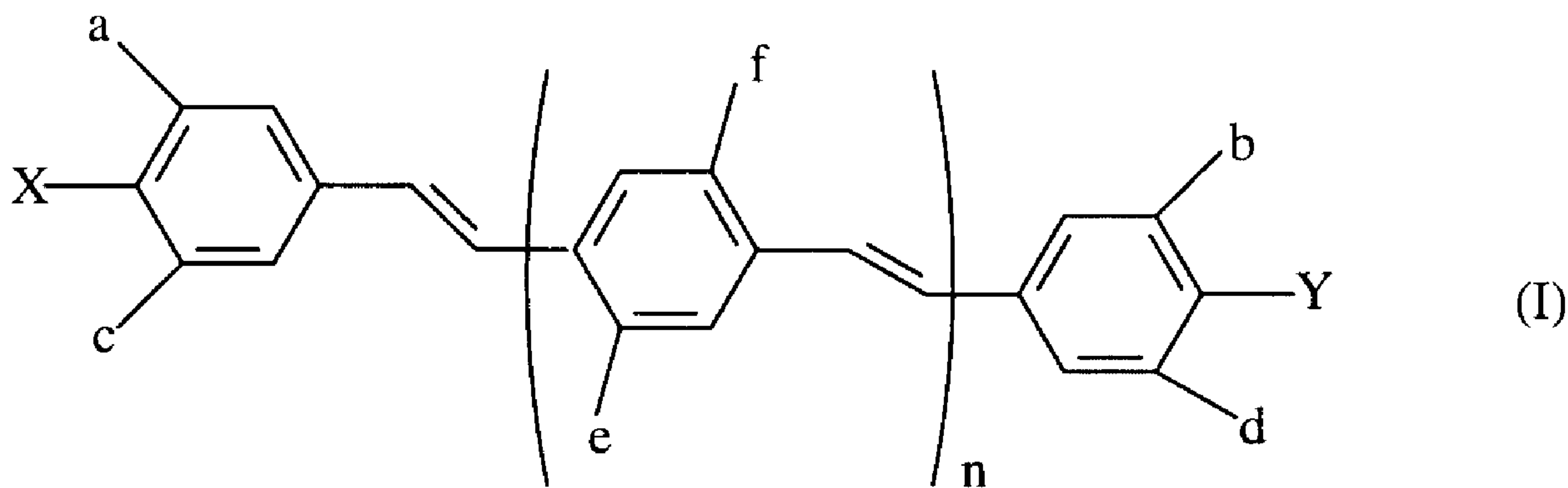




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ELECTROLUMINESCENTS ORGANIQUES
(54) Title: USE OF OLIGO (PHENYLENEVINYLENE) S IN ORGANIC LIGHT-EMITTING DEVICES



(57) **Abrégé/Abstract:**

An organic light-emitting device comprising an anode, a cathode, and an emissive layer between the anode and cathode, wherein either the emissive layer is an oligo(phenylenevinylene) or derivative thereof is described. The device may further include a hole transport layer and/or an electron transport layer coupled with either the anode or cathode. Also described are displays employing such devices and a method of making such a device.

Abstract

5 An organic light-emitting device comprising an anode, a cathode, and an emissive
layer between the anode and cathode, wherein either the emissive layer is an
oligo(phenylenevinylene) or derivative thereof is described. The device may further
include a hole transport layer and/or an electron transport layer coupled with either
the anode or cathode. Also described are displays employing such devices and a
10 method of making such a device.

USE OF OLIGO(PHENYLENEVINYLENE)S IN ORGANIC LIGHT-EMITTING DEVICES

This application claims the benefit of U.S. Provisional Application No.
5 60/218,530 filed July 17, 2000, incorporated by reference herein.

Field of the Invention

The present invention relates to multicolor organic light-emitting materials
and devices constructed using such materials. More specifically, the present
invention relates to the use of oligo(phenylenevinylene)s in organic light-emitting
10 devices (OLED).

Background of the Invention

Electronic displays are utilized in television sets, computer terminals and in a
host of other applications. Such a medium offers speed, versatility, and interactivity.
Manufacturers of electronic devices are working to develop displays that provide
15 brighter, sharper pictures and provide a high resolution full color display at good
light level and at competitive pricing.

The drive to improved displays has lead to the development of liquid crystal
displays (LCDs). LCDs operate fairly reliably. However, LCD technology has a
number of shortcomings, including weak brightness, relatively low contrast and
20 resolution, large power requirements and high power backlighting requirements.

One alternative to LCDs are light-emitting displays (LEDs). Light-emitting
displays make use of thin film materials which emit light when excited by electric
current. Light-emitting displays are often fabricated using inorganic materials, such
as manganese (Mn)-doped zinc sulfide (ZnS). Although inorganic light-emitting
25 displays can provide high performance and durability, they suffer from large power
requirements and expensive manufacturing.

Organic light-emitting displays (OLEDS), on the other hand, can be realized in
a flexible form. Their electroluminescent wavelength can be selected from a wider
range than inorganic displays. Furthermore, organic electroluminescent devices can

easily be fabricated by means of a coating technique and large devices of this type can be easily produced at low cost. Another advantage is that a low voltage can drive organic electroluminescent devices.

OLEDs, whose structure is based upon the use of layers of organic optoelectronic materials, generally use radiative recombination of excitons as a mechanism to produce optical emission. OLEDs are typically comprised of at least two thin organic layers between an anode and a cathode, as shown in Figure 1. The material of one of these layers is specifically chosen based on the material's ability to transport holes, a "hole transporting layer" (HTL) 13, and the material of the other layer is specifically selected according to its ability to transport electrons, an "electron transporting layer" (ETL) 17. The electroluminescent material may be present in a separate emissive layer (EML) 15 between the HTL and the ETL in what is referred to as a "double heterostructure" (DH). With the application of an electric potential (typically 100 MV/m), the anode 11 injects holes (positive charge carriers) into the HTL 13, while the cathode 19 injects electrons into the ETL 17. The injected holes and electrons each migrate toward the oppositely charged electrode. When an electron and hole localize in the EML 15 on the same molecule, a Frenkel exciton is formed. These excitons are trapped in the material which has the lowest energy. Recombination of the short-lived excitons may be visualized as an electron dropping from its conduction potential to a valence band, with relaxation occurring, under certain conditions, preferentially via a photoemissive mechanism.

Alternatively, the materials that function as the ETL or HTL of an OLED may also serve as the medium in which exciton formation and electroluminescent emission occur. Such OLEDs are referred to as having a "single heterostructure" (SH).

Various compounds have been used as HTL materials or ETL materials. HTL materials often consist of triaryl amines in various forms which show high hole mobilities (approximately 10^{-3} cm²/Vs). The most common hole transporter used in the HTL of OLEDs is a biphenyl bridged diamine, N,N'-diphenyl-N,N'-bis(3-methylphenyl)-1,1-biphenyl-4,4'-diamine (TPD). Aluminum tris-(8-

hydroxyquinolate) (Alq_3) is the most common ETL material, and others include oxidiazol, triazol, and triazine.

Various compounds have been employed as electroluminescent emitters. Such compounds may present in the EML, separate from the ETL and HTL layers. 5 Alternatively, such compounds may be combined into or be the same as the compounds used in the ETL or HTL layers.

Burroughes et al., *Nature*, Vol. 347, 1990, pp. 539 describe the use of a highly fluorescent conjugated polymer, poly (phenylenevinylene) (PPV), as the active material in a single-layer OLED, in which a thin layer of the active organic material is 10 sandwiched between two electrode. The use of PPV in electroluminescent devices is also described in US 5,247,190 (issued September 21, 1993). Both references are incorporated herein by reference. Some difficulties associated with PPV include the use of wet processes such as spin-coating, difficulties in fabricating multilayer devices for confined structures, and emission peaks in the green, or green-yellow 15 regions of the spectrum, rather than in the blue.

Initially synthesized as model compounds in order to gain more insight into the structural and electronic peculiarities of the corresponding polymers, conjugated oligomers have also been investigated as potential materials in electrooptical applications. The use of oligo(phenylenevinylene)s (OPV), oligo(phenylene)s, and 20 oligothiophenes, for example, has been investigated (see a review article on OLEDs by Mitschke et al. *J. Mater. Chem.* 2000, Vol. 10, 1471-1507, incorporated by reference herein)

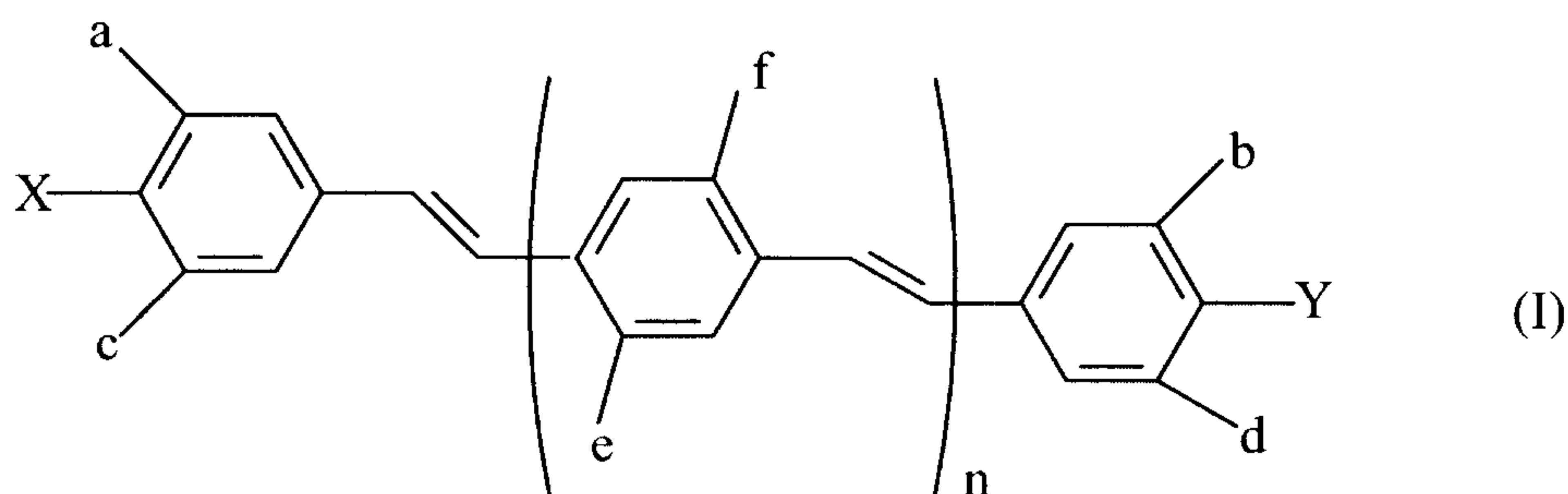
The shorter conjugated segment of OPVs compared with PPVs improves the fluorescence yields and the electroluminescent efficiency, and the wavelength for 25 absorption and emission decreases with decreasing conjugated length.

However, there still exists a need for efficient and stable materials, especially blue emitters, such as in the 420-450 nm range.

Summary of the Invention

The use of oligo(phenylenevinylene) (OPV) and its derivatives in light-emitting devices (LEDs) is disclosed. Also disclosed are light-emitting devices made from oligo(phenylenevinylene)s, as well as displays employing such devices.

5 Thus, according to one aspect, the invention provides a light-emitting device comprising an anode; a cathode; and an emissive layer between the anode and cathode, comprising an oligo(phenylenevinylene) of the Formula (I):



wherein

n is 0 to 8;

10 X is H, NHR, NR_2 , $(O(CH_2)_2)_2OR$, OR, NO_2 , or SO_2R ;

Y is H, NHR, NR_2 , $(O(CH_2)_2)_2OR$, OR, NO_2 , or SO_2R ;

a , b , c , and d are each independently selected from the group consisting of H, R, OR, NHR, and NR_2 ;

15 e and f are each independently selected from the group consisting of H, SiR_3 , alkyl, and aryl groups; and

each R is independently selected from the group consisting of a substituted and unsubstituted alkyl and aryl groups; and

20 wherein if both X and Y are OR, at least one of a , b , c , d , e , and f is other than H; if both X and Y are one of $(O(CH_2)_2)_2OCH_3$ and $SO_2C_6H_{13}$, at least one of a , b , c , d , e , and f is other than H; if X, Y, e , and f are all H, at least one of a , b , c , and d is other than H, and a , b , c , and d are not all tert-butyl; and if X, Y, a , b , c , and d are all H, e and f are not both C_6H_{13} or both C_8H_{17} .

Also disclosed is a display employing the device.

In another aspect, the invention provides a method of making a light-emitting

device, the method comprising the steps of preparing an oligo(phenylenevinylene) of the Formula (I); and layering the oligo(phenylenevinylene) of the Formula (I) between an anode and a cathode to form a light-emitting diode.

In a further aspect, a method of the invention further comprises the step of selecting n , X , Y , a , b , c , d , e , f , and R of the OPV of Formula (I) to selectively tune the emissive wavelength of the OPV to a desired wavelength

In another aspect, the invention provides the use of an oligo(phenylenevinylene) according to Formula (I) for electroluminescent emission in a light-emitting device.

There are many advantages in using low molecular weight OPVs of the invention for light-emitting devices. First, OPVs can be sublimated in vacuum, which eliminates the use of organic solvents and makes multilayer structures possible. Secondly, the emission peak of OPVs can be shifted to the blue or green-blue regions of the spectrum by reducing the length of the π -conjugated backbone. Thirdly, OPVs have well-defined chain lengths and molecular structure, that makes data analysis easier than on polymer system, and provides a better basis for understanding the relationship between the molecular structures and the chemical/physical properties.

Other aspects and advantages of embodiments of the invention will be readily apparent to those ordinarily skilled in the art upon a review of the following description.

Brief Description of the Drawings

Embodiments of the invention will now be described in conjunction with the accompanying drawings, wherein:

Figure 1 illustrates a schematic representation of a double heterostructure organic light-emitting device (DH-OLED);

Figures 2A, 2B, and 2C illustrate examples of light-emitting materials in accordance with an aspect of the invention;

Figure 3 illustrates an organic light-emitting device in accordance with one aspect of the invention;

Figure 4 illustrates the effect of co-deposition on emission color;

Figure 5 illustrates a typical current density-voltage curve of an OPV-based organic light-emitting device;

Figure 6 illustrates the luminance-voltage characteristics of an organic light-emitting device based on OPV; and

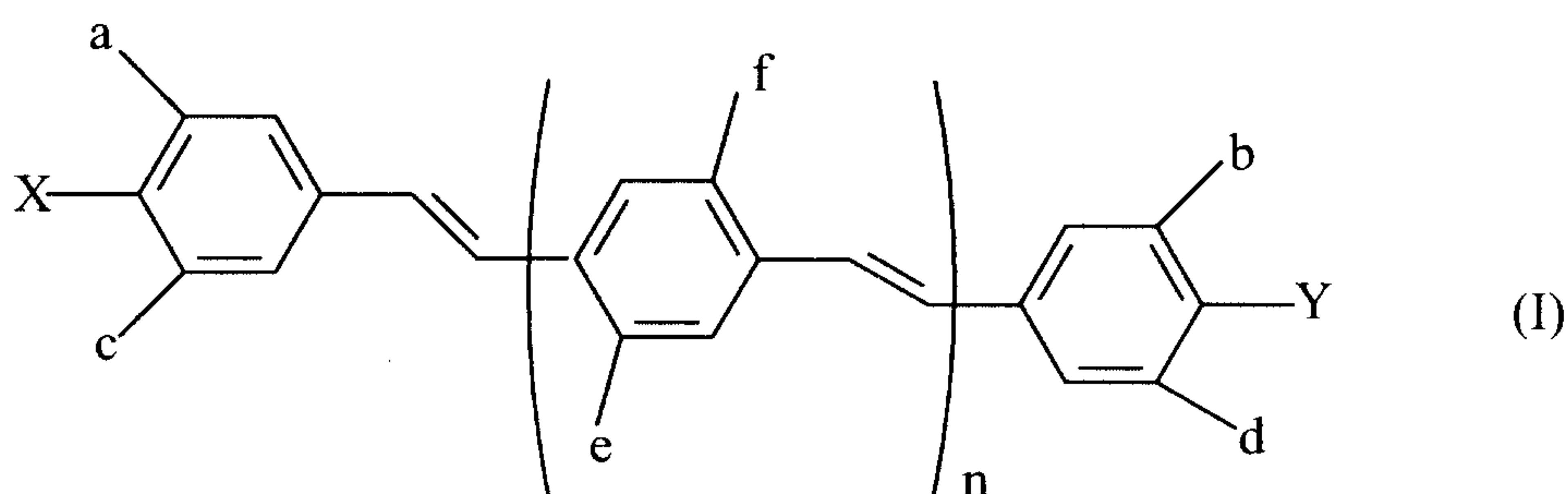
Figure 7 illustrates the luminance-current density characteristics of an organic light-emitting device based on OPV.

This invention will now be described in detail with respect to showing how certain specific representative embodiments thereof can be made, the materials, apparatus and process steps being understood as examples that are intended to be illustrative only. In particular, the invention is not intended to be limited to the methods, materials, conditions, process parameters, apparatus and the like specifically recited herein.

Detailed Description of the Preferred Embodiments

Referring to Figures 2a, 2b and 2c, some oligo(phenylenevinylene)s (OPVs) for use in accordance with one aspect of the invention are illustrated, and are examples of OPVs of the invention. The OPVs of the invention are represented by the Formula

(I):



wherein

n is 0 to 8;

X is H, NHR, NR_2 , $(O(CH_2)_2)_2OR$, OR, NO_2 , or SO_2R ;

Y is H, NHR, NR_2 , $(O(CH_2)_2)_2OR$, OR, NO_2 , or SO_2R ;

a, b, c, and d are each independently selected from the group consisting of H, R, OR, NHR, and NR₂;

e and f are each independently selected from the group consisting of H, SiR₃, alkyl, and aryl groups; and

5 each R is independently selected from the group consisting of a substituted and unsubstituted alkyl and aryl groups; and

wherein if both X and Y are OR, at least one of a, b, c, d, e, and f is other than H; if both X and Y are one of (O(CH₂)₂)₂OCH₃ and SO₂C₆H₁₃, at least one of a, b, c, d, e, and f is other than H; if X, Y, e, and f are all H, at least one of a, b, c, and d is other
 10 than H, and a, b, c, and d are not all tert-butyl; and if X, Y, a, b, c, and d are all H, e and f are not both C₆H₁₃ or both C₈H₁₇.

The oligo(phenylenevinylene) (OPV) of Formula (I) may be selected such that:

n is 1 to 4;

X is H, NHR, NR₂, (O(CH₂)₂)₂OCH₃, OC₃H₇, OC₄H₉, OC₅H₁₁, OC₆H₁₃, NO₂,
 15 or SO₂C₆H₁₃;

Y is H, NHR, NR₂, (O(CH₂)₂)₂OCH₃, OC₃H₇, OC₄H₉, OC₅H₁₁, OC₆H₁₃, NO₂,
 or SO₂C₆H₁₃;

a, b, c, and d are each independently selected from the group consisting of H, CH₃, OCH₃, NH(C₃₋₈-alkyl), and N(C₃₋₈-alkyl)₂;

20 e and f are each independently selected from the group consisting of H, Si(C₃₋₈-alkyl)₃, and C₆₋₁₄-aryl groups; and

each R is independently selected from the group consisting of C₃₋₈-alkyl and C₆₋₁₄-aryl groups;

wherein if both X and Y are OR, at least one of a, b, c, d, e, and f is other than
 25 H; if both X and Y are one of (O(CH₂)₂)₂OCH₃ and SO₂C₆H₁₃, at least one of a, b, c, d, e, and f is other than H; if X, Y, e, and f are all H, at least one of a, b, c, and d is other than H, and a, b, c, and d are not all tert-butyl; and if X, Y, a, b, c, and d are all H, e and f are not both C₆H₁₃ or both C₈H₁₇.

30 Examples of R groups include substituted or unsubstituted methyl, propyl, butyl, hexyl, phenyl, and methylphenyl groups.

In one aspect, both or one of the terminal ends of the OPV are dialkylamino, diarylamino, alkylamino, and/or arylamino groups with a chain length of 2 to 5 phenyl rings. Thus, the OPV of Formula (I) may be selected such that:

n is 0 to 3;

5 X is NHR or NR₂;

Y is H, NHR, or NR₂;

a, b, c, d, e, and f are each H; and

each R is independently selected from the group consisting of C₃₋₈-alkyl and C₆₋₁₄-aryl groups.

10 Specifically mentioned as an example of an OPV is 1,4-bis-4-(dibutylamine)styrylbenzene (OPV(1)-NBu), illustrated in Figure 2A. OPV(1)-NBu is a very efficient and bright green-blue emitter, with an efficiency of about 5 cd/A. This is because the oxidation potential of the OPV(1)-NBu is relatively low compared with other materials. Since it has a relatively low oxidation potential, it can also be
15 used as hole injection or transport material in the HTL. The luminance of OPV(1)-NBu at 20 V is about 5000 cd/m².

Further examples are given in Figure 2.

By changing the chain length and adding different functional groups as side- or end- group, the emission colour of the OPV can be tuned from yellow to blue.
20 Selection of particular side- or end- groups based on their electronic property, such as by using strong electron donating or accepting groups, influences the emission colour. Furthermore, such a selection can be used to select OPVs which are particularly useful as hole injection/transporting or electron injection/transporting materials. For example, use of electron accepting groups in the OPV favours its
25 lectron injection/transporting capabilities, whereas use of strong electron donating groups favours its hole injection/transporting capabilities (see for example, Tao et al., Nonlinear Optics (2000) Vol. 25, 491; Tao et al., Synthetic Metals 111-112 (2000) 417; and Tao et al., Thin Solid Films 363 (2000) 298, all of which are incorporated by reference herein).

The OPVs of the invention may be synthesized using techniques generally known in the art. Examples of synthetic routes using the stereoselective Wadsworth-Emmons reaction as a key step (see for example M.S. Wong, et al, J. Mater. Chem. 8 (1998) 2005, incorporated by reference herein).

5 Referring to Figure 3, there is illustrated the structure of an organic light-emitting device in accordance with one aspect of the invention. A substrate layer of glass 31 is partially coated with a transparent conductive oxide, in this case indium-tin-oxide (ITO) to form the anode 33. On the ITO anode 33 is a layer of N,N'-diphenyl-N,N'-bis(3-methylphenyl)-1,1-biphenyl-4,4'-diamine (TPD) as hole
10 transport layer (HTL) 35, followed by a layer of an OPV as emissive layer 38, and a layer of 2-(4-biphenyl)-5-(4-tert-butylphenyl)-1,3,4-oxadiazole (PBD) as electron transporting layer (ETL) 37. The cathode is an aluminum cathode 39. The device may also include an ITO pad 43 to connect the cathode with the environment.

The substrate may be opaque or transparent, rigid, or flexible, and/or plastic,
15 metal, or glass. The substrate may be as thin as 10 microns, if present as a flexible plastic or metal foil substrate, such as aluminum foil, or substantially thicker if present as a rigid, transparent or opaque, substrate, or if the substrate is comprised of a silicon-based display driver.

Materials that may be used as the hole transport anode layer, aside from ITO,
20 include Zn-In-SnO₂, SbO₂, and other materials known in the art. The hole transport anode layer may be from about 50 nm to greater than 400nm thick.

The HTL layer shown in Figure 3 is 50 nm thick; however other thicknesses can be used, usually in the range of 5 or 10 to 100 nm. Other materials may be incorporated into or used instead of TPD as the hole transport layer. Examples other
25 hole transport layer materials include 4,4'-bis[N-(1-naphthyl)-N-phenylamino]biphenyl (NPB), OPVs, and molecules disclosed in the art (see for example US 6,150,043 issued November 21, 2000, and US 6,023,073 issued February 8, 2001, both of which are incorporated herein by reference). In one embodiment, the oligo(phenylenevinylene) of the Formula (I) may be used as the HTL.

The EML layer may have a variety of thicknesses, such as 5 to 100 nm. As shown in Figure 3, the EML layer has a thickness of 50 nm. In some devices, the emissive layer may be purely made by OPV of Formula (I). More than one OPV may be used in the EML. Further, the OPVs may be mixed with other emitters such as anthracene, ATP, BNVP, coumarin, or other known emitters. In some devices, the emissive layer may be made by co-deposition of a hole transporting material, such as TPD or NPD, and OPV.

Co-deposition can achieve high quality thin films and may reduce red-shifts in emission color. In some cases, the EML may be TPD, NPD, or other hole transport layer material, doped with OPV. The effect of co-deposition on emission color in the case of OPV(1)-NBu is shown in Figure 4. A comparison of 2:1 TPD:OPV(1)-NBu to 1:2 TPD:OPV(1)-NBu to pure OPV(1)-NBu, shows that the devices using co-deposited TPD:OPV(1)-NBu as emitter have shorter emission wavelengths.

In some devices of the invention, the OPV will not be present in the EML layer, but will be present solely in the ETL or HTL layer.

The ETL layer shown in Figure 3 is 20 nm thick. Other thicknesses may be used such as 5 or 10 to 100 nm. Materials other than PBD may be used and are known in the art, such as Alq₃, a carbazole, an oxadiazole, a triazole, a thiphen, or oligothiphen group (see also US 6,023,073, issued February 8, 2001, incorporated by reference herein). An OPV of Formula (I) may also be used in the ETL layer.

An electron transport cathode layer may also be included. Materials that maybe used as the electron transport cathode layer include Mg-Ag, Li-Al or Ca, or a non-metallic material such as ITO, and other materials known in the art. It typically has a thickness of about 5 to 30 nm.

Generally, any material that meets the necessary requirements (such as oxidation potential, charge mobility, HOMO, and LUMO positions) may be used as HTL and ETL layers, as well as for the anode and/or cathode.

LiF can be added between the cathode and the ETL in order to enhance the

electron injection efficiency, in a thickness of, for example, 0.1 to 2.0 nm.

A capping layer 41 may optionally be used for encapsulation to prevent oxygen and moisture from contaminating the device. The capping layer may be glass, metal, polymer/metal multilayers, or any other suitable material. A patterned
 5 insulating layer 47 is used to define the emissive area or pixel size of an OLED; such materials are known in the art and include SiO_2 , SiN_x , and Al_2O_3 , or substantially any other material that may be used as the insulating material of an OLED, which may be deposited by a variety of processes such as plasma enhanced chemical vapour deposition (PECVD), electron beam, or the like.

10 The electroluminescent (OPV) materials of this invention may be present alone in an EML which also functions as an HTL and ETL layer, sandwiched between an anode and a cathode. Alternatively, they may be present as part of a heterostructure comprising HTL and ETL layer, in which the electroluminescent material is incorporated into one of the HTL and ETL layers, or as part of a structure having an
 15 HTL, EML, and ETL layer.

Figure 5 shows the current density-voltage characteristics of an OLED having a structure as shown in Figure 3, and using the OPV, OPV(1)-Nbu, as the EML. It shows typical rectifying behavior with a rectifying ration of 10^5 at $\pm 15\text{V}$.

The luminance-voltage and luminance-current density characteristics of the
 20 test device of Figure 3 comprising OPV(1)-Nbu as the OPV are shown in Figures 6 and 7, respectively. The luminance-current density relationship is not exactly linear, but may be improved, however, by adjusting the layer thickness to realize balanced charge injection. The dependence of the device's external efficiency on bias voltage is also shown in Figure 6. In the luminance range of 20 to 1600 cd/m^2 , the efficiency
 25 varies between 5.4 to 4.0 cd/A. In the luminance range typically used for display 100 to 200 cd/m^2 , the efficiency varies between 5.3 and 5.0 cd/A. The external efficiency may be further improved by optimizing the layer thickness and co-deposition ratio.

The OLEDs of the present invention have the advantage that they can be fabricated entirely from vacuum-deposited molecular organic materials as distinct,

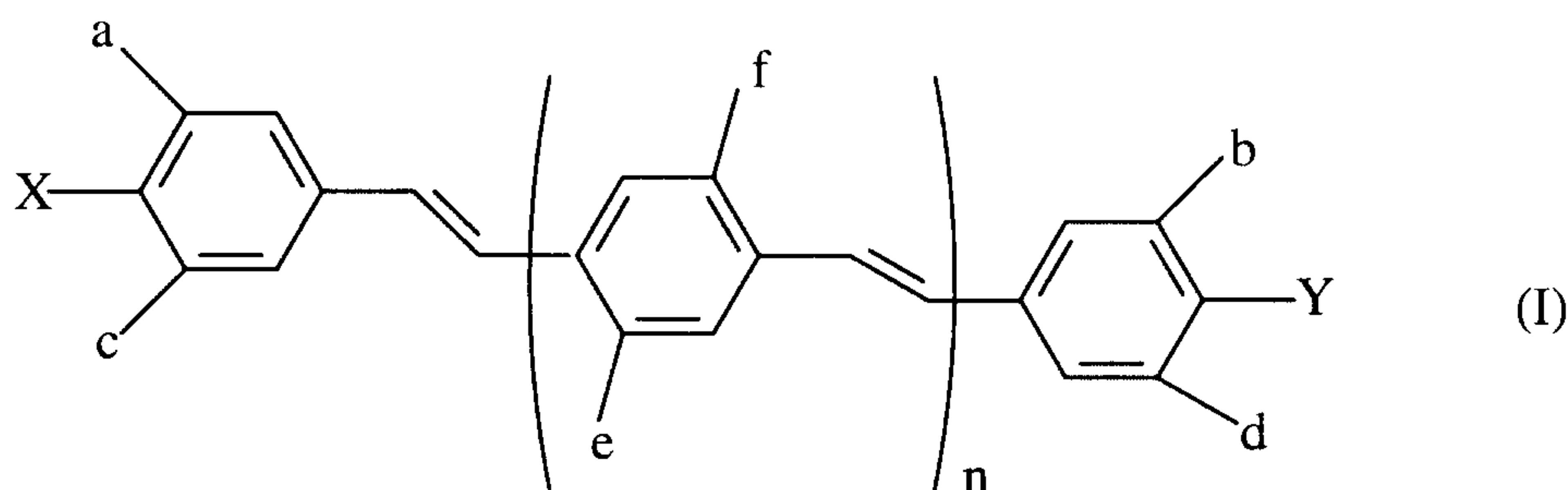
for example, from OLEDs in which some of the layers are comprised of polymeric materials, which cannot be readily deposited using vacuum deposition techniques. A vacuum-deposited material is one which can be deposited in a vacuum typically having a background pressure less than one atmosphere, preferably about 10^{-5} to
5 about 10^{-11} torr for vacuum deposition, or about 50 torr to about 10^{-5} torr for vapour deposition.

The OLED of the present invention may be used in substantially any type of device which is comprised of an OLED, for example, in OLEDs that are incorporated into a larger display, a vehicle, a computer, a television, a printer, a large area wall,
10 theater or stadium screen, a billboard or a sign

Numerous modifications may be made without departing from the spirit and scope of the invention as defined in the appended claims.

What is claimed is:

1. A light-emitting device comprising:
 an anode;
 a cathode; and
 a first layer between the anode and cathode, comprising an oligo(phenylenevinylene) (OPV) of the Formula (I):



wherein

n is 0 to 8;

X is H, NHR, NR_2 , $(\text{O}(\text{CH}_2)_2)_2\text{OR}$, OR, NO_2 , or SO_2R ;

Y is H, NHR, NR_2 , $(\text{O}(\text{CH}_2)_2)_2\text{OR}$, OR, NO_2 , or SO_2R ;

a , b , c , and d are each independently selected from the group consisting of H, R, OR, NHR, and NR_2 ;

e and f are each independently selected from the group consisting of H, SiR_3 , alkyl, and aryl groups; and

each R is independently selected from the group consisting of a substituted and unsubstituted alkyl and aryl groups; and

wherein if both X and Y are OR, at least one of a , b , c , d , e , and f is other than H; if

both X and Y are one of $(\text{O}(\text{CH}_2)_2)_2\text{OCH}_3$ and $\text{SO}_2\text{C}_6\text{H}_{13}$, at least one of a , b , c , d , e , and

f is other than H; if X , Y , e , and f are all H, at least one of a , b , c , and d is other than H,

and a , b , c , and d are not all tert-butyl; and if X , Y , a , b , c , and d are all H, e and f are

not both C_6H_{13} or both C_8H_{17} .

2. The device of claim 1, wherein in Formula (I):

n is 1 to 4;

X is H, NHR, NR₂, (O(CH₂)₂)₂OCH₃, OC₃H₇, OC₄H₉, OC₅H₁₁, OC₆H₁₃, NO₂, or SO₂C₆H₁₃;

Y is H, NHR, NR₂, (O(CH₂)₂)₂OCH₃, OC₃H₇, OC₄H₉, OC₅H₁₁, OC₆H₁₃, NO₂, or SO₂C₆H₁₃;

a, b, c, and d are each independently selected from the group consisting of H, CH₃, OCH₃, NH(C₃₋₈-alkyl), and N(C₃₋₈-alkyl)₂;

e and f are each independently selected from the group consisting of H, Si(C₃₋₈-alkyl)₃, and C₆₋₁₄-aryl groups; and

each R is independently selected from the group consisting of C₃₋₈-alkyl and C₆₋₁₄-aryl groups.

3. The device of claim 1, wherein in the OPV of Formula (I):

n is 0 to 3;

X is NHR or NR₂;

Y is H, NHR, or NR₂;

a, b, c, d, e, and f are each H; and

each R is independently selected from the group consisting of C₃₋₈-alkyl and C₆₋₁₄-aryl groups.

4. The device of claim 3, wherein the OPV is 1,4-bis-4-(dibutylamine)styrylbenzene.

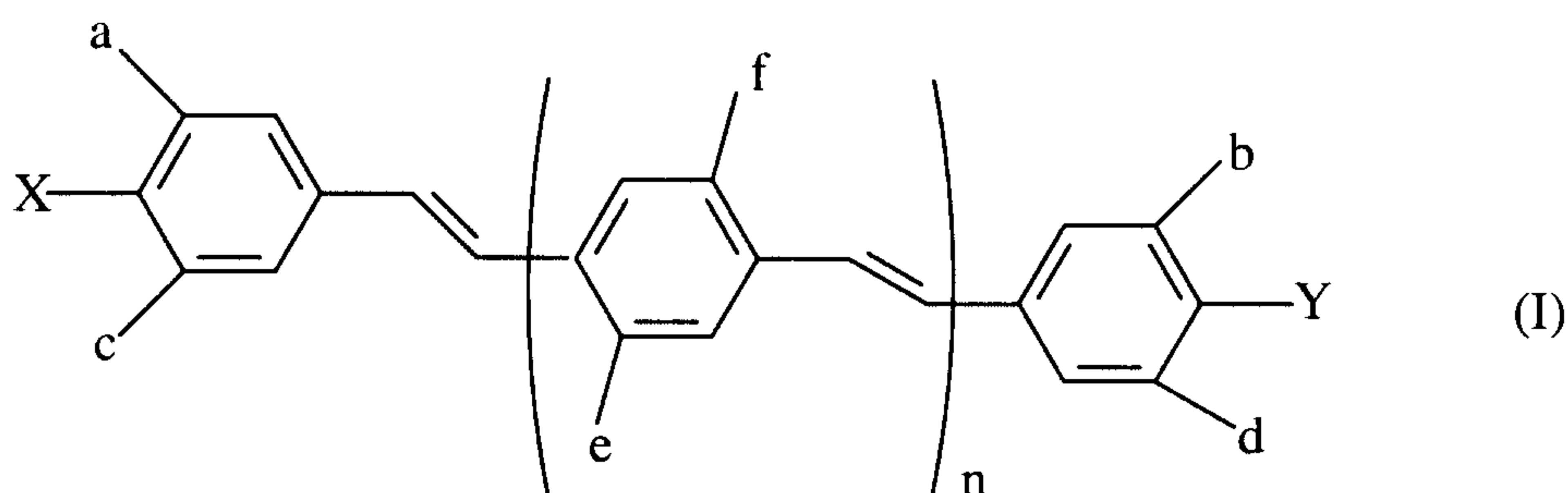
5. The device of any one of claims 1 to 4, further comprising a second layer, the second layer being either a hole transport layer coupled to the anode, or an electron transport layer coupled to the cathode.

6. The device of claim 5, further comprising a third layer, wherein the second layer is a hole transport layer coupled to the anode, and the third layer is an electron transport layer coupled to the cathode.

7. The device of claim 6, wherein the hole transport layer comprises the OPV of

Formula (I).

8. The device of claim 6 or 7, wherein the electron transport layer comprises the OPV of Formula (I).
9. The device of any one of claims 1 to 8, wherein the first layer is an emissive layer, the emissive layer comprising the OPV of Formula (I).
10. The device of claim 9, wherein the emissive layer further includes N,N'-diphenyl-N,N'-bis(3-methylphenyl)-1,1-biphenyl-4,4'-diamine (TPD).
11. The device of any one of claims 6 to 10, wherein the electron transport layer comprises 2-(4-biphenyl)-5-(4-tert-butylphenyl)-1,3,4-oxadiazole (PBD) and the hole transport layer comprises N,N'-diphenyl-N,N'-bis(3-methylphenyl)-1,1-biphenyl-4,4'-diamine (TPD).
12. A display including a light-emitting device in accordance with any one of claims 1 to 11.
13. A method of making a light-emitting device, the method comprising the steps of:
preparing an oligo(phenylenevinylene) of the Formula (I):



wherein

n is 0 to 8;

X is H, NHR, NR_2 , $(O(CH_2)_2)_2OR$, OR, NO_2 , or SO_2R ;

Y is H, NHR, NR₂, (O(CH₂)₂)₂OR, OR, NO₂, or SO₂R;

a, b, c, and d are each independently selected from the group consisting of H, R, OR, NHR, and NR₂;

e and f are each independently selected from the group consisting of H, SiR₃, alkyl, and aryl groups; and

each R is independently selected from the group consisting of a substituted and unsubstituted alkyl and aryl groups; and

wherein if both X and Y are OR, at least one of a, b, c, d, e, and f is other than H; if both X and Y are one of (O(CH₂)₂)₂OCH₃ and SO₂C₆H₁₃, at least one of a, b, c, d, e, and f is other than H; if X, Y, e, and f are all H, at least one of a, b, c, and d is other than H, and a, b, c, and d are not all tert-butyl; and if X, Y, a, b, c, and d are all H, e and f are not both C₆H₁₃ or both C₈H₁₇; and

layering the oligo(phenylenevinylene) of the Formula (I) between an anode and a cathode to form a light-emitting diode.

14. The method of claim 13, wherein in the OPV of Formula (I):

n is 1 to 4;

X is H, NHR, NR₂, (O(CH₂)₂)₂OCH₃, OC₃H₇, OC₄H₉, OC₅H₁₁, OC₆H₁₃, NO₂, or SO₂C₆H₁₃;

Y is H, NHR, NR₂, (O(CH₂)₂)₂OCH₃, OC₃H₇, OC₄H₉, OC₅H₁₁, OC₆H₁₃, NO₂, or SO₂C₆H₁₃;

a, b, c, and d are each independently selected from the group consisting of H, CH₃, OCH₃, NH(C₃₋₈-alkyl), and N(C₃₋₈-alkyl)₂;

e and f are each independently selected from the group consisting of H, Si(C₃₋₈-alkyl)₃, and C₆₋₁₄-aryl groups; and

each R is independently selected from the group consisting of C₃₋₈-alkyl and C₆₋₁₄-aryl groups.

15. The method of claim 13, wherein in the OPV of Formula (I):

n is 0 to 3;

X is NHR or NR₂;

Y is H, NHR, or NR₂;

a, b, c, d, e, and f are each H; and

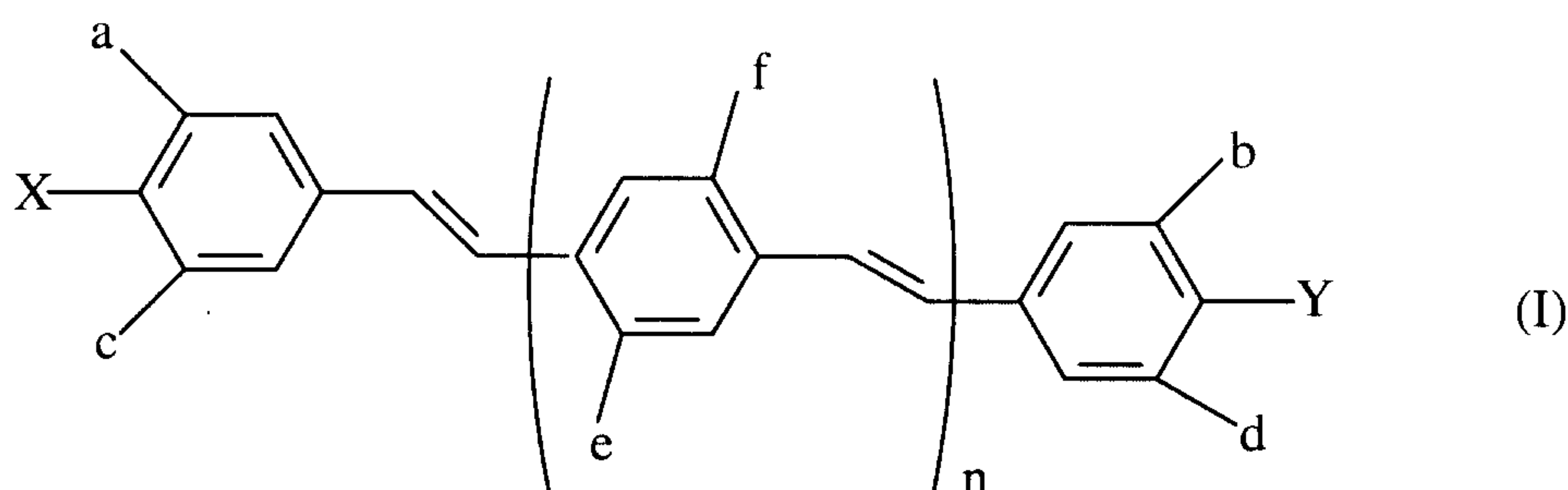
each R is independently selected from the group consisting of C₃₋₈-alkyl and C₆₋₁₄-aryl groups.

16. The method of claim 15, wherein the OPV is 1,4-bis-4-(dibutylamine)styrylbenzene.

17. The method of any one of claims 13 to 16, further comprising:

selecting n, X, Y, a, b, c, d, e, f, and R of the OPV of Formula (I) to selectively tune the emissive wavelength of the OPV to a desired wavelength.

18. Use of an oligo(phenylenevinylene) (OPV) represented by Formula (I) for electroluminescent emission in a light-emitting device:



wherein

n is 0 to 8;

X is H, NHR, NR₂, (O(CH₂)₂)₂OR, OR, NO₂, or SO₂R;

Y is H, NHR, NR₂, (O(CH₂)₂)₂OR, OR, NO₂, or SO₂R;

a, b, c, and d are each independently selected from the group consisting of H, R, OR, NHR, and NR₂;

e and f are each independently selected from the group consisting of H, SiR₃, alkyl, and aryl groups; and

each R is independently selected from the group consisting of a substituted and unsubstituted alkyl and aryl groups; and

wherein if both X and Y are OR, at least one of a, b, c, d, e, and f is other than H; if both X and Y are one of $(\text{O}(\text{CH}_2)_2)_2\text{OCH}_3$ and $\text{SO}_2\text{C}_6\text{H}_{13}$, at least one of a, b, c, d, e, and f is other than H; if X, Y, e, and f are all H, at least one of a, b, c, and d is other than H, and a, b, c, and d are not all tert-butyl; and if X, Y, a, b, c, and d are all H, e and f are not both C_6H_{13} or both C_8H_{17} .

19. The use of claim 18, wherein in the OPV of Formula (I):

n is 1 to 4;

X is H, NHR, NR_2 , $(\text{O}(\text{CH}_2)_2)_2\text{OCH}_3$, OC_3H_7 , OC_4H_9 , OC_5H_{11} , OC_6H_{13} , NO_2 , or $\text{SO}_2\text{C}_6\text{H}_{13}$;

Y is H, NHR, NR_2 , $(\text{O}(\text{CH}_2)_2)_2\text{OCH}_3$, OC_3H_7 , OC_4H_9 , OC_5H_{11} , OC_6H_{13} , NO_2 , or $\text{SO}_2\text{C}_6\text{H}_{13}$;

a, b, c, and d are each independently selected from the group consisting of H, CH_3 , OCH_3 , $\text{NH}(\text{C}_{3-8}\text{-alkyl})$, and $\text{N}(\text{C}_{3-8}\text{-alkyl})_2$;

e and f are each independently selected from the group consisting of H, $\text{Si}(\text{C}_{3-8}\text{-alkyl})_3$, and $\text{C}_{6-14}\text{-aryl}$ groups; and

each R is independently selected from the group consisting of $\text{C}_{3-8}\text{-alkyl}$ and $\text{C}_{6-14}\text{-aryl}$ groups.

20. The use of claim 18, wherein in the OPV of Formula (I):

n is 0 to 3;

X is NHR or NR_2 ;

Y is H, NHR, or NR_2 ;

a, b, c, d, e, and f are each H; and

each R is independently selected from the group consisting of $\text{C}_{3-8}\text{-alkyl}$ and $\text{C}_{6-14}\text{-aryl}$ groups.

21. The use of claim 18, wherein the oligo(phenylenevinylene) is 1,4-bis-4-(dibutylamine)styrylbenzene.

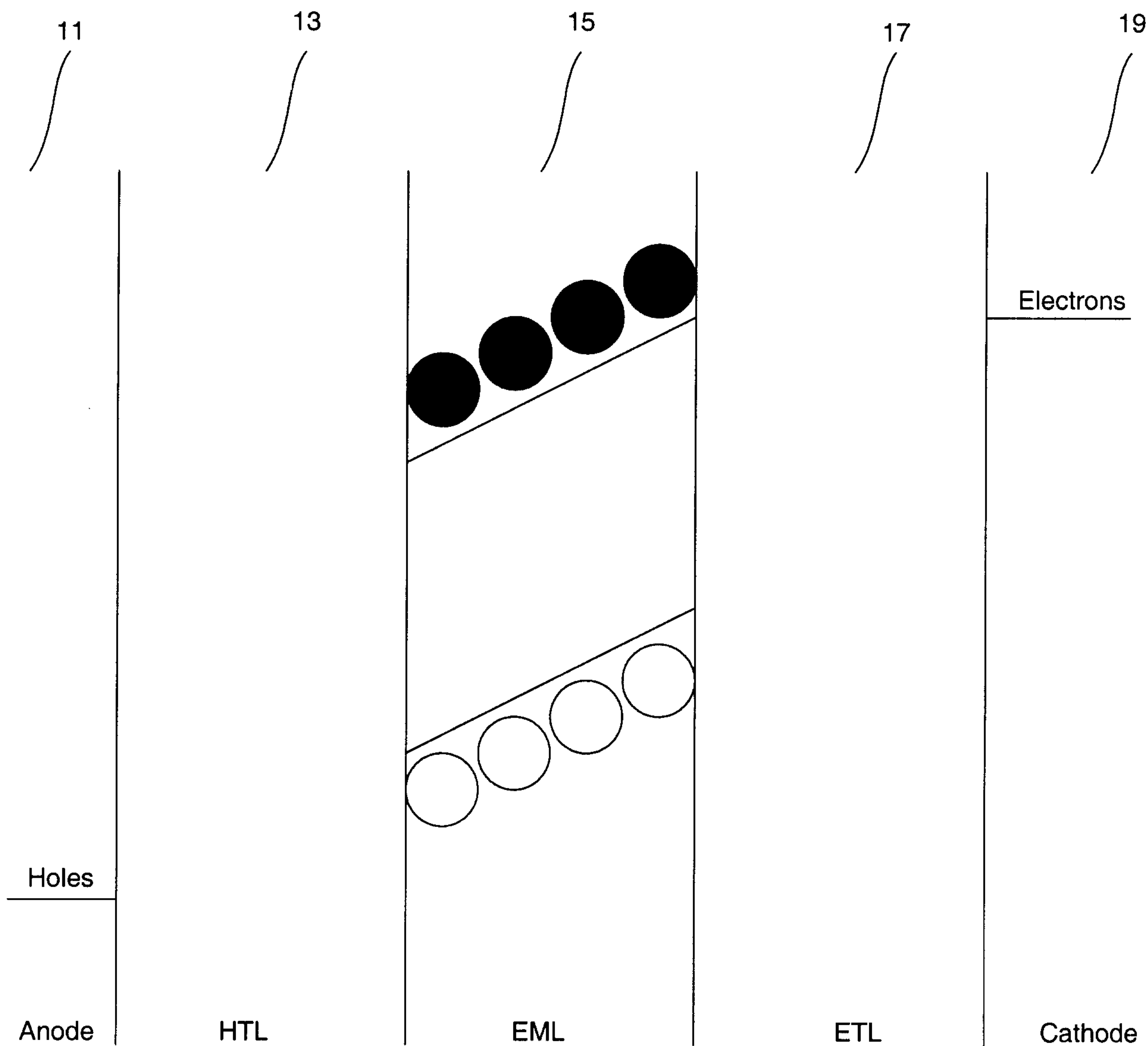


Figure 1 (PRIOR ART)

Marks & Clerk

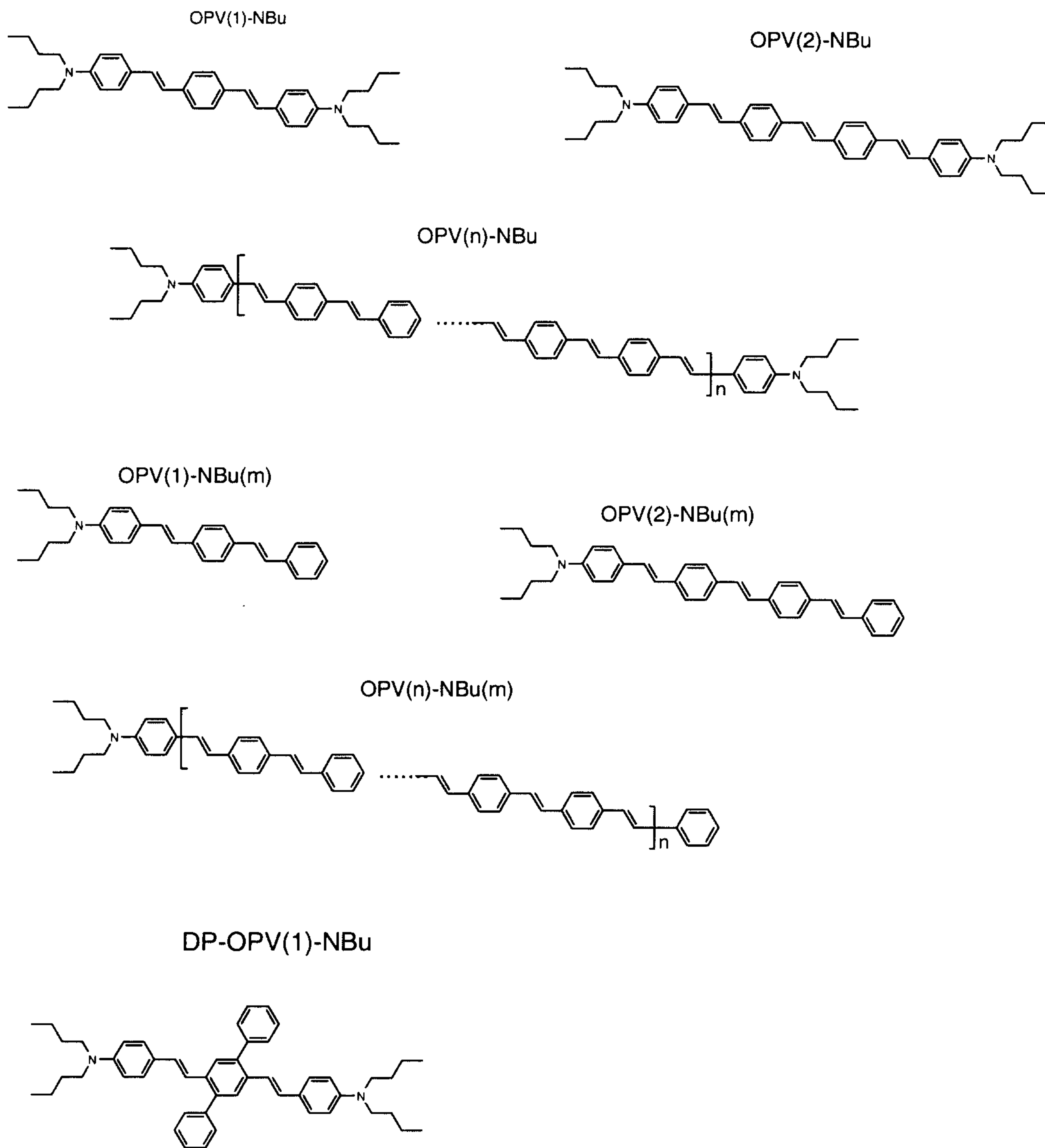
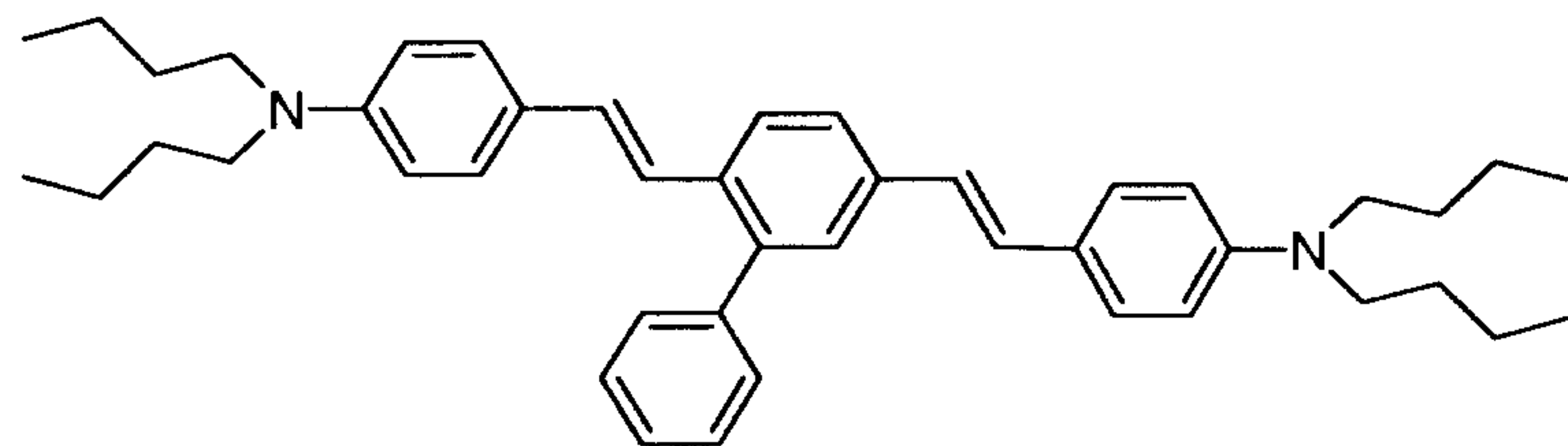
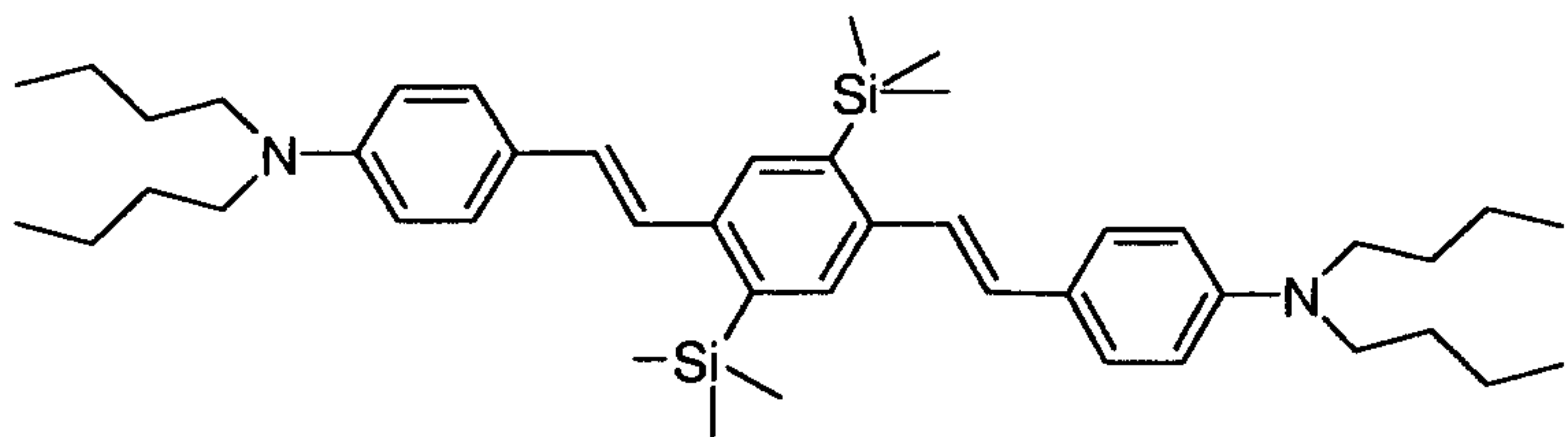


Figure 2A

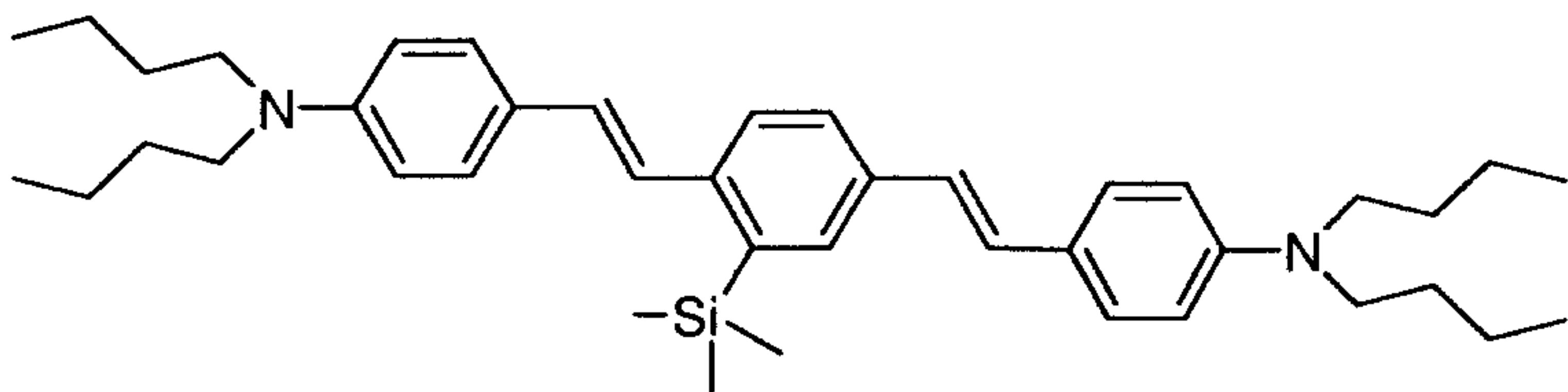
Marks & Clerk



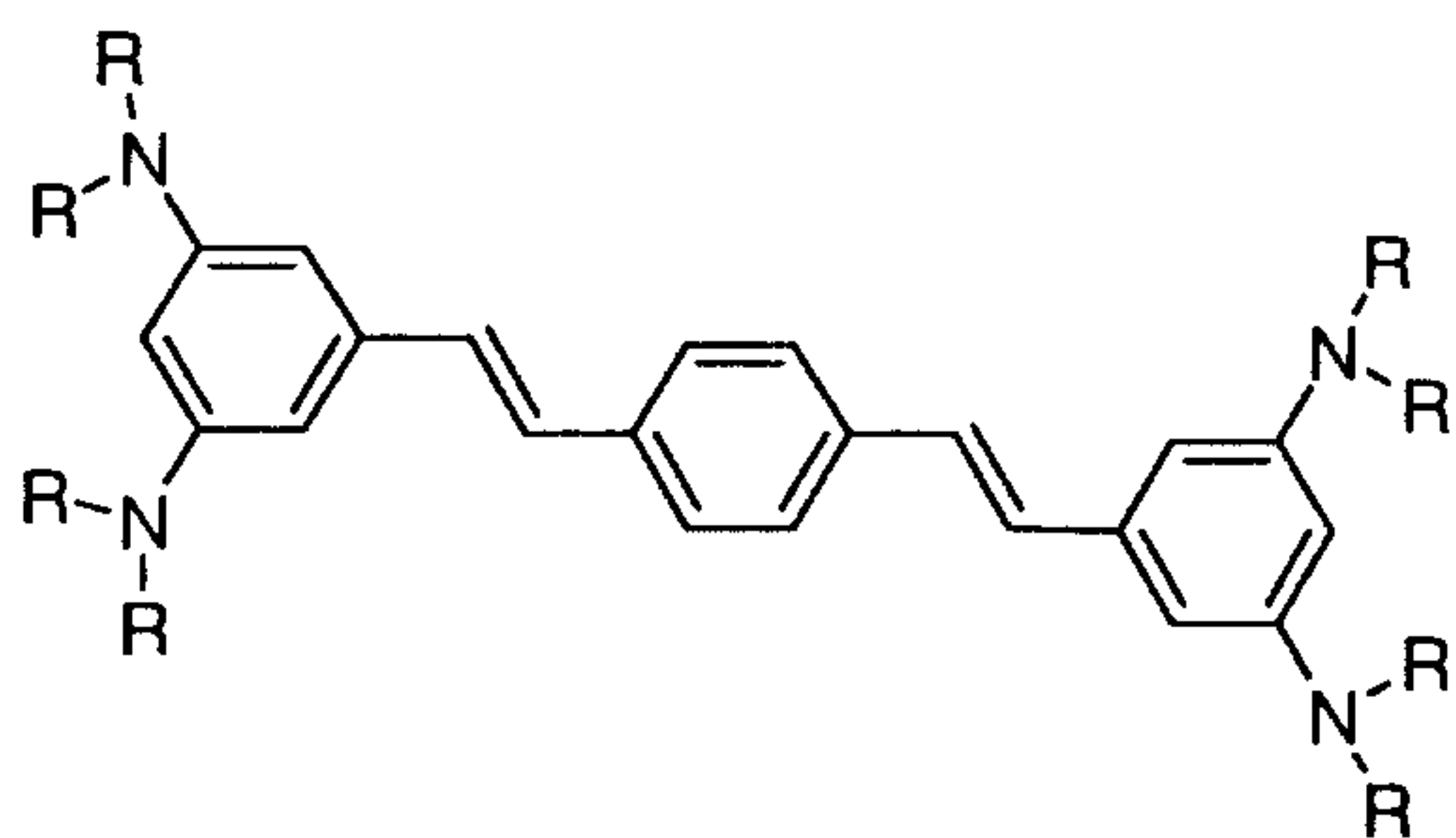
MP-OPV(1)-NBu



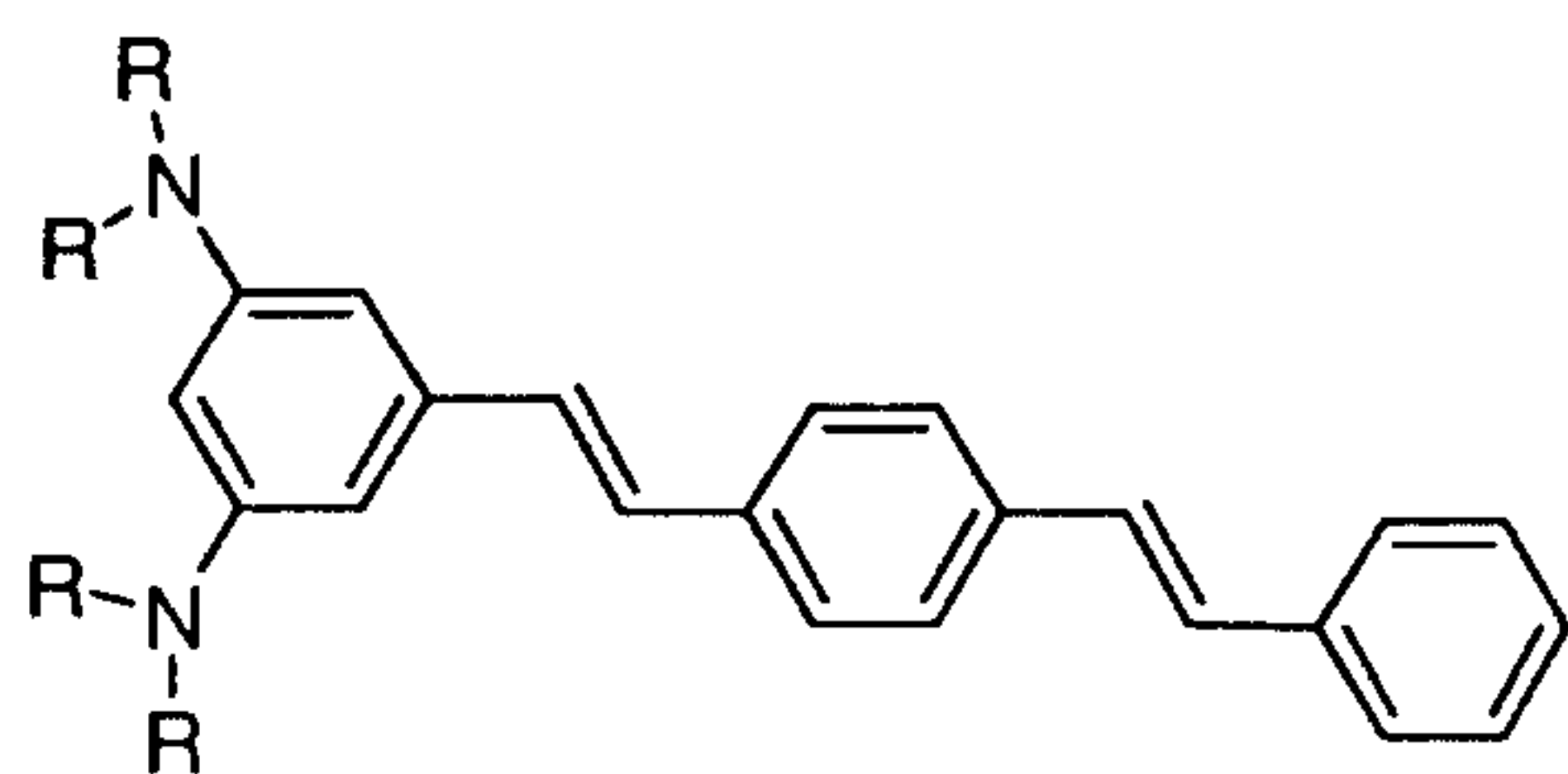
DSi-OPV(1)-NBu



MSi-OPV(1)-NBu



G[0]-OPV(1)-NR



G[0]-OPV(1)-NR(m)

Figure 2B

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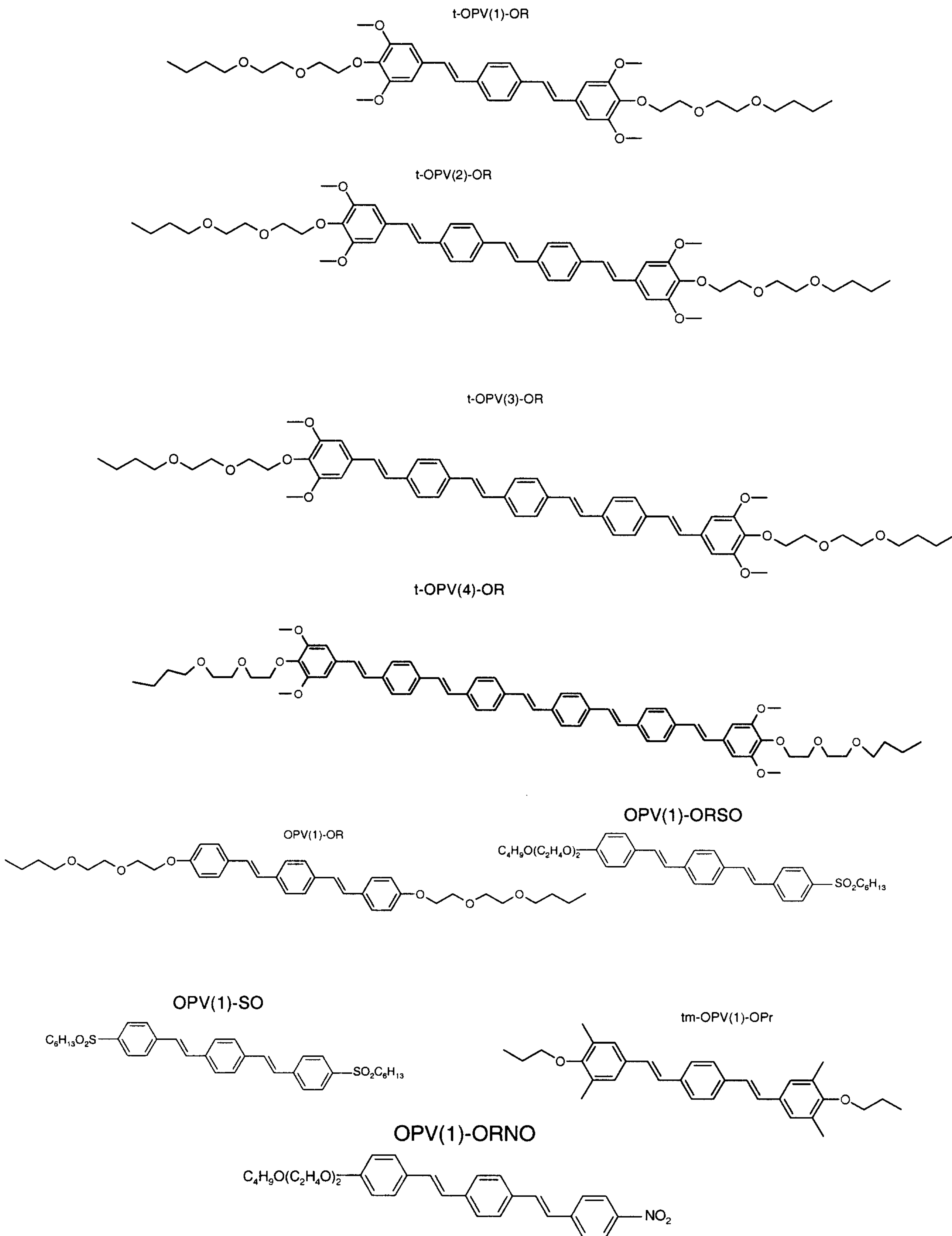


Figure 2C

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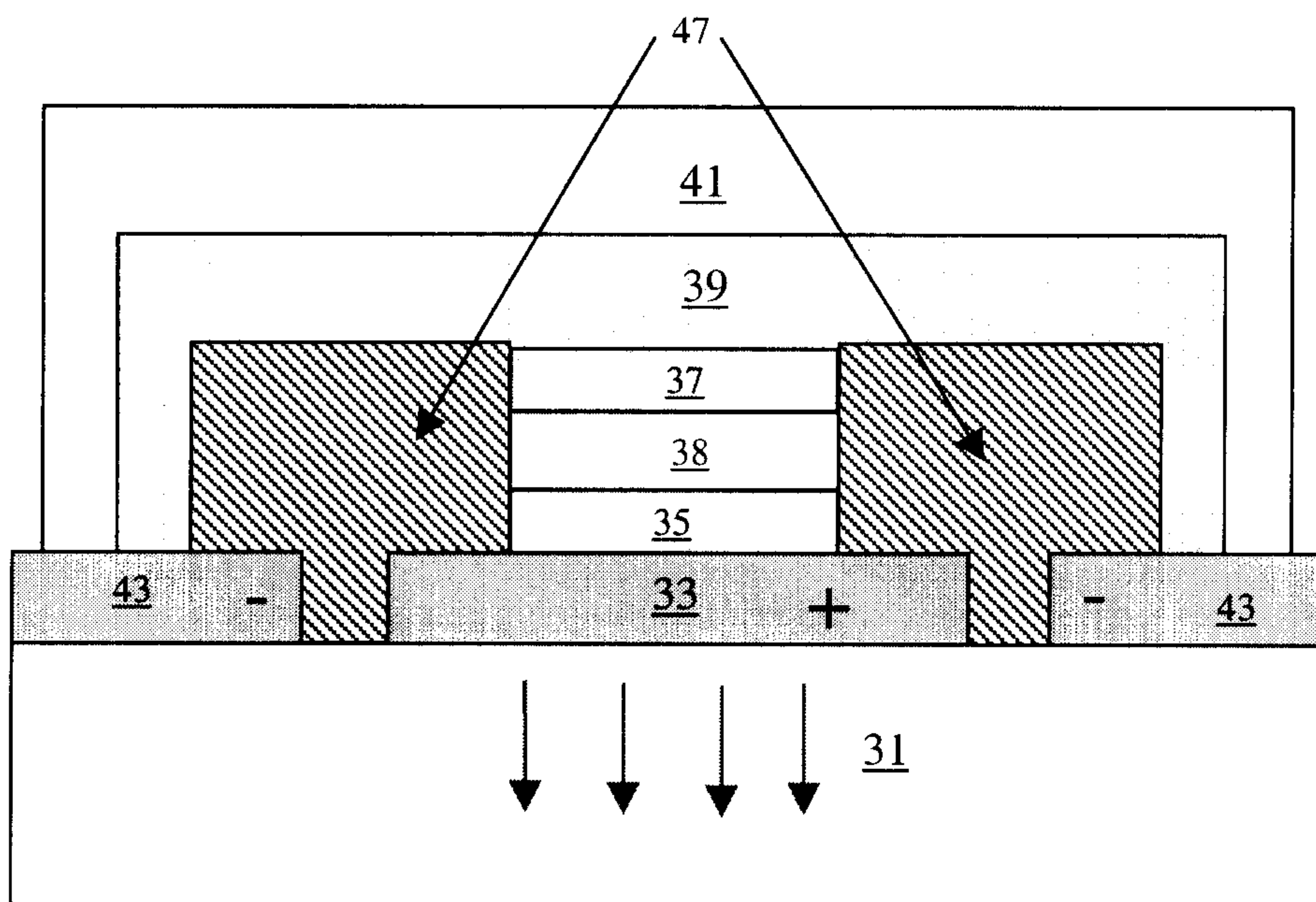


Figure 3

Marks & Clerk

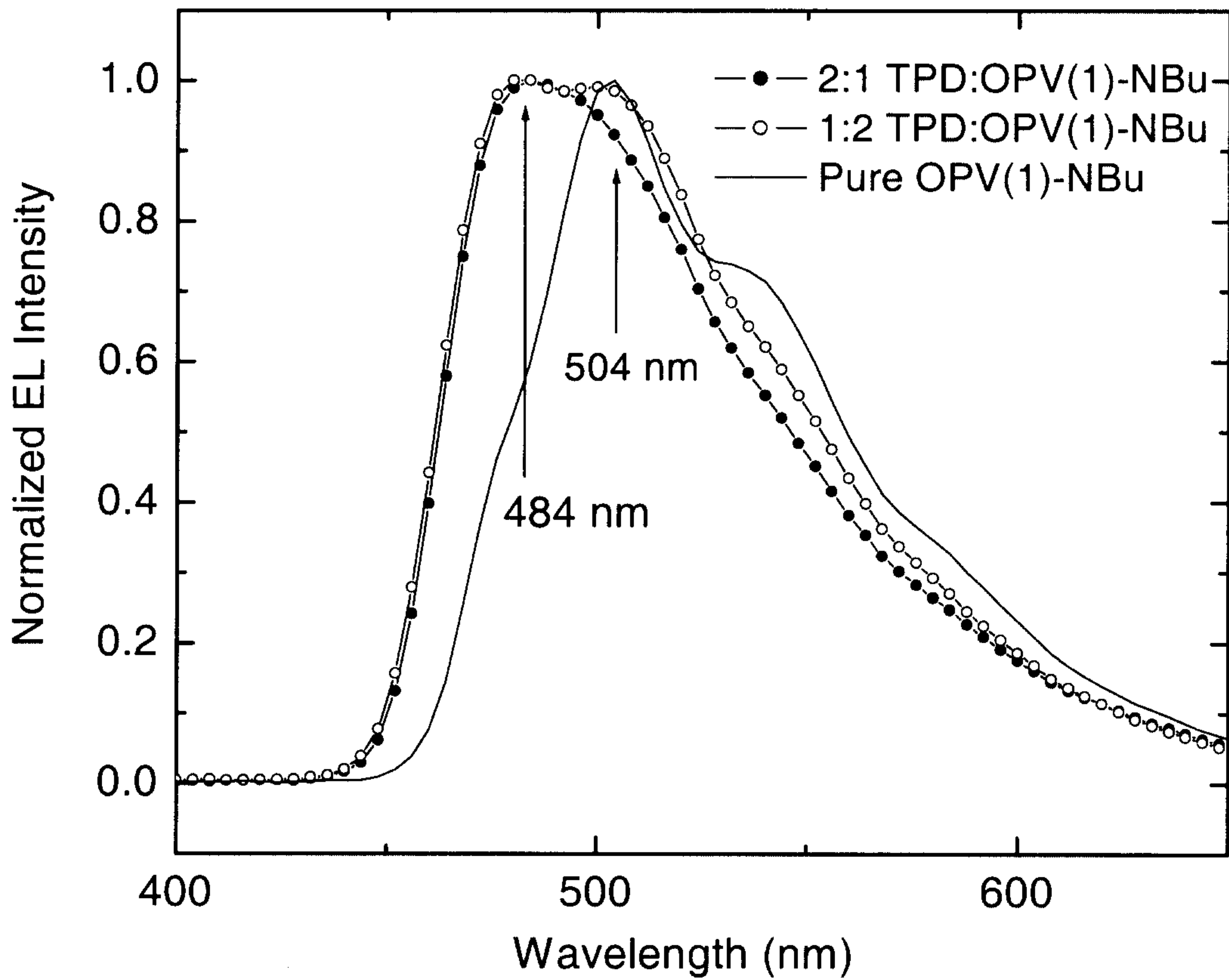


Figure 4

Marks & Clerk

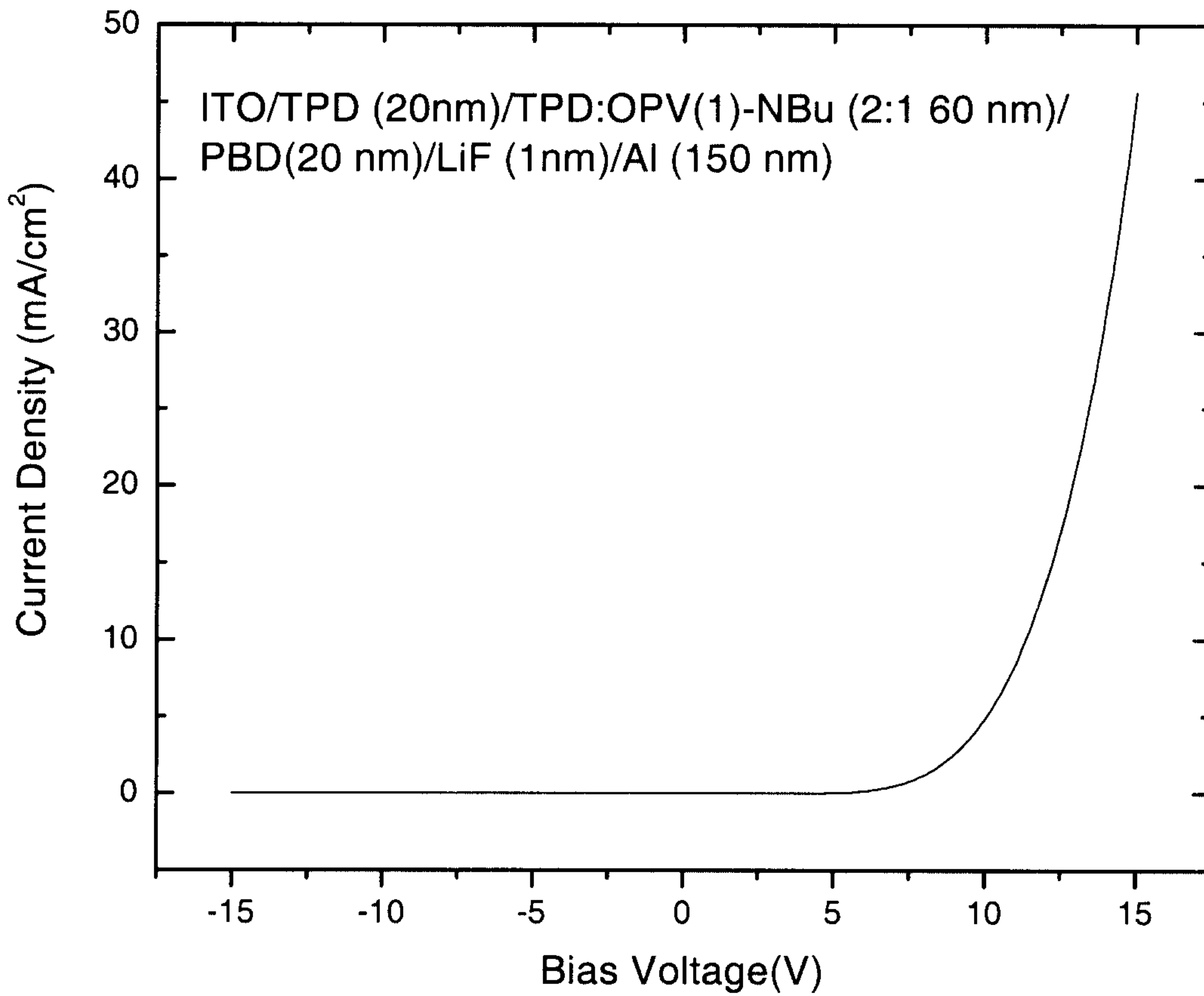


Figure 5

Marks & Clerk

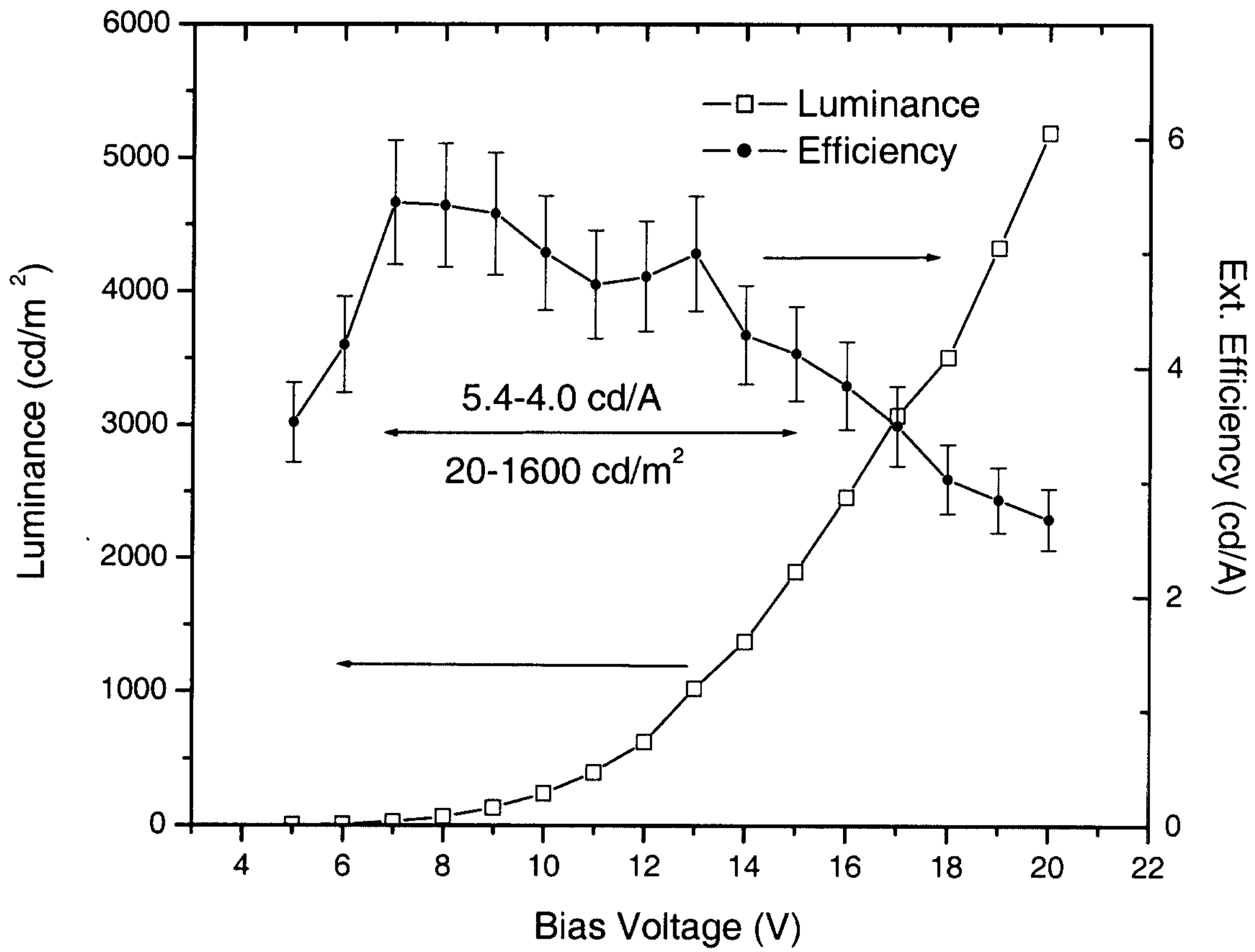


Figure 6

Marks & Clerk

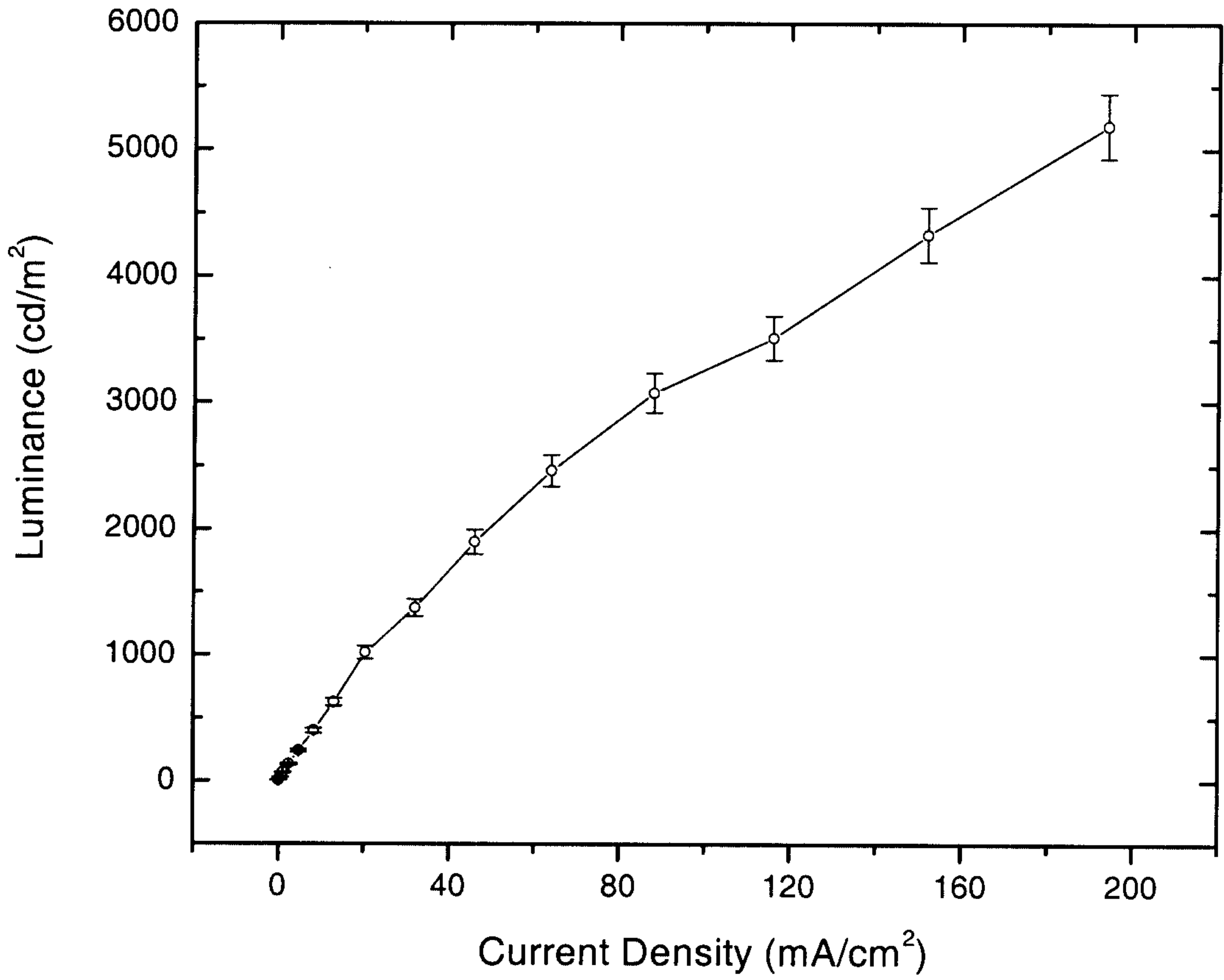
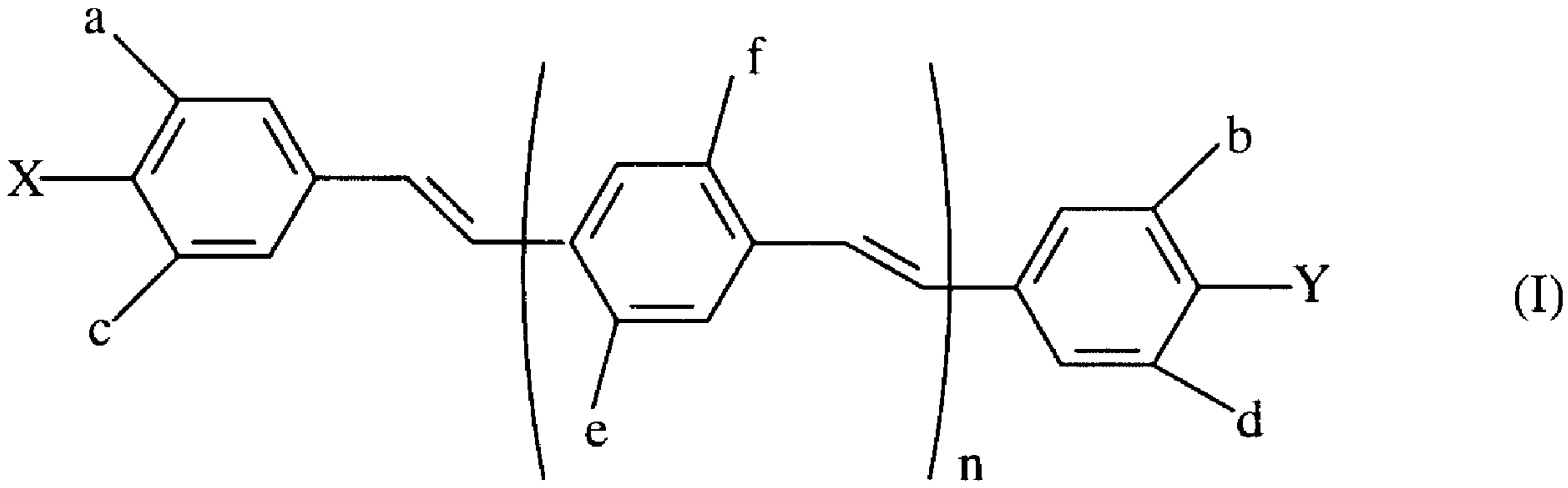


Figure 7

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(I)