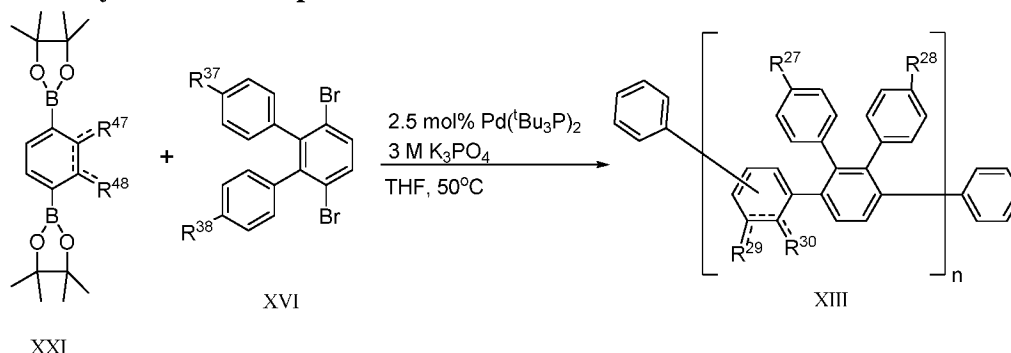
Scheme 17. Synthesis of compounds of Formula XII.



In some examples, R²³, R²⁴, R²⁵, R²⁶, R⁴⁹ and R⁵⁰ are hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C₁-C₄₀ alkyl, substituted or unsubstituted C₂-C₄₀ alkenyl, substituted or unsubstituted C₂-C₄₀ alkynyl, substituted or unsubstituted C₃-C₄₀ aryl, substituted or unsubstituted C₃-C₄₀ cycloalkyl, substituted or unsubstituted C₃-C₄₀ cycloalkenyl, substituted or unsubstituted C₁-C₄₀ acyl, substituted or unsubstituted C₁-C₄₀ alkoxy, P(O)(OR^a)₂, SR^a, S(O)₂R^a, SiR^aR^bR^c, or NR^aR^b; and R^a, R^b, and R^c, are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C₁-C₄₀ alkyl, substituted or unsubstituted C₂-C₄₀ alkenyl, substituted or unsubstituted C₂-C₄₀ alkynyl, substituted or unsubstituted C₃-C₄₀ aryl, substituted or unsubstituted C₃-C₄₀ cycloalkyl, substituted or unsubstituted C₃-C₄₀ cycloalkenyl, substituted or unsubstituted C₁-C₄₀ acyl, or substituted or unsubstituted C₁-C₄₀ alkoxy. In some examples, R²³, R²⁴, R²⁵, R²⁶, R⁴⁹ and R⁵⁰ are independently substituted or unsubstituted C₁-C₂₀ alkyl. In some examples, R²³, R²⁴, R²⁵, R²⁶, R⁴⁹ and R⁵⁰ are independently unsubstituted C₂-C₁₅ alkyl. In some examples, R²³, R²⁴, R²⁵, R²⁶, R⁴⁹ and R⁵⁰ are the same. In some examples, R²³, R²⁴, R²⁵, R²⁶, R⁴⁹ and R⁵⁰ are each C₁₀H₂₁.

In some examples, the methods of making the compound of Formula XIII can comprise performing a Suzuki-Miyaura cross coupling reaction between an aryl bromide of Formula XVI and an aryl boronate ester of Formula XXI, for example as shown in Scheme 18.

5 **Scheme 18. Synthesis of compounds of Formula XIII.**

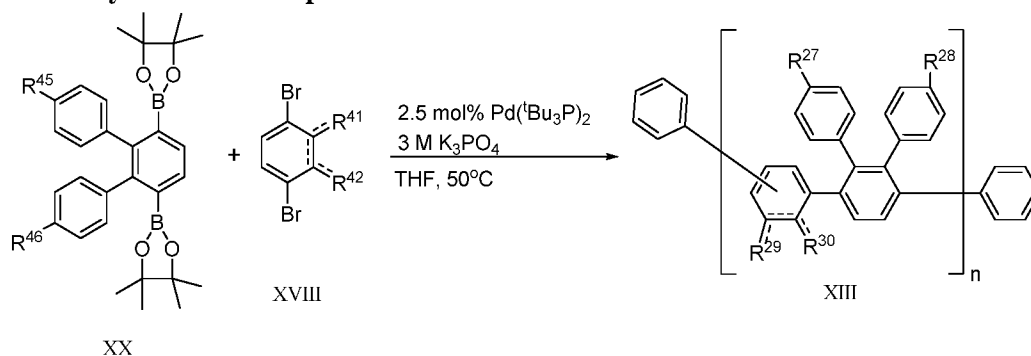


In some examples, the dotted lines to R^{29} , R^{30} , R^{47} , R^{48} , between the carbons within the ring to which R^{29} and R^{30} are bonded, and between the carbons within the ring to which R^{47} and R^{48} are bonded, independently indicate that the bond can be a single bond or a double bond, as valence permits; R^{27} , R^{28} , R^{29} , R^{30} , R^{37} , R^{38} , R^{47} , and R^{48} are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted $\text{C}_1\text{-C}_{40}$ alkyl, substituted or unsubstituted $\text{C}_2\text{-C}_{40}$ alkenyl, substituted or unsubstituted $\text{C}_2\text{-C}_{40}$ alkynyl, substituted or unsubstituted $\text{C}_3\text{-C}_{40}$ aryl, substituted or unsubstituted $\text{C}_3\text{-C}_{40}$ cycloalkyl, substituted or unsubstituted $\text{C}_3\text{-C}_{40}$ cycloalkenyl, substituted or unsubstituted $\text{C}_1\text{-C}_{40}$ acyl, substituted or unsubstituted $\text{C}_1\text{-C}_{40}$ alkoxy, $\text{P}(\text{O})(\text{OR}^a)_2$, SR^a , $\text{S}(\text{O})_2\text{R}^a$, $\text{SiR}^a\text{R}^b\text{R}^c$, or NR^aR^b , or wherein, as valence permits, R^{29} and R^{30} and/or R^{47} and R^{48} , together with the atoms to which they are attached, form a 3-10 membered substituted or unsubstituted cyclic moiety optionally including from 1 to 3 heteroatoms; and R^a , R^b , and R^c are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted $\text{C}_1\text{-C}_{40}$ alkyl, substituted or unsubstituted $\text{C}_2\text{-C}_{40}$ alkenyl, substituted or unsubstituted $\text{C}_2\text{-C}_{40}$ alkynyl, substituted or unsubstituted $\text{C}_3\text{-C}_{40}$ aryl, substituted or unsubstituted $\text{C}_3\text{-C}_{40}$ cycloalkyl, substituted or unsubstituted $\text{C}_3\text{-C}_{40}$ cycloalkenyl, substituted or unsubstituted $\text{C}_1\text{-C}_{40}$ acyl, or substituted or unsubstituted $\text{C}_1\text{-C}_{40}$ alkoxy. In some examples, R^{27} , R^{28} , R^{37} , and R^{38} are independently substituted or unsubstituted $\text{C}_1\text{-C}_{20}$ alkyl. In some examples, R^{27} , R^{28} , R^{37} , and R^{38} are the same. In some examples, R^{29} , R^{30} , R^{47} , and R^{48} are independently hydrogen, halogen, hydroxyl, substituted or unsubstituted $\text{C}_1\text{-C}_{20}$ alkyl, substituted or unsubstituted $\text{C}_1\text{-C}_{20}$ acyl, or wherein, as valence permits, R^{29} and R^{30} and/or R^{47} and R^{48} , together with the atoms to which

they are attached, form a 3-10 membered substituted or unsubstituted cyclic moiety optionally including from 1 to 3 heteroatoms. In some examples, R^{29} , R^{30} , R^{47} , and R^{48} are independently hydrogen or unsubstituted C_1 - C_5 acyl. In some examples, R^{29} , R^{30} , R^{47} , and R^{48} are the same. In some examples, R^{29} and R^{30} and/or R^{47} and R^{48} together with the atoms to which they are attached, form a 5-10 membered substituted or unsubstituted cyclic moiety optionally including from 1 to 3 heteroatoms.

In some examples, the methods of making the compound of Formula XIII can comprise performing a Suzuki-Miyaura cross coupling reaction between an aryl bromide of Formula XVIII and an aryl boronate ester of Formula XX, for example as shown in Scheme 19.

Scheme 19. Synthesis of compounds of Formula XIII.

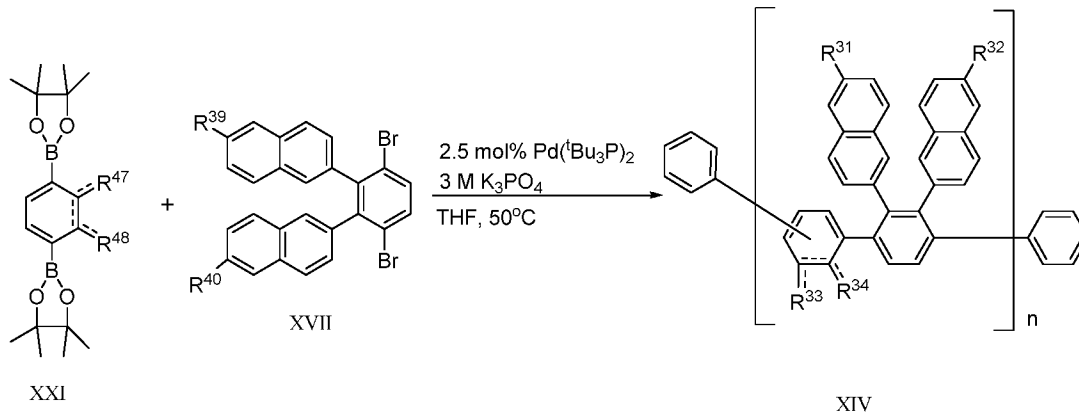


In some examples, the dotted lines to R^{29} , R^{30} , R^{41} , R^{42} , between the carbons within the ring to which R^{29} and R^{30} are bonded, and between the carbons within the ring to which R^{41} and R^{42} are bonded, independently indicate that the bond can be a single bond or a double bond, as valence permits; R^{27} , R^{28} , R^{29} , R^{30} , R^{41} , R^{42} , R^{45} , and R^{46} are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C_1 - C_{40} alkyl, substituted or unsubstituted C_2 - C_{40} alkenyl, substituted or unsubstituted C_2 - C_{40} alkynyl, substituted or unsubstituted C_3 - C_{40} aryl, substituted or unsubstituted C_3 - C_{40} cycloalkyl, substituted or unsubstituted C_3 - C_{40} cycloalkenyl, substituted or unsubstituted C_1 - C_{40} acyl, substituted or unsubstituted C_1 - C_{40} alkoxy, $P(O)(OR^a)_2$, SR^a , $S(O)_2R^a$, $SiR^aR^bR^c$, or NR^aR^b , or wherein, as valence permits, R^{29} and R^{30} and/or R^{41} and R^{42} , together with the atoms to which they are attached, form a 3-10 membered substituted or unsubstituted cyclic moiety optionally including from 1 to 3 heteroatoms; and R^a , R^b , and R^c are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C_1 - C_{40} alkyl, substituted or unsubstituted C_2 - C_{40} alkenyl, substituted or unsubstituted C_2 - C_{40} alkynyl, substituted or unsubstituted C_3 - C_{40} aryl, substituted or unsubstituted C_3 - C_{40} cycloalkyl,

substituted or unsubstituted C₃-C₄₀ cycloalkenyl, substituted or unsubstituted C₁-C₄₀ acyl, or substituted or unsubstituted C₁-C₄₀ alkoxy. In some examples, R²⁷, R²⁸, R⁴⁵, and R⁴⁶ are independently substituted or unsubstituted C₁-C₂₀ alkyl. In some examples, R²⁷, R²⁸, R⁴⁵, and R⁴⁶ are the same. In some examples, R²⁹, R³⁰, R⁴¹, and R⁴² are independently hydrogen, halogen, hydroxyl, substituted or unsubstituted C₁-C₂₀ alkyl, substituted or unsubstituted C₁-C₂₀ acyl, or wherein, as valence permits, R²⁹ and R³⁰ and/or R⁴¹ and R⁴², together with the atoms to which they are attached, form a 3-10 membered substituted or unsubstituted cyclic moiety optionally including from 1 to 3 heteroatoms. In some examples, R²⁹, R³⁰, R⁴¹, and R⁴² are independently hydrogen or unsubstituted C₁-C₅ acyl. In some examples, R²⁹, R³⁰, R⁴¹, and R⁴² are the same. In some examples, R²⁹ and R³⁰ and/or R⁴¹ and R⁴² together with the atoms to which they are attached, form a 5-10 membered substituted or unsubstituted cyclic moiety optionally including from 1 to 3 heteroatoms.

In some examples, the methods of making the compound of Formula XIV can comprise performing a Suzuki-Miyaura cross coupling reaction between an aryl bromide of Formula XVII and an aryl boronate ester of Formula XXI, for example as shown in Scheme 20.

Scheme 20. Synthesis of compounds of Formula XIV.



In some examples, the dotted lines to R³³, R³⁴, R⁴⁷, R⁴⁸, between the carbons within the ring to which R³³ and R³⁴ are bonded, and between the carbons within the ring to which R⁴⁷ and R⁴⁸ are bonded, independently indicate that the bond can be a single bond or a double bond, as valence permits; R³¹, R³², R³³, R³⁴, R³⁹, R⁴⁰, R⁴⁷, and R⁴⁸ are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C₁-C₄₀ alkyl, substituted or unsubstituted C₂-C₄₀ alkenyl, substituted or unsubstituted C₂-C₄₀ alkynyl, substituted or unsubstituted C₃-C₄₀ aryl, substituted or unsubstituted C₃-C₄₀ cycloalkyl, substituted or unsubstituted C₃-C₄₀ cycloalkenyl,

substituted or unsubstituted C₁-C₄₀ acyl, substituted or unsubstituted C₁-C₄₀ alkoxy, P(O)(OR^a)₂, SR^a, S(O)₂R^a, SiR^aR^bR^c, or NR^aR^b, or wherein, as valence permits, R³³ and R³⁴ and/or R⁴⁷ and R⁴⁸, together with the atoms to which they are attached, form a 3-10 membered substituted or unsubstituted cyclic moiety optionally including from 1 to 3 heteroatoms; and R^a, R^b, and R^c are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C₁-C₄₀ alkyl, substituted or unsubstituted C₂-C₄₀ alkenyl, substituted or unsubstituted C₂-C₄₀ alkynyl, substituted or unsubstituted C₃-C₄₀ aryl, substituted or unsubstituted C₃-C₄₀ cycloalkyl, substituted or unsubstituted C₃-C₄₀ cycloalkenyl, substituted or unsubstituted C₁-C₄₀ acyl, or substituted or unsubstituted C₁-C₄₀ alkoxy. In some examples, R³¹, R³², R³⁹, and R⁴⁰ are independently substituted or unsubstituted C₁-C₂₀ alkyl. In some examples, R³¹, R³², R³⁹, and R⁴⁰ are the same. In some examples, R³³, R³⁴, R⁴⁷, and R⁴⁸ are independently hydrogen, halogen, hydroxyl, substituted or unsubstituted C₁-C₂₀ alkyl, substituted or unsubstituted C₁-C₂₀ acyl, or wherein, as valence permits, R³³ and R³⁴ and/or R⁴⁷ and R⁴⁸, together with the atoms to which they are attached, form a 3-10 membered substituted or unsubstituted cyclic moiety optionally including from 1 to 3 heteroatoms. In some examples, R³³, R³⁴, R⁴⁷, and R⁴⁸ are independently hydrogen or unsubstituted C₁-C₅ acyl. In some examples, R³³, R³⁴, R⁴⁷, and R⁴⁸ are the same. In some examples, R³³ and R³⁴ and/or R⁴⁷ and R⁴⁸ together with the atoms to which they are attached, form a 5-10 membered substituted or unsubstituted cyclic moiety optionally including from 1 to 3 heteroatoms.

In some examples, the methods of making the compounds of Formulas VIII-XIV can comprise performing a Suzuki Miyaura coupling reaction between an aryl bromide and an aryl boronate ester, followed by a cyclodehydrogenation.

Methods of Use

Also provided herein are methods of use of the compounds described herein. Graphitic compounds, such as the compounds described herein, can be of interest to the semiconductor industry and can have applications in nanoelectronic devices and chemical and biological sensors. For example, the compounds described herein can be used as conductors in, for example, transistors, solar cells, and light emitting diodes (LEDs). Such devices can be fabricated by methods known in the art. For example, the device can be transistors, solar cells, LEDs, and chemical and biological sensors.

In some examples, the compounds disclosed herein can be used in various articles of manufacture including electronic devices, optical devices, and optoelectronic devices, such as

field effect transistors (e.g., thin film transistors), photovoltaics, organic light emitting diodes (OLEDs), complementary inverters, D flip-flops, rectifiers, and ring oscillators.

Also disclosed herein are methods of preparing a semiconductor material exhibiting a well-defined electronic band gap that can be tailored to specific applications by the choice of molecular precursor. The methods can include preparing a composition that includes one or more of the compounds of the invention disclosed herein dissolved or dispersed in a liquid medium such as a solvent or a mixture of solvents, depositing the composition on a substrate to provide a semiconductor material precursor, and processing (e.g., heating) the semiconductor precursor to provide a semiconductor material (e.g., a thin film semiconductor) that includes one or more of the compounds disclosed herein. In some examples, the liquid medium can be an organic solvent, an inorganic solvent such as water, or combinations thereof. In some examples, the composition can further include one or more additives independently selected from detergents, dispersants, binding agents, compatibilizing agents, curing agents, initiators, humectants, antifoaming agents, wetting agents, pH modifiers, biocides, and bacteriostats. For example, surfactants and/or polymers (e.g., polystyrene, polyethylene, poly-alpha-methylstyrene, polyisobutene, polypropylene, polymethylmethacrylate, and the like) can be included as a dispersant, a binding agent, a compatibilizing agent, and/or an antifoaming agent. In some examples, the depositing step can be carried out by printing, including inkjet printing and various contact printing techniques (e.g., screen-printing, gravure printing, offset printing, pad printing, lithographic printing, flexographic printing, and microcontact printing). In other embodiments, the depositing step can be carried out by spin coating, drop-casting, zone casting, dip coating, blade coating, spraying or vacuum filtration.

Also disclosed herein are articles of manufacture such as the various devices described herein that include a composite having a semiconductor material comprising any of the compounds described herein and a substrate component and/or a dielectric component. The substrate component can, for example, be selected from doped silicon, an indium tin oxide (ITO), ITO-coated glass, ITO-coated polyimide or other plastics, aluminum or other metals alone or coated on a polymer or other substrate, a doped polythiophene, and the like. The dielectric component can be prepared, for example, from inorganic dielectric materials such as various oxides (e.g., SiO₂, Al₂O₃, HfO₂), organic dielectric materials such as various polymeric materials (e.g., polycarbonate, polyester, polystyrene, polyhaloethylene, polyacrylate), and self-assembled superlattice/self-assembled nanodielectric (SAS/SAND) materials (e.g., described in Yoon, M-H. et al., PNAS, 102 (13): 4678-4682 (2005)), as well as hybrid organic/inorganic

dielectric materials (e.g., described in US 2007/0181961 A1). The composite also can include one or more electrical contacts. Suitable materials for the source, drain, and gate electrodes include metals (e.g., Au, Al, Ni, Cu), transparent conducting oxides (e.g., ITO, IZO, ZITO, GZO, GIO, GITO), and conducting polymers (e.g., poly(3,4-ethylenedioxythiophene) poly(styrene- sulfonate) (PEDOT:PSS), polyaniline (PANI), polypyrrole (PPy). One or more of the composites described herein can be embodied within various organic electronic, optical, and optoelectronic devices such as organic thin film transistors (OTFTs), such as, organic field effect transistors (OFETs), as well as sensors, capacitors, unipolar circuits, complementary circuits (e.g., inverter circuits), and the like.

Other articles of manufacture, in which the compounds described herein can be used, can include, for example, photovoltaics and/or solar cells. The compounds described herein can, in some example, exhibit broad optical absorption, which can make them desirable for such applications.

Also disclosed herein are methods of fabricating an organic field effect transistor (OFET) that incorporates a semiconductor material comprising any of the compounds described herein. The semiconductor materials described herein can be used to fabricate various types of organic field effect transistors including top-gate top-contact capacitor structures, top-gate bottom-contact capacitor structures, bottom-gate top- contact capacitor structures, and bottom-gate bottom-contact capacitor structures.

In certain embodiments, OTFT devices can be fabricated with the compounds described herein on doped silicon substrates, using SiO₂ as the dielectric, in top-contact geometries. In some examples, the active semiconductor layer which incorporates at least a compound described herein can be deposited at room temperature or at an elevated temperature. In some examples, the active semiconductor layer which incorporates at least a compound described herein can be applied by spin-coating or printing. For top-contact devices, metallic contacts can be patterned on top of the films using shadow masks, electron beam lithography and lift-off techniques, or other suitable structuring methods that are within the knowledge of a skilled artisan.

EXAMPLES

The following examples are set forth to illustrate the methods and results according to the disclosed subject matter. These examples are not intended to be inclusive of all aspects of the subject matter disclosed herein, but rather to illustrate representative methods and results. These

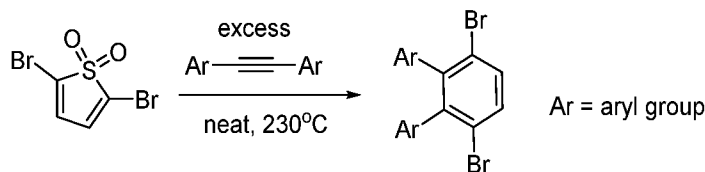
examples are not intended to exclude equivalents and variations which are apparent to one skilled in the art.

Efforts have been made to ensure accuracy with respect to numbers (*e.g.*, amounts, temperature, etc.) but some errors and deviations should be accounted for. Unless indicated otherwise, parts are parts by weight, temperature is in °C or is at ambient temperature, and pressure is at or near atmospheric. There are numerous variations and combinations of reaction conditions, *e.g.*, component concentrations, temperatures, pressures and other reaction ranges and conditions that can be used to optimize the product purity and yield obtained from the described process. Only reasonable and routine experimentation will be required to optimize such process conditions.

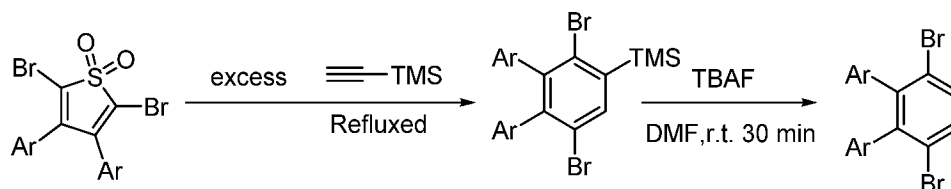
Example 1

1,4-Dibromo-substituted aryl compounds can be synthesized via [4+2] cycloaddition (Scheme 21), [4+2] cycloaddition followed by bromodesilylation (Scheme 22), or a silylation reaction followed by Suzuki coupling and bromodesilylation (Scheme 23).

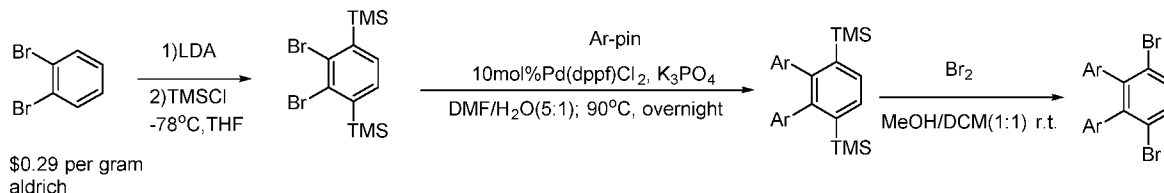
Scheme 21. Synthesis of dibromo substituted aryl compounds via [4+2] cycloaddition.



Scheme 22. Synthesis of dibromo substituted aryl compounds via [4+2] cycloaddition and bromodesilylation.



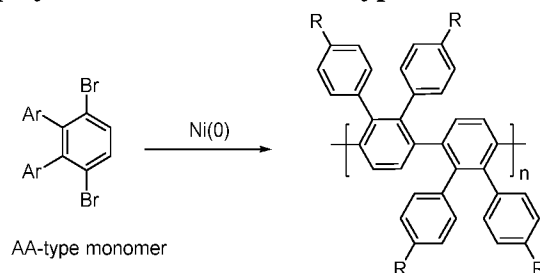
Scheme 23. Synthesis of dibromo substituted aryl compounds via a silylation reaction, Suzuki coupling, and bromodesilylation.



A Yamamoto polycondensation reaction using an “AA-type monomer” was performed with a Ni(0) catalyst, as shown in Scheme 24. The Yamamoto polycondensation resulted in low molecular weight “oligomers” instead of high molecular weight polymers (e.g., graphene nanoribbon precursors).

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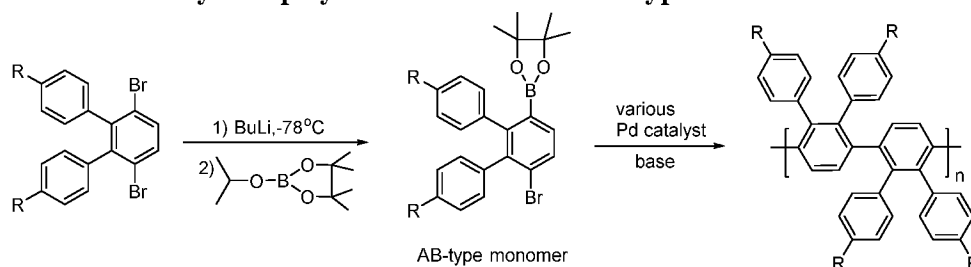
Scheme 24. Yamamoto polycondensation of an AA-type monomer.



AA/BB-type Suzuki-Miyaura cross coupling (e.g., polycondensation) reactions are sensitive to stoichiometry, whereas AB-type Suzuki-Miyaura cross coupling reactions are not. Therefore, Suzuki-Miyaura cross coupling reactions can facilitate the chain growth mechanism and allow for the production of high molecular weight polymers (e.g., graphene nanoribbon precursors). As will be described in more detail below, “AB-type bifunctional monomers” can be synthesized and used to form precursors to graphene nanoribbons, as summarized in Scheme 25. The precursors shown in Scheme 25 can then undergo dehydrogenation to form the graphene nanoribbons (Scheme 26).

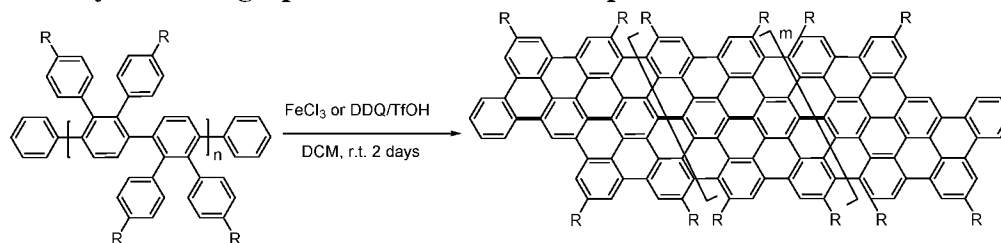
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Scheme 25. Suzuki-Miyaura polycondensation of an AB-type monomer.



20

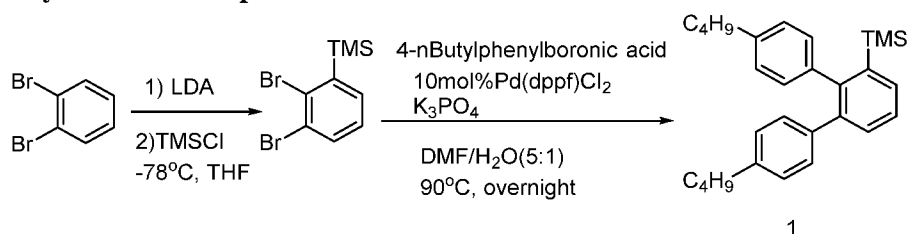
Scheme 26. Synthesis of graphene nanoribbons from precursors.



Example 2: Synthesis of Nanographene Dimer

(2,3-dibromophenyl)trimethylsilane and (2,3-dibromo-1,4-phenylene)bis(trimethylsilane) were synthesized known procedures (Diemer V et al. *Eur. J. Org. Chem.* **2011**, 327-340).

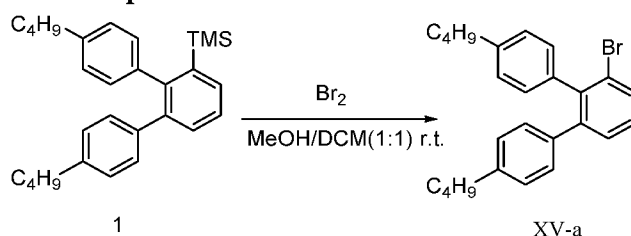
(2,3-dibromophenyl)trimethylsilane (2.6 g, 8.5 mmol), 4-nButylphenylboronic acid (4.54 g, 25.5 mmol, 3 equiv.), K₃PO₄ (11.73 g, 51 mmol, 6 equiv.) and [1,1'-bis(diphenylphosphino)ferrocene]dichloropalladium(II) complex with dichloromethane (528 mg, 0.65 mmol, 7.6 mol%) were mixed in a solution of dimethylformamide (DMF) (15 mL) and water (3 mL). The mixture was degassed by freeze-pumping three times. Then, the mixture was heated to 90°C and stirred overnight. The black mixture was then cooled to room temperature, and 100 mL of ethyl acetate (EtOAc) and 100 mL of water were added. The aqueous phase was extracted by ether (3×50 mL). The combined organic phase was washed with brine and water, and dried over MgSO₄. After the solvents were removed by rotary evaporation, the residue was purified by silica gel chromatography using hexanes as the eluent, affording compound **1** as a colorless oil (1.71 g, 49%). ¹H NMR (CDCl₃, 400 MHz): 7.62 (m, 1H, Ar-*H*), 7.39(m, 2H, Ar-*H*), 6.97-6.91 (m, 8H, Ar-*H*), 2.53 (m, 4H, CH₂), 1.52 (m, 4H, CH₂), 1.28 (m, 4H, CH₂), 0.89 (m, 6H, CH₃), -0.04 (s, 9H, Si-CH₃) ppm. ¹³C NMR (CDCl₃, 101 MHz): 147.15, 141.29, 141.01, 140.33, 139.30, 133.49, 130.80, 130.72, 129.70, 127.30, 127.16, 126.42, 35.22, 35.17, 33.60, 33.45, 22.28, 21.95, 13.97, 0.68 ppm. Rf: 0.39 (hexane). HRMS (CI) for C₂₉H₃₈Si [M⁺]: 414.2743. Found: 414.2741. FTIR (KBr, cm⁻¹): 3047.51, 3021.59, 2955.49, 2928.66, 2857.78, 1512.13, 1465.30, 1400.56, 1247.05, 856.61, 836.30, 797.18, 763.31686.66.

Scheme 27. Synthesis of compound 1.

Bromine (0.576 g, 3.62 mmol) was added dropwise to a solution of compound **1** (1 g, 2.4 mmol) in 5 mL of methanol and 5 mL of dichloromethane (DCM). The mixture was stirred at room temperature overnight (12.5 hours). The reaction was quenched by the addition of a saturated aqueous sodium sulfite solution and DCM (100 mL). The aqueous phase was extracted by DCM (3×50 mL). The combined organic phase was washed with brine and water, and dried over MgSO₄. After the solvents were removed by rotary evaporation, the residue was purified by silica gel chromatography using hexanes as the eluent, affording a compound of Formula XV-a

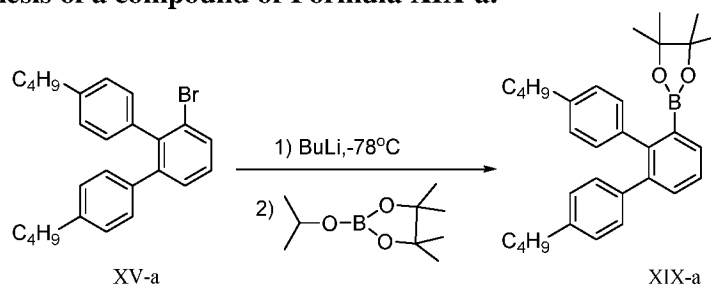
as a colorless oil (0.85 g, 87.5%). ^1H NMR (CDCl_3 , 400 MHz): 7.66 (m, 1H, Ar-*H*), 7.36(m, 1H, Ar-*H*), 7.21 (m, 1H, Ar-*H*), 7.09-6.89 (m, 8H, Ar-*H*), 2.55 (m, 4H, CH_2), 1.54 (m, 4H, CH_2), 1.29 (m, 4H, CH_2), 0.91 (m, 6H, CH_3) ppm. ^{13}C NMR (CDCl_3 , 101 MHz): 143.73, 141.42, 141.19, 141.06, 138.31, 137.32, 131.53, 130.35, 129.40, 129.16, 128.39, 127.54, 127.51, 124.67, 35.27, 35.14, 33.40, 33.33, 22.21, 22.08, 13.97, 13.93 ppm. Rf: 0.49 (hexane). ESI-MS(CI) Calcd. for $\text{C}_{26}\text{H}_{29}^{81}\text{Br}$ $[\text{M}]^+$: 422.1432. Found: 422.1445. FTIR (KBr, cm^{-1}): 3048.43, 3022.99, 2955.58, 2928.24, 2870.51, 2857.36, 1549.09, 1514.61, 1465.01, 1444.24, 1404.22, 1377.52, 1186.30, 1136.63, 1115.17, 1033.68, 836.04, 786.21, 752.87.

Scheme 28. Synthesis of a compound of Formula XV-a.



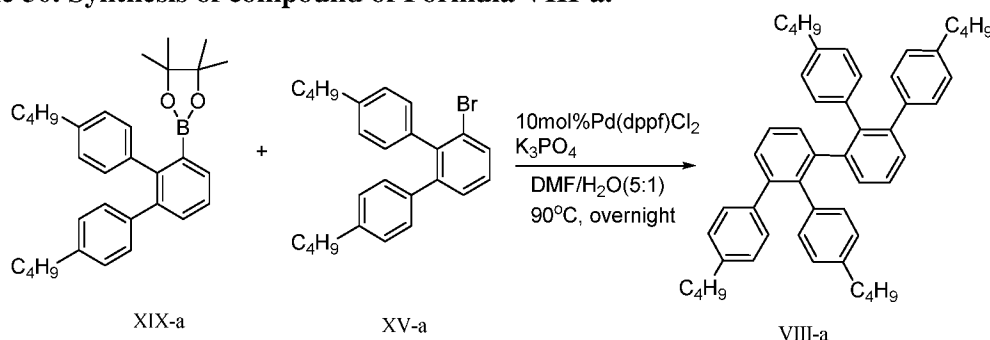
To a solution of the compound of Formula XV-a in 15 mL of THF at -78°C , BuLi (0.93 mL, 1.1 equiv., 2.5 M) was added dropwise. The yellow solution was stirred at -78°C for 1 hour. 2-isopropoxy-4,4,5,5-tetramethyl-1,3,2-dioxaborolane (449 mg, 2.4 mmol) in 2 mL of THF was added dropwise into the solution. The solution was warmed to room temperature for 3 hours. After that, the reaction was quenched by the addition of 100 mL of water. The aqueous phase was extracted by DCM (3x50 mL). The combined organic phase was washed with water and brine, and dried over MgSO_4 . After the solvents were removed by rotary evaporation, the residue was purified by silica gel chromatography using DCM:hexanes (1:9) as the eluent, affording a compound of Formula XIX-a as a colorless oil (0.75 g, 76.3 %). ^1H NMR (CDCl_3 , 400 MHz): 7.61 (dd, 1H, Ar-*H*), 7.43-7.35 (m, 2H, Ar-*H*), 6.98-6.94(m, 8H, Ar-*H*), 2.54 (m, 4H, CH_2), 1.55 (m, 4H, CH_2), 1.13 (s, 12H, CH_3), 0.90 (m, 6H, CH_3) ppm. ^{13}C NMR (CDCl_3 , 101 MHz): 145.23, 140.63, 140.52, 140.49, 139.44, 139.08, 132.32, 131.80, 130.32, 129.69, 127.50, 127.29, 126.45, 83.52, 35.26, 35.21, 33.76, 33.46, 24.53, 22.30, 22.02, 13.97, 13.96 ppm. Rf: 0.13 (DCM/Hexane:1/4). ESI-MS(EI) Calcd for $\text{C}_{32}\text{H}_{41}^{11}\text{BO}_2$ $[\text{M}]^+$: 468.3200. Found: 468.3204. FTIR (KBr, cm^{-1}): 3047.10, 3020.59, 2976.03, 2956.43, 2928.84, 2871.12, 2857.80, 1581.94, 1512.41, 1465.86, 1433.71, 1354.97, 1308.62, 1164.87, 1147.74, 1048.35, 963.34, 832.35, 764.46, 681.97.

Scheme 29. Synthesis of a compound of Formula XIX-a.



The compound of Formula XV-a (210 mg, 0.5 mmol), the compound of Formula XIX-a (280 mg, 0.6 mmol), $K_3PO_4 \cdot H_2O$ (234 mg, 1.2 mmol, 2.4 equiv.) and [1,1'-bis(diphenylphosphino)ferrocene]dichloropalladium(II) complex with dichloromethane (49 mg, 0.06 mmol) were mixed in a solution of DMF (3 mL) and few drops of water. The mixture was degassed by freeze-pumping three times. The orange mixture was heated to 90°C and stirred overnight. After that, the black mixture was cooled to room temperature, and 50 mL of EtOAc and 50 mL of water were added. The aqueous phase was extracted by ether (3×50 mL). The combined organic phase was washed with brine and water, and dried over anhydrous magnesium sulfate. After the solvents were removed by rotary evaporation, the residue was purified by silica gel chromatography using hexanes as the eluent, affording the compound of Formula VIII-a as a white solid (0.276 g, 67.4%). 1H NMR (CD_2Cl_2 , 400 MHz): δ 7.24 (s, 6H, Ar-*H*), 6.91-6.84 (m, 8H, Ar-*H*), 6.70 (br, 8H, Ar-*H*), 2.48 (m, 8H, CH_2), 1.49 (m, 8H, CH_2), 1.25 (m, 8H, CH_2), 0.89 (m, 12H, CH_3) ppm. ^{13}C NMR ($CDCl_3$, 101 MHz): δ 141.60, 141.45, 140.23, 139.67, 139.56, 139.40, 136.20, 131.63, 130.77, 129.66, 129.01, 127.32, 126.63, 125.87, 35.14, 35.08, 33.53, 33.45, 22.20, 21.82, 13.98, 13.94 ppm. Rf: 0.1 (hexane). HR-MS(CI) Calcd. for $C_{52}H_{58}$ $[M]^+$: 682.4539. Found: 682.4526. FTIR (KBr, cm^{-1}): 3049.78, 3022.97, 2955.61, 2927.87, 2870.77, 2857.38, 1513.76, 1456.39, 1445.82, 834.22, 802.54, 759.63.

Scheme 30. Synthesis of compound of Formula VIII-a.

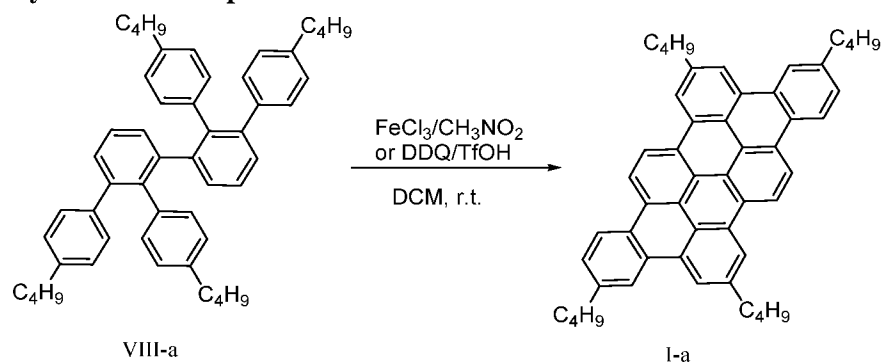


Two methods for the cyclodehydrogenation of the compound of Formula VIII-a to form the compound of Formula I-a are shown in Scheme 31 and described below.

Method 1: The compound of Formula VIII-a (34 mg, 0.05 mmol) was dissolved in 100 mL of dichloromethane. The colorless solution was degassed by bubbling with argon for 20 minutes. Then, ferric chloride (454 mg, 2.8 mmol, 7 eqv./H) in 2.0 mL of nitromethane was added dropwise and the resulting black solution was stirred for 24 hours with continuous bubbling of argon. After that, an excess amount of methanol was added, and the black solid was filtered and washed with water and methanol. After drying under vacuum, a brown black solid was obtained in 98% yield (33.0 mg).

Method 2: The compound of Formula VIII-a (13.6 mg, 0.02 mmol) was dissolved in 10 mL of dry dichloromethane under argon. The colorless solution was cooled to 0°C and 0.5 mL of CF₃SO₃H was added dropwise. Then, the resulting black solution was stirred for 6 hours. After that, the reaction was quenched by the addition of a saturated aqueous NaHCO₃ solution. The solution was extracted by dichloromethane (3×50 mL). The organic phase was collected and washed with water and brine, and dried by Na₂SO₄. After removal of solvent by rotary evaporation and drying under vacuum, a brown black solid was obtained in 60% yield (8 mg).

Scheme 31. Synthesis of compound of Formula I-a.



The compound of Formula I-a was characterized by X-ray diffraction and matrix-assisted laser desorption/ionization time-of-flight (MALDI-TOF) mass spectrometry (MS) spectroscopy. The X-ray structure (Figure 1) and MALDI-TOF-MS analysis (Figure 2) revealed that the compounds can be fully dehydrogenated by either FeCl₃/CH₃NO₂ or DDQ/CF₃SO₃H.

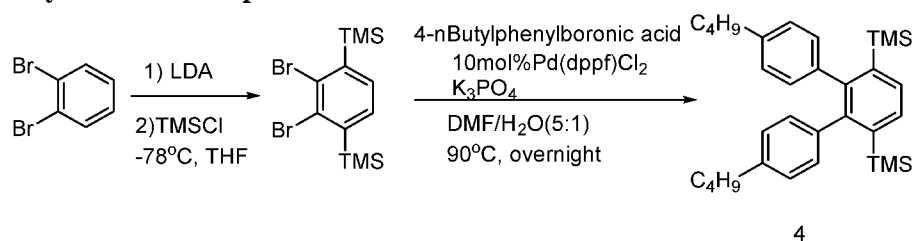
¹H NMR (CD₂Cl₂, 400 MHz): 9.21-8.56 (m, 12H, Ar-H), 7.80 (m, 2H, Ar-H), 3.14-2.96 (m, 8H, CH₂), 1.99-1.88 (m, 9H, CH₂), 1.27-0.89 (m, 19H, CH₂ and CH₃) ppm. FTIR (KBr, cm⁻¹

¹): 3064.25, 2954.87, 2927.57, 2855.85, 1612.12, 1454.35, 1377.09, 1101.82, 811.54. HR-MS(CI) Calcd. for C₅₂H₅₀ [M]⁺: 674.3913. Found: 674.3906.

Example 3: Synthesis of Nanographene Trimer

(2,3-dibromophenyl)trimethylsilane (0.76 g, 2 mmol), 4-nButylphenylboronic acid (1.07 g, 6 mmol, 3 equiv.), K₃PO₄·7H₂O (4.06 g, 12 mmol, 6 equiv.) and [1,1'-bis(diphenylphosphino)ferrocene]dichloropalladium(II) complex with dichloromethane (164 mg, 0.2 mmol, 10 mol%) were mixed in a solution of DMF (15 mL). After degassing by freeze-pumping three times, the mixture was heated to 90°C and stirred overnight. After that, the black mixture was cooled to room temperature, and 100 mL of EtOAc and 100 mL of water were added. The aqueous phase was extracted by ether (3×50 mL). The combined organic phase was washed with brine and water, and dried over magnesium sulfate. After the solvents were removed by rotary evaporation, the residue was purified by silica gel chromatography using hexanes as the eluent, affording compound **4** as a colorless oil (0.93 g, 96 %). ¹H NMR (CDCl₃, 400 MHz): 7.62 (s, 2H, Ar-*H*), 6.84(m, 8H, Ar-*H*), 2.48 (t, 4H, CH₂), 1.48 (m, 4H, CH₂), 1.23 (m, 4H, CH₂), 0.87 (t, 6H, CH₃), -0.06 (s, 18H, Si-CH₃) ppm. ¹³C NMR (CDCl₃, 101 MHz): 147.54, 140.37, 140.00, 139.56, 132.42, 130.72, 126.63, 35.12, 33.53, 21.91, 13.92, 0.42 ppm. Rf: 0.76 (hexane). HR-MS(CI) Calcd. for C₃₂H₄₆Si₂ [M]⁺: 486.3138. Found: 486.3125. FTIR (KBr, cm⁻¹): 3088.76, 3056.07, 3023.38, 2953.92, 2933.48, 2855.85, 1511.46, 1466.52, 1376.62, 1245.86, 1184.56, 1021.11, 833.14, 665.61.

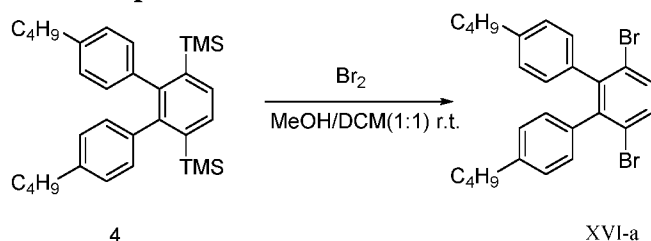
Scheme 32. Synthesis of compound 4



Bromine (0.406 g, 2.56 mmol) was slowly added to a solution of compound **4** (0.414 g, 0.85 mmol) in 5 mL of methanol and 5 mL of DCM in an ice water bath. The mixture was stirred at room temperature overnight (12.5 hours). The reaction was quenched by the addition of a saturated aqueous sodium sulfite solution and dichloromethane (50 mL). The aqueous phase was extracted by DCM (3×50 mL). The combined organic phase was washed with brine and water, and dried over MgSO₄. After the solvents were removed by rotary evaporation, the

residue was purified by silica gel chromatography using hexanes as the eluent, affording a compound of Formula XVI-a as a white solid (0.309 g, 73%). ¹H NMR (CDCl₃, 400 MHz): δ 7.51 (s, 2H, Ar-H), 6.95-6.83 (m, 8H, Ar-H), 2.50 (t, 4H, CH₂), 1.50 (m, 4H, CH₂), 1.23 (m, 4H, CH₂), 0.88 (t, 6H, CH₃) ppm. ¹³C NMR (CDCl₃, 101 MHz): δ 144.18, 141.47, 137.33, 132.49, 129.64, 127.37, 123.30, 35.22, 33.30, 22.06, 13.95 ppm. Rf: 0.4 (hexane). HR-MS(CI) Calcd. for C₂₆H₂₈⁷⁹Br⁸¹Br [M]⁺: 500.0537. Found: 500.0539. FTIR (KBr, cm⁻¹): 3084.68, 3047.90, 3023.38, 2958.00, 2929.40, 2851.76, 1617.71, 1515.55, 1425.65, 1405.22, 1376.62, 1147.79, 1029.28, 1004.77, 837.23, 804.54, 608.40.

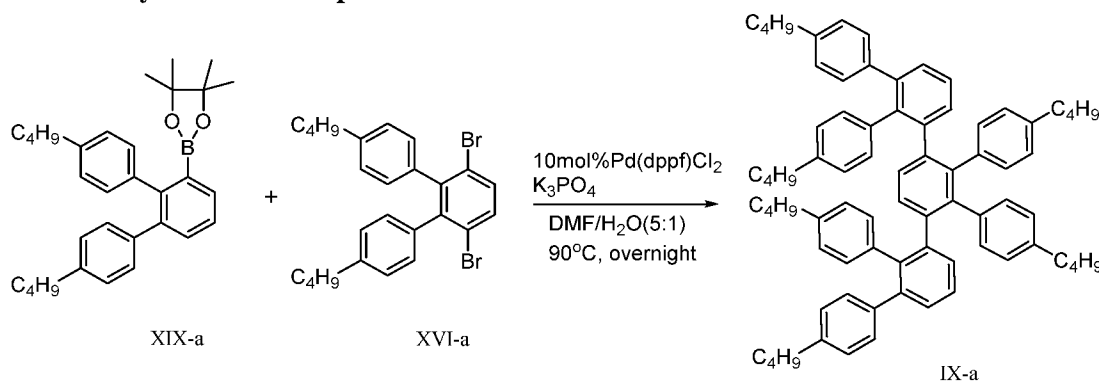
Scheme 33. Synthesis of a compound of Formula XVI-a.



The compound of Formula XIX-a (351 mg, 0.75 mmol), the compound of Formula XVI-a (149 mg, 0.3 mmol, 2.5 equiv.), K₃PO₄·H₂O (345 mg, 1.5 mmol, 5 equiv.) and [1,1'-bis(diphenylphosphino) ferrocene]dichloropalladium(II) complex with dichloromethane (24 mg, 0.03 mmol) were mixed in a solution of DMF (3 mL) and water (0.6 mL). The mixture was degassed by freeze-pumping three times. The orange mixture was heated to 90°C and stirred overnight (14 hours). After that, the black mixture was cooled to room temperature, and 50 mL of EtOAc and 50 mL of water were added. The aqueous phase was extracted by ether (3×50 mL). The combined organic phase was washed with brine and water, and dried over anhydrous magnesium sulfate. After the solvents were removed by rotary evaporation, the residue was purified by silica gel chromatography using hexanes as the eluent, affording the compound of Formula IX-a as a white solid (0.238 g, 78%). ¹H NMR (CD₂Cl₂, 400 MHz): δ 7.25-7.07 (m, 8H, Ar-H), 6.94-5.99 (m, 24H, Ar-H), 2.59-2.33(m, 12 H, CH₂), 1.60-1.13(m, 24 H, CH₂), 0.95-0.83(m, 12H, CH₃) ppm. ¹³C NMR (CD₂Cl₂, 101 MHz) δ 141.97, 141.83, 141.49, 141.34, 140.47, 140.30, 140.20, 140.01, 139.97, 139.84, 139.75, 139.56, 139.40, 139.17, 136.97, 136.83, 136.49, 136.46, 131.93, 131.57, 130.83, 129.79, 129.67, 129.59, 129.37, 128.85, 127.36, 127.29, 126.78, 126.53, 125.81, 125.67, 35.23, 35.06, 34.91, 33.84, 33.71, 33.54, 33.50, 22.23, 22.04, 21.89, 21.83, 21.78, 13.81, 13.77, 13.69, 13.67 ppm. Rf: 0.4 (DCM/Hexane:1/4) HR-MS(CI) Calcd. for C₇₈H₈₆ [M]⁺: 1022.6730. Found: 1022.6700. FTIR (KBr, cm⁻¹): 3084.81, 3060.29,

3023.51, 2958.13, 2925.44, 2860.06, 1511.61, 1454.40, 1409.45, 1376.76, 1115.25, 1000.83, 833.30, 804.69, 759.74.

Scheme 34. Synthesis of compound of Formula IX-a.



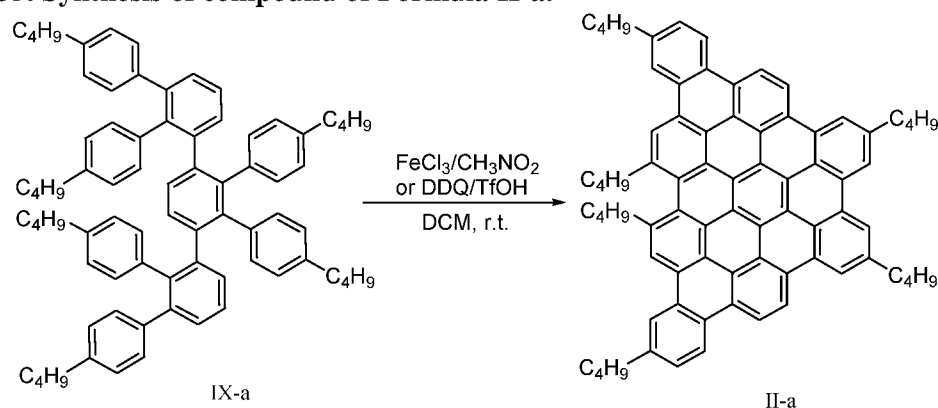
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Two methods for the cyclodehydrogenation of the compound of Formula IX-a to form the compound of Formula II-a are shown in Scheme 35 and described below.

Method 1: The compound of Formula IX-a (30.5 mg, 0.03 mmol) was dissolved in 100 mL of dichloromethane. The colorless solution was degassed by bubbling with argon for 20 minutes. Then, ferric chloride (544 mg, 3.36 mmol, 7 eqv./H) in 2.0 mL of nitromethane was added dropwise and the resulting black solution was stirred for 24 hours with continuous bubbling of argon. After that, an excess amount of methanol was added and the black solid filtered, and washed with water and methanol. After drying under vacuum, a brown black solid was obtained in 83% yield (25.0 mg, 0.025 mmol).

Method 2: The compound of Formula IX-a (10 mg, 0.01 mmol) was dissolved in 10 mL of dry dichloromethane under argon. The colorless solution was cooled to 0°C, and 0.5 mL of CF₃SO₃H was added dropwise. Then, the resulting black solution was stirred for 8 hours. After that, the reaction was quenched by the addition of a saturated aqueous NaHCO₃ solution. The solution was extracted by dichloromethane (3×50 mL). The organic phase was collected and washed with water and brine, and dried by Na₂SO₄. After removal of the solvent by rotary evaporation and drying under vacuum, a brown black solid was obtained in 70% yield (7 mg).

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Scheme 35. Synthesis of compound of Formula II-a.

The compound of Formula II-a was characterized by X-ray diffraction and matrix-assisted laser desorption/ionization time-of-flight (MALDI-TOF) mass spectrometry (MS) spectroscopy. The X-ray structure (Figure 3) and MALDI-TOF-MS analysis (Figure 4) revealed that the compounds can be fully dehydrogenated by either $\text{FeCl}_3/\text{CH}_3\text{NO}_2$ or $\text{DDQ}/\text{CF}_3\text{SO}_3\text{H}$.

^1H NMR (CD_2Cl_2 , 400 MHz, 25°C): 9.39 (s, 2H, Ar-*H*), 9.08 (s, 2H, Ar-*H*), 8.83 (s, 2H, Ar-*H*), 8.74 (s, 2H, Ar-*H*), 8.16 (s, 2H, Ar-*H*), 7.82 (s, 2H, Ar-*H*), 7.23 (s, 2H, Ar-*H*), 6.44 (s, 2H, Ar-*H*), 4.13 (s, 4H, CH_2), 4.13 (s, 4H, CH_2), 3.25 (t, 4H, CH_2), 2.12-0.65 (m, 46H, CH_2 and CH_3) ppm. FTIR (KBr, cm^{-1}): 3064.25, 2962.09, 2925.31, 2851.76, 1609.53, 1450.17, 1331.67, 1098.75, 808.63.

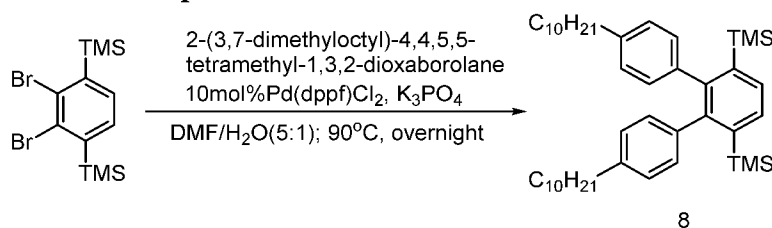
Example 4: Synthesis of Graphene Nanoribbons

1-bromo-4-(3,7-dimethyloctyl)benzene (4.71 g, 15.9 mmol), 4,4,4',4',5,5,5',5'-octamethyl-2,2'-Bi-(1,3,2-dioxaborolane (4.45 g, 17.5 mmol), potassium acetate (4.67 g, 47.7 mmol), and [1,1'-bis(diphenylphosphino)ferrocene] dichloropalladium(II) complex with dichloromethane (650 mg, 0.795 mmol) were mixed in 30 mL of *N,N*-dimethylformamide (DMF). The mixture was freeze-pumped three times and then heated to 110°C for 28 hours. After cooling to room temperature, 100 mL of water and 100 mL of ethyl acetate were added. The aqueous phase was extracted by ether (3×100 mL). The combined organic phase was washed with brine and water, and dried over anhydrous magnesium sulfate. After the solvents were removed by rotary evaporation, the residue was purified by silica gel chromatography using DCM:hexanes (1:4) as the eluent, affording 2-(3,7-dimethyloctyl)-4,4,5,5-tetramethyl-1,3,2-dioxaborolane as a light-yellow oil (4 g, 73%). ^1H NMR (400 MHz, CDCl_3) δ 7.75 (d, J = 8 Hz, 2H, Ar-*H*), 7.22 (d, J = 8 Hz, 2H, Ar-*H*), 2.60 (m, 2H, CH_2), 1.63-1.13(m, 15H, CH_2), 0.94

(d, $J = 8\text{ Hz}$, 3H, CH_3), 0.89(d, $J = 8\text{ Hz}$, 6H, CH_3) ppm. ^{13}C NMR (101 MHz, CDCl_3) δ 146.70, 134.85, 127.85, 83.58, 39.33, 38.84, 37.14, 33.74, 32.50, 27.97, 24.86 (2C), 24.70, 22.73, 22.63, 19.60 ppm. Rf: 0.5 (DCM/Hexane:1/4). HR-MS(CI) Calcd. for $\text{C}_{22}\text{H}_{37}^{11}\text{BO}_2$ $[\text{M}]^+$: 344.2887. Found: 344.2889. FTIR (KBr, cm^{-1}): 3080.59, 3043.81, 2962.09, 2929.40, 2868.10, 1613.62, 1466.52, 1405.22, 1356.19, 1315.32, 1270.37, 1143.70, 1090.58, 1025.20, 967.99, 857.66, 657.43.

(2,3-dibromophenyl)trimethylsilane (2.41 g, 6.38 mmol), 2-(4-(3,7-dimethyloctyl)phenyl)-4,4,5,5-tetramethyl-1,3,2-dioxaborolane (6.58 g, 19.14 mmol, 3 equiv.), $\text{K}_3\text{PO}_4 \cdot 7\text{H}_2\text{O}$ (12.94 g, 12 mmol, 6 equiv.), and [1,1'-bis(diphenylphosphino)ferrocene] dichloropalladium(II) complex with dichloromethane (521 mg, 0.64 mmol, 10 mol%) were mixed in a solution of DMF (15 mL) and 1 mL of water. After degassing by freeze-pumping three times, the mixture was heated to 90°C and stirred overnight. After that, the black mixture was cooled to room temperature, and 100 mL of EtOAc and 50 mL of water were added. The aqueous phase was extracted by ether ($3 \times 100\text{ mL}$). The combined organic phase was washed with brine and water, and dried over magnesium sulfate. After the solvents were removed by rotary evaporation, the residue was purified by silica gel chromatography using hexanes as the eluent, affording compound **8** as a colorless oil (2.59 g, 62 %). ^1H NMR (400 MHz, CDCl_3) δ 7.62 (s, 2H, Ar- H), 6.86 (m, 8H, Ar- H), 2.49 (m, 4H, CH_2), 1.53-1.14 (m, 20H, CH and CH_2), 0.89-0.85(m, 18H, CH_3), -0.07(s, 18H, SiCH_3) ppm. ^{13}C NMR (101 MHz, CDCl_3) δ 147.51, 140.68, 140.08, 139.55, 132.45, 130.77, 130.75, 126.65, 126.61, 39.32, 38.86, 37.12, 32.99, 32.06, 27.96, 24.74, 22.72, 22.63, 19.58, 0.46 ppm. Rf: 0.78 (hexane). HR-MS(CI) Calcd. for $\text{C}_{44}\text{H}_{70}\text{Si}_2$ $[\text{M}]^+$: 654.5016. Found: 654.5001. FTIR (KBr, cm^{-1}): 3080.59, 3051.99, 3019.30, 2962.09, 2929.40, 2868.10, 1511.46, 1462.43, 1380.70, 1249.94, 1184.56, 1045.63, 1021.11, 845.40, 755.51, 686.04, 645.18.

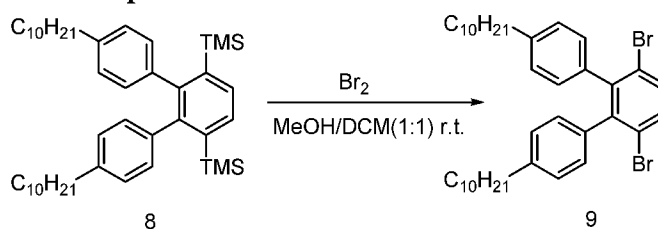
Scheme 36. Synthesis of Compound 8.



Bromine (0.954 g, 6 mmol) was added dropwise to a solution of compound **8** (1.3 g, 2 mmol) in dichloromethane (5 mL) and methanol (5 mL). The mixture was stirred at room

temperature overnight (19 hours). The reaction was quenched by the addition of a saturated aqueous sodium sulfite solution and dichloromethane (100 mL). The aqueous phase was extracted by dichloromethane (3×50 mL). The combined organic phase was washed with water and brine, and dried over magnesium sulfate. After the solvents were removed by rotary evaporation, the residue was purified by silica gel chromatography using hexanes as the eluent, affording compound **9** as a colorless oil (0.95 g, 71.3%). ¹H NMR (400 MHz, CDCl₃) δ 7.51 (s, 2H, Ar-*H*), 6.95 (m, 4H, Ar-*H*), 6.85(m, 4H, Ar-*H*), 2.50 (m, 4H, CH₂), 1.52-1.07 (m, 20H, CH₂), 0.86 (m, 18H, CH₃) ppm. ¹³C NMR (101 MHz, CDCl₃) δ 144.14, 141.78, 137.29, 132.49, 129.67, 129.64, 127.31, 123.37, 39.32, 38.56, 37.09, 33.11, 32.36, 27.96, 24.69, 22.71, 22.63, 19.62 ppm. Rf: 0.4 (hexane). HRMS (ESI) for C₃₈H₅₂⁷⁹Br⁸¹Br [M]⁺: 668.2415. Found: 668.2435. FTIR (KBr, cm⁻¹): 3088.76, 3056.07, 3023.38, 2958.00, 2933.48, 2868.10, 1515.55, 1462.43, 1425.65, 1384.79, 1147.79, 1029.28, 1004.45, 665.61, 604.31.

Scheme 37. Synthesis of Compound 9.

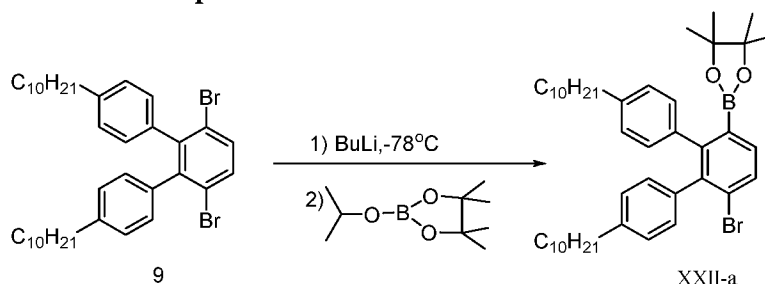


To a solution of compound **9** (3.12 g, 4.69 mmol) in THF (15 mL) at -78°C, BuLi (2.1 mL, 5.16 mmol, 1.1 equiv., 2.5 M) was added dropwise. The yellow solution was stirred at -78°C for 1 hour. 2-isopropoxy-4,4,5,5-tetramethyl-1,3,2-dioxaborolane (1.1 mg, 5.93 mmol) in 5 mL of THF was added dropwise to the solution. The solution was warmed to room temperature and stirred for 3 hours. After that, the reaction was quenched by the addition of 100 mL of water. The aqueous phase was extracted by DCM (3×50 mL). The combined organic phase was washed with water and brine, and dried over MgSO₄. After the solvents were removed by rotary evaporation, the residue was purified by silica gel chromatography using DCM/hexanes (1:4) as the eluent, affording a compound of Formula XXII-a as a colorless oil (2.7 g, 80.6 %). ¹H NMR (400 MHz, CDCl₃) δ 7.64 (d, J = 8 Hz, 1H, Ar-*H*), 7.45(d, J = 8 Hz, 1H, Ar-*H*), 7.26-6.83(m, 8H, Ar-*H*), 2.50 (m, 4H, CH₂), 1.56-1.09 (m, 20H, CH₂ and CH), 1.07 (s, 12H, CH₃), 0.87 (m, 18H, CH₃) ppm. ¹³C NMR (101 MHz, CDCl₃) δ 148.33, 141.49, 141.32, 140.93, 138.93, 137.45, 133.39, 130.80, 130.14, 130.11, 129.89, 127.25, 126.91, 126.59, 83.66, 39.36, 39.33, 39.11, 38.53, 37.13, 33.13, 33.02, 32.33, 32.19, 27.96, 27.95, 24.71, 24.69, 24.48, 22.73, 22.71,

22.65, 22.61, 19.64, 19.53 ppm. Rf: 0.2 (DCM/Hexane:1/4). HRMS (ESI) for $C_{44}H_{64}^{11}BO_2^{81}Br$ $[M]^+$: 716.4162. Found: 716.4192. FTIR (KBr, cm^{-1}): 3088.76, 3047.90, 3031.55, 2958.00, 2925.31, 2868.10, 1560.50, 14666.52, 1356.19, 1311.24, 1266.29, 1147.79, 1033.37, 849.49, 812.71, 690.12.

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Scheme 38. Synthesis of a compound of Formula XXII-a.



The compound of Formula XXII-a (e.g., an AB-type bifunctional monomer) was polymerized under various conditions to form various precursors (e.g., compounds of Formula XII-a), as summarized in Table 1 and shown in Scheme 39.

In general, the compound of Formula XXII-a (143 mg, 0.2 mmol), a catalyst, a base (aqueous, 3M) and a degassed solvent were mixed in an 8 mL of vial in a glovebox. The vial was sealed and the solution was stirred and thermostated at a desired temperature. After a desired time, phenylboronic acid (1 equiv.) was added, and the mixture was stirred for 12 hours. Then, bromobenzene (1 equiv.) was added, and the resulting mixture was stirred for 12 hours. After that, 30 mL of water and 30 mL of DCM were added. The aqueous phase was extracted by DCM (3×10 mL). The combined organic phase was washed with water. The solution was reduced by rotary evaporation to 2 mL, and the resulting solution was added to 30 mL of acidic methanol. After stirring at room temperature for 2-3 hours, the polymer (e.g., compound of Formula XII-a; also referred to herein as a polymer precursor, which indicates the compound is a precursor to a graphene nanoribbon and comprises a polymer) was filtered and dried at room temperature for overnight. After that, the solid was fractionated by soxhlet extraction with boiling acetone for 2 days, and then dried in vacuum at room temperature.

Scheme 39. General synthesis of compounds of Formula XII-a.

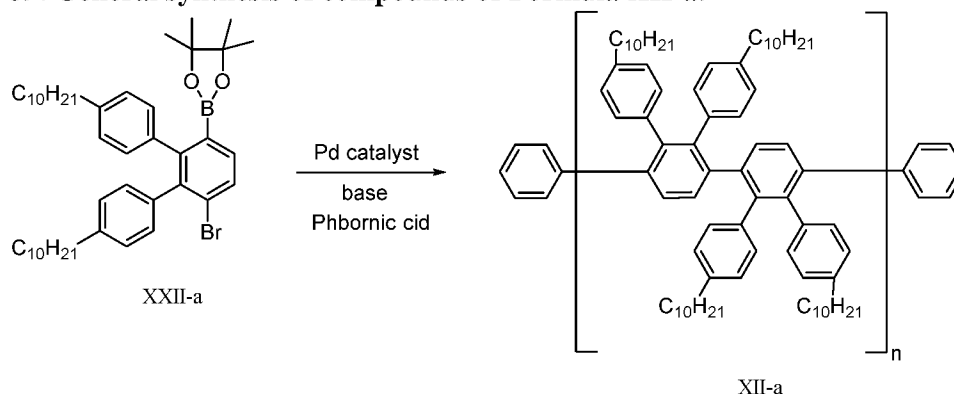


Table 1. Summary of synthetic parameters for synthesis of compounds of Formula XII-a from a compound of Formula XXII-a.^a

Entry	Cat.	solvent	time	temp. (°C)	Isolated yield %	Mn ^b (10 ³)	Mw ^b (10 ³)	PDI ^b	Repeated unit number (n)
1	PhPd(^t Bu ₃ P)Br	DCM	15 h	25	95	10.5	15.1	1.44	22
2 ^c	PhPd(^t Bu ₃ P)Br	DCM	15h	25	70	11.5	16.3	1.42	27
3 ^d	PhPd(^t Bu ₃ P)Br	DCM	24h	50	97	15.3	25.0	1.63	30
4 ^e					71	19.3	27.5	1.42	38
5 ^d	PhPd(^t Bu ₃ P)Br	DCM	3d	25	96	13.2	20.7	1.57	26
6 ^e					70	20.6	25.7	1.25	41
7	Pd(PPh ₃) ₄	Toluene	3d	120	92	14.5	18.7	1.29	29
8	Pd(<i>o</i> -tol ₃ P) ₂	DCM	3d	25	-	4.5	5.8	1.3	8
9	Pd(^t Bu ₃ P) ₂	dioxane	3d	110	78	6.2	9.7	1.57	12

^aGeneral conditions: [M]:0.4 M; the amount of catalyst: 3 mol%; base: 3M K₃PO₄; ^bdetermined GPC using THF as the eluent at 30 °C and polystyrene standards for calibration; ^c base: K₃PO₄·H₂O (solid). ^d the amount of catalyst: 0.5 mol%; ^e samples are fractionated by soxhlet extraction by boiling acetone.

As shown in Table 1, the polymerization performance with PhPd(^tBu₃P)Br as a catalyst was studied at several sets of conditions. Polymerization with 3M K₃PO₄ as the base and DCM as the solvent at 50°C showed the best performance, producing the highest molecular weight polymers (Table 1, Entry 3; isolated yield of 97%, Mn of 15.3 kda, Mw of 25.0 kda, PDI of 1.63, and a degree of polymerization of 30). Further purification of the crude polymer by soxhlet extraction with boiling acetone separated the higher molecular weight polymers (Table 1, Entry 4; Mn of 19.3 kda, Mw of 27.5 kda, PDI of 1.43).

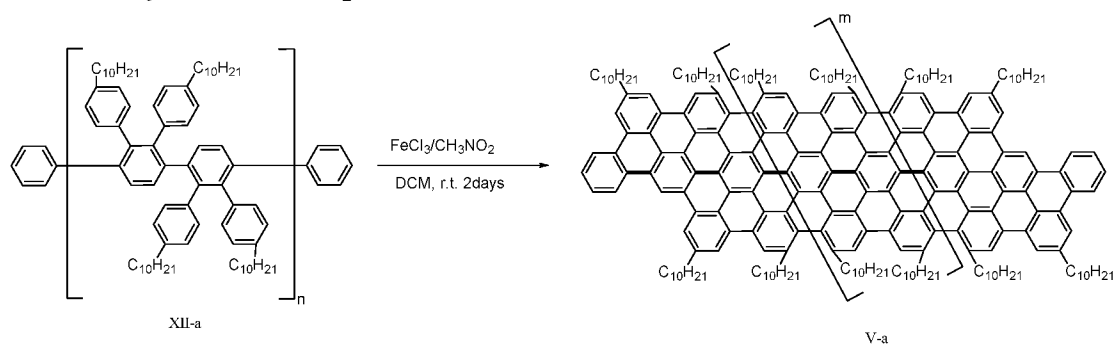
Changing the catalytic system, for example to Pd(PPh₃)₄/ K₃PO₄/toluene, Pd(*o*-tol₃P)₂/ K₃PO₄/DCM, or Pd(^tBu₃P)₂ K₃PO₄/Dioxane, resulted in relatively lower molecular weight polymers (Table 1, Entries 7-9).

The polymer samples were characterized using various techniques. Gel permeation chromatography (GPC) analysis of the polymers generally showed a sharp signal, for example as shown in Figure 5 for Entry 4 of Table 1.

The obtained polymer samples were also characterized by ^1H NMR and ^{13}C NMR spectroscopy. Like NMR spectroscopy of typical polymers, the protons in the ^1H NMR spectra of the polymer samples generally displayed broad signals (for example, as shown in Figure 6) and the carbon atoms in the ^{13}C NMR spectra of the polymer samples similarly displayed broad signals (for example, as shown in Figure 7). The broadness of the signals in the NMR spectra makes it difficult to distinguish the signals originating from the end groups in the NMR spectra of the high molecular weight polymer samples.

Graphene nanoribbons (e.g., compounds of Formula V-a) were subsequently prepared from the polymer precursors (e.g., compounds of Formula XII-a) via cyclodehydrogenation with $\text{FeCl}_3/\text{CH}_3\text{NO}_2$ as Lewis acid and oxidant in dichloromethane (DCM). Generally, the polymer precursor (30.9 mg) was dissolved in 100 mL of dichloromethane. The colorless solution was degassed by bubbling with argon for 20 minutes. Then, ferric chloride (544 mg, 7 eqv./H) in 3.0 mL of nitromethane was added dropwise and the resulting black solution was stirred for two days with continuous bubbling of argon. After that, an excess amount of acidic methanol was added, and the black solid filtered and washed with water and methanol. After drying under vacuum and soxhlet extraction with boiling acetone for 2 days, a black solid was obtained in 95% yield.

Scheme 40. Synthesis of compounds of Formula V-a.



The efficiency of the cyclodehydrogenation was investigated by Fourier transform infrared (FTIR), Raman, and UV-visible spectroscopic analysis. A comparison of the FTIR spectra of a polymer precursor and the resulting graphene nanoribbon revealed the disappearance of the band at 4054.14 cm^{-1} which originates from the rotation of free phenyl rings, the

attenuation of the signal triad from aromatic C-H stretching vibrations at 3024.29, 3050.17, and 3082.86 cm^{-1} , as well as the disappearance of out of plane (opla) C-H deformation bands at 825.58 cm^{-1} , which are attributed to disubstituted benzene rings (Figure 8A, 8B, 8C). Taken together, the results of the FTIR analysis indicate the successful conversion of the precursor into the graphene nanoribbon.

The Raman spectrum of a powder sample of a graphene nanoribbon was measured, and showed a first-order D band (disorder band) at 1308 cm^{-1} and a G band (graphite band) at 1596 cm^{-1} (Figure 9), consistent with literature values for graphene nanoribbons. The relatively high intensity of the D band can be attributed to the contribution of the edges as defects in the spectrum. Moreover, the Raman signals at 2632 cm^{-1} , 2910 cm^{-1} were assigned to the 2D and D+D' bands, respectively.

The UV-vis absorption spectra of the nanographene trimer, a graphene nanoribbon formed from an oligomer precursor (GNR G1), and a graphene nanoribbon formed from a polymer precursor (GNR G1S) were recorded on a solid film and are shown in Figure 10. The UV-vis absorption spectrum of the graphene nanoribbon formed from a polymer precursor displayed an overall broad absorption that extended into the near-infrared (NIR) region. The absorption edges of two graphene nanoribbons were estimated from the spectra to be 1170 nm and 1110 nm, corresponding to an optical band gap of 1.06 eV and 1.12 eV, respectively.

In summary, described herein are methods for synthesizing small nanographenes and graphene nanoribbons. The structures of the small nanographenes and the graphene nanoribbons were supported by x-ray diffraction; Maldi-ToF-MS; FTIR, Raman and ultraviolet-visible absorption spectroscopy; and ^1H and ^{13}C NMR spectroscopy. The small nanographenes and graphene nanoribbons described herein can, for example, be used in electronic devices and biological sensors.

In general, the methods described herein for synthesizing graphene nanoribbons involved the use of a monomer to synthesize poly(*p*-phenylenes) with high molecular weights under mild conditions (room temperature or 50 °C).

The methods described herein provide "bottom-up" synthetic routes to small nanographenes with clear x-ray structures and longer graphene nanoribbons with precise width and edges that cannot be obtained by "top-down" methods. Compared to other graphene nanoribbons synthesized from bottom-up routes, the graphene nanoribbons described herein exhibit different terminal-edge structures (on the short side of the ribbon). The length of the graphene nanoribbons described herein are also longer than a related graphene nanoribbon

reported in the literature in 2008 (*J. Am. Chem. Soc.* 2008, 130, 4216-4217). The edge (e.g., the terminal edge) structure of graphene nanoribbons can affect the physical properties of the material (Brey, L.; Fertig, H. A. *Phys. Rev. B* 2006, 73, 235411; Son, Y. -W.; Cohen, M. L.; Louie, S. G. *Nature* 2006, 444, 347).

5 The methods described herein can be more efficient and/or more modular than previously described methods. The methods described herein can be cost- and step-economical, because the monomer used can be made from inexpensive starting materials in a short sequence. The methods described herein are also modular, thus the methods can have the potential for synthesizing other graphene nanoribbons with different widths and edge functions. The graphene
10 nanoribbons described herein have a different structure than those previously described, for example with respect to the terminal-edge structure. The methods described herein can, for example, be used to investigate factors affecting the electronic properties of graphene nanoribbons.

15 **Example 5: Synthesis of functionalized nanographenes and graphene nanoribbons**

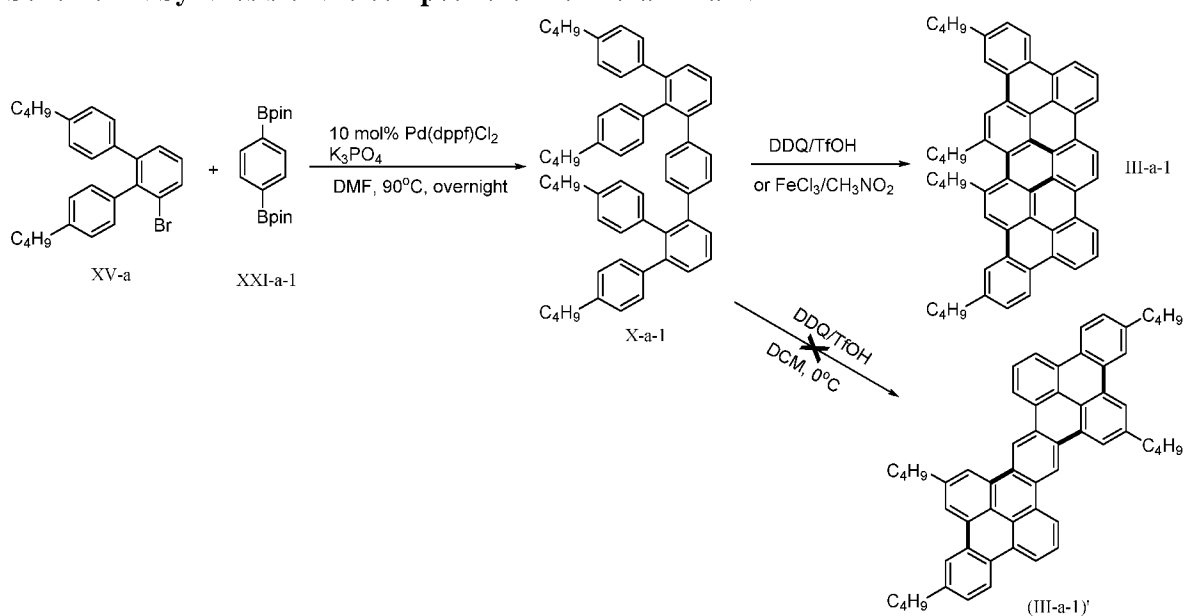
Also discussed herein are “bottom-up” synthetic routes to obtain functionalized graphene nanoribbons (GNRs) with precise width and edges structures, including, for example, graphene nanoribbons with edges fused by heterocycles. The methods described herein involve copolymerization of a sterically less hindered but functionalized monomer and a more rigid
20 triaryl monomer to synthesize the edge-functionalized poly(phenylenes) with a high molecular weight under mild conditions (50°C). The edge structures and width of graphene nanoribbons can affect the physical properties of the material (Brey, L.; Fertig, H. A. *Phys. Rev. B* 2006, 73, 235411; Son, Y. -W.; Cohen, M. L.; Louie, S. G. *Nature* 2006, 444, 347). Some examples of the graphene nanoribbons discussed herein have electron deficient groups as acceptors on the edge,
25 which can be used as semi-conducting materials.

In order to test the graphitization step and help us to understand the final graphene nanoribbons, nanographenes were designed and synthesized, for example as shown in Scheme 41-Scheme 44. The corresponding precursors were prepared by Suzuki-Miyaura coupling reaction either triaryl bromide with aryl-1,4-diboronic acid ester (Scheme 41- Scheme 44) or
30 triarylboronic acid ester with 1,4-dibromoaryl compound in moderate to high yields (Scheme 44).

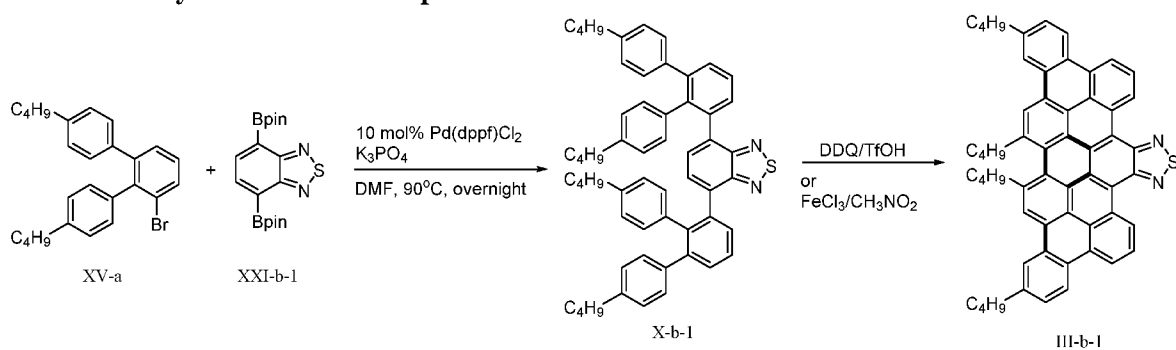
The small nanographenes were synthesized by the Scholl oxidation of the corresponding precursors with an oxidant such as 2,3-dichloro-5,6-dicyano-1,4-benzoquinone

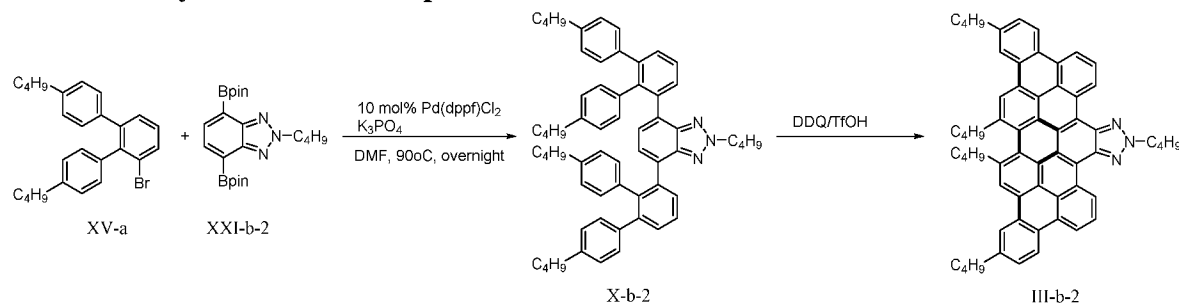
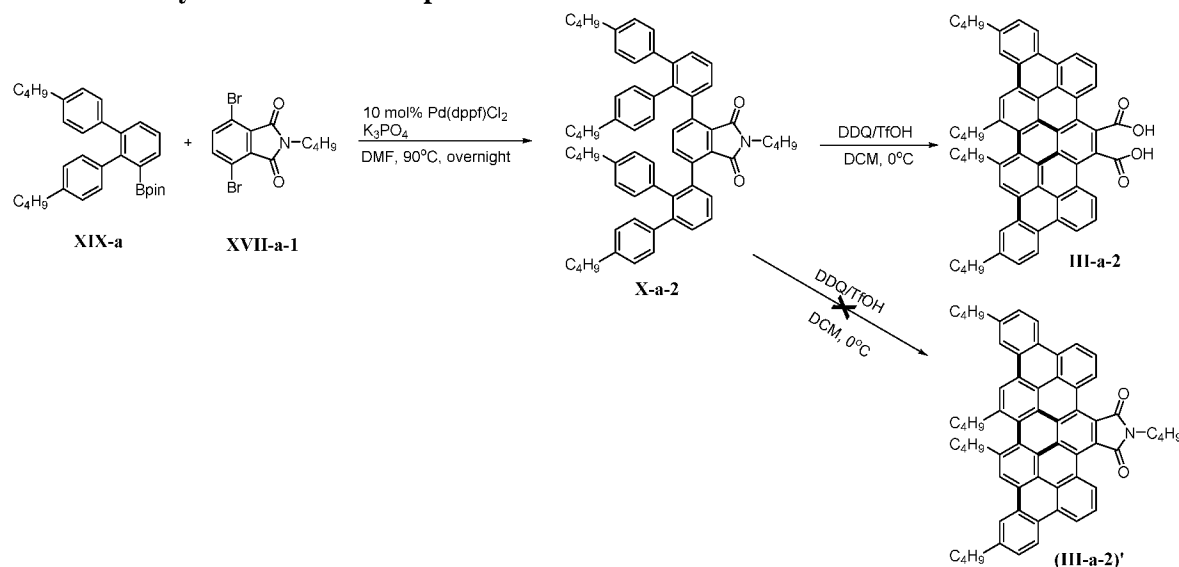
(DDQ)/trifloromethanesulfonic acid (TfOH) or ferric chloride and the products were fully characterized by MALDI-TOF MS, FTIR, and ^1H (^{13}C) NMR spectroscopy. The Scholl oxidation of the compound of Formula X-a-1 shows regioselectivity, and NMR and MALDI-TOF MS and X-ray analyses on the sample show the compound of Formula III-a-1 as the exclusive product (Scheme 41). However, the reaction of the compound of Formula X-a-2 with DDQ/TfOH under the same conditions generated the compound of Formula III-a-2 as final product, and the (Formula III-a-2)' is not detected by MALDI-TOF MS and NMR techniques (Scheme 44).

Scheme 41. Synthesis of the compound of Formula III-a-1.



Scheme 42. Synthesis of the compound of Formula III-b-1.



Scheme 43. Synthesis of the compound of Formula III-b-2.**Scheme 44. Synthesis of the compound of Formula III-a-2.**

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A variety of edge functionalized graphene nanoribbons with desired width can be prepared from well-designed co-monomers. Firstly, the high molecular weights' polymer precursors can be synthesized via Suzuki–Miyaura copolymerization of the co-monomers using a Pd catalyst such as $\text{PhPd}(\text{tBu}_3\text{P})\text{Br}$, $\text{Pd}(\text{PPh}_3)_4$, $\text{Pd}(o\text{-tol}_3\text{P})_2$ and $\text{Pd}(\text{tBu}_3\text{P})_2$ under basic conditions. The obtained polymeric samples were fully characterized by MALDI-TOF MS, FTIR, and ^1H (^{13}C) NMR spectroscopy.

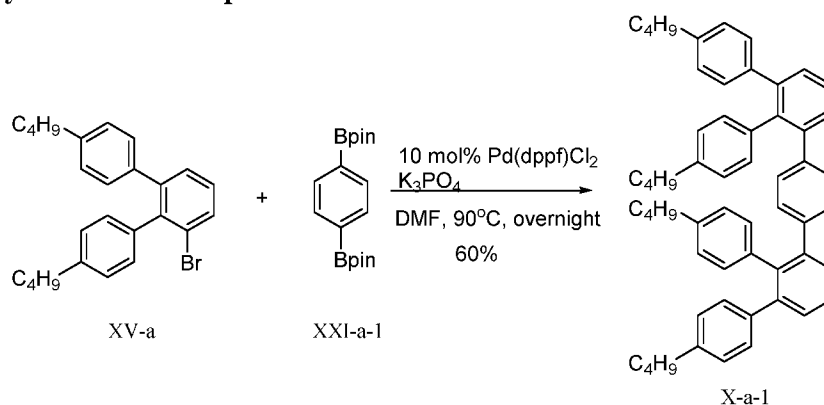
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A compound of Formula XXI-a-1 (66 mg, 0.2 mmol), and a compound of Formula XV-a (210 mg, 0.5 mmol), $\text{K}_3\text{PO}_4 \cdot \text{H}_2\text{O}$ (230 mg, 1 mmol, 5 equiv.) and [1,1'-bis(diphenylphosphino)ferrocene] dichloropalladium(II) complex with dichloromethane (16 mg) were mixed in a solution of DMF (3 mL) and water (0.6 mL). The mixture was degassed by freeze-pump three times. The orange mixture was heated to 90°C and stirred overnight. After cooling to room temperature, 50 mL of EtOAc and 50 mL of water was added. The aqueous phase was extracted by ether ($3 \times 50 \text{ mL}$). The combined organic phase was washed with brine and water, dried over

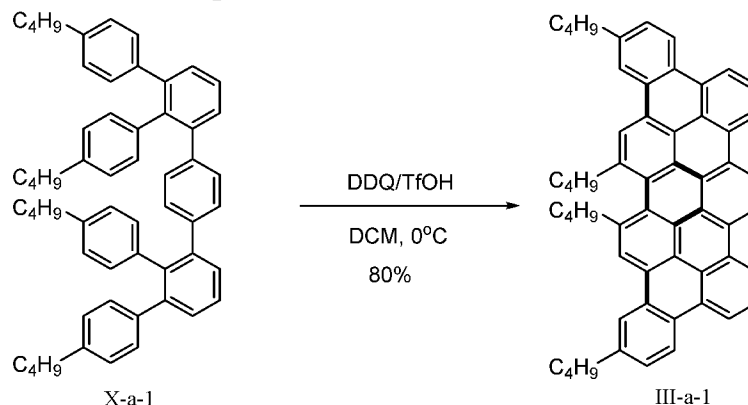
anhydrous Magnesium sulfate. After the solvents were removed by rotary evaporation, the residue was purified by silica gel chromatography using Hexanes as eluent, affording the compound of Formula X-a-1 as a white solid (91 mg, 60%). ^1H NMR (400 MHz, cdCl_3) δ 7.41-7.35(m, 6H, Ar-*H*), 6.94 (s, 8H, Ar-*H*), 6.78 (d, 4H, Ar-*H*), 6.65 (d, 4H, Ar-*H*), 2.52 (m, 8H, CH_2), 1.52 (m, 8H, CH_2), 1.33-1.11 (m, 8H, CH_2), 0.90(t, 6H, CH_3), 0.88(t, 6H, CH_3). ^{13}C NMR (101 MHz, cdCl_3) δ 141.93, 141.67, 140.51, 140.07, 139.71, 139.29, 139.16, 136.73, 131.52, 129.73, 129.40, 129.19, 129.07, 127.46, 127.13, 126.97, 35.19, 35.17, 33.46, 22.25, 21.92, 13.97.

Scheme 45. Synthesis of a compound of Formula X-a-1.



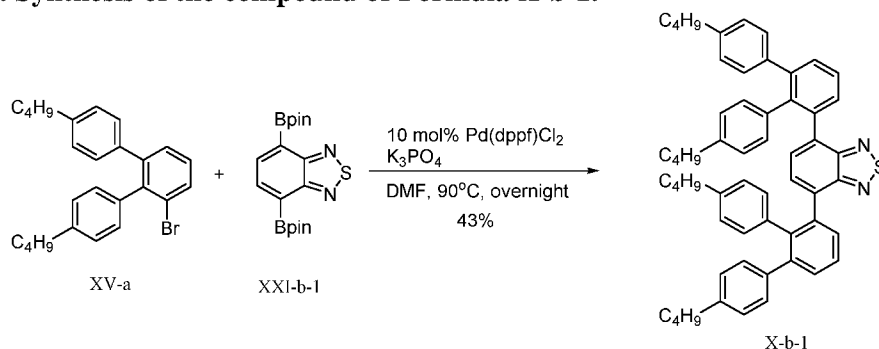
The compound of Formula X-a-1 (16 mg, 0.02 mmol) and DDQ (46 mg, 0.2 mmol) were dissolved in 10 mL of dry dichloromethane under Argon atmosphere. The colorless solution was cooled down to 0°C and 0.5 mL of $\text{CF}_3\text{SO}_3\text{H}$ was added dropwise. Then, the resulting black solution was stirred for 8 hours. After that, the reaction was quenched by saturated aqueous NaHCO_3 solution. The aqueous phase was extracted by dichloromethane (3 × 50 mL). The organic phase was collected and washed with water and brine and dried by Na_2SO_4 . The solvent was removed by rotary evaporation and drying under vacuum, affording the compound of Formula III-a-1 as a yellow solid in 80% yield (12 mg). ^1H NMR (400 MHz, cdCl_3) δ 9.20(d, 1H), 9.06(s, 1H), 9.02(m, 1H), 8.92 (m, 1H), 8.82-8.79(m, 2H), 8.06(m, 1H), 7.64(m, 1H), 3.81-3.67 (m, 2H), 3.04(m, 2H), 1.95-1.88(m, 2H), 1.61-1.43(m, 5H), 1.08 (t, 3H), 0.87-0.78(m, 3H), 0.48 (t, 3H). ^{13}C NMR (101 MHz, cdCl_3) δ 142.35, 139.31, 130.24, 129.74, 129.69, 128.29, 128.24, 127.91, 127.75, 126.47, 126.08, 125.51, 124.43, 124.07, 123.80, 123.45, 121.88, 121.66, 121.33, 121.16, 121.08, 36.23, 35.73, 35.50, 34.02, 22.71, 22.08, 14.14, 13.64.

Scheme 46. Synthesis of the compound of Formula III-a-1.



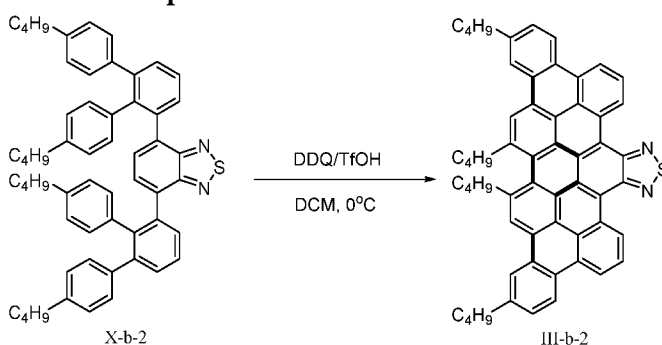
The compound of Formula XXI-b-1, 4,7-bis(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)benzo[c][1,2,5]thiadiazole, was synthesized following previous procedures (Zhang M *et al.* *JACS*, **2007**, 129, 3472).

The compound of Formula XXI-b-1 (86.3 mg, 0.2 mmol), the compound of Formula XV-a (210 mg, 0.5 mmol), $\text{K}_3\text{PO}_4 \cdot \text{H}_2\text{O}$ (230 mg, 1 mmol, 5 equiv.) and [1,1'-bis(diphenylphosphino)ferrocene] dichloropalladium(II) complex with dichloromethane (16 mg) were mixed in a solution of DMF (3 mL) and water (0.6 mL). The mixture was degassed by freeze-pump three times. The orange mixture was heated to 90°C and stirred for overnight (14 hours). After cooling to room temperature, 50 mL of EtOAc and 50 mL of water was added. The aqueous phase was extracted by ether (3×50 mL). The combined organic phase was washed with brine and water, dried over anhydrous Magnesium sulfate. After the solvents were removed by rotary evaporation, the residue was purified by silica gel chromatography using Hexanes as eluent, affording the title compound as a yellow gel (43%). ^1H NMR (400 MHz, cdcl_3) δ 7.51 (m, 6H, Ar-H), 6.98 (m, 10H, Ar-H), 6.65 (s, 8H, Ar-H), 2.54 (m, 4H, CH_2), 2.41 (m, 4H, CH_2), 1.58-1.13 (m, 16H, CH_2), 0.91(t, 6H, CH_3), 0.84(t, 6H, CH_3). ^{13}C NMR (101 MHz, cdcl_3) δ 153.97, 142.07, 140.66, 140.14, 140.09, 139.08, 137.44, 136.70, 133.56, 130.92, 130.51, 130.02, 129.78, 129.71, 127.52, 126.95, 126.90, 35.21, 35.08, 33.47, 33.41, 22.28, 21.87, 13.98, 13.95.

Scheme 47. Synthesis of the compound of Formula X-b-1.

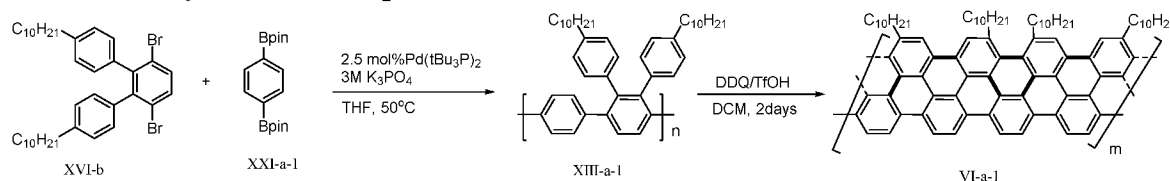
The compound of Formula X-b-1 (10 mg, 0.012 mmol) and DDQ (55 mg, 0.25 mmol) were dissolved in 10 mL of dry dichloromethane under Argon. The colorless solution was cooled down to 0°C and 0.5 mL of CF₃SO₃H was added dropwise. Then, the resulting black solution was stirred for 6 hours. After that, the reaction was quenched by saturated aqueous NaHCO₃ solution. The solution was extracted by dichloromethane (3 × 50 mL). The organic phase was collected and washed with water and brine and dried by Na₂SO₄. The solvent was removed by rotary evaporation and drying under vacuum, affording the compound of Formula III-b-2 as a black red solid in 63% yield (6.2 mg). ¹H NMR (400 MHz, cdcl₃) δ 10.50 (m, 1H), 9.11(s, 1H), 8.77 (m, 2H), 8.68 (d, 1H), 7.96 (t, 1H), 7.62 (m, 1H), 3.65 (m, 2H), 3.05(t, 2H), 1.94(m, 2H), 1.62 (m, 3H), 1.26(m, 2H), 1.10(t, 3H), 0.98-0.86 (m, 3H), 0.58(t, 3H). ¹³C NMR (101 MHz, cdcl₃) δ 152.33, 142.26, 139.20, 129.56, 128.67, 128.42, 128.21, 127.79, 127.68, 127.26, 127.12, 126.55, 125.67, 124.07, 123.76, 123.13, 122.86, 121.64, 121.14, 119.96, 36.25, 35.46, 35.07, 34.06, 22.73, 22.31, 14.17, 13.73.

The matrix-assisted laser desorption/ionization time-of-flight (MALDI-TOF) mass spectrum of the compound of Formula III-b-2 is shown in Figure 11 (linear mode, matrix: DCTB). The X-ray structure of the compound of Formula III-b-2 is shown in Figure 12.

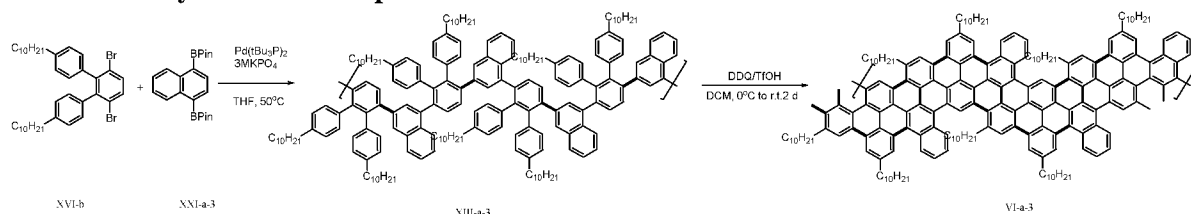
Scheme 48. Synthesis of the compound of Formula III-b-2.

The intramolecular dehydrogenation of corresponding precursor with DDQ/TfOH as oxidant generated the desired graphene nanoribbons, as shown in Scheme 49 – Scheme 54.

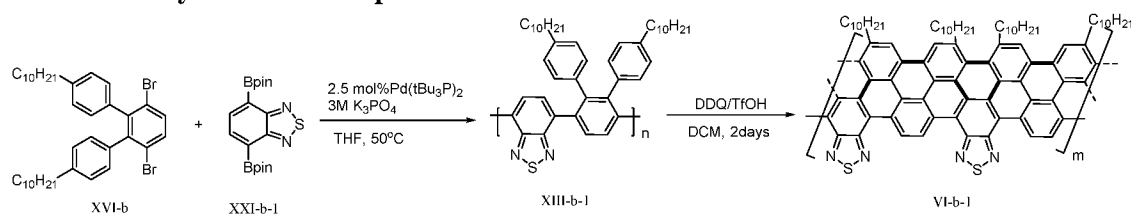
Scheme 49. Synthesis of compound of Formula VI-a-1.



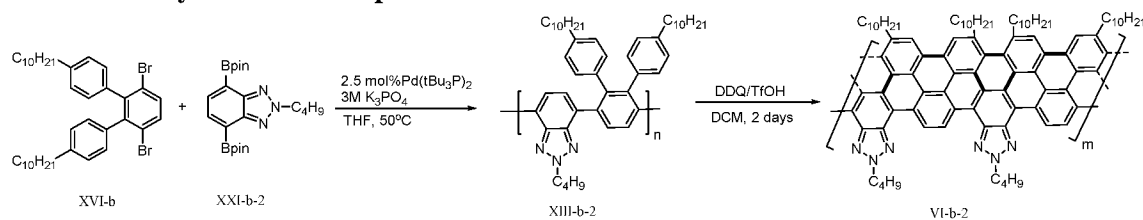
Scheme 50. Synthesis of compound of Formula VI-a-3.



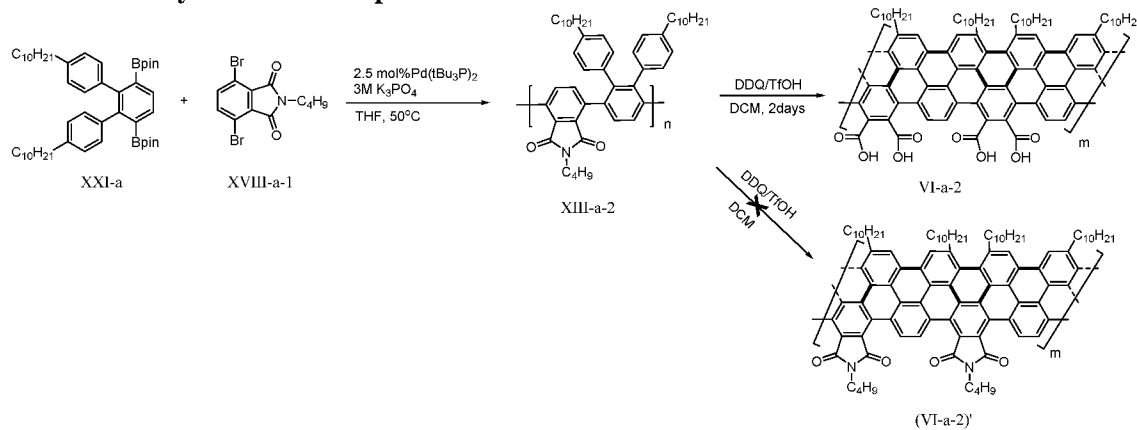
Scheme 51. Synthesis of compound of Formula VI-b-1.

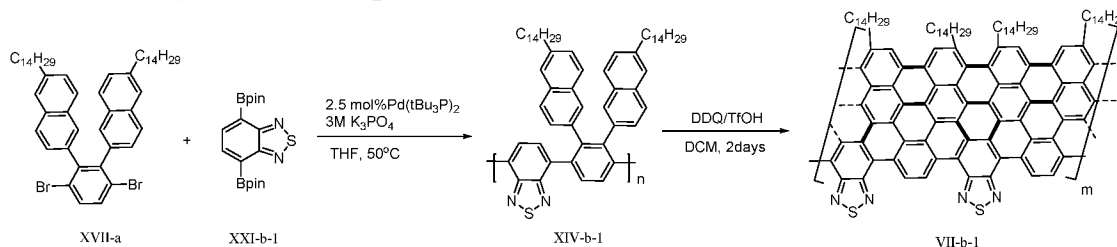


Scheme 52. Synthesis of compound of Formula VI-b-2.

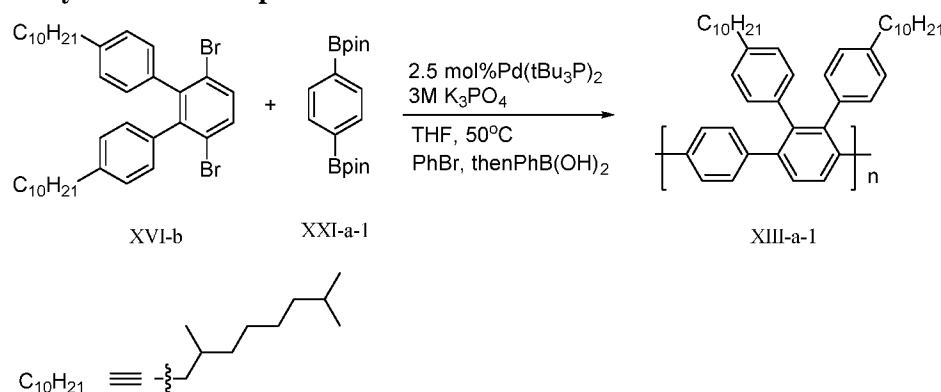


Scheme 53. Synthesis of compound of Formula VI-a-2.



Scheme 54. Synthesis of compound of Formula VII-b-1.

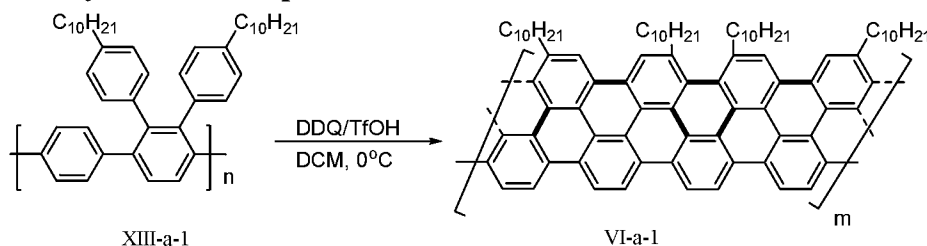
The compound of Formula XVI-b (133 mg, 0.2 mmol), the compound of Formula XXI-a-2 (66 mg, 0.2 mmol), Pd(^tBu₃P)₂ (2.5 mg) and 0.5 mL of (aqueous, 3M) K₃PO₄ and 0.5 mL of degassed THF were mixed in an 8 mL of vial in glovebox. The vial was sealed and the solution was thermostated and stirred at 50°C for 24 hours. After desired time, phenylboronic acid (1 equiv.) was added, and the mixture was stirred for 12 hours. Then, bromobenzene (1 equiv.) was added, and the resulting mixture was stirred for 12 hours. After that, 30 mL of water and 30 mL of DCM were added. The aqueous phase was extracted by DCM (3 × 10 mL). The combined organic phase washed with water. The solution was reduced by rotary evaporation to 2 mL, and the resulting solution was added into 30 mL of acidic methanol. After stirred at room temperature for 2-3 hours, the polymer was filtered and dried at room temperature for overnight (yield: 96%). After that, the solid was fractionated by soxhlet extraction with boiling acetone for 2 days, and then dried in vacuum at room temperature, affording the compound of Formula XIII-a-1 as a white solid (yield: 73%) ¹H NMR (400 MHz, cdcl₃) δ 7.40 (s, 2H, Ar-*H*), 6.84(s, 4H, Ar-*H*), 6.70 (m, 4H, Ar-*H*), 6.58(m, 4H, Ar-*H*), 2.45 (m, 4H, CH₂), 1.51(m, 4H, CH₂), 1.27-1.11(m, 16H, CH₂), 0.85(m, 18H, CH₃). GPC data: Mn: 28916 Da, Mw: 49410 Da; PDI: 1.71

Scheme 55. Synthesis of compound of Formula XIII-a-1.

The compound of Formula XIII-a-1 (17.5 mg) and DDQ (66 mg) were dissolved in 10 mL of dichloromethane under nitrogen atmosphere. The yellow solution was stirred and cooled

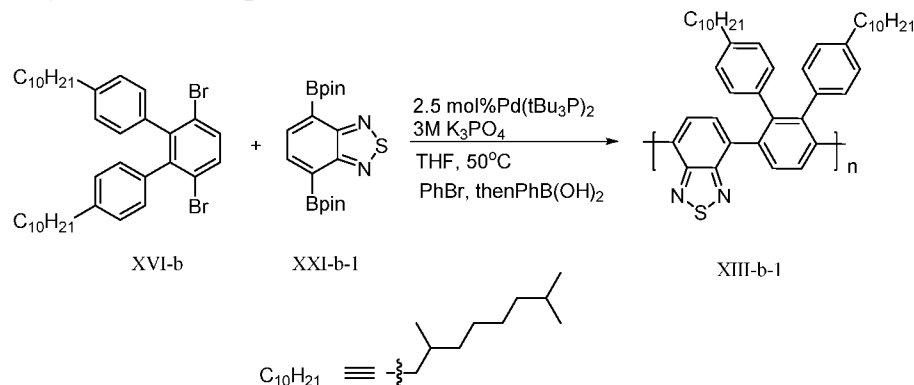
down in an ice/water bath for 10 min. After that, TfOH (0.5 mL) was added, and the black mixture was stirred for two days. The reaction was quenched by saturated aqueous NaHCO₃ solution. The black solid was filtered and washed with water and methanol. The solid was further washed by Soxhlet extraction with boiling acetone for 2 days, and then dried under vacuum at room temperature. The resulting graphene nanoribbon of Formula VI-a-1 was obtained as a black solid in 86 % yield (15 mg).

Scheme 56. Synthesis of compound of Formula VI-a-1.



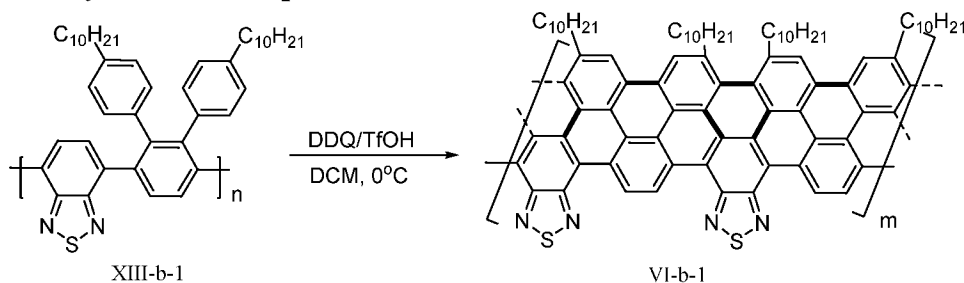
The compound of Formula XVI-b (133 mg, 0.2 mmol), the compound of Formula XXI-b-1 (86.3 mg, 0.2 mmol), catalyst (2.5 mg) and 0.5 mL of (aqueous, 3M) K₃PO₄ and 0.5 mL of degassed THF were mixed in an 8 mL of vial in glovebox. The vial was sealed and the solution was thermostated and stirred at 50°C for 24 hours. After desired time, phenylborinic acid (1 equiv.) was added, and the mixture was stirred for 12 hours. Then, bromobenzene (1 equiv.) was added, and the resulting mixture was stirred for 12 hours. After that, 30 ml of water and 30 mL of DCM were added. The aqueous phase was extracted by DCM (3 × 10 mL). The combined organic phase washed with water. The solution was reduced by rotary evaporation to 2 mL, and the resulting solution was added into 30 mL of acidic methanol. After stirred at room temperature for 2-3 hours, the polymer was filtered and dried at room temperature for overnight (yield: 97%). After that, the solid was fractionated by soxhlet extraction with boiling acetone for 2 days, and then dried in vacuum at room temperature yielding the compound of Formula XIII-b-1 as a yellow solid (yield: 79%). The ¹H NMR spectrum (400 MHz, CDCl₃) of the compound of Formula XIII-b-1 is shown in Figure 13 and exhibited peaks at δ 7.65(s, 2H, Ar-H), 7.00(s, 2H, Ar-H), 6.97(s, 8H, Ar-H), 2.37 (m, 4H, CH₂), 1.54-1.05(m, 16H, CH₂), 0.88-0.80(m, 18H, CH₃). The ¹³C NMR (400 MHz, CD₂Cl₂) spectrum of the compound of Formula XIII-b-1 is shown in Figure 14 and exhibited peaks at δ 154.08, 141.52, 140.28, 136.78, 133.31, 130.93, 130.30, 129.52, 126.60, 39.34, 38.78, 37.07, 32.98, 32.31, 27.92, 24.70, 22.73, 22.64, 19.59. GPC data: Mn: 37848 Da, Mw: 80058 Da; PDI: 2.12. The Raman spectrum of the compound of Formula XIII-b-1 is shown in Figure 15.

Scheme 57. Synthesis of compound of Formula XIII-b-1.



The compound of Formula XIII-b-1 (18.9 mg) and DDQ (65 mg) were dissolved in 10 mL of dichloromethane under nitrogen atmosphere. The yellow solution was stirred and cooled down in an ice/water bath for 10 min. After that, TFOH (0.5 mL) was added, and the black mixture was stirred for two days. The reaction was quenched by saturated aqueous NaHCO_3 solution. The black solid was filtered and washed with water and methanol. The solid was further washed by Soxhlet extraction with boiling acetone for 2 days, and then dried under vacuum at room temperature. The resulting graphene nanoribbon of Formula VI-b-1 was obtained as a black solid in 95 % yield (18 mg). The Raman spectrum of the compound of Formula VI-b-1 is shown in Figure 16. The FTIR spectra of the compounds of Formula XIII-b-1 and Formula VI-b-1 are shown in Figure 17.

Scheme 58. Synthesis of compound of Formula VI-b-1.



Discussed herein are methods to access edge-functionalized nanographenes and graphene nanoribbons (GNRs). These methods can provide nanographenes and graphene nanoribbons with controllable parameters such as width and edge structures, such as having electron-deficient groups on the edge. The polymer precursors for the nanographenes and graphene nanoribbons can be synthesized from simple feedstock. The synthesis is cost- and step-economical, because the monomer used was made from inexpensive starting materials in a short sequence or

commercially available small molecules. The synthetic route is also modular; thus it holds great potentials for easy access to functionalized graphene nanoribbons with tailored bandgaps.

The solution-phase “bottom-up” modular synthetic strategy holds potential for rapid access to various functionalized graphene nanoribbons with precise width and edge structure. In view of tailored bandgaps, these nanographene and graphene nanoribbons have the great potential in semi-conducting materials and (micro)electronic devices.

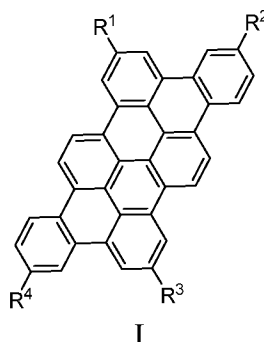
Unless defined otherwise, all technical and scientific terms used herein have the same meanings as commonly understood by one of skill in the art to which the disclosed invention belongs. Publications cited herein and the materials for which they are cited are specifically incorporated by reference.

Those skilled in the art will recognize, or be able to ascertain using no more than routine experimentation, many equivalents to the specific embodiments of the invention described herein. Such equivalents are intended to be encompassed by the following claims.

CLAIMS

What is claimed is:

1. A compound defined by Formula I:



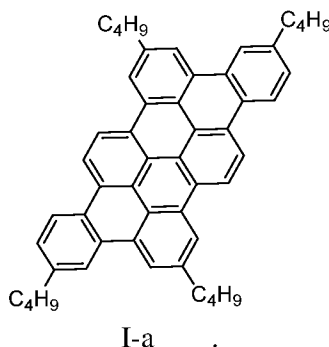
wherein

R^1 , R^2 , R^3 , and R^4 are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C_1 - C_{40} alkyl, substituted or unsubstituted C_2 - C_{40} alkenyl, substituted or unsubstituted C_2 - C_{40} alkynyl, substituted or unsubstituted C_3 - C_{40} aryl, substituted or unsubstituted C_3 - C_{40} cycloalkyl, substituted or unsubstituted C_3 - C_{40} cycloalkenyl, substituted or unsubstituted C_1 - C_{40} acyl, substituted or unsubstituted C_1 - C_{40} alkoxy, $P(O)(OR^a)_2$, SR^a , $S(O)_2R^a$, $SiR^aR^bR^c$, or NR^aR^b ; and

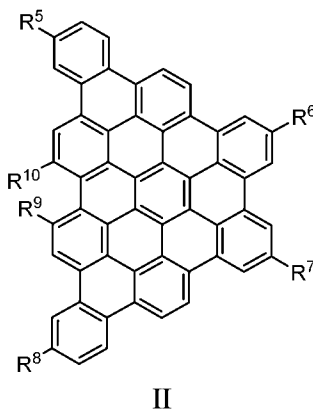
R^a , R^b , and R^c are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C_1 - C_{40} alkyl, substituted or unsubstituted C_2 - C_{40} alkenyl, substituted or unsubstituted C_2 - C_{40} alkynyl, substituted or unsubstituted C_3 - C_{40} aryl, substituted or unsubstituted C_3 - C_{40} cycloalkyl, substituted or unsubstituted C_3 - C_{40} cycloalkenyl, substituted or unsubstituted C_1 - C_{40} acyl, or substituted or unsubstituted C_1 - C_{40} alkoxy.

2. The compound of claim 1, wherein R^1 , R^2 , R^3 , and R^4 are independently substituted or unsubstituted C_1 - C_{20} alkyl.
3. The compound of claim 1 or claim 2, wherein R^1 , R^2 , R^3 , and R^4 are independently unsubstituted C_1 - C_{10} alkyl.
4. The compound of any one of claims 1-3, wherein R^1 , R^2 , R^3 , and R^4 are the same.

5. The compound of any one of claims 1-4, wherein the compound is defined by Formula I-a:



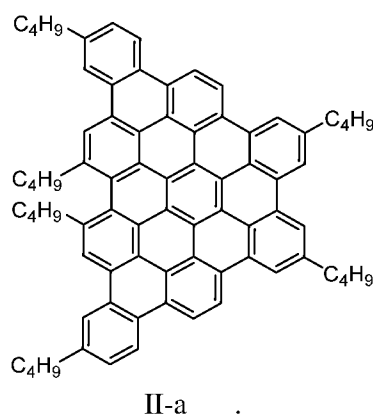
6. A compound defined by Formula II:



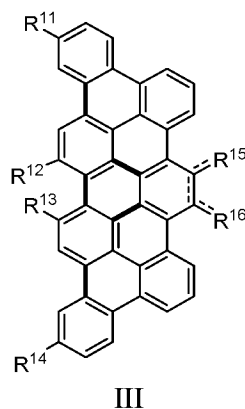
wherein

R^5 , R^6 , R^7 , R^8 , R^9 , and R^{10} are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C_1 - C_{40} alkyl, substituted or unsubstituted C_2 - C_{40} alkenyl, substituted or unsubstituted C_2 - C_{40} alkynyl, substituted or unsubstituted C_3 - C_{40} aryl, substituted or unsubstituted C_3 - C_{40} cycloalkyl, substituted or unsubstituted C_3 - C_{40} cycloalkenyl, substituted or unsubstituted C_1 - C_{40} acyl, substituted or unsubstituted C_1 - C_{40} alkoxy, $P(O)(OR^a)_2$, SR^a , $S(O)_2R^a$, $SiR^aR^bR^c$, or NR^aR^b ; and R^a , R^b , and R^c are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C_1 - C_{40} alkyl, substituted or unsubstituted C_2 - C_{40} alkenyl, substituted or unsubstituted C_2 - C_{40} alkynyl, substituted or unsubstituted C_3 - C_{40} aryl, substituted or unsubstituted C_3 - C_{40} cycloalkyl, substituted or unsubstituted C_3 - C_{40} cycloalkenyl, substituted or unsubstituted C_1 - C_{40} acyl, or substituted or unsubstituted C_1 - C_{40} alkoxy.

7. The compound of claim 6, wherein R^5 , R^6 , R^7 , R^8 , R^9 , and R^{10} are independently substituted or unsubstituted C_1 - C_{20} alkyl.
8. The compound of claim 6 or claim 7, wherein R^5 , R^6 , R^7 , R^8 , R^9 , and R^{10} are independently unsubstituted C_1 - C_{10} alkyl.
9. The compound of any one of claims 6-8, wherein R^5 , R^6 , R^7 , R^8 , R^9 , and R^{10} are the same.
10. The compound of any one of claims 6-9, wherein the compounds is defined by Formula II-a:



11. A compound defined by Formula III:



wherein

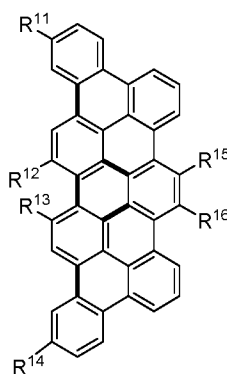
the dotted lines to R^{15} , R^{16} , and between the carbons within the ring to which R^{15} and R^{16} are bonded, independently indicate that the bond can be a single bond or a double bond, as valence permits;

R^{11} , R^{12} , R^{13} , R^{14} , R^{15} , and R^{16} are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C_1 - C_{40} alkyl, substituted or unsubstituted C_2 - C_{40} alkenyl, substituted or unsubstituted C_2 - C_{40} alkynyl, substituted or unsubstituted C_3 - C_{40} aryl, substituted or unsubstituted C_3 - C_{40} cycloalkyl, substituted or unsubstituted C_3 - C_{40} cycloalkenyl, substituted or unsubstituted C_1 - C_{40} acyl, substituted or unsubstituted C_1 - C_{40} alkoxy, $P(O)(OR^a)_2$, SR^a , $S(O)_2R^a$, $SiR^aR^bR^c$, or NR^aR^b , or wherein, as valence permits, R^{15} and R^{16} , together with the atoms to which they are attached, form a 3-10 membered substituted or unsubstituted cyclic moiety optionally including from 1 to 3 heteroatoms; and

R^a , R^b , and R^c are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C_1 - C_{40} alkyl, substituted or unsubstituted C_2 - C_{40} alkenyl, substituted or unsubstituted C_2 - C_{40} alkynyl, substituted or unsubstituted C_3 - C_{40} aryl, substituted or unsubstituted C_3 - C_{40} cycloalkyl, substituted or unsubstituted C_3 - C_{40} cycloalkenyl, substituted or unsubstituted C_1 - C_{40} acyl, or substituted or unsubstituted C_1 - C_{40} alkoxy.

12. The compound of claim 11, wherein R^{11} , R^{12} , R^{13} , and R^{14} are independently substituted or unsubstituted C_1 - C_{20} alkyl.
13. The compound of any one of claim 11 or claim 12, wherein R^{11} , R^{12} , R^{13} , and R^{14} are independently unsubstituted C_1 - C_{10} alkyl.
14. The compound of any one of claims 11-13, wherein R^{11} , R^{12} , R^{13} , and R^{14} are the same.
15. The compound of any one of claims 11-14, wherein R^{15} and R^{16} are independently hydrogen, halogen, hydroxyl, substituted or unsubstituted C_1 - C_{20} alkyl, substituted or unsubstituted C_1 - C_{20} acyl, or wherein, as valence permits, R^{15} and R^{16} , together with the atoms to which they are attached, form a 3-10 membered substituted or unsubstituted cyclic moiety optionally including from 1 to 3 heteroatoms.
16. The compound of any one of claims 11-15, wherein R^{15} and R^{16} are independently hydrogen or unsubstituted C_1 - C_5 acyl.
17. The compound of any one of claims 11-16, wherein R^{15} and R^{16} are the same.

18. The compound of any one of claims 11-15, wherein R^{15} and R^{16} together with the atoms to which they are attached, form a 5-10 membered substituted or unsubstituted cyclic moiety optionally including from 1 to 3 heteroatoms.
19. The compound of any one of claims 11-18, wherein the compound is defined by Formula III-a:



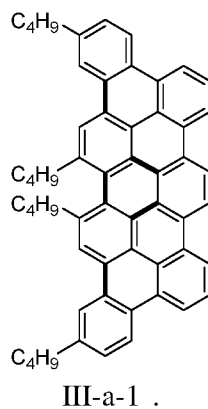
III-a

wherein

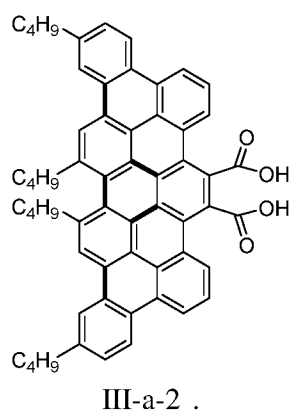
R^{11} , R^{12} , R^{13} , R^{14} , R^{15} , and R^{16} are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C_1 - C_{40} alkyl, substituted or unsubstituted C_2 - C_{40} alkenyl, substituted or unsubstituted C_2 - C_{40} alkynyl, substituted or unsubstituted C_3 - C_{40} aryl, substituted or unsubstituted C_3 - C_{40} cycloalkyl, substituted or unsubstituted C_3 - C_{40} cycloalkenyl, substituted or unsubstituted C_1 - C_{40} acyl, substituted or unsubstituted C_1 - C_{40} alkoxy, $P(O)(OR^a)_2$, SR^a , $S(O)_2R^a$, $SiR^aR^bR^c$, or NR^aR^b , or wherein, as valence permits, R^{15} and R^{16} , together with the atoms to which they are attached, form a 3-10 membered substituted or unsubstituted cyclic moiety optionally including from 1 to 3 heteroatoms; and

R^a , R^b , and R^c are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C_1 - C_{40} alkyl, substituted or unsubstituted C_2 - C_{40} alkenyl, substituted or unsubstituted C_2 - C_{40} alkynyl, substituted or unsubstituted C_3 - C_{40} aryl, substituted or unsubstituted C_3 - C_{40} cycloalkyl, substituted or unsubstituted C_3 - C_{40} cycloalkenyl, substituted or unsubstituted C_1 - C_{40} acyl, or substituted or unsubstituted C_1 - C_{40} alkoxy.

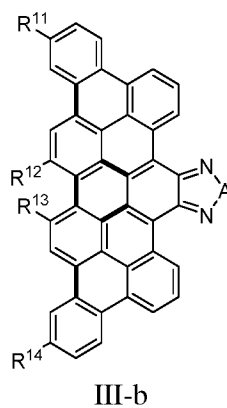
20. The compound of any one of claims 11-17, wherein the compound is defined by Formula III-a-1:



21. The compound of any one of claims 11-17, wherein the compound is defined by Formula III-a-2:



22. The compound of claim 18, wherein the compound can be defined by Formula III-b:



wherein

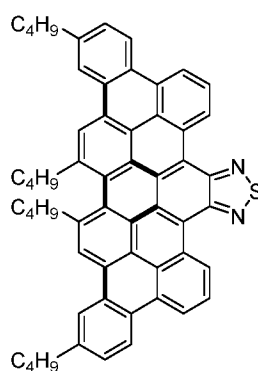
R¹¹, R¹², R¹³, and R¹⁴ are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C₁-C₄₀ alkyl, substituted or unsubstituted C₂-C₄₀ alkenyl,

substituted or unsubstituted C₂-C₄₀ alkynyl, substituted or unsubstituted C₃-C₄₀ aryl, substituted or unsubstituted C₃-C₄₀ cycloalkyl, substituted or unsubstituted C₃-C₄₀ cycloalkenyl, substituted or unsubstituted C₁-C₄₀ acyl, substituted or unsubstituted C₁-C₄₀ alkoxy, P(O)(OR^a)₂, SR^a, S(O)₂R^a, SiR^aR^bR^c, or NR^aR^b;

A is O, S, Se, Te, or NR^a; and

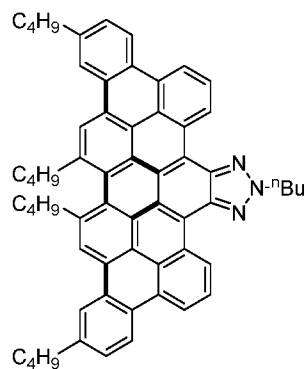
R^a, R^b, and R^c are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C₁-C₄₀ alkyl, substituted or unsubstituted C₂-C₄₀ alkenyl, substituted or unsubstituted C₂-C₄₀ alkynyl, substituted or unsubstituted C₃-C₄₀ aryl, substituted or unsubstituted C₃-C₄₀ cycloalkyl, substituted or unsubstituted C₃-C₄₀ cycloalkenyl, substituted or unsubstituted C₁-C₄₀ acyl, or substituted or unsubstituted C₁-C₄₀ alkoxy.

23. The compound of claim 22, wherein A is S or NR^a.
24. The compound of claim 22 or claim 23, wherein A is NR^a and R^a is a substituted or unsubstituted C₁-C₂₀ alkyl.
25. The compound of any one of claims 22-24, wherein A is NR^a and R^a is an unsubstituted C₁₋₁₀ alkyl.
26. The compound of claim 23, wherein the compound is defined by Formula III-b-1:



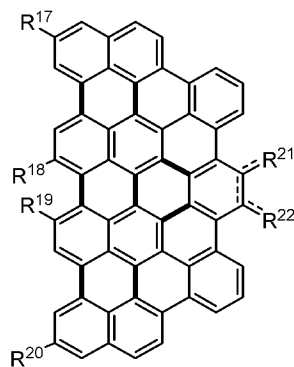
III-b-1 .

27. The compound of any one of claims 22-25, wherein the compound is defined by Formula III-b-2:



III-b-2 .

28. A compound defined by Formula IV:



IV

wherein

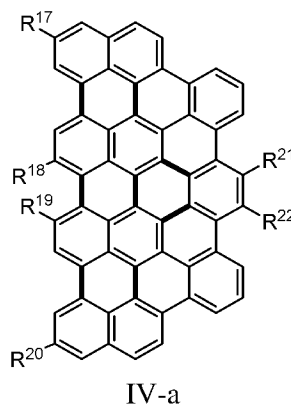
the dotted lines to R^{21} , R^{22} , and between the carbons within the ring to which R^{21} and R^{22} are bonded, independently indicate that the bond can be a single bond or a double bond, as valence permits;

R^{17} , R^{18} , R^{19} , R^{20} , R^{21} , and R^{22} are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C_1 - C_{40} alkyl, substituted or unsubstituted C_2 - C_{40} alkenyl, substituted or unsubstituted C_2 - C_{40} alkynyl, substituted or unsubstituted C_3 - C_{40} aryl, substituted or unsubstituted C_3 - C_{40} cycloalkyl, substituted or unsubstituted C_3 - C_{40} cycloalkenyl, substituted or unsubstituted C_1 - C_{40} acyl, substituted or unsubstituted C_1 - C_{40} alkoxy, $P(O)(OR^a)_2$, SR^a , $S(O)_2R^a$, $SiR^aR^bR^c$, or NR^aR^b , or wherein, as valence permits, R^{21} and R^{22} , together with the atoms to which they are attached, form a 3-10 membered substituted or unsubstituted cyclic moiety optionally including from 1 to 3 heteroatoms; and

R^a, R^b, and R^c are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C₁-C₄₀ alkyl, substituted or unsubstituted C₂-C₄₀ alkenyl, substituted or unsubstituted C₂-C₄₀ alkynyl, substituted or unsubstituted C₃-C₄₀ aryl, substituted or unsubstituted C₃-C₄₀ cycloalkyl, substituted or unsubstituted C₃-C₄₀ cycloalkenyl, substituted or unsubstituted C₁-C₄₀ acyl, or substituted or unsubstituted C₁-C₄₀ alkoxy.

29. The compound of claim 28, wherein R¹⁷, R¹⁸, R¹⁹, and R²⁰ are independently substituted or unsubstituted C₁-C₂₀ alkyl.
30. The compound of claim 28 or claim 29, wherein R¹⁷, R¹⁸, R¹⁹, and R²⁰ are independently unsubstituted C₁-C₁₀ alkyl.
31. The compound of any one of claims 28-30, wherein R¹⁷, R¹⁸, R¹⁹, and R²⁰ are the same.
32. The compound of any one of claims 28-31, wherein R²¹ and R²² are independently hydrogen, halogen, hydroxyl, substituted or unsubstituted C₁-C₂₀ alkyl, substituted or unsubstituted C₁-C₂₀ acyl, or wherein, as valence permits, R²¹ and R²², together with the atoms to which they are attached, form a 3-10 membered substituted or unsubstituted cyclic moiety optionally including from 1 to 3 heteroatoms.
33. The compound of any one of claims 28-32, wherein R²¹ and R²² are independently hydrogen or unsubstituted C₁-C₅ acyl.
34. The compound of any one of claims 28-33, wherein R²¹ and R²² are the same.
35. The compound of any one of claims 28-32, wherein R²¹ and R²² together with the atoms to which they are attached, form a 5-10 membered substituted or unsubstituted cyclic moiety optionally including from 1 to 3 heteroatoms.

36. The compound of any one of claims 28-35, wherein the compound is defined by Formula IV-a:

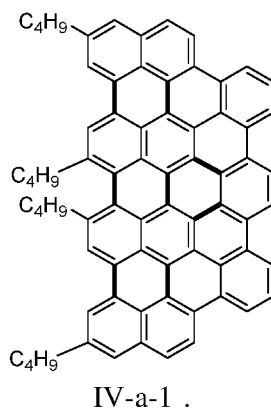


wherein

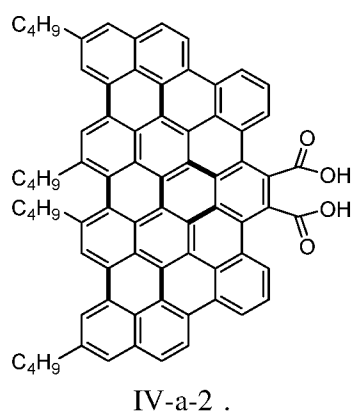
R^{17} , R^{18} , R^{19} , R^{20} , R^{21} , and R^{22} are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C_1 - C_{40} alkyl, substituted or unsubstituted C_2 - C_{40} alkenyl, substituted or unsubstituted C_2 - C_{40} alkynyl, substituted or unsubstituted C_3 - C_{40} aryl, substituted or unsubstituted C_3 - C_{40} cycloalkyl, substituted or unsubstituted C_3 - C_{40} cycloalkenyl, substituted or unsubstituted C_1 - C_{40} acyl, substituted or unsubstituted C_1 - C_{40} alkoxy, $P(O)(OR^a)_2$, SR^a , $S(O)_2R^a$, $SiR^aR^bR^c$, or NR^aR^b , or wherein, as valence permits, R^{21} and R^{22} , together with the atoms to which they are attached, form a 3-10 membered substituted or unsubstituted cyclic moiety optionally including from 1 to 3 heteroatoms; and

R^a , R^b , and R^c are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C_1 - C_{40} alkyl, substituted or unsubstituted C_2 - C_{40} alkenyl, substituted or unsubstituted C_2 - C_{40} alkynyl, substituted or unsubstituted C_3 - C_{40} aryl, substituted or unsubstituted C_3 - C_{40} cycloalkyl, substituted or unsubstituted C_3 - C_{40} cycloalkenyl, substituted or unsubstituted C_1 - C_{40} acyl, or substituted or unsubstituted C_1 - C_{40} alkoxy.

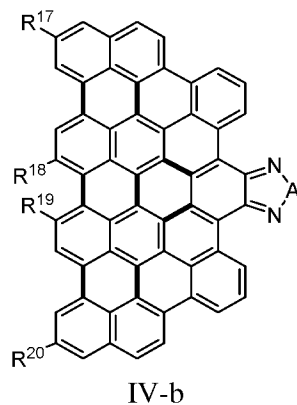
37. The compound of any one of claims 28-34, wherein the compound is defined by Formula IV-a-1:



38. The compound of any one of claims 28-34, wherein the compound is defined by Formula IV-a-2:



39. The compound of claim 35, wherein the compound is defined by Formula IV-b:



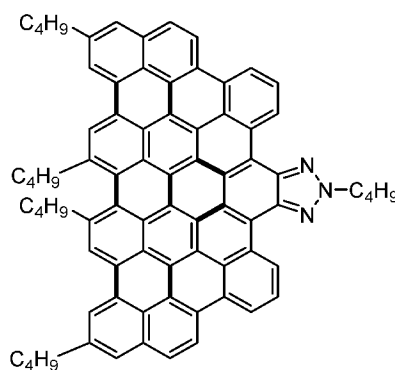
wherein

R^{17} , R^{18} , R^{19} , and R^{20} are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C_1 - C_{40} alkyl, substituted or unsubstituted C_2 - C_{40} alkenyl, substituted or unsubstituted C_2 - C_{40} alkynyl, substituted or unsubstituted C_3 - C_{40} aryl, substituted or unsubstituted C_3 - C_{40} cycloalkyl, substituted or unsubstituted C_3 - C_{40} cycloalkenyl, substituted or unsubstituted C_1 - C_{40} acyl, substituted or unsubstituted C_1 - C_{40} alkoxy, $P(O)(OR^a)_2$, SR^a , $S(O)_2R^a$, $SiR^aR^bR^c$, or NR^aR^b ;

A is O, S, Se, Te, or NR^a ; and

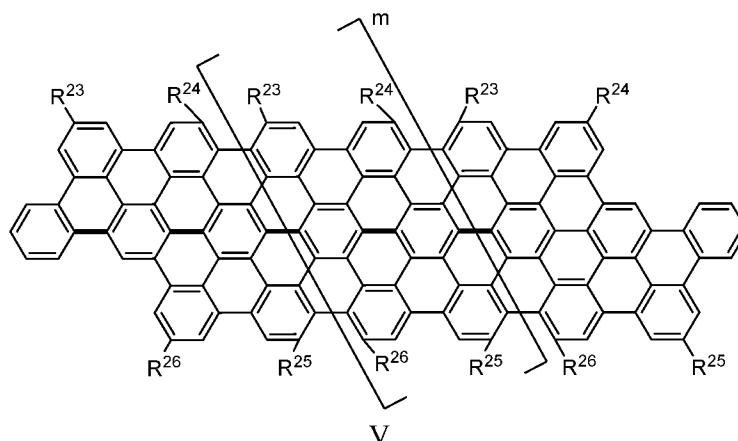
R^a , R^b , and R^c are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C_1 - C_{40} alkyl, substituted or unsubstituted C_2 - C_{40} alkenyl, substituted or unsubstituted C_2 - C_{40} alkynyl, substituted or unsubstituted C_3 - C_{40} aryl, substituted or unsubstituted C_3 - C_{40} cycloalkyl, substituted or unsubstituted C_3 - C_{40} cycloalkenyl, substituted or unsubstituted C_1 - C_{40} acyl, or substituted or unsubstituted C_1 - C_{40} alkoxy.

40. The compound of claim 39, wherein A is S or NR^a .
41. The compound of claim 39 or claim 40, wherein A is NR^a and R^a is a substituted or unsubstituted C_1 - C_{20} alkyl.
42. The compound of any one of claims 39-41, wherein A is NR^a and R^a is an unsubstituted C_{1-10} alkyl.
43. The compound of any one of claims 39-42, wherein the compound is defined by Formula IV-b-1:



IV-b-1 .

44. A compound defined by Formula V:



wherein

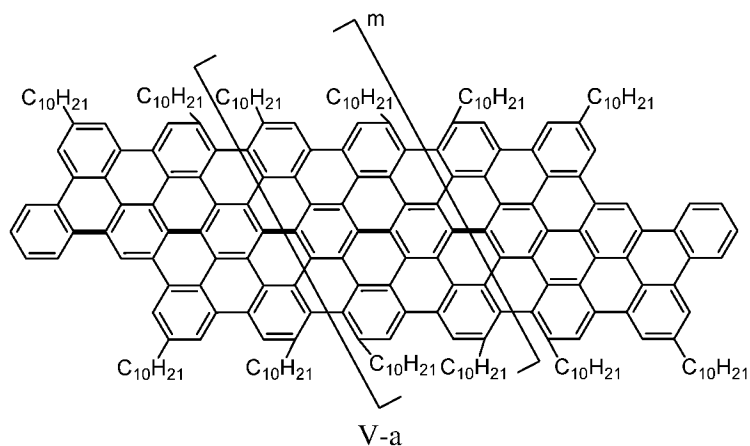
m is from 1 to 1000;

R^{23} , R^{24} , R^{25} , and R^{26} are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C_1 - C_{40} alkyl, substituted or unsubstituted C_2 - C_{40} alkenyl, substituted or unsubstituted C_2 - C_{40} alkynyl, substituted or unsubstituted C_3 - C_{40} aryl, substituted or unsubstituted C_3 - C_{40} cycloalkyl, substituted or unsubstituted C_3 - C_{40} cycloalkenyl, substituted or unsubstituted C_1 - C_{40} acyl, substituted or unsubstituted C_1 - C_{40} alkoxy, $P(O)(OR^a)_2$, SR^a , $S(O)_2R^a$, $SiR^aR^bR^c$, or NR^aR^b ; and

R^a , R^b , and R^c are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C_1 - C_{40} alkyl, substituted or unsubstituted C_2 - C_{40} alkenyl, substituted or unsubstituted C_2 - C_{40} alkynyl, substituted or unsubstituted C_3 - C_{40} aryl, substituted or unsubstituted C_3 - C_{40} cycloalkyl, substituted or unsubstituted C_3 - C_{40} cycloalkenyl, substituted or unsubstituted C_1 - C_{40} acyl, or substituted or unsubstituted C_1 - C_{40} alkoxy.

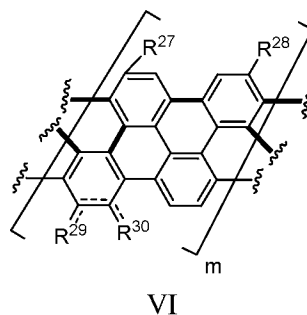
45. The compound of claim 44, wherein R^{23} , R^{24} , R^{25} , and R^{26} are independently substituted or unsubstituted C_1 - C_{20} alkyl.
46. The compound of claim 44 or claim 45, wherein R^{23} , R^{24} , R^{25} , and R^{26} are independently unsubstituted C_2 - C_{15} alkyl.
47. The compound of any one of claims 44-46, wherein R^{23} , R^{24} , R^{25} , and R^{26} are the same.
48. The compound of any one of claims 44-47, wherein m is from 1 to 100.

49. The compound of any one of claims 44-48, wherein the compound defined by Formula V-a:



wherein m is from 1 to 1000.

50. A compound defined by Formula VI:



wherein

m is from 1 to 1000;

the dotted lines to R^{29} , R^{30} , and between the carbons within the ring to which R^{29} and R^{30} are bonded, independently indicate that the bond can be a single bond or a double bond, as valence permits;

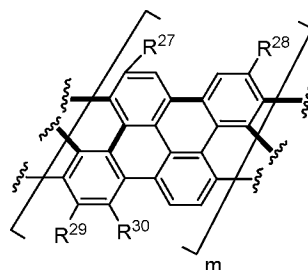
R^{27} , R^{28} , R^{29} , and R^{30} are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C_1 - C_{40} alkyl, substituted or unsubstituted C_2 - C_{40} alkenyl, substituted or unsubstituted C_2 - C_{40} alkynyl, substituted or unsubstituted C_3 - C_{40} aryl, substituted or unsubstituted C_3 - C_{40} cycloalkyl, substituted or unsubstituted C_3 - C_{40} cycloalkenyl, substituted or unsubstituted C_1 - C_{40} acyl, substituted or unsubstituted C_1 - C_{40} alkoxy, $P(O)(OR^a)_2$, SR^a , $S(O)_2R^a$, $SiR^aR^bR^c$, or NR^aR^b , or wherein, as valence permits, R^{29} and R^{30} , together with the atoms to which they are attached,

form a 3-10 membered substituted or unsubstituted cyclic moiety optionally including from 1 to 3 heteroatoms; and

R^a, R^b, and R^c are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C₁-C₄₀ alkyl, substituted or unsubstituted C₂-C₄₀ alkenyl, substituted or unsubstituted C₂-C₄₀ alkynyl, substituted or unsubstituted C₃-C₄₀ aryl, substituted or unsubstituted C₃-C₄₀ cycloalkyl, substituted or unsubstituted C₃-C₄₀ cycloalkenyl, substituted or unsubstituted C₁-C₄₀ acyl, or substituted or unsubstituted C₁-C₄₀ alkoxy.

51. The compound of claim 50, wherein R²⁷ and R²⁸ are independently substituted or unsubstituted C₁-C₂₀ alkyl.
52. The compound of claim 50 or claim 51, wherein R²⁷ and R²⁸ are independently unsubstituted C₂-C₁₅ alkyl.
53. The compound of any one of claims 50-52, wherein R²⁷ and R²⁸ are the same.
54. The compound of any one of claims 50-53, wherein R²⁹ and R³⁰ are independently hydrogen, halogen, hydroxyl, substituted or unsubstituted C₁-C₂₀ alkyl, substituted or unsubstituted C₁-C₂₀ acyl, or wherein, as valence permits, R²⁹ and R³⁰, together with the atoms to which they are attached, form a 3-10 membered substituted or unsubstituted cyclic moiety optionally including from 1 to 3 heteroatoms.
55. The compound of any one of claims 50-54, wherein R²⁹ and R³⁰ are independently hydrogen or unsubstituted C₁-C₅ acyl.
56. The compound of any one of claims 50-55, wherein R²⁹ and R³⁰ are the same.
57. The compound of any one of claims 50-54, wherein R²⁹ and R³⁰ together with the atoms to which they are attached, form a 5-10 membered substituted or unsubstituted cyclic moiety optionally including from 1 to 3 heteroatoms.

58. The compound of any one of claims 50-57, wherein the compound is defined by Formula VI-a:



VI-a

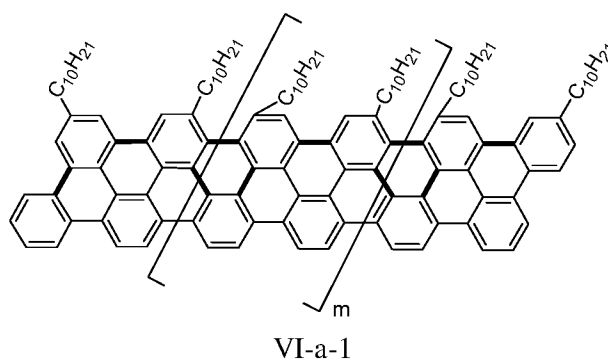
wherein

m is from 1 to 1000;

R^{27} , R^{28} , R^{29} , and R^{30} are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C_1 - C_{40} alkyl, substituted or unsubstituted C_2 - C_{40} alkenyl, substituted or unsubstituted C_2 - C_{40} alkynyl, substituted or unsubstituted C_3 - C_{40} aryl, substituted or unsubstituted C_3 - C_{40} cycloalkyl, substituted or unsubstituted C_3 - C_{40} cycloalkenyl, substituted or unsubstituted C_1 - C_{40} acyl, substituted or unsubstituted C_1 - C_{40} alkoxy, $P(O)(OR^a)_2$, SR^a , $S(O)_2R^a$, $SiR^aR^bR^c$, or NR^aR^b , or wherein, as valence permits, R^{29} and R^{30} , together with the atoms to which they are attached, form a 3-10 membered substituted or unsubstituted cyclic moiety optionally including from 1 to 3 heteroatoms; and

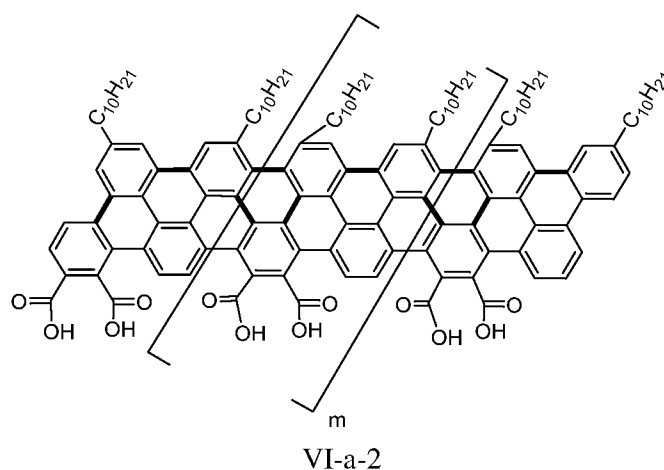
R^a , R^b , and R^c are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C_1 - C_{40} alkyl, substituted or unsubstituted C_2 - C_{40} alkenyl, substituted or unsubstituted C_2 - C_{40} alkynyl, substituted or unsubstituted C_3 - C_{40} aryl, substituted or unsubstituted C_3 - C_{40} cycloalkyl, substituted or unsubstituted C_3 - C_{40} cycloalkenyl, substituted or unsubstituted C_1 - C_{40} acyl, or substituted or unsubstituted C_1 - C_{40} alkoxy.

59. The compound of any one of claims 50-56, wherein the compound is defined by Formula VI-a-1:



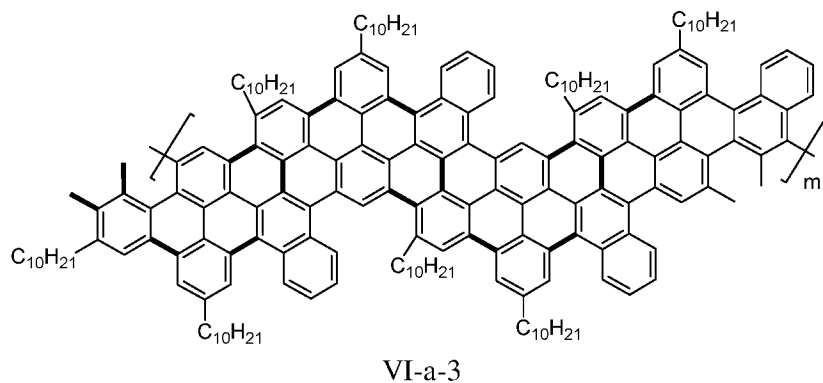
wherein m is from 1 to 1000.

60. The compound of any one of claims 50-56, wherein the compound is defined by Formula VI-a-2



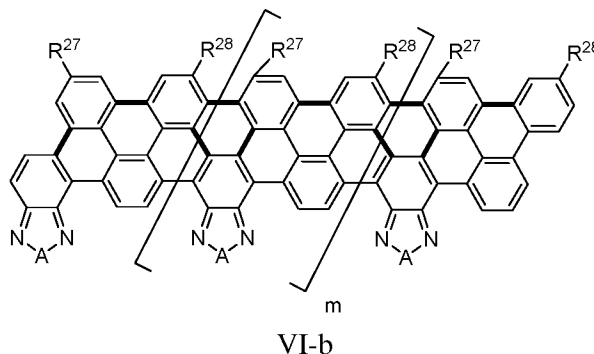
wherein m is from 1 to 1000.

61. The compound of claim 57, wherein the compound is defined by Formula VI-a-3:



wherein m is from 1 to 1000.

62. The compound of claim 57, wherein the compound is defined by Formula VI-b:



wherein

m is from 1 to 1000;

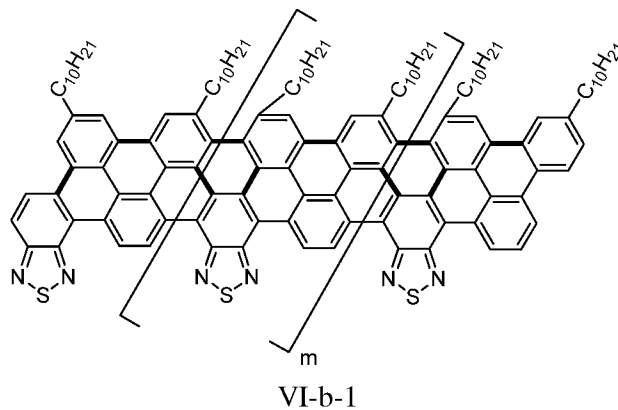
R^{27} and R^{28} are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C_1 - C_{40} alkyl, substituted or unsubstituted C_2 - C_{40} alkenyl, substituted or unsubstituted C_2 - C_{40} alkynyl, substituted or unsubstituted C_3 - C_{40} aryl, substituted or unsubstituted C_3 - C_{40} cycloalkyl, substituted or unsubstituted C_3 - C_{40} cycloalkenyl, substituted or unsubstituted C_1 - C_{40} acyl, substituted or unsubstituted C_1 - C_{40} alkoxy, $P(O)(OR^a)_2$, SR^a , $S(O)_2R^a$, $SiR^aR^bR^c$, or NR^aR^b ;

A is O, S, Se, Te, or NR^a ; and

R^a , R^b , and R^c are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C_1 - C_{40} alkyl, substituted or unsubstituted C_2 - C_{40} alkenyl, substituted or unsubstituted C_2 - C_{40} alkynyl, substituted or unsubstituted C_3 - C_{40} aryl, substituted or unsubstituted C_3 - C_{40} cycloalkyl, substituted or unsubstituted C_3 - C_{40} cycloalkenyl, substituted or unsubstituted C_1 - C_{40} acyl, or substituted or unsubstituted C_1 - C_{40} alkoxy.

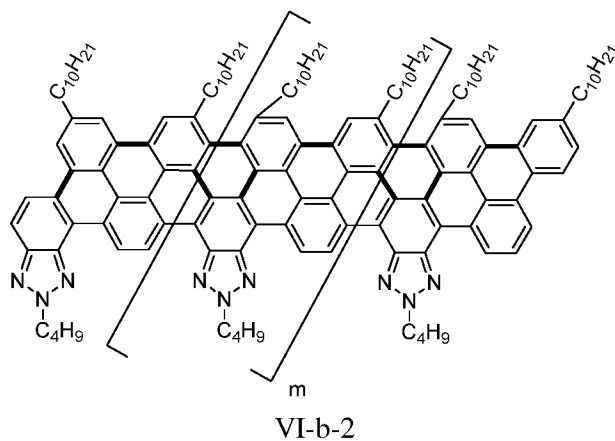
63. The compound of claim 62, wherein A is S or NR^a .
64. The compound of claim 62 or claim 63, wherein A is NR^a and R^a is a substituted or unsubstituted C_1 - C_{20} alkyl.
65. The compound of any one of claims 62-64, wherein A is NR^a and R^a is an unsubstituted C_{1-10} alkyl.

66. The compound of claim 63, wherein the compound is defined by Formula VI-b-1:



wherein m is from 1 to 1000.

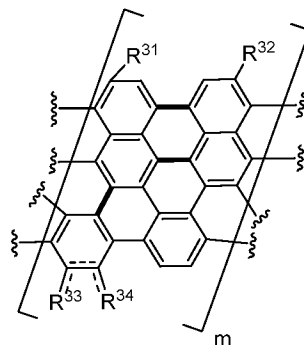
67. The compound of any one of claims 62-65, wherein the compound is defined by Formula VI-b-2:



wherein m is from 1 to 1000.

68. The compound of any one of claims 50-67, wherein m is from 1 to 500.
69. The compound of any one of claims 50-68, wherein m is from 1 to 100.
70. The compound of any one of claims 50-69, wherein m is from 1 to 50.

71. A compound defined by Formula VII:



VII

wherein

m is from 1 to 1000;

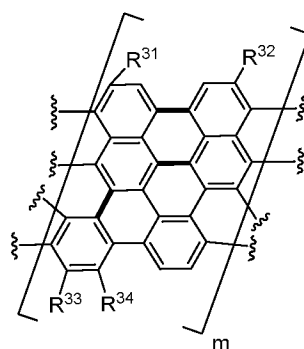
the dotted lines to R^{33} , R^{34} , and between the carbons within the ring to which R^{33} and R^{34} are bonded, independently indicate that the bond can be a single bond or a double bond, as valence permits;

R^{31} , R^{32} , R^{33} , and R^{34} are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C_1 - C_{40} alkyl, substituted or unsubstituted C_2 - C_{40} alkenyl, substituted or unsubstituted C_2 - C_{40} alkynyl, substituted or unsubstituted C_3 - C_{40} aryl, substituted or unsubstituted C_3 - C_{40} cycloalkyl, substituted or unsubstituted C_3 - C_{40} cycloalkenyl, substituted or unsubstituted C_1 - C_{40} acyl, substituted or unsubstituted C_1 - C_{40} alkoxy, $P(O)(OR^a)_2$, SR^a , $S(O)_2R^a$, $SiR^aR^bR^c$, or NR^aR^b , or wherein, as valence permits, R^{33} and R^{34} , together with the atoms to which they are attached, form a 3-10 membered substituted or unsubstituted cyclic moiety optionally including from 1 to 3 heteroatoms; and

R^a , R^b , and R^c are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C_1 - C_{40} alkyl, substituted or unsubstituted C_2 - C_{40} alkenyl, substituted or unsubstituted C_2 - C_{40} alkynyl, substituted or unsubstituted C_3 - C_{40} aryl, substituted or unsubstituted C_3 - C_{40} cycloalkyl, substituted or unsubstituted C_3 - C_{40} cycloalkenyl, substituted or unsubstituted C_1 - C_{40} acyl, or substituted or unsubstituted C_1 - C_{40} alkoxy.

72. The compound of claim 71, wherein R^{31} and R^{32} are independently substituted or unsubstituted C_1 - C_{20} alkyl.

73. The compound of claim 71 or claim 72, wherein R^{31} and R^{32} are independently unsubstituted C_2 - C_{15} alkyl.
74. The compound of any one of claims 71-73, wherein R^{31} and R^{32} are the same.
75. The compound of any one of claims 71-74, wherein R^{33} and R^{34} are independently hydrogen, halogen, hydroxyl, substituted or unsubstituted C_1 - C_{20} alkyl, substituted or unsubstituted C_1 - C_{20} acyl, or wherein, as valence permits, R^{33} and R^{34} , together with the atoms to which they are attached, form a 3-10 membered substituted or unsubstituted cyclic moiety optionally including from 1 to 3 heteroatoms.
76. The compound of any one of claims 71-75, wherein R^{33} and R^{34} are independently hydrogen or unsubstituted C_1 - C_5 acyl.
77. The compound of any one of claims 71-76, wherein R^{33} and R^{34} are the same.
78. The compound of any one of claims 71-75, wherein R^{33} and R^{34} together with the atoms to which they are attached, form a 5-10 membered substituted or unsubstituted cyclic moiety optionally including from 1 to 3 heteroatoms.
79. The compound of any one of claims claim 71-78, wherein the compound is defined by Formula VII-a:



VII-a

wherein

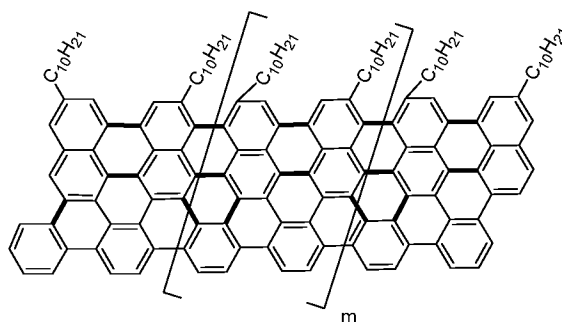
m is from 1 to 1000;

R^{31} , R^{32} , R^{33} , and R^{34} are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C_1 - C_{40} alkyl, substituted or unsubstituted C_2 - C_{40} alkenyl, substituted or unsubstituted C_2 - C_{40} alkynyl, substituted or unsubstituted C_3 - C_{40} aryl, substituted or unsubstituted C_3 - C_{40} cycloalkyl, substituted or unsubstituted C_3 - C_{40}

cycloalkenyl, substituted or unsubstituted C₁-C₄₀ acyl, substituted or unsubstituted C₁-C₄₀ alkoxy, P(O)(OR^a)₂, SR^a, S(O)₂R^a, SiR^aR^bR^c, or NR^aR^b, or wherein, as valence permits, R³³ and R³⁴, together with the atoms to which they are attached, form a 3-10 membered substituted or unsubstituted cyclic moiety optionally including from 1 to 3 heteroatoms; and

R^a, R^b, and R^c are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C₁-C₄₀ alkyl, substituted or unsubstituted C₂-C₄₀ alkenyl, substituted or unsubstituted C₂-C₄₀ alkynyl, substituted or unsubstituted C₃-C₄₀ aryl, substituted or unsubstituted C₃-C₄₀ cycloalkyl, substituted or unsubstituted C₃-C₄₀ cycloalkenyl, substituted or unsubstituted C₁-C₄₀ acyl, or substituted or unsubstituted C₁-C₄₀ alkoxy.

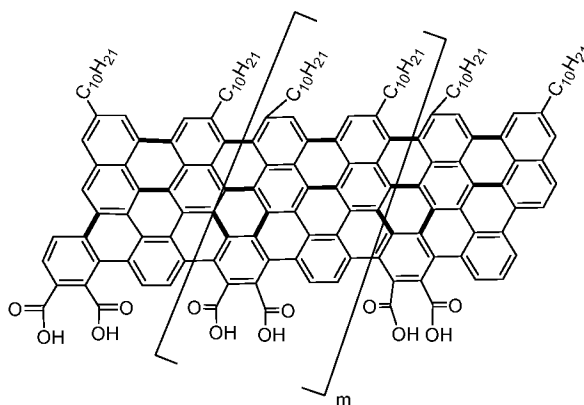
80. The compound of any one of claims 71-77, wherein the compound is defined by Formula VII-a-1:



VII-a-1

wherein m is from 1 to 1000.

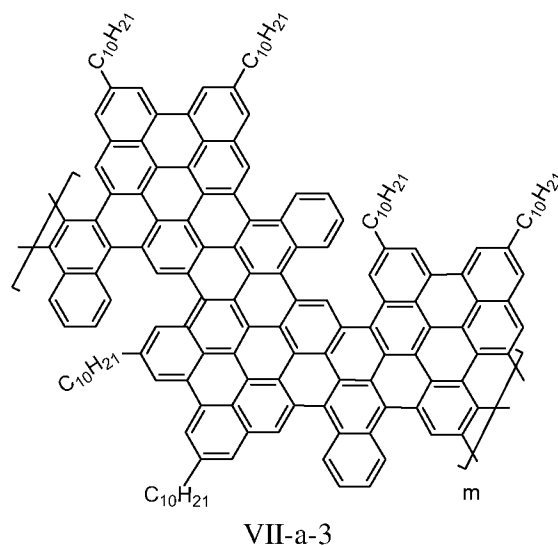
81. The compound of any one of claims 71-77, wherein the compound is defined by Formula VII-a-2:



VII-a-2

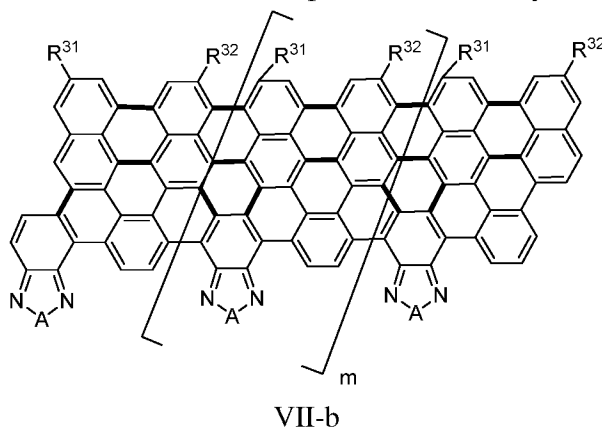
wherein m is from 1 to 1000.

82. The compound of any one of claims 71-77, wherein the compound is defined by Formula VII-a-3:



wherein m is from 1 to 1000.

83. The compound of claim 78, wherein the compound is defined by Formula VII-b:



wherein

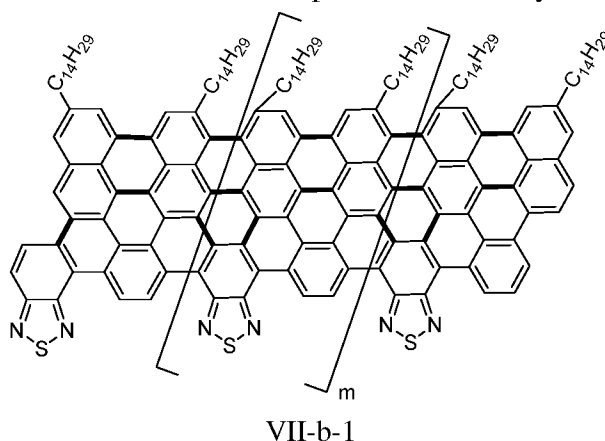
m is from 1 to 1000;

R^{31} and R^{32} are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C_1 - C_{40} alkyl, substituted or unsubstituted C_2 - C_{40} alkenyl, substituted or unsubstituted C_2 - C_{40} alkynyl, substituted or unsubstituted C_3 - C_{40} aryl, substituted or unsubstituted C_3 - C_{40} cycloalkyl, substituted or unsubstituted C_3 - C_{40} cycloalkenyl, substituted or unsubstituted C_1 - C_{40} acyl, substituted or unsubstituted C_1 - C_{40} alkoxy, $P(O)(OR^a)_2$, SR^a , $S(O)_2R^a$, $SiR^aR^bR^c$, or NR^aR^b ;

A is O, S, Se, Te, or NR^a ; and

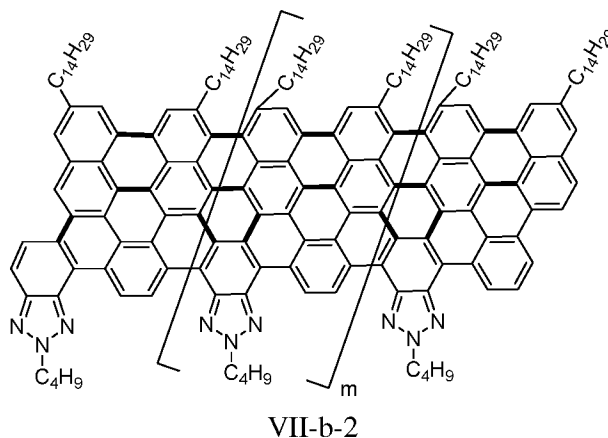
R^a , R^b , and R^c are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C_1 - C_{40} alkyl, substituted or unsubstituted C_2 - C_{40} alkenyl, substituted or unsubstituted C_2 - C_{40} alkynyl, substituted or unsubstituted C_3 - C_{40} aryl, substituted or unsubstituted C_3 - C_{40} cycloalkyl, substituted or unsubstituted C_3 - C_{40} cycloalkenyl, substituted or unsubstituted C_1 - C_{40} acyl, or substituted or unsubstituted C_1 - C_{40} alkoxy.

84. The compound of claim 83, wherein A is S or NR^a .
85. The compound of claim 83 or claim 84, wherein A is NR^a and R^a is a substituted or unsubstituted C_1 - C_{20} alkyl.
86. The compound of any one of claims 83-85, wherein A is NR^a and R^a is an unsubstituted C_{1-10} alkyl.
87. The compound of claim 84, wherein the compound is defined by Formula VII-b-1:



wherein m is from 1 to 1000.

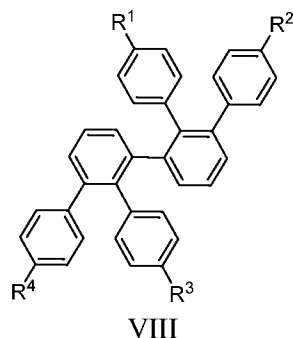
88. The compound of any one of claims 83-86, wherein the compound is defined by Formula VII-b-2:



wherein m is from 1 to 1000.

89. The compound of any one of claims 71-88, wherein m is from 1 to 500.
90. The compound of any one of claims 71-89, wherein m is from 1 to 100.
91. The compound of any one of claims 71-90, wherein m is from 1 to 50.
92. The compound of any one of claims 1-91, wherein the compound has an average maximum dimension of 1000 nm or less.
93. The compound of any one of claims 1-92, wherein the compound has an average maximum dimension of from 1 nm to 900 nm.
94. The compound of any one of claims 1-93, wherein the compound has a bandgap energy of from 0.5 eV to 2.5 eV.
95. The compound of any one of claims 1-94, wherein the compound has a bandgap energy of from 0.75 eV to 2 eV.

96. A compound defined by Formula VIII:



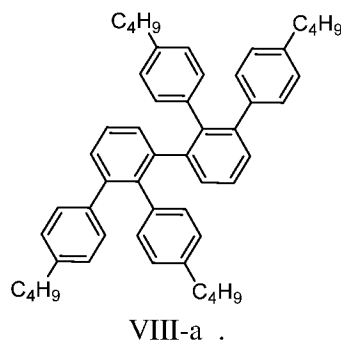
wherein

R^1 , R^2 , R^3 , and R^4 are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C_1 - C_{40} alkyl, substituted or unsubstituted C_2 - C_{40} alkenyl, substituted or unsubstituted C_2 - C_{40} alkynyl, substituted or unsubstituted C_3 - C_{40} aryl, substituted or unsubstituted C_3 - C_{40} cycloalkyl, substituted or unsubstituted C_3 - C_{40} cycloalkenyl, substituted or unsubstituted C_1 - C_{40} acyl, substituted or unsubstituted C_1 - C_{40} alkoxy, $P(O)(OR^a)_2$, SR^a , $S(O)_2R^a$, $SiR^aR^bR^c$, or NR^aR^b ; and

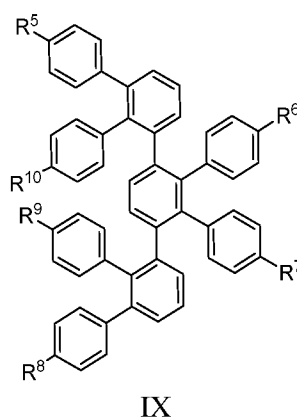
R^a , R^b , and R^c are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C_1 - C_{40} alkyl, substituted or unsubstituted C_2 - C_{40} alkenyl, substituted or unsubstituted C_2 - C_{40} alkynyl, substituted or unsubstituted C_3 - C_{40} aryl, substituted or unsubstituted C_3 - C_{40} cycloalkyl, substituted or unsubstituted C_3 - C_{40} cycloalkenyl, substituted or unsubstituted C_1 - C_{40} acyl, or substituted or unsubstituted C_1 - C_{40} alkoxy.

97. The compound of claim 96, wherein R^1 , R^2 , R^3 , and R^4 are independently substituted or unsubstituted C_1 - C_{20} alkyl.
98. The compound of claim 96 or claim 97, wherein R^1 , R^2 , R^3 , and R^4 are independently unsubstituted C_1 - C_{10} alkyl.
99. The compound of any one of claims 96-98, wherein R^1 , R^2 , R^3 , and R^4 are the same.

100. The compound of any one of claims 96-99, wherein the compound is defined by Formula VIII-a:



101. A compound defined by Formula IX:

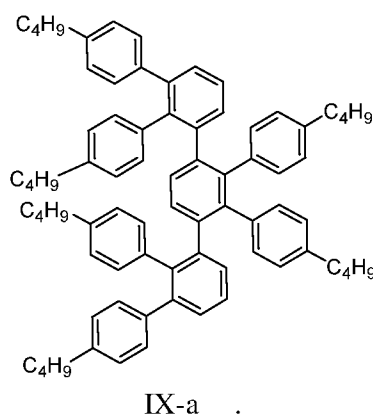


wherein

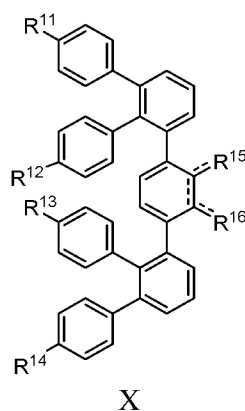
R^5 , R^6 , R^7 , R^8 , R^9 , and R^{10} are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C_1 - C_{40} alkyl, substituted or unsubstituted C_2 - C_{40} alkenyl, substituted or unsubstituted C_2 - C_{40} alkynyl, substituted or unsubstituted C_3 - C_{40} aryl, substituted or unsubstituted C_3 - C_{40} cycloalkyl, substituted or unsubstituted C_3 - C_{40} cycloalkenyl, substituted or unsubstituted C_1 - C_{40} acyl, substituted or unsubstituted C_1 - C_{40} alkoxy, $P(O)(OR^a)_2$, SR^a , $S(O)_2R^a$, $SiR^aR^bR^c$, or NR^aR^b ; and

R^a , R^b , and R^c are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C_1 - C_{40} alkyl, substituted or unsubstituted C_2 - C_{40} alkenyl, substituted or unsubstituted C_2 - C_{40} alkynyl, substituted or unsubstituted C_3 - C_{40} aryl, substituted or unsubstituted C_3 - C_{40} cycloalkyl, substituted or unsubstituted C_3 - C_{40} cycloalkenyl, substituted or unsubstituted C_1 - C_{40} acyl, or substituted or unsubstituted C_1 - C_{40} alkoxy.

102. The compound of claim 101, wherein R^5 , R^6 , R^7 , R^8 , R^9 , and R^{10} are independently substituted or unsubstituted C_1 - C_{20} alkyl.
103. The compound of claim 101 or claim 102, wherein R^5 , R^6 , R^7 , R^8 , R^9 , and R^{10} are independently unsubstituted C_1 - C_{10} alkyl.
104. The compound of any one of claims 101-103, wherein R^5 , R^6 , R^7 , R^8 , R^9 , and R^{10} are the same.
105. The compound of any one of claims 101-104, wherein the compound is defined by Formula IX-a:



106. A compound defined by Formula X:



wherein

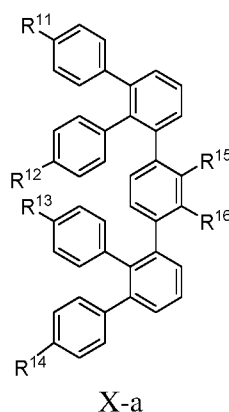
the dotted lines to R^{15} , R^{16} , and between the carbons within the ring to which R^{15} and R^{16} are bonded, independently indicate that the bond can be a single bond or a double bond, as valence permits;

R^{11} , R^{12} , R^{13} , R^{14} , R^{15} , and R^{16} are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C_1 - C_{40} alkyl, substituted or unsubstituted C_2 - C_{40} alkenyl, substituted or unsubstituted C_2 - C_{40} alkynyl, substituted or unsubstituted C_3 - C_{40} aryl, substituted or unsubstituted C_3 - C_{40} cycloalkyl, substituted or unsubstituted C_3 - C_{40} cycloalkenyl, substituted or unsubstituted C_1 - C_{40} acyl, substituted or unsubstituted C_1 - C_{40} alkoxy, $P(O)(OR^a)_2$, SR^a , $S(O)_2R^a$, $SiR^aR^bR^c$, or NR^aR^b , or wherein, as valence permits, R^{15} and R^{16} , together with the atoms to which they are attached, form a 3-10 membered substituted or unsubstituted cyclic moiety optionally including from 1 to 3 heteroatoms; and

R^a , R^b , and R^c are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C_1 - C_{40} alkyl, substituted or unsubstituted C_2 - C_{40} alkenyl, substituted or unsubstituted C_2 - C_{40} alkynyl, substituted or unsubstituted C_3 - C_{40} aryl, substituted or unsubstituted C_3 - C_{40} cycloalkyl, substituted or unsubstituted C_3 - C_{40} cycloalkenyl, substituted or unsubstituted C_1 - C_{40} acyl, or substituted or unsubstituted C_1 - C_{40} alkoxy.

107. The compound of claim 106, wherein In some examples of Formula X, R^{11} , R^{12} , R^{13} , and R^{14} are independently substituted or unsubstituted C_1 - C_{20} alkyl.
108. The compound of claim 106 or claim 107, wherein R^{11} , R^{12} , R^{13} , and R^{14} are independently unsubstituted C_1 - C_{10} alkyl.
109. The compound of any one of claims 106-108, wherein R^{11} , R^{12} , R^{13} , and R^{14} are the same.
110. The compound of any one of claims 106-109, wherein R^{15} and R^{16} are independently hydrogen, halogen, hydroxyl, substituted or unsubstituted C_1 - C_{20} alkyl, substituted or unsubstituted C_1 - C_{20} acyl, or wherein, as valence permits, R^{15} and R^{16} , together with the atoms to which they are attached, form a 3-10 membered substituted or unsubstituted cyclic moiety optionally including from 1 to 3 heteroatoms.
111. The compound of any one of claims 106-110, wherein R^{15} and R^{16} are independently hydrogen or unsubstituted C_1 - C_5 acyl.
112. The compound of any one of claims 106-111, wherein R^{15} and R^{16} are the same.

113. The compound of any one of claims 106-110, wherein R^{15} and R^{16} together with the atoms to which they are attached, form a 5-10 membered substituted or unsubstituted cyclic moiety optionally including from 1 to 3 heteroatoms.
114. The compound of any one of claims 106-113, wherein the compound is defined by Formula X-a:

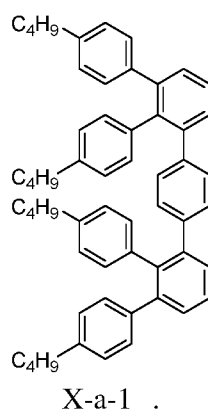


wherein

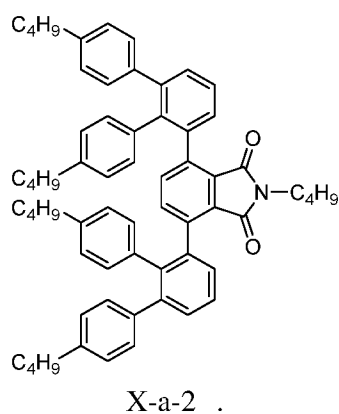
R^{11} , R^{12} , R^{13} , R^{14} , R^{15} , and R^{16} are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C_1 - C_{40} alkyl, substituted or unsubstituted C_2 - C_{40} alkenyl, substituted or unsubstituted C_2 - C_{40} alkynyl, substituted or unsubstituted C_3 - C_{40} aryl, substituted or unsubstituted C_3 - C_{40} cycloalkyl, substituted or unsubstituted C_3 - C_{40} cycloalkenyl, substituted or unsubstituted C_1 - C_{40} acyl, substituted or unsubstituted C_1 - C_{40} alkoxy, $P(O)(OR^a)_2$, SR^a , $S(O)_2R^a$, $SiR^aR^bR^c$, or NR^aR^b , or wherein, as valence permits, R^{15} and R^{16} , together with the atoms to which they are attached, form a 3-10 membered substituted or unsubstituted cyclic moiety optionally including from 1 to 3 heteroatoms; and

R^a , R^b , and R^c are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C_1 - C_{40} alkyl, substituted or unsubstituted C_2 - C_{40} alkenyl, substituted or unsubstituted C_2 - C_{40} alkynyl, substituted or unsubstituted C_3 - C_{40} aryl, substituted or unsubstituted C_3 - C_{40} cycloalkyl, substituted or unsubstituted C_3 - C_{40} cycloalkenyl, substituted or unsubstituted C_1 - C_{40} acyl, or substituted or unsubstituted C_1 - C_{40} alkoxy.

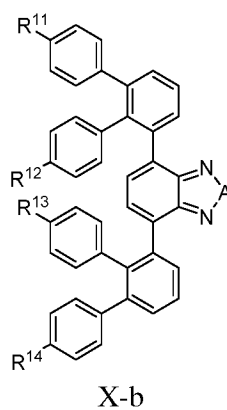
115. The compound of any one of claims 106-112, wherein the compound is defined by Formula X-a-1:



116. The compound of any one of claims 106-112, wherein the compound is defined by Formula X-a-2:



117. The compound of claim 113, wherein the compound is defined by Formula X-b:



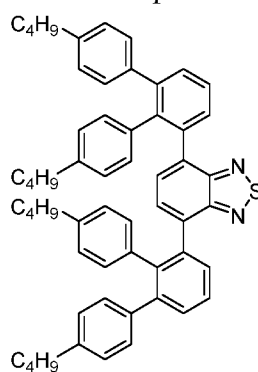
wherein

R^{11} , R^{12} , R^{13} , and R^{14} are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C_1 - C_{40} alkyl, substituted or unsubstituted C_2 - C_{40} alkenyl, substituted or unsubstituted C_2 - C_{40} alkynyl, substituted or unsubstituted C_3 - C_{40} aryl, substituted or unsubstituted C_3 - C_{40} cycloalkyl, substituted or unsubstituted C_3 - C_{40} cycloalkenyl, substituted or unsubstituted C_1 - C_{40} acyl, substituted or unsubstituted C_1 - C_{40} alkoxy, $P(O)(OR^a)_2$, SR^a , $S(O)_2R^a$, $SiR^aR^bR^c$, or NR^aR^b ;

A is O, S, Se, Te, or NR^a ; and

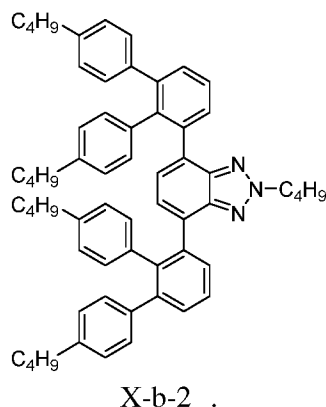
R^a , R^b , and R^c are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C_1 - C_{40} alkyl, substituted or unsubstituted C_2 - C_{40} alkenyl, substituted or unsubstituted C_2 - C_{40} alkynyl, substituted or unsubstituted C_3 - C_{40} aryl, substituted or unsubstituted C_3 - C_{40} cycloalkyl, substituted or unsubstituted C_3 - C_{40} cycloalkenyl, substituted or unsubstituted C_1 - C_{40} acyl, or substituted or unsubstituted C_1 - C_{40} alkoxy.

118. The compound of claim 117, wherein A is S or NR^a .
119. The compound of claim 117 or claim 118, wherein A is NR^a and R^a is a substituted or unsubstituted C_1 - C_{20} alkyl.
120. The compound of any one of claims 117-119, wherein A is NR^a and R^a is an unsubstituted C_{1-10} alkyl.
121. The compound of claim 118, wherein the compound is defined by Formula X-b-1:

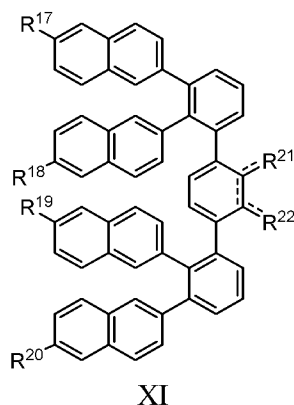


X-b-1 .

122. The compound of any one of claims 117-120, wherein the compound is defined by Formula X-b-2:



123. A compound defined by Formula XI:



wherein

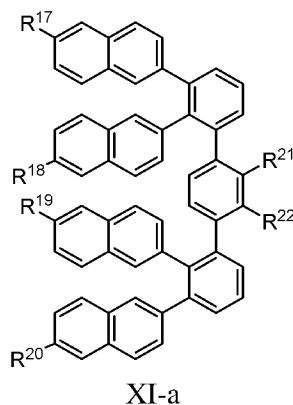
the dotted lines to R^{21} , R^{22} , and between the carbons within the ring to which R^{21} and R^{22} are bonded, independently indicate that the bond can be a single bond or a double bond, as valence permits;

R^{17} , R^{18} , R^{19} , R^{20} , R^{21} , and R^{22} are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C_1 - C_{40} alkyl, substituted or unsubstituted C_2 - C_{40} alkenyl, substituted or unsubstituted C_2 - C_{40} alkynyl, substituted or unsubstituted C_3 - C_{40} aryl, substituted or unsubstituted C_3 - C_{40} cycloalkyl, substituted or unsubstituted C_3 - C_{40} cycloalkenyl, substituted or unsubstituted C_1 - C_{40} acyl, substituted or unsubstituted C_1 - C_{40} alkoxy, $P(O)(OR^a)_2$, SR^a , $S(O)_2R^a$, $SiR^aR^bR^c$, or NR^aR^b , or wherein, as valence permits, R^{21} and R^{22} , together with the atoms to which they are attached, form a 3-10 membered substituted or unsubstituted cyclic moiety optionally including from 1 to 3 heteroatoms; and

R^a, R^b, and R^c are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C₁-C₄₀ alkyl, substituted or unsubstituted C₂-C₄₀ alkenyl, substituted or unsubstituted C₂-C₄₀ alkynyl, substituted or unsubstituted C₃-C₄₀ aryl, substituted or unsubstituted C₃-C₄₀ cycloalkyl, substituted or unsubstituted C₃-C₄₀ cycloalkenyl, substituted or unsubstituted C₁-C₄₀ acyl, or substituted or unsubstituted C₁-C₄₀ alkoxy.

124. The compound of claim 123, wherein R¹⁷, R¹⁸, R¹⁹, and R²⁰ are independently substituted or unsubstituted C₁-C₂₀ alkyl.
125. The compound of claim 123 or claim 124, wherein R¹⁷, R¹⁸, R¹⁹, and R²⁰ are independently unsubstituted C₁-C₁₀ alkyl.
126. The compound of any one of claims 123-125, wherein R¹⁷, R¹⁸, R¹⁹, and R²⁰ are the same.
127. The compound of any one of claims 123-126, wherein R²¹ and R²² are independently hydrogen, halogen, hydroxyl, substituted or unsubstituted C₁-C₂₀ alkyl, substituted or unsubstituted C₁-C₂₀ acyl, or wherein, as valence permits, R²¹ and R²², together with the atoms to which they are attached, form a 3-10 membered substituted or unsubstituted cyclic moiety optionally including from 1 to 3 heteroatoms.
128. The compound of any one of claims 123-127, wherein R²¹ and R²² are independently hydrogen or unsubstituted C₁-C₅ acyl.
129. The compound of any one of claims 123-128, wherein R²¹ and R²² are the same.
130. The compound of any one of claims 123-127, wherein R²¹ and R²² together with the atoms to which they are attached, form a 5-10 membered substituted or unsubstituted cyclic moiety optionally including from 1 to 3 heteroatoms.

131. The compound of any one of claims 123-130, wherein the compound is defined by Formula XI-a:

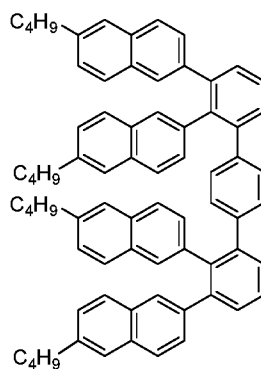


wherein

R^{17} , R^{18} , R^{19} , R^{20} , R^{21} , and R^{22} are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C_1 - C_{40} alkyl, substituted or unsubstituted C_2 - C_{40} alkenyl, substituted or unsubstituted C_2 - C_{40} alkynyl, substituted or unsubstituted C_3 - C_{40} aryl, substituted or unsubstituted C_3 - C_{40} cycloalkyl, substituted or unsubstituted C_3 - C_{40} cycloalkenyl, substituted or unsubstituted C_1 - C_{40} acyl, substituted or unsubstituted C_1 - C_{40} alkoxy, $P(O)(OR^a)_2$, SR^a , $S(O)_2R^a$, $SiR^aR^bR^c$, or NR^aR^b , or wherein, as valence permits, R^{21} and R^{22} , together with the atoms to which they are attached, form a 3-10 membered substituted or unsubstituted cyclic moiety optionally including from 1 to 3 heteroatoms; and

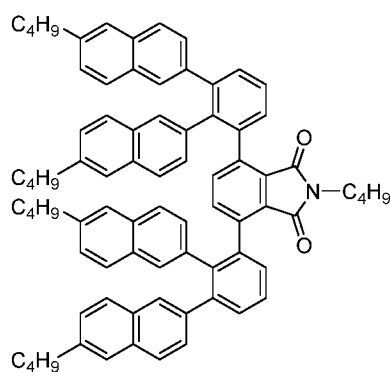
R^a , R^b , and R^c are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C_1 - C_{40} alkyl, substituted or unsubstituted C_2 - C_{40} alkenyl, substituted or unsubstituted C_2 - C_{40} alkynyl, substituted or unsubstituted C_3 - C_{40} aryl, substituted or unsubstituted C_3 - C_{40} cycloalkyl, substituted or unsubstituted C_3 - C_{40} cycloalkenyl, substituted or unsubstituted C_1 - C_{40} acyl, or substituted or unsubstituted C_1 - C_{40} alkoxy.

132. The compound of any one of claims 123-129, wherein the compound is defined by Formula XI-a-1:



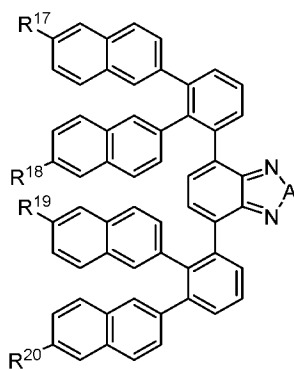
XI-a-1 .

133. The compound of any one of claims 123-131, wherein the compound is defined by Formula XI-a-2.:



XI-a-2 .

134. The compound of claim 130, wherein the compound is defined by Formula XI-b:



XI-b

wherein

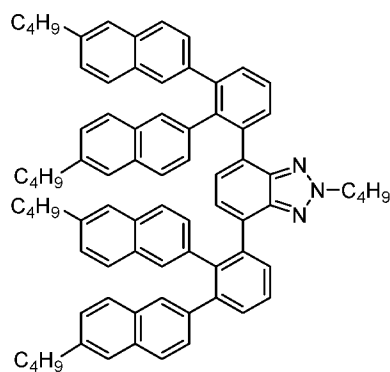
R^{17} , R^{18} , R^{19} , and R^{20} are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C_1 - C_{40} alkyl, substituted or unsubstituted C_2 - C_{40} alkenyl,

substituted or unsubstituted C₂-C₄₀ alkynyl, substituted or unsubstituted C₃-C₄₀ aryl, substituted or unsubstituted C₃-C₄₀ cycloalkyl, substituted or unsubstituted C₃-C₄₀ cycloalkenyl, substituted or unsubstituted C₁-C₄₀ acyl, substituted or unsubstituted C₁-C₄₀ alkoxy, P(O)(OR^a)₂, SR^a, S(O)₂R^a, SiR^aR^bR^c, or NR^aR^b;

A is O, S, Se, Te, or NR^a; and

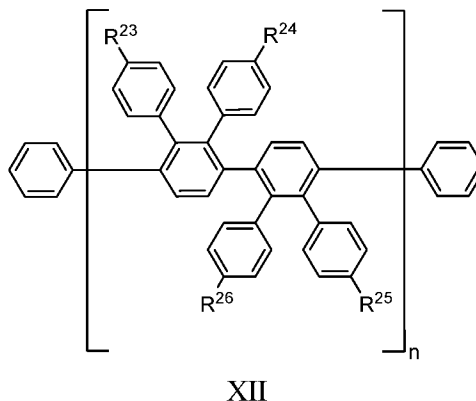
R^a, R^b, and R^c are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C₁-C₄₀ alkyl, substituted or unsubstituted C₂-C₄₀ alkenyl, substituted or unsubstituted C₂-C₄₀ alkynyl, substituted or unsubstituted C₃-C₄₀ aryl, substituted or unsubstituted C₃-C₄₀ cycloalkyl, substituted or unsubstituted C₃-C₄₀ cycloalkenyl, substituted or unsubstituted C₁-C₄₀ acyl, or substituted or unsubstituted C₁-C₄₀ alkoxy.

135. The compound of claim 134, wherein A is S or NR^a.
136. The compound of claim 134 or claim 135, wherein A is NR^a and R^a is a substituted or unsubstituted C₁-C₂₀ alkyl.
137. The compound of any one of claims 134-136, wherein A is NR^a and R^a is an unsubstituted C₁₋₁₀ alkyl.
138. The compound of any one of claims 134-137, wherein the compound is defined by Formula XI-b-1:



XI-b-1 .

139. A compound defined by Formula XII:



wherein

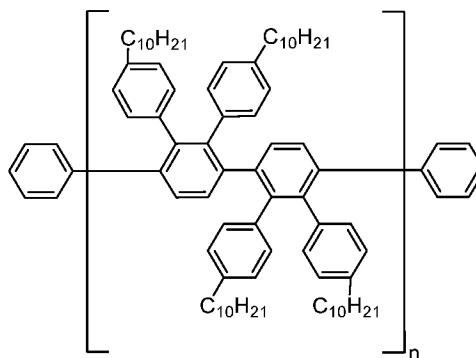
n is from 3 to 1000;

R^{23} , R^{24} , R^{25} , and R^{26} are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C_1 - C_{40} alkyl, substituted or unsubstituted C_2 - C_{40} alkenyl, substituted or unsubstituted C_2 - C_{40} alkynyl, substituted or unsubstituted C_3 - C_{40} aryl, substituted or unsubstituted C_3 - C_{40} cycloalkyl, substituted or unsubstituted C_3 - C_{40} cycloalkenyl, substituted or unsubstituted C_1 - C_{40} acyl, substituted or unsubstituted C_1 - C_{40} alkoxy, $P(O)(OR^a)_2$, SR^a , $S(O)_2R^a$, $SiR^aR^bR^c$, or NR^aR^b ; and

R^a , R^b , and R^c are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C_1 - C_{40} alkyl, substituted or unsubstituted C_2 - C_{40} alkenyl, substituted or unsubstituted C_2 - C_{40} alkynyl, substituted or unsubstituted C_3 - C_{40} aryl, substituted or unsubstituted C_3 - C_{40} cycloalkyl, substituted or unsubstituted C_3 - C_{40} cycloalkenyl, substituted or unsubstituted C_1 - C_{40} acyl, or substituted or unsubstituted C_1 - C_{40} alkoxy.

140. The compound of claim 139, wherein R^{23} , R^{24} , R^{25} , and R^{26} are independently substituted or unsubstituted C_1 - C_{20} alkyl.
141. The compound of claim 139 or claim 140, wherein R^{23} , R^{24} , R^{25} , and R^{26} are independently unsubstituted C_2 - C_{15} alkyl.
142. The compound of any one of claims 139-141, wherein R^{23} , R^{24} , R^{25} , and R^{26} are the same.

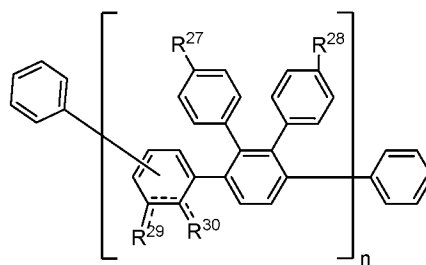
143. The compound of any one of claims 139-142, wherein the compound is defined by Formula XII-a:



XII-a

wherein n is from 3 to 1000.

144. A compound of Formula XIII:



XIII

wherein

n is from 3 to 1000;

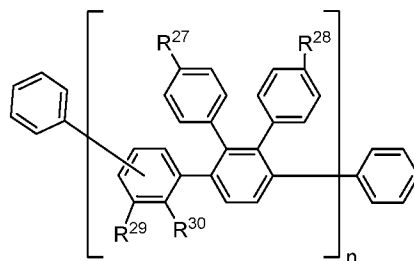
the dotted lines to R^{29} , R^{30} , and between the carbons within the ring to which R^{29} and R^{30} are bonded, independently indicate that the bond can be a single bond or a double bond, as valence permits;

R^{27} , R^{28} , R^{29} , and R^{30} are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C_1 - C_{40} alkyl, substituted or unsubstituted C_2 - C_{40} alkenyl, substituted or unsubstituted C_2 - C_{40} alkynyl, substituted or unsubstituted C_3 - C_{40} aryl, substituted or unsubstituted C_3 - C_{40} cycloalkyl, substituted or unsubstituted C_3 - C_{40} cycloalkenyl, substituted or unsubstituted C_1 - C_{40} acyl, substituted or unsubstituted C_1 - C_{40} alkoxy, $P(O)(OR^a)_2$, SR^a , $S(O)_2R^a$, $SiR^aR^bR^c$, or NR^aR^b , or wherein, as valence permits, R^{29} and R^{30} , together with the atoms to which they are attached, form a 3-10 membered substituted or unsubstituted cyclic moiety optionally including from 1 to 3 heteroatoms; and

R^a, R^b, and R^c are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C₁-C₄₀ alkyl, substituted or unsubstituted C₂-C₄₀ alkenyl, substituted or unsubstituted C₂-C₄₀ alkynyl, substituted or unsubstituted C₃-C₄₀ aryl, substituted or unsubstituted C₃-C₄₀ cycloalkyl, substituted or unsubstituted C₃-C₄₀ cycloalkenyl, substituted or unsubstituted C₁-C₄₀ acyl, or substituted or unsubstituted C₁-C₄₀ alkoxy.

145. The compound of claim 144, wherein R²⁷ and R²⁸ are independently substituted or unsubstituted C₁-C₂₀ alkyl.
146. The compound of claim 144 or claim 145, wherein R²⁷ and R²⁸ are independently unsubstituted C₂-C₁₅ alkyl.
147. The compound of any one of claims 144-146, wherein R²⁷ and R²⁸ are the same.
148. The compound of any one of claims 144-147, wherein R²⁹ and R³⁰ are independently hydrogen, halogen, hydroxyl, substituted or unsubstituted C₁-C₂₀ alkyl, substituted or unsubstituted C₁-C₂₀ acyl, or wherein, as valence permits, R²⁹ and R³⁰, together with the atoms to which they are attached, form a 3-10 membered substituted or unsubstituted cyclic moiety optionally including from 1 to 3 heteroatoms.
149. The compound of any one of claims 144-148, wherein R²⁹ and R³⁰ are independently hydrogen or unsubstituted C₁-C₅ acyl.
150. The compound of any one of claims 144-149, wherein R²⁹ and R³⁰ are the same.
151. The compound of any one of claims 144-148, wherein R²⁹ and R³⁰ together with the atoms to which they are attached, form a 5-10 membered substituted or unsubstituted cyclic moiety optionally including from 1 to 3 heteroatoms.

152. The compound of any one of claims 144-151, wherein the compound is defined by Formula XIII-a:



XIII-a

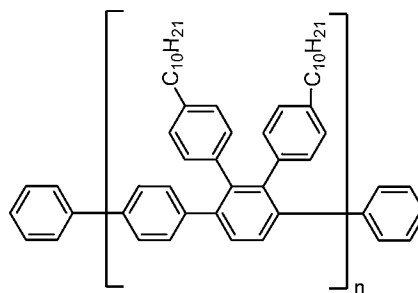
wherein

n is from 3 to 1000;

R^{27} , R^{28} , R^{29} , and R^{30} are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C_1 - C_{40} alkyl, substituted or unsubstituted C_2 - C_{40} alkenyl, substituted or unsubstituted C_2 - C_{40} alkynyl, substituted or unsubstituted C_3 - C_{40} aryl, substituted or unsubstituted C_3 - C_{40} cycloalkyl, substituted or unsubstituted C_3 - C_{40} cycloalkenyl, substituted or unsubstituted C_1 - C_{40} acyl, substituted or unsubstituted C_1 - C_{40} alkoxy, $P(O)(OR^a)_2$, SR^a , $S(O)_2R^a$, $SiR^aR^bR^c$, or NR^aR^b , or wherein, as valence permits, R^{29} and R^{30} , together with the atoms to which they are attached, form a 3-10 membered substituted or unsubstituted cyclic moiety optionally including from 1 to 3 heteroatoms; and

R^a , R^b , and R^c are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C_1 - C_{40} alkyl, substituted or unsubstituted C_2 - C_{40} alkenyl, substituted or unsubstituted C_2 - C_{40} alkynyl, substituted or unsubstituted C_3 - C_{40} aryl, substituted or unsubstituted C_3 - C_{40} cycloalkyl, substituted or unsubstituted C_3 - C_{40} cycloalkenyl, substituted or unsubstituted C_1 - C_{40} acyl, or substituted or unsubstituted C_1 - C_{40} alkoxy.

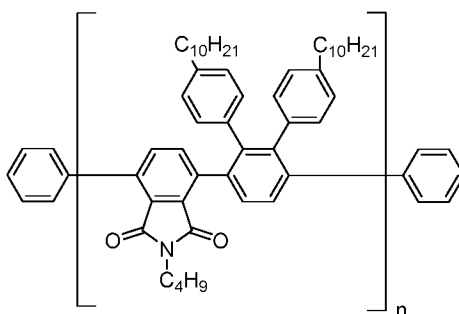
153. The compound of any one of claims 144-150, wherein the compound is defined by Formula XIII-a-1:



XIII-a-1

wherein n is from 3 to 1000.

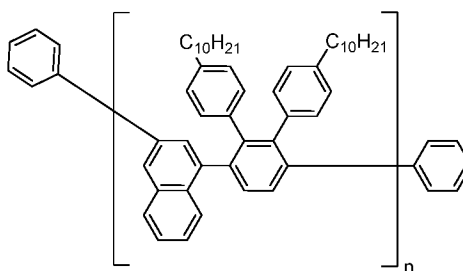
154. The compound of any one of claims 144-152, wherein the compound is defined by Formula XIII-a-2:



XIII-a-2

wherein n is from 3 to 1000.

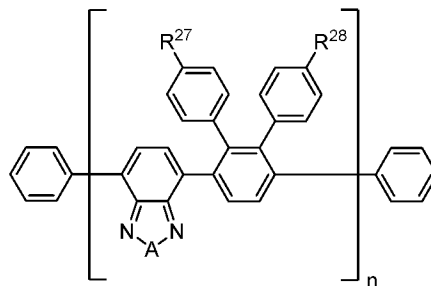
155. The compound of any one of claims 144-152, wherein the compound is defined by Formula XIII-a-3:



XIII-a-3

wherein n is from 3 to 1000.

156. The compound of claim 151, wherein the compound is defined by Formula XIII-b:



XIII-b

wherein

n is from 3 to 1000;

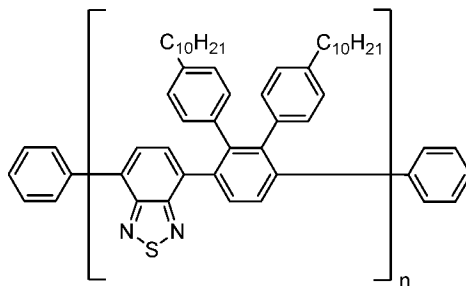
R^{27} and R^{28} are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C_1 - C_{40} alkyl, substituted or unsubstituted C_2 - C_{40} alkenyl, substituted or unsubstituted C_2 - C_{40} alkynyl, substituted or unsubstituted C_3 - C_{40} aryl, substituted or unsubstituted C_3 - C_{40} cycloalkyl, substituted or unsubstituted C_3 - C_{40} cycloalkenyl, substituted or unsubstituted C_1 - C_{40} acyl, substituted or unsubstituted C_1 - C_{40} alkoxy, $P(O)(OR^a)_2$, SR^a , $S(O)_2R^a$, $SiR^aR^bR^c$, or NR^aR^b ;

A is O, S, Se, Te, or NR^a ; and

R^a , R^b , and R^c are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C_1 - C_{40} alkyl, substituted or unsubstituted C_2 - C_{40} alkenyl, substituted or unsubstituted C_2 - C_{40} alkynyl, substituted or unsubstituted C_3 - C_{40} aryl, substituted or unsubstituted C_3 - C_{40} cycloalkyl, substituted or unsubstituted C_3 - C_{40} cycloalkenyl, substituted or unsubstituted C_1 - C_{40} acyl, or substituted or unsubstituted C_1 - C_{40} alkoxy.

157. The compound of claim 156, wherein A is S or NR^a .
158. The compound of claim 156 or claim 157, wherein A is NR^a and R^a is a substituted or unsubstituted C_1 - C_{20} alkyl.
159. The compound of any one of claims 156-158, wherein A is NR^a and R^a is an unsubstituted C_1 - C_{10} alkyl.

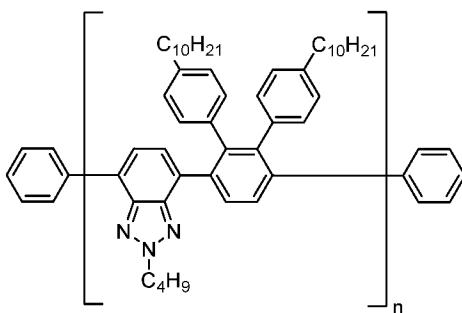
160. The compound of claim 157, wherein the compound is defined by Formula XIII-b-1:



XIII-b-1

wherein n is from 3 to 1000.

161. The compound of any one of claims 156-159, wherein the compound is defined by Formula XIII-b-2:



XIII-b-2

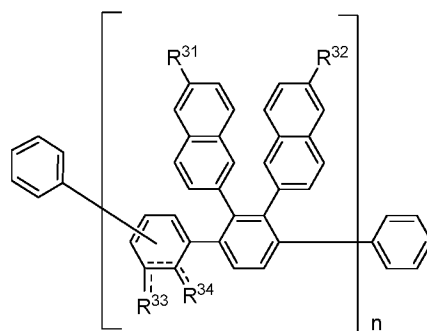
wherein n is from 3 to 1000.

162. The compound of any one of claims 144-161, wherein n is from 3 to 500.

163. The compound of any one of claims 144-162, wherein n is from 3 to 100.

164. The compound of any one of claims 144-163, wherein n is from 3 to 50.

165. A compound of Formula XIV



XIV

wherein

n is from 3 to 1000;

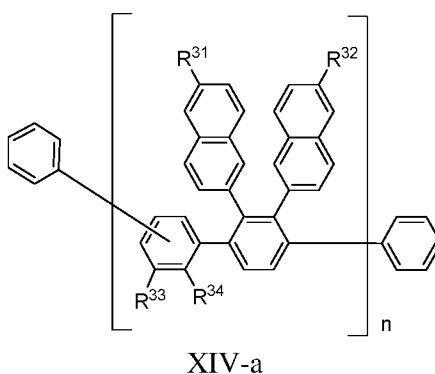
the dotted lines to R³³, R³⁴, and between the carbons within the ring to which R³³ and R³⁴ are bonded, independently indicate that the bond can be a single bond or a double bond, as valence permits;

R³¹, R³², R³³, and R³⁴ are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C₁-C₄₀ alkyl, substituted or unsubstituted C₂-C₄₀ alkenyl, substituted or unsubstituted C₂-C₄₀ alkynyl, substituted or unsubstituted C₃-C₄₀ aryl, substituted or unsubstituted C₃-C₄₀ cycloalkyl, substituted or unsubstituted C₃-C₄₀ cycloalkenyl, substituted or unsubstituted C₁-C₄₀ acyl, substituted or unsubstituted C₁-C₄₀ alkoxy, P(O)(OR^a)₂, SR^a, S(O)₂R^a, SiR^aR^bR^c, or NR^aR^b, or wherein, as valence permits, R³³ and R³⁴, together with the atoms to which they are attached, form a 3-10 membered substituted or unsubstituted cyclic moiety optionally including from 1 to 3 heteroatoms; and

R^a, R^b, and R^c are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C₁-C₄₀ alkyl, substituted or unsubstituted C₂-C₄₀ alkenyl, substituted or unsubstituted C₂-C₄₀ alkynyl, substituted or unsubstituted C₃-C₄₀ aryl, substituted or unsubstituted C₃-C₄₀ cycloalkyl, substituted or unsubstituted C₃-C₄₀ cycloalkenyl, substituted or unsubstituted C₁-C₄₀ acyl, or substituted or unsubstituted C₁-C₄₀ alkoxy.

166. The compound of 165, wherein R³¹ and R³² are independently substituted or unsubstituted C₁-C₂₀ alkyl.
167. The compound of claim 165 or claim 166, wherein R³¹ and R³² are independently unsubstituted C₂-C₁₅ alkyl.
168. The compound of any one of claims 165-167, wherein R³¹ and R³² are the same.
169. The compound of any one of claims 165-168, wherein R³³ and R³⁴ are independently hydrogen, halogen, hydroxyl, substituted or unsubstituted C₁-C₂₀ alkyl, substituted or unsubstituted C₁-C₂₀ acyl, or wherein, as valence permits, R³³ and R³⁴, together with the atoms to which they are attached, form a 3-10 membered substituted or unsubstituted cyclic moiety optionally including from 1 to 3 heteroatoms.

170. The compound of any one of claims 165-169, wherein R^{33} and R^{34} are independently hydrogen or unsubstituted C_1 - C_5 acyl.
171. The compound of any one of claims 165-170, wherein R^{33} and R^{34} are the same.
172. The compound of any one of claims 165-169, wherein R^{33} and R^{34} together with the atoms to which they are attached, form a 5-10 membered substituted or unsubstituted cyclic moiety optionally including from 1 to 3 heteroatoms.
173. The compound of any one of claims 165-172, wherein the compound is defined by Formula XIV-a:



wherein

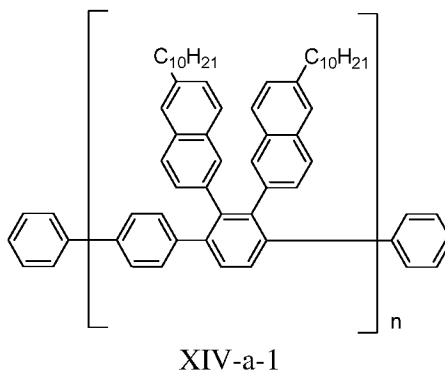
n is from 3 to 1000;

R^{31} , R^{32} , R^{33} , and R^{34} are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C_1 - C_{40} alkyl, substituted or unsubstituted C_2 - C_{40} alkenyl, substituted or unsubstituted C_2 - C_{40} alkynyl, substituted or unsubstituted C_3 - C_{40} aryl, substituted or unsubstituted C_3 - C_{40} cycloalkyl, substituted or unsubstituted C_3 - C_{40} cycloalkenyl, substituted or unsubstituted C_1 - C_{40} acyl, substituted or unsubstituted C_1 - C_{40} alkoxy, $P(O)(OR^a)_2$, SR^a , $S(O)_2R^a$, $SiR^aR^bR^c$, or NR^aR^b , or wherein, as valence permits, R^{33} and R^{34} , together with the atoms to which they are attached, form a 3-10 membered substituted or unsubstituted cyclic moiety optionally including from 1 to 3 heteroatoms; and

R^a , R^b , and R^c are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C_1 - C_{40} alkyl, substituted or unsubstituted C_2 - C_{40} alkenyl, substituted or unsubstituted C_2 - C_{40} alkynyl, substituted or unsubstituted C_3 - C_{40} aryl, substituted or unsubstituted C_3 - C_{40} cycloalkyl, substituted or unsubstituted C_3 - C_{40} cycloalkenyl,

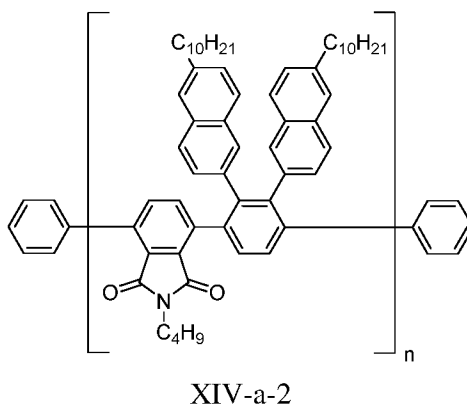
substituted or unsubstituted C_1 - C_{40} acyl, or substituted or unsubstituted C_1 - C_{40} alkoxy.

174. The compound of any one of claims 165-168, wherein the compound is defined by Formula XIV-a-1:



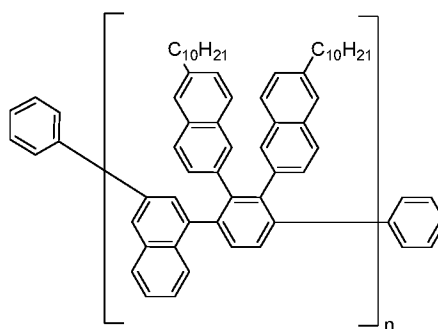
wherein n is from 3 to 1000.

175. The compound of any one of claims 165-173, wherein the compound is defined by Formula XIV-a-2:



wherein n is from 3 to 1000.

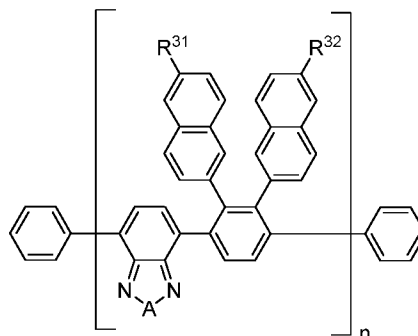
176. The compound of any one of claims 165-173, wherein the compound is defined by Formula XIV-a-3:



XIV-a-3

wherein n is from 3 to 1000.

177. The compound of claim 172, wherein the compound is defined by Formula XIV-b:



XIV-b

wherein

n is from 3 to 1000;

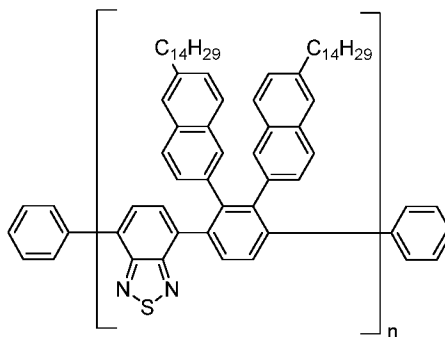
R^{31} and R^{32} are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C_1 - C_{40} alkyl, substituted or unsubstituted C_2 - C_{40} alkenyl, substituted or unsubstituted C_2 - C_{40} alkynyl, substituted or unsubstituted C_3 - C_{40} aryl, substituted or unsubstituted C_3 - C_{40} cycloalkyl, substituted or unsubstituted C_3 - C_{40} cycloalkenyl, substituted or unsubstituted C_1 - C_{40} acyl, substituted or unsubstituted C_1 - C_{40} alkoxy, $P(O)(OR^a)_2$, SR^a , $S(O)_2R^a$, $SiR^aR^bR^c$, or NR^aR^b ;

A is O, S, Se, Te, or NR^a ; and

R^a , R^b , and R^c are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C_1 - C_{40} alkyl, substituted or unsubstituted C_2 - C_{40} alkenyl, substituted or unsubstituted C_2 - C_{40} alkynyl, substituted or unsubstituted C_3 - C_{40} aryl, substituted or unsubstituted C_3 - C_{40} cycloalkyl, substituted or unsubstituted C_3 - C_{40} cycloalkenyl,

substituted or unsubstituted C_1 - C_{40} acyl, or substituted or unsubstituted C_1 - C_{40} alkoxy.

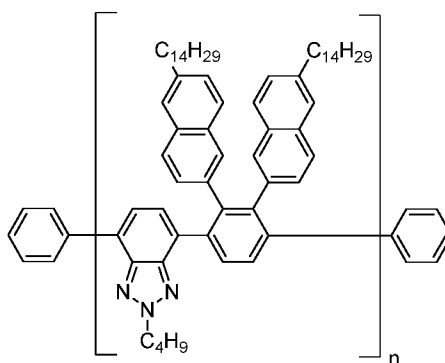
178. The compound of claim 177, wherein A is S or NR^a .
179. The compound of claim 177 or claim 178, wherein A is NR^a and R^a is a substituted or unsubstituted C_1 - C_{20} alkyl.
180. The compound of any one of claims 177-179, wherein A is NR^a and R^a is an unsubstituted C_{1-10} alkyl.
181. The compound of claim 178, wherein the compound is defined by Formula XIV-b-1:



XIV-b-1

wherein n is from 3 to 1000.

182. The compound of any one of claims 177-180, wherein the compound is defined by Formula XIV-b-2:



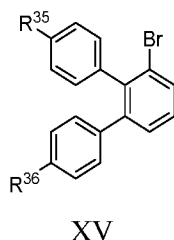
XIV-b-2

wherein n is from 3 to 1000.

183. The compound of any one of claims 165-182, wherein n is from 3 to 500.

184. The compound of any one of claims 165-183, wherein n is from 3 to 100.
185. The compound of any one of claims 165-184, wherein n is from 3 to 50.
186. A method of making the compound of any one of claims 1-5, comprising cyclodehydrogenating a compound of any one of claims 96-100.
187. A method of making the compound of any one of claims 6-10, comprising cyclodehydrogenating a compound of any one of claims 101-105.
188. A method of making the compound of any one of claims 11-27, comprising cyclodehydrogenating a compound of any one of claims 106-122.
189. A method of making the compound of any one of claims 28-43, comprising cyclodehydrogenating a compounds of any one of claims 123-138.
190. A method of making the compound of any one of claims 44-49, comprising cyclodehydrogenating a compound of any one of claims 139-143.
191. A method of making the compound of any one of claims 50-70, comprising cyclodehydrogenating a compound of any one of claims 144-164.
192. A method of making the compound of any one of claims 71-91, comprising cyclodehydrogenating a compound of any one of claims 165-185.
193. The method of any one of claims 186-192, wherein the cyclodehydrogenation comprises contacting the compound with FeCl_3 and CH_3NO_2 .
194. The method of any one of claims 186-192, wherein the cyclodehydrogenation comprises contacting the compound with 2,3-dichloro-5,6-dicyano-1,4-benzoquinone and $\text{CF}_3\text{SO}_3\text{H}$.
195. A method of making the compound of any of claims 96-185, comprising: performing a polycondensation reaction between an aryl bromide and an aryl boronate ester.
196. The method of claim 195, wherein the polycondensation reaction comprises a Suzuki-Miyaura cross coupling reaction.

197. The method of claim 195 or claim 196, wherein the aryl bromide is a compound defined by Formula XV:

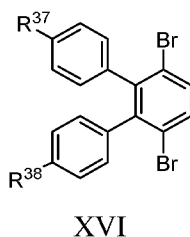


wherein

R^{35} and R^{36} are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C_1 - C_{40} alkyl, substituted or unsubstituted C_2 - C_{40} alkenyl, substituted or unsubstituted C_2 - C_{40} alkynyl, substituted or unsubstituted C_3 - C_{40} aryl, substituted or unsubstituted C_3 - C_{40} cycloalkyl, substituted or unsubstituted C_3 - C_{40} cycloalkenyl, substituted or unsubstituted C_1 - C_{40} acyl, substituted or unsubstituted C_1 - C_{40} alkoxy, $P(O)(OR^a)_2$, SR^a , $S(O)_2R^a$, $SiR^aR^bR^c$, or NR^aR^b ; and

R^a , R^b , and R^c are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C_1 - C_{40} alkyl, substituted or unsubstituted C_2 - C_{40} alkenyl, substituted or unsubstituted C_2 - C_{40} alkynyl, substituted or unsubstituted C_3 - C_{40} aryl, substituted or unsubstituted C_3 - C_{40} cycloalkyl, substituted or unsubstituted C_3 - C_{40} cycloalkenyl, substituted or unsubstituted C_1 - C_{40} acyl, or substituted or unsubstituted C_1 - C_{40} alkoxy.

198. The method of claim 197, wherein R^{35} and R^{36} are independently substituted or unsubstituted C_1 - C_{20} alkyl.
199. The method of claim 197 or claim 198, wherein R^{35} and R^{36} are the same.
200. The method of claim 195 or claim 196, wherein the aryl bromide is a compound defined by Formula XVI:

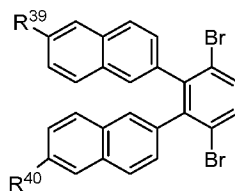


wherein

R^{37} and R^{38} are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C_1 - C_{40} alkyl, substituted or unsubstituted C_2 - C_{40} alkenyl, substituted or unsubstituted C_2 - C_{40} alkynyl, substituted or unsubstituted C_3 - C_{40} aryl, substituted or unsubstituted C_3 - C_{40} cycloalkyl, substituted or unsubstituted C_3 - C_{40} cycloalkenyl, substituted or unsubstituted C_1 - C_{40} acyl, substituted or unsubstituted C_1 - C_{40} alkoxy, $P(O)(OR^a)_2$, SR^a , $S(O)_2R^a$, $SiR^aR^bR^c$, or NR^aR^b ; and

R^a , R^b , and R^c are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C_1 - C_{40} alkyl, substituted or unsubstituted C_2 - C_{40} alkenyl, substituted or unsubstituted C_2 - C_{40} alkynyl, substituted or unsubstituted C_3 - C_{40} aryl, substituted or unsubstituted C_3 - C_{40} cycloalkyl, substituted or unsubstituted C_3 - C_{40} cycloalkenyl, substituted or unsubstituted C_1 - C_{40} acyl, or substituted or unsubstituted C_1 - C_{40} alkoxy.

201. The method of claim 200, wherein R^{37} and R^{38} are independently substituted or unsubstituted C_1 - C_{20} alkyl.
202. The method of claim 200 or claim 201, wherein R^{37} and R^{38} are the same.
203. The method of claim 195 or claim 196, wherein the aryl bromide is a compound defined by Formula XVII:



XVII

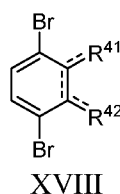
wherein

R^{39} and R^{40} are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C_1 - C_{40} alkyl, substituted or unsubstituted C_2 - C_{40} alkenyl, substituted or unsubstituted C_2 - C_{40} alkynyl, substituted or unsubstituted C_3 - C_{40} aryl, substituted or unsubstituted C_3 - C_{40} cycloalkyl, substituted or unsubstituted C_3 - C_{40} cycloalkenyl, substituted or unsubstituted C_1 - C_{40} acyl, substituted or unsubstituted C_1 - C_{40} alkoxy, $P(O)(OR^a)_2$, SR^a , $S(O)_2R^a$, $SiR^aR^bR^c$, or NR^aR^b ; and

R^a , R^b , and R^c are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C_1 - C_{40} alkyl, substituted or unsubstituted C_2 - C_{40} alkenyl, substituted

or unsubstituted C₂-C₄₀ alkynyl, substituted or unsubstituted C₃-C₄₀ aryl, substituted or unsubstituted C₃-C₄₀ cycloalkyl, substituted or unsubstituted C₃-C₄₀ cycloalkenyl, substituted or unsubstituted C₁-C₄₀ acyl, or substituted or unsubstituted C₁-C₄₀ alkoxy.

204. The method of claim 203, wherein R³⁹ and R⁴⁰ are independently substituted or unsubstituted C₁-C₂₀ alkyl.
205. The method of claim 203 or claim 204, wherein R³⁹ and R⁴⁰ are the same.
206. The method of claim 195 or claim 196, wherein the aryl bromide is a compound defined by Formula XVIII:



wherein

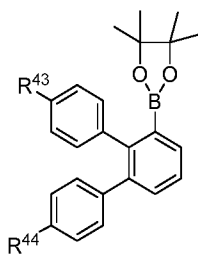
the dotted lines to R⁴¹, R⁴², and between the carbons within the ring to which R⁴¹ and R⁴² are bonded, independently indicate that the bond can be a single bond or a double bond, as valence permits;

R⁴¹ and R⁴² are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C₁-C₄₀ alkyl, substituted or unsubstituted C₂-C₄₀ alkenyl, substituted or unsubstituted C₂-C₄₀ alkynyl, substituted or unsubstituted C₃-C₄₀ aryl, substituted or unsubstituted C₃-C₄₀ cycloalkyl, substituted or unsubstituted C₃-C₄₀ cycloalkenyl, substituted or unsubstituted C₁-C₄₀ acyl, substituted or unsubstituted C₁-C₄₀ alkoxy, P(O)(OR^a)₂, SR^a, S(O)₂R^a, SiR^aR^bR^c, or NR^aR^b, or wherein, as valence permits, R⁴¹ and R⁴², together with the atoms to which they are attached, form a 3-10 membered substituted or unsubstituted cyclic moiety optionally including from 1 to 3 heteroatoms; and

R^a, R^b, and R^c are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C₁-C₄₀ alkyl, substituted or unsubstituted C₂-C₄₀ alkenyl, substituted or unsubstituted C₂-C₄₀ alkynyl, substituted or unsubstituted C₃-C₄₀ aryl, substituted or unsubstituted C₃-C₄₀ cycloalkyl, substituted or unsubstituted C₃-C₄₀ cycloalkenyl,

substituted or unsubstituted C₁-C₄₀ acyl, or substituted or unsubstituted C₁-C₄₀ alkoxy.

207. The method of claim 206, wherein R⁴¹ and R⁴² are independently hydrogen, halogen, hydroxyl, substituted or unsubstituted C₁-C₂₀ alkyl, substituted or unsubstituted C₁-C₂₀ acyl, or wherein, as valence permits, R⁴¹ and R⁴², together with the atoms to which they are attached, form a 3-10 membered substituted or unsubstituted cyclic moiety optionally including from 1 to 3 heteroatoms.
208. The method of claim 206 or claim 207, wherein R⁴¹ and R⁴² are independently hydrogen or unsubstituted C₁-C₅ acyl.
209. The method of any one of claims 206-208, wherein R⁴¹ and R⁴² are the same.
210. The method of claim 206 or claim 207, wherein R⁴¹ and R⁴² together with the atoms to which they are attached, form a 5-10 membered substituted or unsubstituted cyclic moiety optionally including from 1 to 3 heteroatoms.
211. The method of any one of claims 195-210, wherein the aryl boronate ester is a compound defined by Formula XIX:



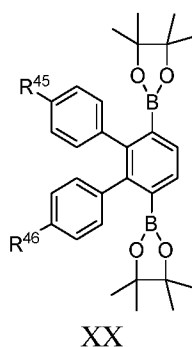
XIX

wherein

R⁴³ and R⁴⁴ are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C₁-C₄₀ alkyl, substituted or unsubstituted C₂-C₄₀ alkenyl, substituted or unsubstituted C₂-C₄₀ alkynyl, substituted or unsubstituted C₃-C₄₀ aryl, substituted or unsubstituted C₃-C₄₀ cycloalkyl, substituted or unsubstituted C₃-C₄₀ cycloalkenyl, substituted or unsubstituted C₁-C₄₀ acyl, substituted or unsubstituted C₁-C₄₀ alkoxy, P(O)(OR^a)₂, SR^a, S(O)₂R^a, SiR^aR^bR^c, or NR^aR^b; and R^a, R^b, and R^c are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C₁-C₄₀ alkyl, substituted or unsubstituted C₂-C₄₀ alkenyl, substituted

or unsubstituted C₂-C₄₀ alkynyl, substituted or unsubstituted C₃-C₄₀ aryl, substituted or unsubstituted C₃-C₄₀ cycloalkyl, substituted or unsubstituted C₃-C₄₀ cycloalkenyl, substituted or unsubstituted C₁-C₄₀ acyl, or substituted or unsubstituted C₁-C₄₀ alkoxy.

212. The method of claim 211, wherein R⁴³ and R⁴⁴ are independently substituted or unsubstituted C₁-C₂₀ alkyl.
213. The method of claim 211 or claim 212, wherein R⁴³ and R⁴⁴ are the same.
214. The method of any one of claims 195-210, wherein the aryl boronate ester is a compound defined by Formula XX:



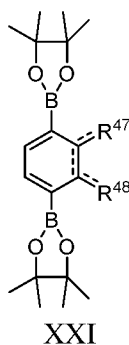
wherein

R⁴⁵ and R⁴⁶ are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C₁-C₄₀ alkyl, substituted or unsubstituted C₂-C₄₀ alkenyl, substituted or unsubstituted C₂-C₄₀ alkynyl, substituted or unsubstituted C₃-C₄₀ aryl, substituted or unsubstituted C₃-C₄₀ cycloalkyl, substituted or unsubstituted C₃-C₄₀ cycloalkenyl, substituted or unsubstituted C₁-C₄₀ acyl, substituted or unsubstituted C₁-C₄₀ alkoxy, P(O)(OR^a)₂, SR^a, S(O)₂R^a, SiR^aR^bR^c, or NR^aR^b; and

R^a, R^b, and R^c are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C₁-C₄₀ alkyl, substituted or unsubstituted C₂-C₄₀ alkenyl, substituted or unsubstituted C₂-C₄₀ alkynyl, substituted or unsubstituted C₃-C₄₀ aryl, substituted or unsubstituted C₃-C₄₀ cycloalkyl, substituted or unsubstituted C₃-C₄₀ cycloalkenyl, substituted or unsubstituted C₁-C₄₀ acyl, or substituted or unsubstituted C₁-C₄₀ alkoxy.

215. The method of claim 214, wherein R⁴⁵ and R⁴⁶ are independently substituted or unsubstituted C₁-C₂₀ alkyl.

216. The method of claim 214 or 215, wherein R^{45} and R^{46} are the same.
217. The method of any one of claims 195-210, wherein the aryl boronate ester is a compound defined by Formula XXI:



wherein

the dotted lines to R^{47} , R^{48} , and between the carbons within the ring to which R^{47} and R^{48} are bonded, independently indicate that the bond can be a single bond or a double bond, as valence permits

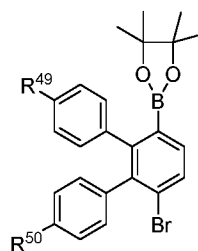
R^{47} and R^{48} are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C_1 - C_{40} alkyl, substituted or unsubstituted C_2 - C_{40} alkenyl, substituted or unsubstituted C_2 - C_{40} alkynyl, substituted or unsubstituted C_3 - C_{40} aryl, substituted or unsubstituted C_3 - C_{40} cycloalkyl, substituted or unsubstituted C_3 - C_{40} cycloalkenyl, substituted or unsubstituted C_1 - C_{40} acyl, substituted or unsubstituted C_1 - C_{40} alkoxy, $P(O)(OR^a)_2$, SR^a , $S(O)_2R^a$, $SiR^aR^bR^c$, or NR^aR^b , or wherein, as valence permits, R^{47} and R^{48} , together with the atoms to which they are attached, form a 3-10 membered substituted or unsubstituted cyclic moiety optionally including from 1 to 3 heteroatoms; and

R^a , R^b , and R^c are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C_1 - C_{40} alkyl, substituted or unsubstituted C_2 - C_{40} alkenyl, substituted or unsubstituted C_2 - C_{40} alkynyl, substituted or unsubstituted C_3 - C_{40} aryl, substituted or unsubstituted C_3 - C_{40} cycloalkyl, substituted or unsubstituted C_3 - C_{40} cycloalkenyl, substituted or unsubstituted C_1 - C_{40} acyl, or substituted or unsubstituted C_1 - C_{40} alkoxy.

218. The method of claim 217, wherein R^{47} and R^{48} are independently hydrogen, halogen, hydroxyl, substituted or unsubstituted C_1 - C_{20} alkyl, substituted or unsubstituted C_1 - C_{20} acyl, or wherein, as valence permits, R^{47} and R^{48} , together with the atoms to which they

are attached, form a 3-10 membered substituted or unsubstituted cyclic moiety optionally including from 1 to 3 heteroatoms.

219. The method of claim 217 or claim 218, wherein R^{47} and R^{48} are independently hydrogen or unsubstituted C_1 - C_5 acyl.
220. The method of any one of claims 217-219, wherein R^{47} and R^{48} are the same.
221. The method of claim 217 or claim 218, wherein R^{47} and R^{48} together with the atoms to which they are attached, form a 5-10 membered substituted or unsubstituted cyclic moiety optionally including from 1 to 3 heteroatoms.
222. The method of claim or claim 196, wherein the aryl bromide and the aryl boronate ester comprise a single compound.
223. The method of claim 222, wherein the aryl bromide and the aryl boronate ester comprise a compound defined by Formula XXII:



XXII

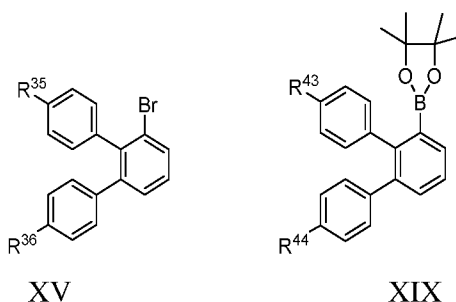
wherein

R^{49} and R^{50} are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C_1 - C_{40} alkyl, substituted or unsubstituted C_2 - C_{40} alkenyl, substituted or unsubstituted C_2 - C_{40} alkynyl, substituted or unsubstituted C_3 - C_{40} aryl, substituted or unsubstituted C_3 - C_{40} cycloalkyl, substituted or unsubstituted C_3 - C_{40} cycloalkenyl, substituted or unsubstituted C_1 - C_{40} acyl, substituted or unsubstituted C_1 - C_{40} alkoxy, $P(O)(OR^a)_2$, SR^a , $S(O)_2R^a$, $SiR^aR^bR^c$, or NR^aR^b ; and

R^a , R^b , and R^c are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C_1 - C_{40} alkyl, substituted or unsubstituted C_2 - C_{40} alkenyl, substituted or unsubstituted C_2 - C_{40} alkynyl, substituted or unsubstituted C_3 - C_{40} aryl, substituted or unsubstituted C_3 - C_{40} cycloalkyl, substituted or unsubstituted C_3 - C_{40} cycloalkenyl,

substituted or unsubstituted C₁-C₄₀ acyl, or substituted or unsubstituted C₁-C₄₀ alkoxy.

224. The method of claim 223, wherein R⁴⁹ and R⁵⁰ are independently substituted or unsubstituted C₁-C₂₀ alkyl.
225. The method of claim 223 or claim 224, wherein R⁴⁹ and R⁵⁰ are the same.
226. A method of making the compound of any one of claims 96-100, comprising performing a Suzuki-Miyaura cross coupling reaction between an aryl bromide of Formula XV and an aryl boronate ester of Formula XIX:

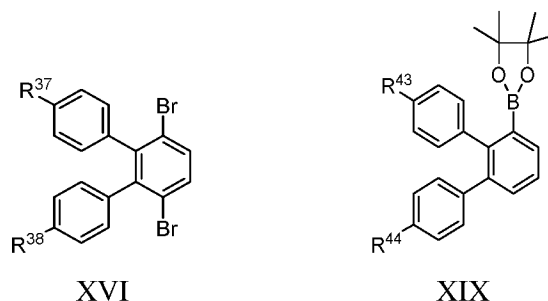


wherein

R³⁵, R³⁶, R⁴³ and R⁴⁴ are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C₁-C₄₀ alkyl, substituted or unsubstituted C₂-C₄₀ alkenyl, substituted or unsubstituted C₂-C₄₀ alkynyl, substituted or unsubstituted C₃-C₄₀ aryl, substituted or unsubstituted C₃-C₄₀ cycloalkyl, substituted or unsubstituted C₃-C₄₀ cycloalkenyl, substituted or unsubstituted C₁-C₄₀ acyl, substituted or unsubstituted C₁-C₄₀ alkoxy, P(O)(OR^a)₂, SR^a, S(O)₂R^a, SiR^aR^bR^c, or NR^aR^b; and R^a, R^b, and R^c are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C₁-C₄₀ alkyl, substituted or unsubstituted C₂-C₄₀ alkenyl, substituted or unsubstituted C₂-C₄₀ alkynyl, substituted or unsubstituted C₃-C₄₀ aryl, substituted or unsubstituted C₃-C₄₀ cycloalkyl, substituted or unsubstituted C₃-C₄₀ cycloalkenyl, substituted or unsubstituted C₁-C₄₀ acyl, or substituted or unsubstituted C₁-C₄₀ alkoxy.

227. The method of claim 226, wherein R³⁵, R³⁶, R⁴³ and R⁴⁴ are independently substituted or unsubstituted C₁-C₂₀ alkyl.

228. The method of claim 226 or claim 227, wherein R^{35} , R^{36} , R^{43} and R^{44} are independently unsubstituted C_1 - C_{10} alkyl.
229. The method of any one of claims 226-228, wherein R^{35} , R^{36} , R^{43} and R^{44} are the same.
230. The method of any one of claims 226-229, wherein R^{35} , R^{36} , R^{43} and R^{44} are each C_4H_9 .
231. A method of making the compound of any one of claims 101-105, comprising performing a Suzuki-Miyaura cross coupling reaction between an aryl bromide of Formula XVI and an aryl boronate ester of Formula XIX:

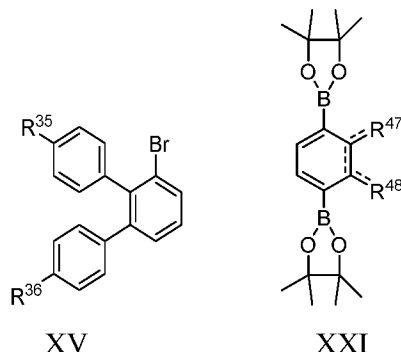


wherein

R^{37} , R^{38} , R^{43} and R^{44} are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C_1 - C_{40} alkyl, substituted or unsubstituted C_2 - C_{40} alkenyl, substituted or unsubstituted C_2 - C_{40} alkynyl, substituted or unsubstituted C_3 - C_{40} aryl, substituted or unsubstituted C_3 - C_{40} cycloalkyl, substituted or unsubstituted C_3 - C_{40} cycloalkenyl, substituted or unsubstituted C_1 - C_{40} acyl, substituted or unsubstituted C_1 - C_{40} alkoxy, $P(O)(OR^a)_2$, SR^a , $S(O)_2R^a$, $SiR^aR^bR^c$, or NR^aR^b ; and R^a , R^b , and R^c are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C_1 - C_{40} alkyl, substituted or unsubstituted C_2 - C_{40} alkenyl, substituted or unsubstituted C_2 - C_{40} alkynyl, substituted or unsubstituted C_3 - C_{40} aryl, substituted or unsubstituted C_3 - C_{40} cycloalkyl, substituted or unsubstituted C_3 - C_{40} cycloalkenyl, substituted or unsubstituted C_1 - C_{40} acyl, or substituted or unsubstituted C_1 - C_{40} alkoxy.

232. The method of claim 231, wherein R^{37} , R^{38} , R^{43} and R^{44} are independently substituted or unsubstituted C_1 - C_{20} alkyl.
233. The method of claim 231 or claim 232, wherein R^{37} , R^{38} , R^{43} and R^{44} are independently unsubstituted C_1 - C_{10} alkyl.

234. The method of any one of claims 231-233, wherein R^{37} , R^{38} , R^{43} and R^{44} are the same.
235. The method of any one of claims 231-234, wherein R^{37} , R^{38} , R^{43} and R^{44} are each C_4H_9 .
236. A method of making the compound of any one of claims 106-122, comprising performing a Suzuki-Miyaura cross coupling reaction between an aryl bromide of Formula XV and an aryl boronate ester of Formula XXI:



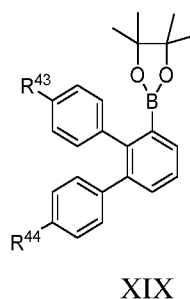
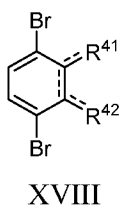
wherein

the dotted lines to R^{47} , R^{48} , and between the carbons within the ring to which R^{47} and R^{48} are bonded, independently indicate that the bond can be a single bond or a double bond, as valence permits;

R^{35} , R^{36} , R^{47} , and R^{48} are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C_1 - C_{40} alkyl, substituted or unsubstituted C_2 - C_{40} alkenyl, substituted or unsubstituted C_2 - C_{40} alkynyl, substituted or unsubstituted C_3 - C_{40} aryl, substituted or unsubstituted C_3 - C_{40} cycloalkyl, substituted or unsubstituted C_3 - C_{40} cycloalkenyl, substituted or unsubstituted C_1 - C_{40} acyl, substituted or unsubstituted C_1 - C_{40} alkoxy, $P(O)(OR^a)_2$, SR^a , $S(O)_2R^a$, $SiR^aR^bR^c$, or NR^aR^b , or wherein, as valence permits, R^{47} and R^{48} , together with the atoms to which they are attached, form a 3-10 membered substituted or unsubstituted cyclic moiety optionally including from 1 to 3 heteroatoms; and

R^a , R^b , and R^c are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C_1 - C_{40} alkyl, substituted or unsubstituted C_2 - C_{40} alkenyl, substituted or unsubstituted C_2 - C_{40} alkynyl, substituted or unsubstituted C_3 - C_{40} aryl, substituted or unsubstituted C_3 - C_{40} cycloalkyl, substituted or unsubstituted C_3 - C_{40} cycloalkenyl, substituted or unsubstituted C_1 - C_{40} acyl, or substituted or unsubstituted C_1 - C_{40} alkoxy.

237. The method of claim 236, wherein R^{35} and R^{36} are independently substituted or unsubstituted C_1 - C_{20} alkyl.
238. The method of claim 236 or claim 237, wherein R^{35} and R^{36} are the same.
239. The method of any one of claims 236-238, wherein R^{47} and R^{48} are independently hydrogen, halogen, hydroxyl, substituted or unsubstituted C_1 - C_{20} alkyl, substituted or unsubstituted C_1 - C_{20} acyl, or wherein, as valence permits, R^{47} and R^{48} , together with the atoms to which they are attached, form a 3-10 membered substituted or unsubstituted cyclic moiety optionally including from 1 to 3 heteroatoms.
240. The method of any one of claims 236-239, wherein R^{47} and R^{48} are independently hydrogen or unsubstituted C_1 - C_5 acyl.
241. The method of any one of claims 236-240, wherein R^{47} and R^{48} are the same.
242. The method of any one of claims 236-239, wherein R^{47} and R^{48} together with the atoms to which they are attached, form a 5-10 membered substituted or unsubstituted cyclic moiety optionally including from 1 to 3 heteroatoms.
243. A method of making the compound of any one of claims 106-122, comprising performing a Suzuki-Miyaura cross coupling reaction between an aryl bromide of Formula XVIII and an aryl boronate ester of Formula XIX:



wherein

the dotted lines to R^{41} and R^{42} , and between the carbons within the ring to which R^{41} and R^{42} are bonded, independently indicate that the bond can be a single bond or a double bond, as valence permits;

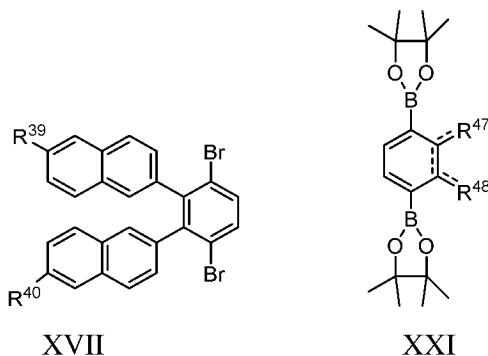
R^{41} , R^{42} , R^{43} , and R^{44} are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C_1 - C_{40} alkyl, substituted or unsubstituted C_2 - C_{40} alkenyl,

substituted or unsubstituted C₂-C₄₀ alkynyl, substituted or unsubstituted C₃-C₄₀ aryl, substituted or unsubstituted C₃-C₄₀ cycloalkyl, substituted or unsubstituted C₃-C₄₀ cycloalkenyl, substituted or unsubstituted C₁-C₄₀ acyl, substituted or unsubstituted C₁-C₄₀ alkoxy, P(O)(OR^a)₂, SR^a, S(O)₂R^a, SiR^aR^bR^c, or NR^aR^b, or wherein, as valence permits, R⁴¹ and R⁴², together with the atoms to which they are attached, form a 3-10 membered substituted or unsubstituted cyclic moiety optionally including from 1 to 3 heteroatoms; and

R^a, R^b, and R^c are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C₁-C₄₀ alkyl, substituted or unsubstituted C₂-C₄₀ alkenyl, substituted or unsubstituted C₂-C₄₀ alkynyl, substituted or unsubstituted C₃-C₄₀ aryl, substituted or unsubstituted C₃-C₄₀ cycloalkyl, substituted or unsubstituted C₃-C₄₀ cycloalkenyl, substituted or unsubstituted C₁-C₄₀ acyl, or substituted or unsubstituted C₁-C₄₀ alkoxy.

244. The method of claim 243, wherein R⁴³, and R⁴⁴ are independently substituted or unsubstituted C₁-C₂₀ alkyl.
245. The method of claim 243 or claim 244, wherein R⁴³ and R⁴⁴ are the same.
246. The method of any one of claims 243-245, wherein R⁴¹ and R⁴² are independently hydrogen, halogen, hydroxyl, substituted or unsubstituted C₁-C₂₀ alkyl, substituted or unsubstituted C₁-C₂₀ acyl, or wherein, as valence permits, R⁴¹ and R⁴², together with the atoms to which they are attached, form a 3-10 membered substituted or unsubstituted cyclic moiety optionally including from 1 to 3 heteroatoms.
247. The method of any one of claims 243-246, wherein R⁴¹ and R⁴² are independently hydrogen or unsubstituted C₁-C₅ acyl.
248. The method of any one of claims 243-247, wherein R⁴¹ and R⁴² are the same.
249. The method of any one of claims 243-246, wherein R⁴¹ and R⁴² together with the atoms to which they are attached, form a 5-10 membered substituted or unsubstituted cyclic moiety optionally including from 1 to 3 heteroatoms.

250. A method of making the compound of any one of claims 123-138, comprising performing a Suzuki-Miyaura cross coupling reaction between an aryl bromide of Formula XVII and an aryl boronate ester of Formula XXI:



wherein

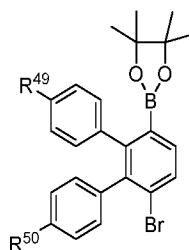
the dotted lines to R^{47} and R^{48} , and between the carbons within the ring to which R^{47} and R^{48} are bonded, independently indicate that the bond can be a single bond or a double bond, as valence permits;

R^{39} , R^{40} , R^{47} , and R^{48} are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C_1 - C_{40} alkyl, substituted or unsubstituted C_2 - C_{40} alkenyl, substituted or unsubstituted C_2 - C_{40} alkynyl, substituted or unsubstituted C_3 - C_{40} aryl, substituted or unsubstituted C_3 - C_{40} cycloalkyl, substituted or unsubstituted C_3 - C_{40} cycloalkenyl, substituted or unsubstituted C_1 - C_{40} acyl, substituted or unsubstituted C_1 - C_{40} alkoxy, $P(O)(OR^a)_2$, SR^a , $S(O)_2R^a$, $SiR^aR^bR^c$, or NR^aR^b , or wherein, as valence permits, R^{47} and R^{48} , together with the atoms to which they are attached, form a 3-10 membered substituted or unsubstituted cyclic moiety optionally including from 1 to 3 heteroatoms; and

R^a , R^b , and R^c are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C_1 - C_{40} alkyl, substituted or unsubstituted C_2 - C_{40} alkenyl, substituted or unsubstituted C_2 - C_{40} alkynyl, substituted or unsubstituted C_3 - C_{40} aryl, substituted or unsubstituted C_3 - C_{40} cycloalkyl, substituted or unsubstituted C_3 - C_{40} cycloalkenyl, substituted or unsubstituted C_1 - C_{40} acyl, or substituted or unsubstituted C_1 - C_{40} alkoxy.

251. The method of claim 250, wherein R^{39} and R^{40} are independently substituted or unsubstituted C_1 - C_{20} alkyl.

252. The method of claim 250 or claim 251, wherein R³⁹ and R⁴⁰ are the same.
253. The method of any one of claims 250-252, wherein R⁴⁷ and R⁴⁸ are independently hydrogen, halogen, hydroxyl, substituted or unsubstituted C₁-C₂₀ alkyl, substituted or unsubstituted C₁-C₂₀ acyl, or wherein, as valence permits, R⁴⁷ and R⁴⁸, together with the atoms to which they are attached, form a 3-10 membered substituted or unsubstituted cyclic moiety optionally including from 1 to 3 heteroatoms.
254. The method of any one of claims 250-253, wherein R⁴⁷ and R⁴⁸ are independently hydrogen or unsubstituted C₁-C₅ acyl.
255. The method of any one of claims 250-254, wherein R⁴⁷ and R⁴⁸ are the same.
256. The method of any one of claims 250-253, wherein R⁴⁷ and R⁴⁸ together with the atoms to which they are attached, form a 5-10 membered substituted or unsubstituted cyclic moiety optionally including from 1 to 3 heteroatoms.
257. A method of making the compound of any one of claims 139-143, comprising performing a Suzuki-Miyaura cross coupling reaction on a compound of Formula XXII:



XXII

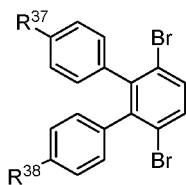
wherein

R⁴⁹ and R⁵⁰ are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C₁-C₄₀ alkyl, substituted or unsubstituted C₂-C₄₀ alkenyl, substituted or unsubstituted C₂-C₄₀ alkynyl, substituted or unsubstituted C₃-C₄₀ aryl, substituted or unsubstituted C₃-C₄₀ cycloalkyl, substituted or unsubstituted C₃-C₄₀ cycloalkenyl, substituted or unsubstituted C₁-C₄₀ acyl, substituted or unsubstituted C₁-C₄₀ alkoxy, P(O)(OR^a)₂, SR^a, S(O)₂R^a, SiR^aR^bR^c, or NR^aR^b; and

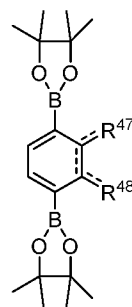
R^a, R^b, and R^c are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C₁-C₄₀ alkyl, substituted or unsubstituted C₂-C₄₀ alkenyl, substituted or unsubstituted C₂-C₄₀ alkynyl, substituted or unsubstituted C₃-C₄₀ aryl, substituted

or unsubstituted C₃-C₄₀ cycloalkyl, substituted or unsubstituted C₃-C₄₀ cycloalkenyl, substituted or unsubstituted C₁-C₄₀ acyl, or substituted or unsubstituted C₁-C₄₀ alkoxy.

258. The method of claim 257, wherein R⁴⁹ and R⁵⁰ are independently substituted or unsubstituted C₁-C₂₀ alkyl.
259. The method of claim 257 or claim 258, wherein R⁴⁹ and R⁵⁰ are independently unsubstituted C₂-C₁₅ alkyl.
260. The method of any one of claims 257-259, wherein R⁴⁹ and R⁵⁰ are the same.
261. The method of any one of claims 257-260, wherein R⁴⁹ and R⁵⁰ are each C₁₀H₂₁.
262. A method of making the compound of any one of claims 144-164, comprising performing a Suzuki-Miyaura cross coupling reaction between an aryl bromide of Formula XVI and an aryl boronate ester of Formula XXI:



XVI



XXI

wherein

the dotted lines to R⁴⁷ and R⁴⁸, and between the carbons within the ring to which R⁴⁷ and R⁴⁸ are bonded, independently indicate that the bond can be a single bond or a double bond, as valence permits;

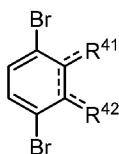
R³⁷, R³⁸, R⁴⁷, and R⁴⁸ are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C₁-C₄₀ alkyl, substituted or unsubstituted C₂-C₄₀ alkenyl, substituted or unsubstituted C₂-C₄₀ alkynyl, substituted or unsubstituted C₃-C₄₀ aryl, substituted or unsubstituted C₃-C₄₀ cycloalkyl, substituted or unsubstituted C₃-C₄₀ cycloalkenyl, substituted or unsubstituted C₁-C₄₀ acyl, substituted or unsubstituted C₁-C₄₀ alkoxy, P(O)(OR^a)₂, SR^a, S(O)₂R^a, SiR^aR^bR^c, or NR^aR^b, or wherein, as valence permits, R⁴⁷ and R⁴⁸, together with the atoms to which they are attached,

form a 3-10 membered substituted or unsubstituted cyclic moiety optionally including from 1 to 3 heteroatoms; and

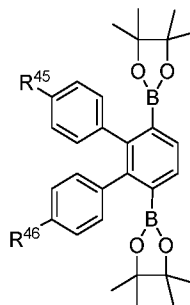
R^a, R^b, and R^c are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C₁-C₄₀ alkyl, substituted or unsubstituted C₂-C₄₀ alkenyl, substituted or unsubstituted C₂-C₄₀ alkynyl, substituted or unsubstituted C₃-C₄₀ aryl, substituted or unsubstituted C₃-C₄₀ cycloalkyl, substituted or unsubstituted C₃-C₄₀ cycloalkenyl, substituted or unsubstituted C₁-C₄₀ acyl, or substituted or unsubstituted C₁-C₄₀ alkoxy.

263. The method of claim 262, wherein R³⁷ and R³⁸ are independently substituted or unsubstituted C₁-C₂₀ alkyl.
264. The method of claim 262 or claim 263, wherein R³⁷ and R³⁸ are the same.
265. The method of any one of claims 262-264, wherein R⁴⁷ and R⁴⁸ are independently hydrogen, halogen, hydroxyl, substituted or unsubstituted C₁-C₂₀ alkyl, substituted or unsubstituted C₁-C₂₀ acyl, or wherein, as valence permits, R⁴⁷ and R⁴⁸, together with the atoms to which they are attached, form a 3-10 membered substituted or unsubstituted cyclic moiety optionally including from 1 to 3 heteroatoms.
266. The method of any one of claims 262-265, wherein R⁴⁷ and R⁴⁸ are independently hydrogen or unsubstituted C₁-C₅ acyl.
267. The method of any one of claims 262-266, wherein R⁴⁷ and R⁴⁸ are the same.
268. The method of any one of claims 262-265, wherein R⁴⁷ and R⁴⁸ together with the atoms to which they are attached, form a 5-10 membered substituted or unsubstituted cyclic moiety optionally including from 1 to 3 heteroatoms.

269. A method of making the compound of any one of claims 144-164, comprising performing a Suzuki-Miyaura cross coupling reaction between an aryl bromide of Formula XVIII and an aryl boronate ester of Formula XX:



XVIII



XX

wherein

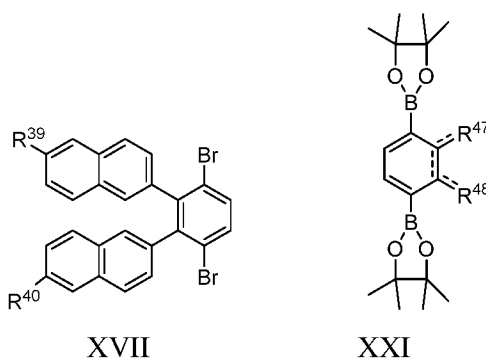
the dotted lines to R^{41} and R^{42} , and between the carbons within the ring to which R^{41} and R^{42} are bonded, independently indicate that the bond can be a single bond or a double bond, as valence permits;

R^{41} , R^{42} , R^{45} , and R^{46} are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C_1 - C_{40} alkyl, substituted or unsubstituted C_2 - C_{40} alkenyl, substituted or unsubstituted C_2 - C_{40} alkynyl, substituted or unsubstituted C_3 - C_{40} aryl, substituted or unsubstituted C_3 - C_{40} cycloalkyl, substituted or unsubstituted C_3 - C_{40} cycloalkenyl, substituted or unsubstituted C_1 - C_{40} acyl, substituted or unsubstituted C_1 - C_{40} alkoxy, $P(O)(OR^a)_2$, SR^a , $S(O)_2R^a$, $SiR^aR^bR^c$, or NR^aR^b , or wherein, as valence permits, R^{41} and R^{42} , together with the atoms to which they are attached, form a 3-10 membered substituted or unsubstituted cyclic moiety optionally including from 1 to 3 heteroatoms; and

R^a , R^b , and R^c are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C_1 - C_{40} alkyl, substituted or unsubstituted C_2 - C_{40} alkenyl, substituted or unsubstituted C_2 - C_{40} alkynyl, substituted or unsubstituted C_3 - C_{40} aryl, substituted or unsubstituted C_3 - C_{40} cycloalkyl, substituted or unsubstituted C_3 - C_{40} cycloalkenyl, substituted or unsubstituted C_1 - C_{40} acyl, or substituted or unsubstituted C_1 - C_{40} alkoxy.

270. The method of claim 269, wherein R^{45} and R^{46} are independently substituted or unsubstituted C_1 - C_{20} alkyl.

271. The method of claim 269 or claim 270, wherein R^{45} and R^{46} are the same.
272. The method of any one of claims 269-271, wherein R^{41} and R^{42} are independently hydrogen, halogen, hydroxyl, substituted or unsubstituted C_1 - C_{20} alkyl, substituted or unsubstituted C_1 - C_{20} acyl, or wherein, as valence permits, R^{41} and R^{42} , together with the atoms to which they are attached, form a 3-10 membered substituted or unsubstituted cyclic moiety optionally including from 1 to 3 heteroatoms.
273. The method of any one of claims 269-272, wherein R^{41} and R^{42} are independently hydrogen or unsubstituted C_1 - C_5 acyl.
274. The method of any one of claims 269-273, wherein R^{41} and R^{42} are the same.
275. The method of any one of claims 269-272, wherein R^{41} and R^{42} together with the atoms to which they are attached, form a 5-10 membered substituted or unsubstituted cyclic moiety optionally including from 1 to 3 heteroatoms.
276. A method of making the compound of any one of claims 165-185, comprising performing a Suzuki-Miyaura cross coupling reaction between an aryl bromide of Formula XVII and an aryl boronate ester of Formula XXI:



wherein

the dotted lines to R^{47} , R^{48} , and between the carbons within the ring to which R^{47} and R^{48} are bonded, independently indicate that the bond can be a single bond or a double bond, as valence permits;

R^{39} , R^{40} , R^{47} , and R^{48} are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C_1 - C_{40} alkyl, substituted or unsubstituted C_2 - C_{40} alkenyl, substituted or unsubstituted C_2 - C_{40} alkynyl, substituted or unsubstituted C_3 - C_{40} aryl, substituted or unsubstituted C_3 - C_{40} cycloalkyl, substituted or unsubstituted C_3 - C_{40}

cycloalkenyl, substituted or unsubstituted C₁-C₄₀ acyl, substituted or unsubstituted C₁-C₄₀ alkoxy, P(O)(OR^a)₂, SR^a, S(O)₂R^a, SiR^aR^bR^c, or NR^aR^b, or wherein, as valence permits, R⁴⁷ and R⁴⁸, together with the atoms to which they are attached, form a 3-10 membered substituted or unsubstituted cyclic moiety optionally including from 1 to 3 heteroatoms; and

R^a, R^b, and R^c are independently hydrogen, halogen, hydroxyl, cyano, nitro, substituted or unsubstituted C₁-C₄₀ alkyl, substituted or unsubstituted C₂-C₄₀ alkenyl, substituted or unsubstituted C₂-C₄₀ alkynyl, substituted or unsubstituted C₃-C₄₀ aryl, substituted or unsubstituted C₃-C₄₀ cycloalkyl, substituted or unsubstituted C₃-C₄₀ cycloalkenyl, substituted or unsubstituted C₁-C₄₀ acyl, or substituted or unsubstituted C₁-C₄₀ alkoxy.

277. The method of claim 276, wherein R³⁹ and R⁴⁰ are independently substituted or unsubstituted C₁-C₂₀ alkyl.
278. The method of claim 276 or claim 277, wherein R³⁹ and R⁴⁰ are the same.
279. The method of any one of claims 276-278, wherein R⁴⁷ and R⁴⁸ are independently hydrogen, halogen, hydroxyl, substituted or unsubstituted C₁-C₂₀ alkyl, substituted or unsubstituted C₁-C₂₀ acyl, or wherein, as valence permits, R⁴⁷ and R⁴⁸, together with the atoms to which they are attached, form a 3-10 membered substituted or unsubstituted cyclic moiety optionally including from 1 to 3 heteroatoms.
280. The method of any one of claims 276-279, wherein R⁴⁷ and R⁴⁸ are independently hydrogen or unsubstituted C₁-C₅ acyl.
281. The method of any one of claims 276-280, wherein R⁴⁷ and R⁴⁸ are the same.
282. The method of any one of claims 276-279, wherein R⁴⁷ and R⁴⁸ together with the atoms to which they are attached, form a 5-10 membered substituted or unsubstituted cyclic moiety optionally including from 1 to 3 heteroatoms.
283. A device comprising the compound of any one of claims 1-185, wherein the device comprises a sensor, an electronic device, an energy storage device, an energy conversion device, an optical device, an optoelectronic device, or a combination thereof.

- 284. The device of claim 283, wherein the electronic device comprises a field effect transistor
- 285. The device of claim 283 or claim 284, wherein the electronic device comprises a microelectronic device.
- 286. The device of claim 283, wherein the energy storage device comprises an electrode and/or a battery.
- 287. The device of claim 283, wherein the optical device comprise s a light emitting diode.
- 288. The device of claim 283, wherein the energy conversion device comprises a solar cell, a fuel cell, a photovoltaic cell, or a combination thereof.
- 289. The device of claim 283, wherein the sensor comprises a biological sensor.

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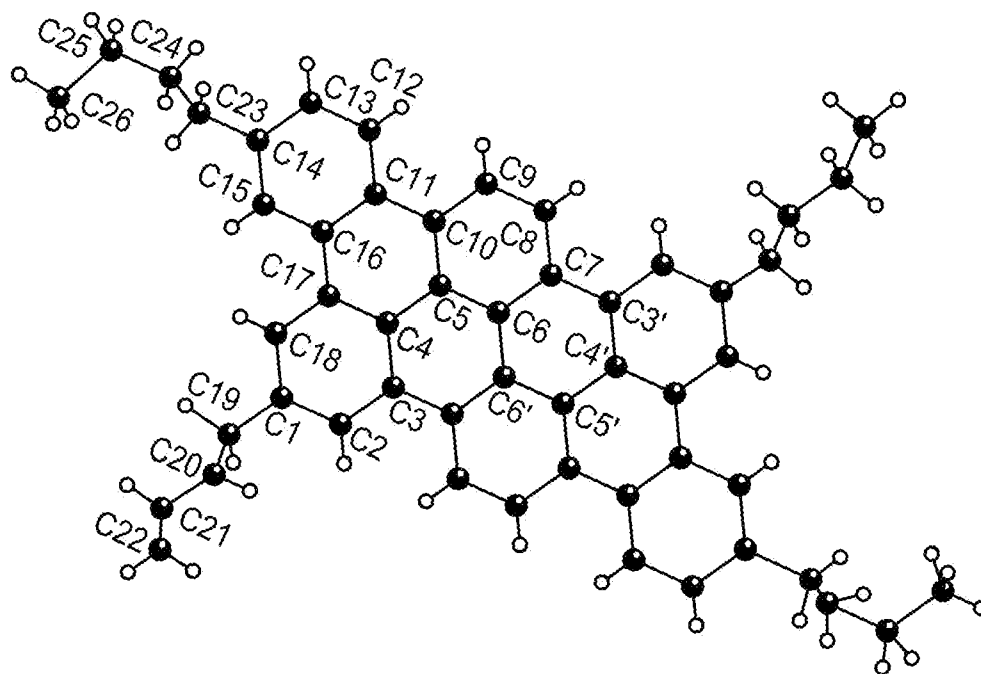


FIGURE 1

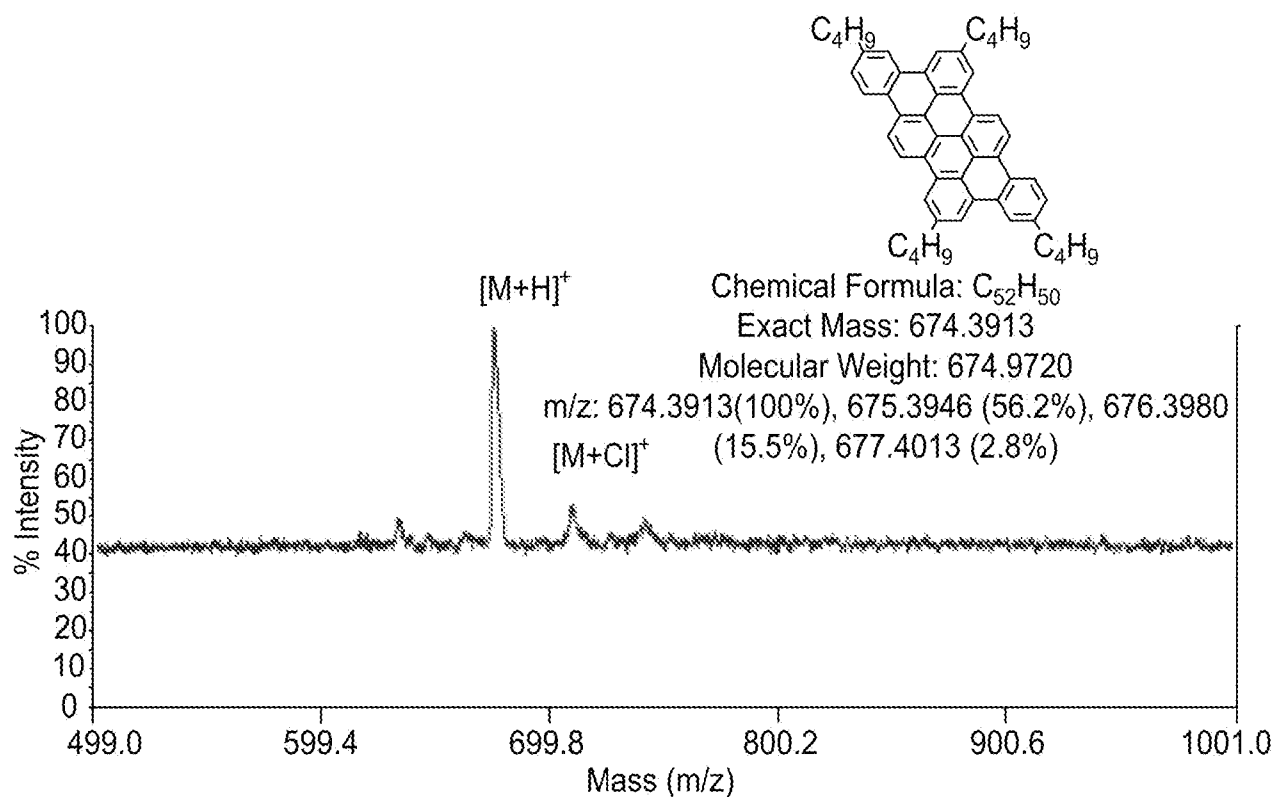


FIGURE 2

SUBSTITUTE SHEET (RULE 26)

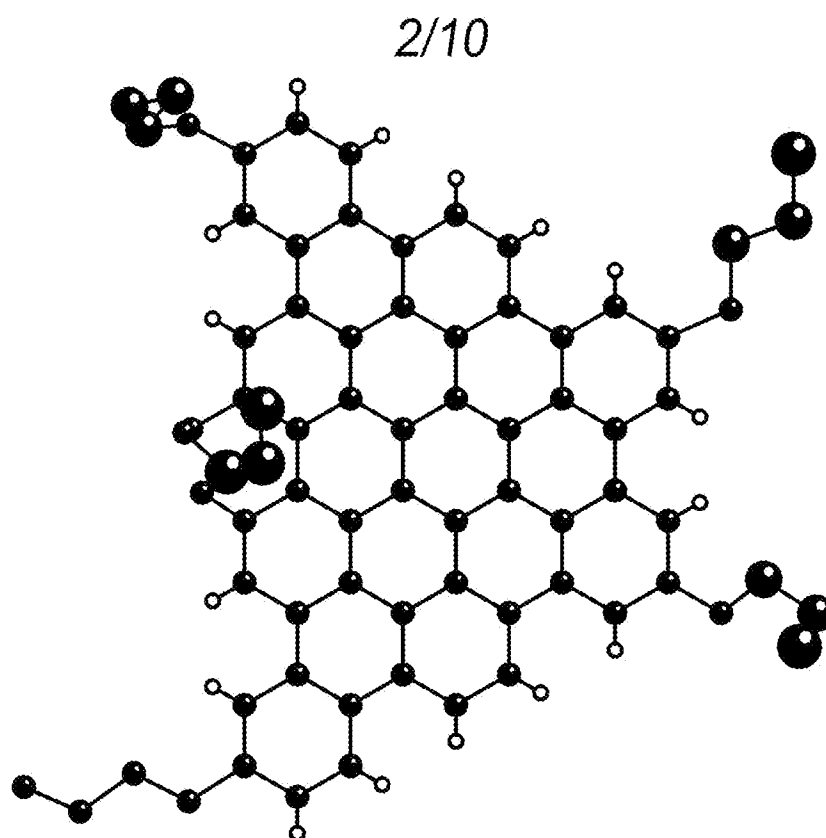


FIGURE 3

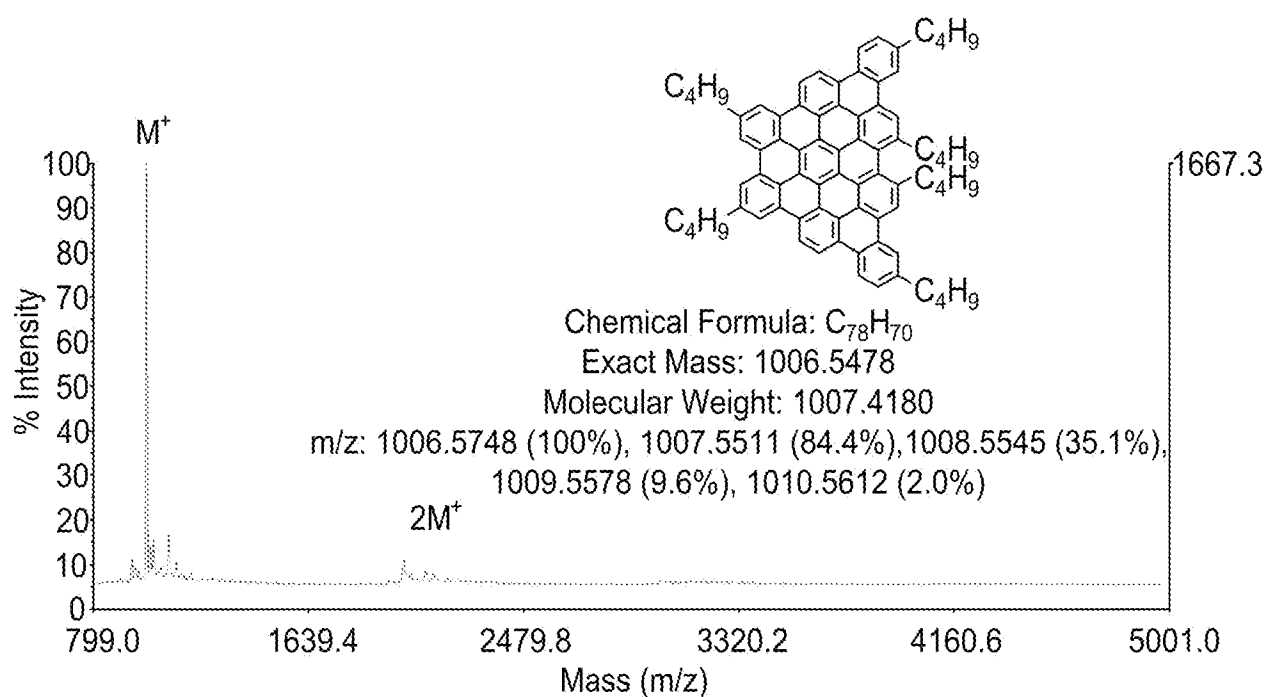


FIGURE 4

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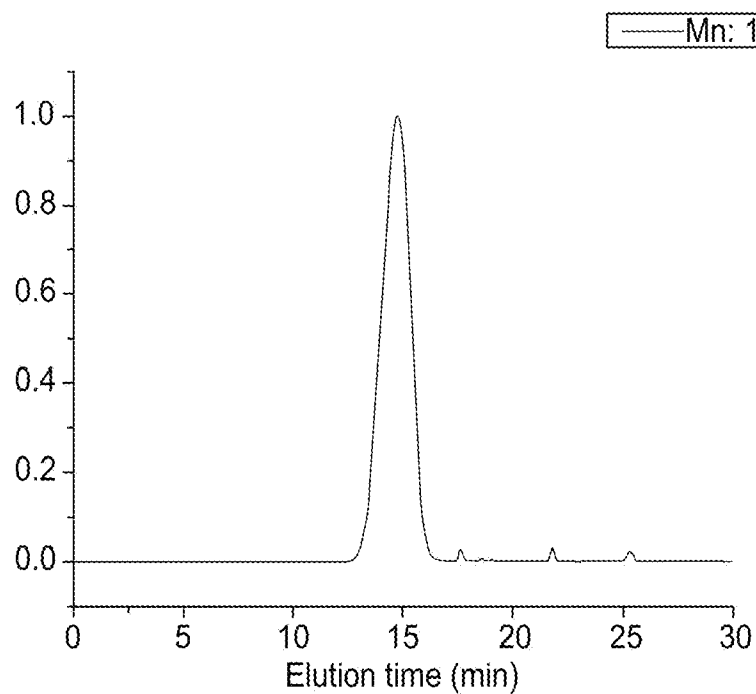


FIGURE 5

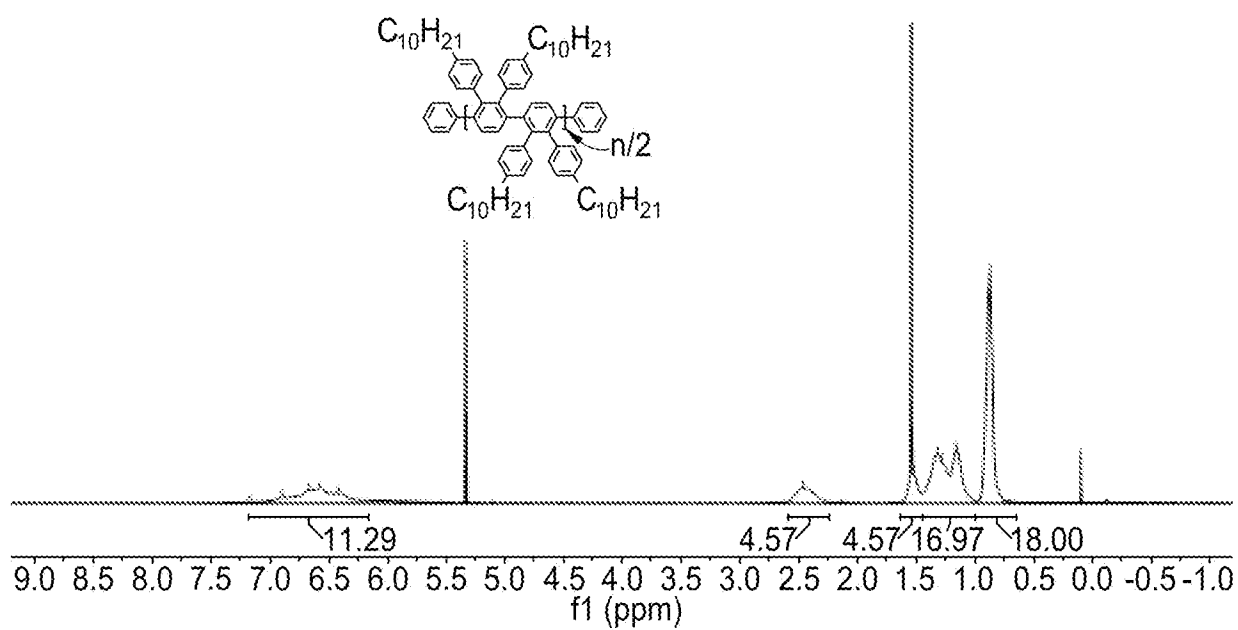


FIGURE 6

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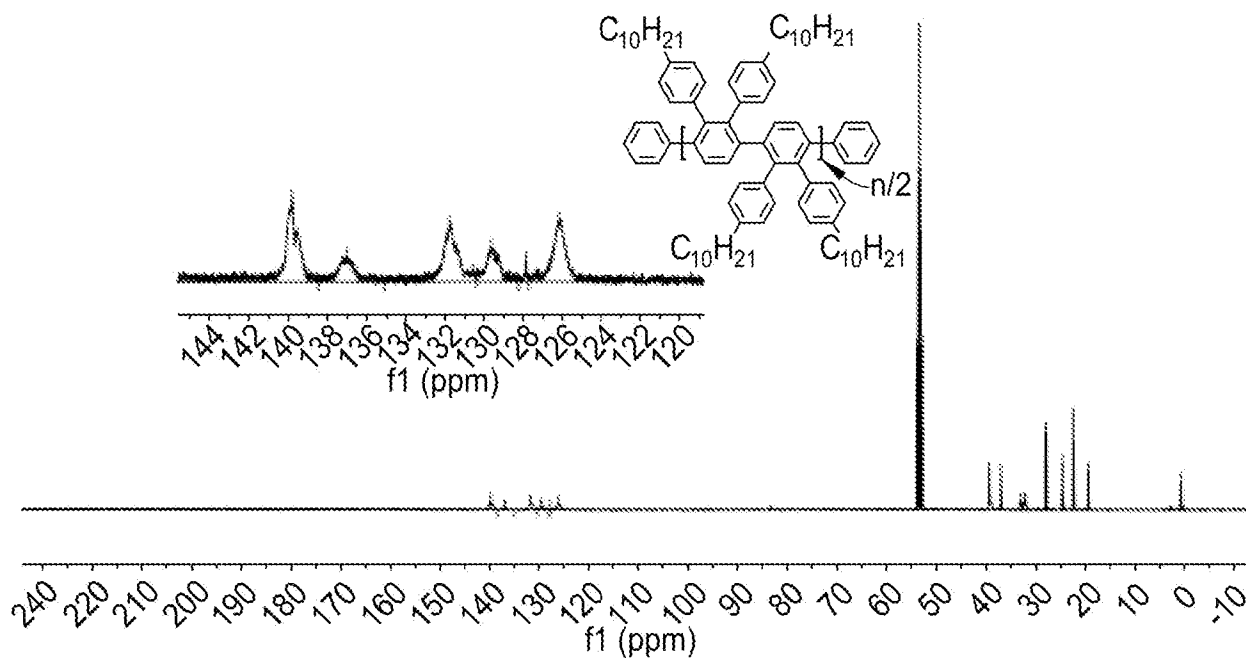


FIGURE 7

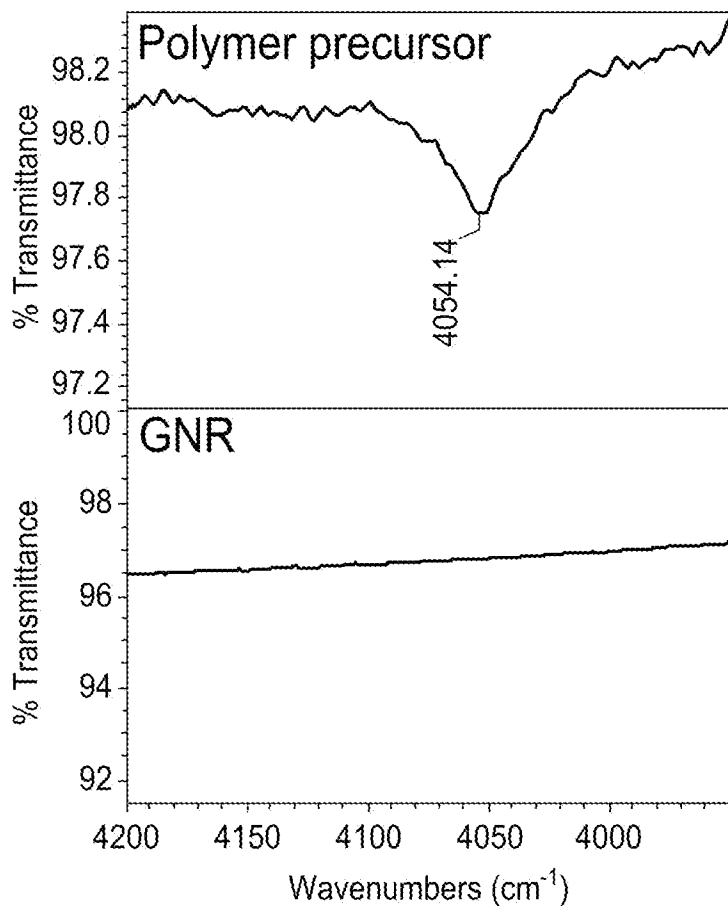
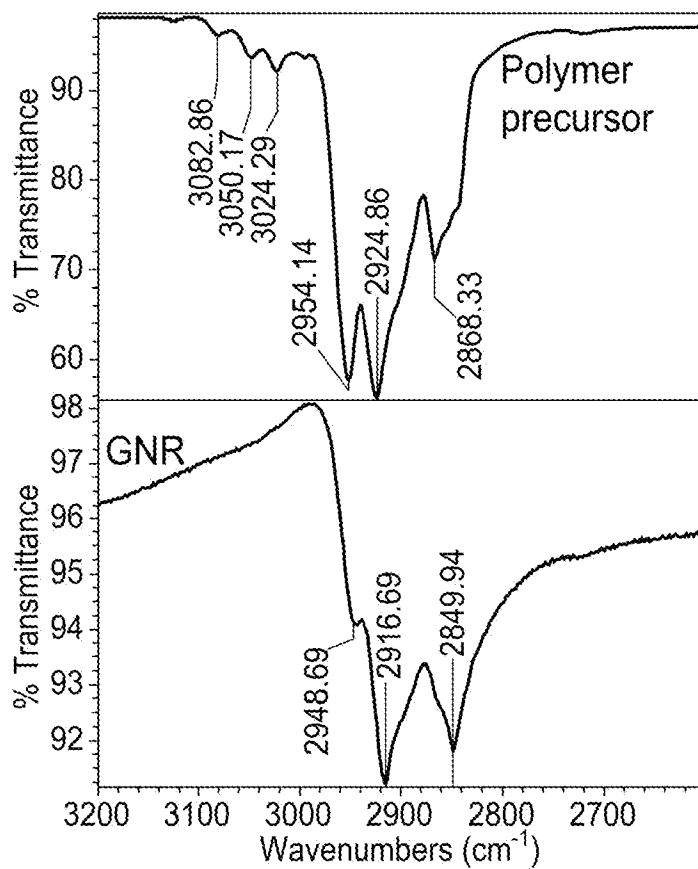
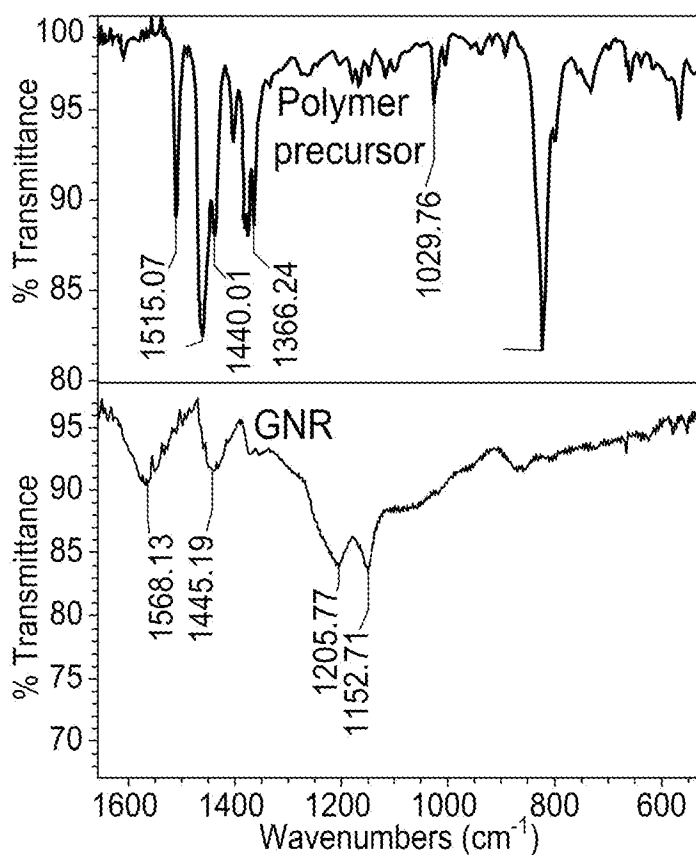


FIGURE 8A

SUBSTITUTE SHEET (RULE 26)

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**FIGURE 8B****FIGURE 8C**

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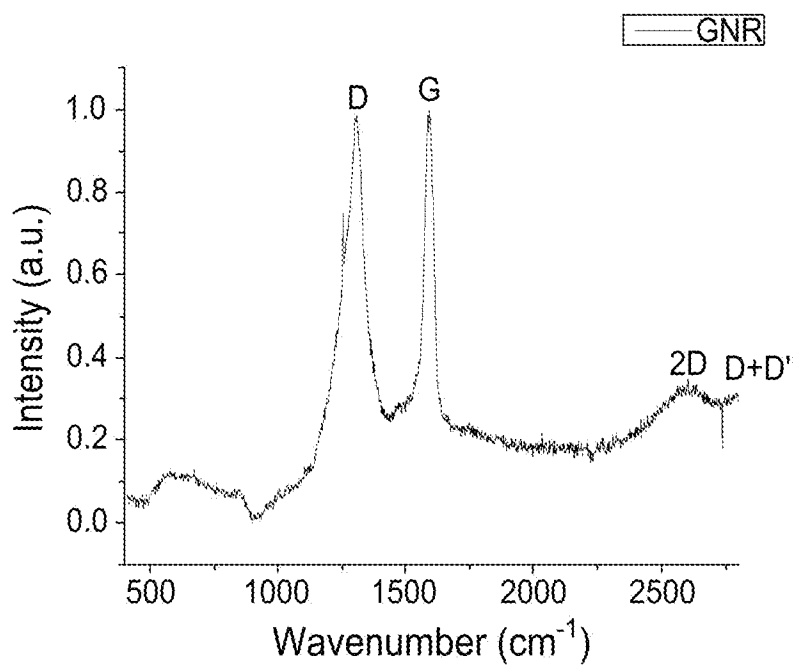


FIGURE 9

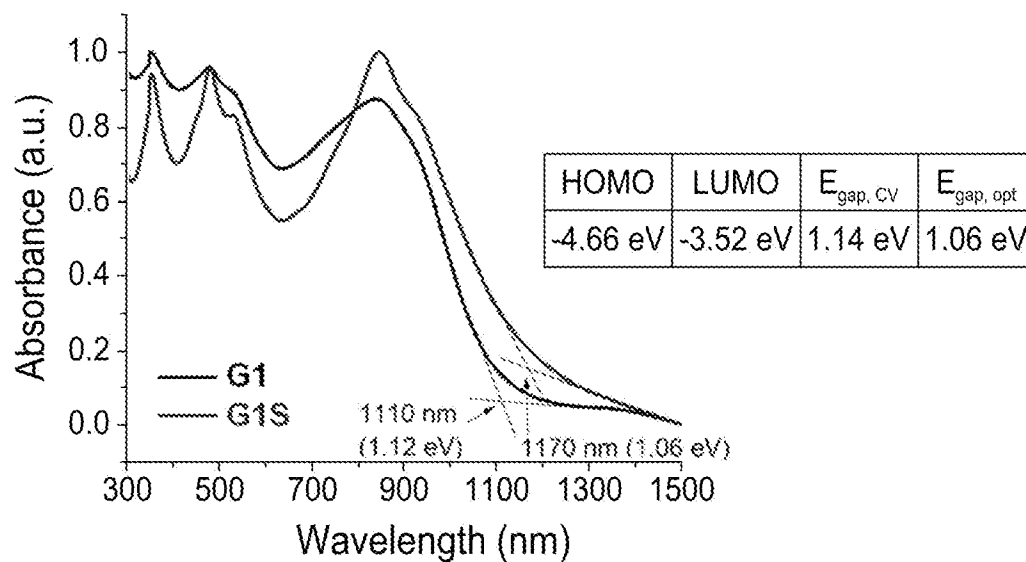


FIGURE 10

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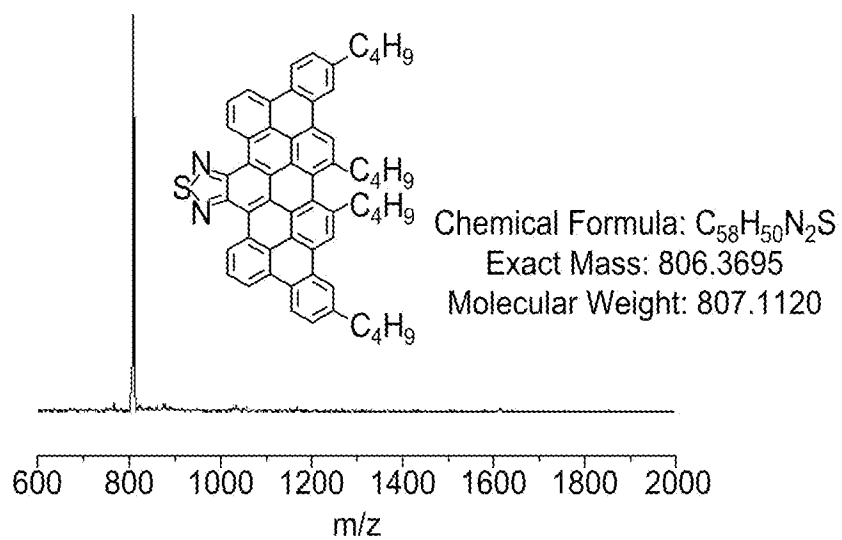


FIGURE 11

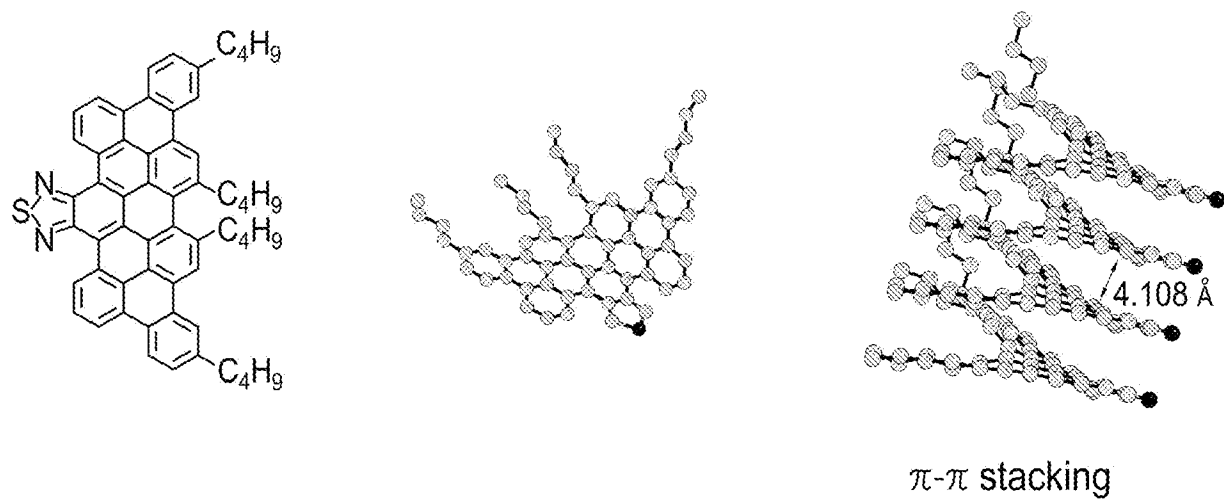


FIGURE 12

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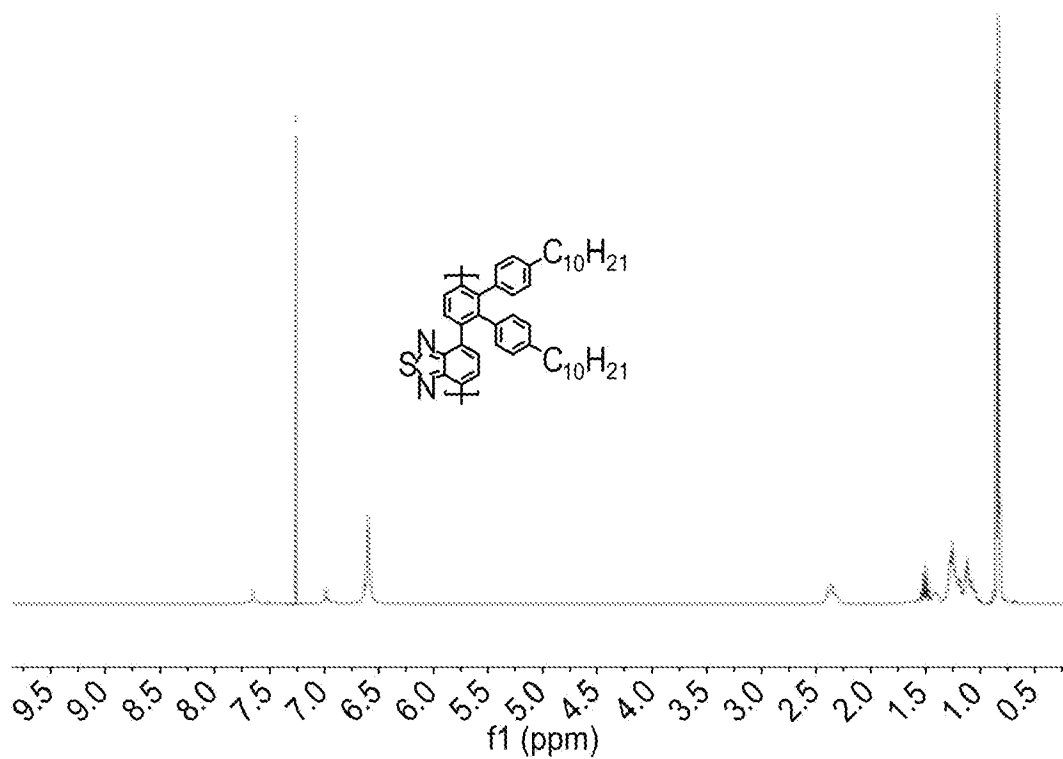


FIGURE 13

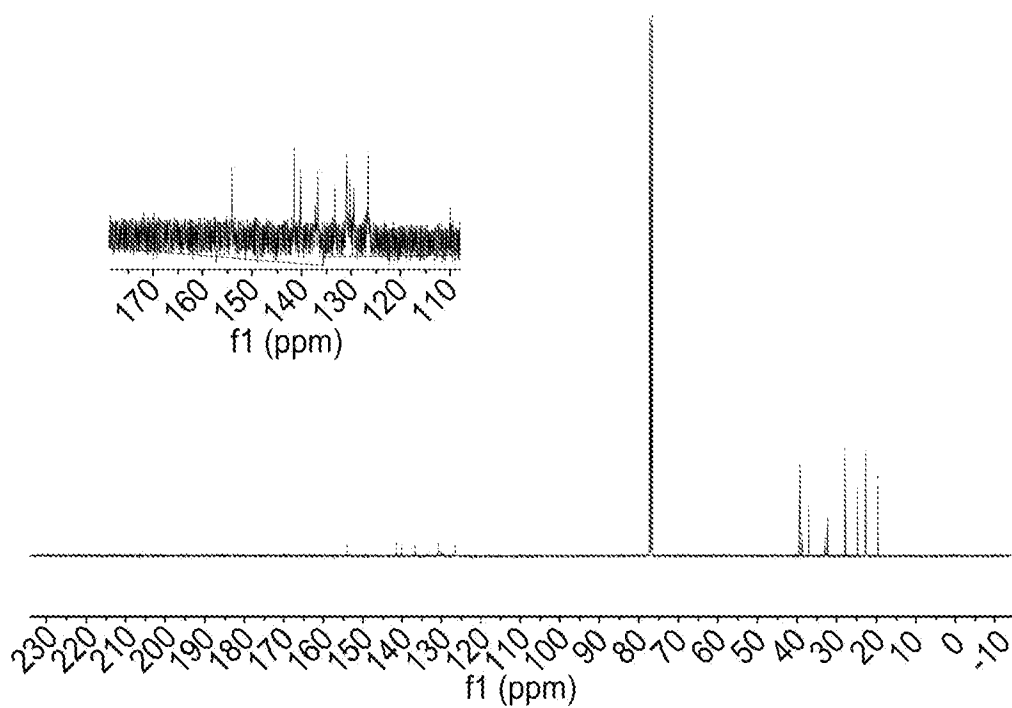


FIGURE 14

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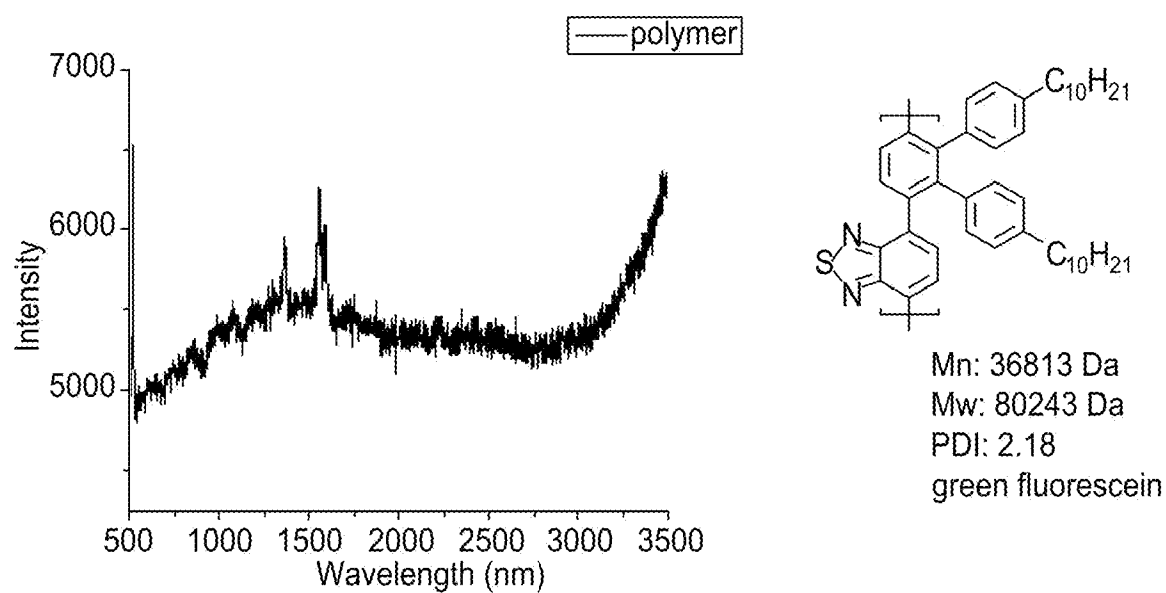


FIGURE 15

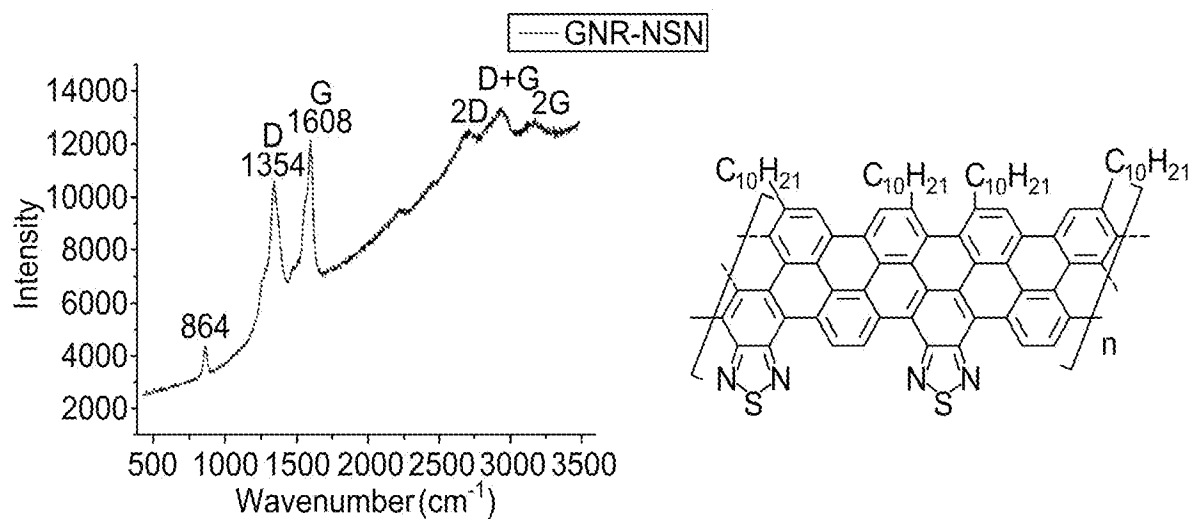
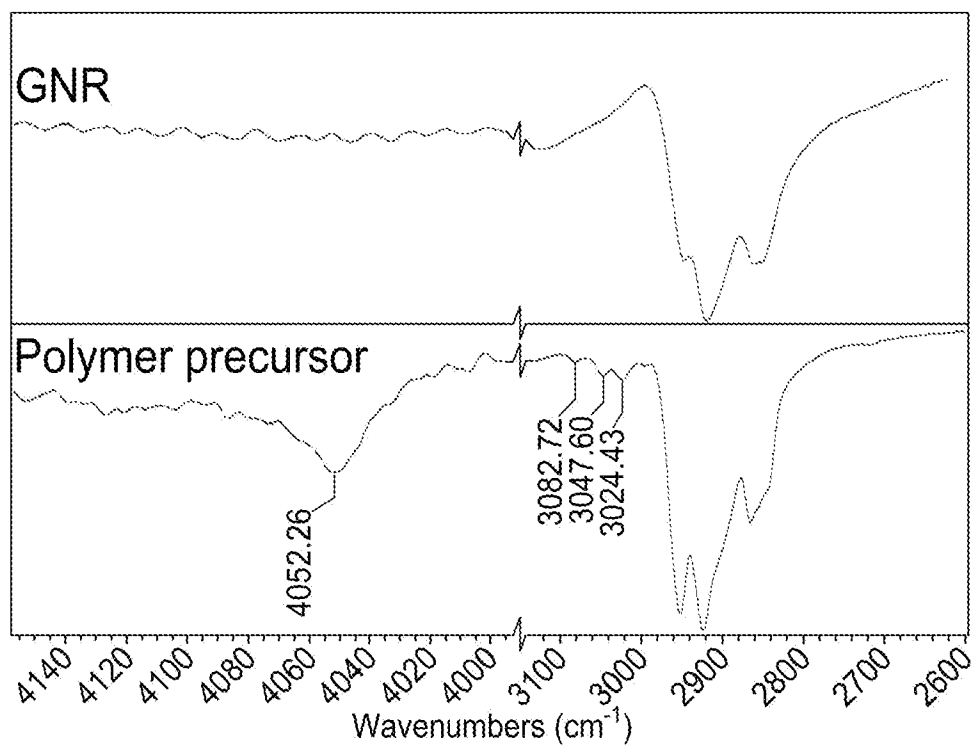


FIGURE 16

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**FIGURE 17**

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 16/44730

A. CLASSIFICATION OF SUBJECT MATTER

IPC(8) - C08G 61/10; C07C 25/18; C01B 31/04 (2016.01)

CPC - C08G61/10; B82Y30/00; C01B31/0446; C07C25/18; C01B2204/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC(8): C08G 61/10; C07C 25/18; C01B 31/04 (2016.01)

CPC: C08G61/10; B82Y30/00; C01B31/0446; C07C25/18; C01B2204/00

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

USPC: 570/182; 528/397; 423/448; 977/755

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

PatBase, Google Scholar, PubWEST

nanographene, graphene nanoribbon, polyphenylene, polycyclic aromatic hydrocarbon, Dibenzo[*ij*,*rst*]phenanthro[9,10,1,2-defg]pentaphene

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	PUBCHEM-CID 21082927 Create Date: 05 December 2007 (05.12.2007) pg 3, Fig	1
X	US 7,175,922 B2 (JARIKOV et al.) 13 February 2007 (13.02.2007) col 2, ln 60 to col 3, ln 30; col 6, ln 51-61; col 9, ln 21-25; col 10, compound 47; col 51, ln 10-30	1-3
A	CAI et al. 'Atomically precise bottom-up fabrication of graphene nanoribbons', Nature, 2010, Vol.466, pp 470-473, pg 470, col 1, para 2; Fig 1; pg 471, Fig 2a, scheme.	1-3

☐ Further documents are listed in the continuation of Box C.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

16 November 2016

Date of mailing of the international search report

15 DEC 2016

Name and mailing address of the ISA/US

Mail Stop PCT, Attn: ISA/US, Commissioner for Patents
P.O. Box 1450 Alexandria, Virginia 22313-1450

Facsimile No. 571-273-8300

Authorized officer:

Lee W. Young

PCT Helpdesk: 571-272-4300

PCT OSP: 571-272-7774

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 16/44730

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

4-5,9-10,14-27,31-43,47-49,53-70,74-95,99-100,104-105,109-122,126-138,142-143,147-164,168-289

3. ☒ Claims Nos.: see above
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:
--Please see attached sheet--

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:
1-3

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 16/44730

Attachment to Box.No.III:

This application contains the following inventions or groups of inventions which are not so linked as to form a single general inventive concept under PCT Rule 13.1.

Group I: Claims 1-3, directed to a compound of Formula I.

Group II: Claims 6-8, directed to a compound of Formula II.

Group III: Claims 11-13, directed to a compound of Formula III.

Group IV: Claims 28-30, directed to a compound of Formula IV.

Group V: Claims 44-46, directed to a compound of Formula V.

Group VI: Claims 50-52, directed to a compound of Formula VI.

Group VII: Claims 71-73, directed to a compound of Formula VII.

Group VIII: Claims 96-98, directed to a compound of Formula VIII.

Group IX: Claims 101-103, directed to a compound of Formula IX.

Group X: Claims 106-108, directed to a compound of Formula X.

Group XI: Claims 123-125, directed to a compound of Formula XI.

Group XII: Claims 139-141, directed to a compound of Formula XII.

Group XIII: Claims 144-146, directed to a compound of Formula XIII.

Group XIV: Claims 165-167, directed to a compound of Formula XIV.

The group of inventions listed above do not relate to a single general inventive concept under PCT Rule 13.1 because, under PCT Rule 13.2, they lack the same or corresponding special technical features for the following reasons:

Group I includes the technical feature of a compound of Formula I, not required by Groups II-XIV.

Group II includes the technical feature of a compound of Formula II, not required by Groups I and III-XIV.

Group III includes the technical feature of a compound of Formula III, not required by Groups I-II and IV-XIV.

Group IV includes the technical feature of a compound of Formula IV, not required by Groups I-III and V-XIV.

Group V includes the technical feature of a compound of Formula V, not required by Groups I-IV and VI-XIV.

Group VI includes the technical feature of a compound of Formula VI, not required by Groups I-V and VII-XIV.

Group VII includes the technical feature of a compound of Formula VII, not required by Groups I-VI and VIII-XIV.

Group VIII includes the technical feature of a compound of Formula VIII, not required by Groups I-VII and IX-XIV.

Group IX includes the technical feature of a compound of Formula IX, not required by Groups I-VIII and X-XIV.

Group X includes the technical feature of a compound of Formula X, not required by Groups I-IX and XI-XIV.

Group XI includes the technical feature of a compound of Formula XI, not required by Groups I-X and XII-XIV.

Group XII includes the technical feature of a compound of Formula XII, not required by Groups I-XI and XIII-XIV.

Group XIII includes the technical feature of a compound of Formula XIII, not required by Groups I-XII and XIV.

Group XIV includes the technical feature of a compound of Formula XIV, not required by Groups I-XIII.

---Continued on next sheet---

Continuation of previous sheet:

Common technical features:

The inventions of Group I-VII share the technical feature of a polycyclic aromatic compound.

This shared technical feature, however, does not provide a contribution over the prior art, as being anticipated by the article entitled, 'Atomically precise bottom-up fabrication of graphene nanoribbons', published in Nature, July 2010, by Cai et al. (hereinafter 'Cai') which discloses a graphitic polycyclic aromatic compound (pg 470, col 1, para 2; Fig 1, graphene nanoribbon; pg 471, Fig 2a, scheme). As said compound was known in the art at the time of the invention, this cannot be considered a special technical feature that would otherwise unify the inventions of Groups I-VII.

Groups VIII-XIV share the technical feature of a polyphenylene compound. This shared technical feature, however, does not provide a contribution over the prior art, as being anticipated by Cai, which discloses a polyphenylene compound (pg 471, Fig 3, compound a to product formed at 250 deg C).

As said compound was known in the art at the time of the invention, this cannot be considered a special technical feature that would otherwise unify the inventions of Groups VIII-XIV.

The inventions of Groups I-XIV thus lack unity under PCT Rule 13.

Note reg. item 4: Claims 4-5, 9-10, 14-27, 31-43, 47-49, 53-70, 74-95, 99-100, 104-105, 109-122, 126-138, 142-143, 147-164 and 168-289 are unsearchable because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a). These claims are, therefore, not included in the above analysis.