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(71) Applicant(s)
Transitions Optical, Inc

(72) Inventor(s)
Anil Kumar

(74) Agent/Attorney
COLLISON and CO,GPO Box 2556,ADELAIDE SA 5001

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~~(71) Applicant: PPG INDUSTRIES, INC. [US/US], One PPG Place, Pittsburgh, PA 15272 (US).~~

(72) Inventor: KUMAR, Anil; 251 Darlan Hill Drive, Pittsburgh, PA 15239 (US).

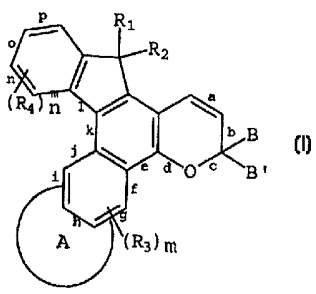
(74) Agents: STEIN, Irwin, M.; PPG Industries, Inc., One PPG Place, Pittsburgh, PA 15272 (US) et al.

(71) TRANSITIONS OPTICAL, INC.
9251 Belcher Road
Pinellas Park IL 33782
United States of America

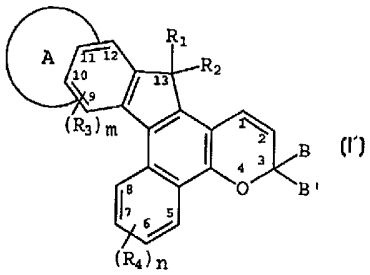
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AUSTRALIAN PATENT OFFICE 92B15 * 18/12/97

(54) Title: NOVEL PHOTOCHROMIC HETEROCYCLIC FUSED INDENONAPHTHOPYRANS



(I)



(I')

(57) Abstract

Described are novel photochromic heterocyclic fused indenonaphthopyran compounds having a substituted or unsubstituted heterocyclic ring fused to the g, h, i, n, o or p side of the indenonephthopyran. These compounds may be represented by either of graphic formulae (I), (I'). Also described are polymeric organic host materials that contain or that are coated with such compounds.

NOVEL PHOTOCHROMIC HETEROCYCLIC FUSED INDENONAPHTHOPYRANS

Cross Reference to Related Applications

This application is a continuation-in-part of application Serial No. 08/783,343 filed January 16, 1997, which is a continuation-in-part of application Serial No. 08/666,942, filed June 17, 1996.

DESCRIPTION OF THE INVENTION

The present invention relates to certain novel naphthopyran compounds. More particularly, this invention relates to novel photochromic heterocyclic fused indenonaphthopyran compounds and to compositions and articles containing such novel indenonaphthopyran compounds. When exposed to electromagnetic radiation containing ultraviolet rays, such as the ultraviolet radiation in sunlight or the light of a mercury lamp, many photochromic compounds exhibit a reversible change in color. When the ultraviolet radiation is discontinued, such a photochromic compound will return to its original color or colorless state.

Various classes of photochromic compounds have been synthesized and suggested for use in applications in which a sunlight-induced reversible color change or darkening is desired. U.S. Patent 3,567,605 (Becker) describes a series of pyran derivatives, including certain benzopyrans and naphthopyrans. These compounds are described as derivatives of chromene and are reported to undergo a color change, e.g., from colorless to yellow-orange, on irradiation by ultraviolet light at temperatures below about -30°C. Irradiation of the compounds with visible light or upon raising the temperature to above about 0°C is reported to reverse the coloration to a colorless state.

U.S. Patent 5,066,818 describes various 3,3-diaryl-3H-naphtho[2,1-b]pyrans as having desirable photochromic properties, i.e., high colorability and acceptable fade, for ophthalmic and other applications. Also disclosed by way of

comparative example in the '818 patent are the isomeric 2,2-diaryl-2H-naphtho[1,2-b]pyrans, which are reported to require unacceptably long periods of time to fade after activation.

U.S. Patent 3,627,690 describes photochromic 2,2-di-substituted-2H-naphtho[1,2-b]pyran compositions containing minor amounts of either a base or weak-to-moderate strength acid. The addition of either an acid or base to the naphthopyran composition is reported to increase the fade rate of the colored naphthopyrans, thereby making them useful in eye protection applications such as sunglasses. It is reported therein further that the fade rate of 2H-naphtho-[1,2-b]pyrans without the aforementioned additives ranges from several hours to many days to reach complete reversion.

U.S. Patent 4,818,096 discloses purple/blue coloring photochromic benzo- or naphthopyrans having at the position alpha to the oxygen of the pyran ring a phenyl group having a nitrogen containing substituent in the ortho or para positions. WO 96/14596 describes novel photochromic indeno-fused naphthopyran compounds, the 2,1- positions of the indeno group being fused to the f side of the naphthopyran.

The present invention relates to novel indenonaphtho[1,2-b]pyran compounds having a substituted or unsubstituted heterocyclic ring, the 2,3 or 3,2 positions of which are fused to the g, h, i, n, o or p side of the indenonaphthopyran, and certain substituents at the 3-position of the pyran ring. These compounds have unexpectedly been found to demonstrate a bathochromic shift for the wavelength in the visible spectrum at which the maximum absorption of the activated (colored) form of the photochromic compound, i.e., the lambda max (Vis), occurs, thereby resulting in activated colors ranging from orange to blue/gray.

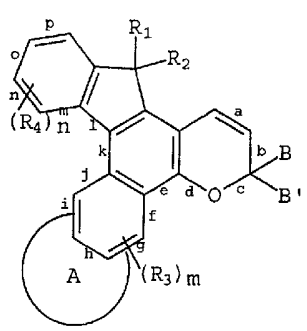
DETAILED DESCRIPTION OF THE INVENTION

In recent years, photochromic plastic materials, particularly plastic materials for optical applications, have been the subject of considerable attention. In particular,

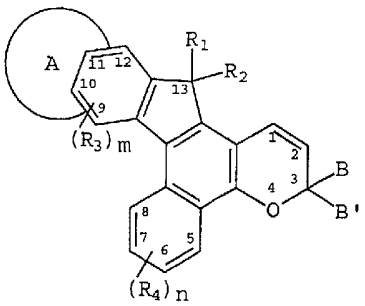
photochromic ophthalmic plastic lenses have been investigated because of the weight advantage they offer, vis-à-vis, glass lenses. Moreover, photochromic transparencies for vehicles, such as cars and airplanes, have been of interest because of the potential safety features that such transparencies offer.

In accordance with the present invention, it has now been discovered that certain novel indeno[2,1-f]naphtho[1,2-b]pyrans having activated colors ranging from orange to blue/gray may be prepared. These compounds may be described as indenonaphthopyrans having an unsubstituted, mono-substituted or di-substituted heterocyclic ring, the 2,3 or 3,2 positions of which are fused to the g, h, i, n, o or p sides of the indenonaphthopyran, and certain substituents at the 3 position of the pyran ring. Certain substituents may also be present at the number 5, 6, 7 or 8 carbon atoms of the naphthopyran compound when the heterocyclic ring is fused to the n, o, or p side of the indenonaphthopyran; or at the 9, 10, 11, or 12 carbon atoms of the naphthopyran compound when the heterocyclic ring is fused to the g, h, or i side of the indenonaphthopyran.

The foregoing described indenonaphthopyran compounds may be represented by the following graphic formulae I and I' in which the letters a through p represent the sides or faces of the various molecular rings comprising the compound, and the numbers 1 through 13 identify the ring atoms of the heterocyclic fused indenonaphthopyran. In the definitions of the substituents shown in formulae I and I', like symbols have the same meaning unless stated otherwise.



I



I'

In graphic formulae I and I', A may be an unsubstituted, mono-substituted or di-substituted heterocyclic ring selected from the group consisting of benzothieno, benzofurano and indolo, the 2,3 or 3,2 positions of the heterocyclic ring being fused to the g, h, i, n, o or p side of the indenonaphthopyran. Each of the aforedescribed heterocyclic ring substituents may be C_1-C_6 alkyl, C_5-C_7 cycloalkyl, C_1-C_6 alkoxy, bromo, chloro or fluoro. Preferably, the heterocyclic ring A is unsubstituted or mono-substituted, and the heterocyclic ring substituents are C_1-C_4 alkyl or C_1-C_4 alkoxy. Most preferably, the heterocyclic ring A is unsubstituted or mono-substituted, the 2,3 or 3,2 position of the heterocyclic ring is fused to the g or p side of the indenonaphthopyran, and the heterocyclic ring substituents are C_1-C_3 alkyl or C_1-C_3 alkoxy.

In graphic formula I, R_1 may be hydrogen, hydroxy, bromo, fluoro or chloro and R_2 may be the group, $-CH(V)_2$, wherein V is -CN or $-COOR_5$, and each R_5 is hydrogen, C_1-C_6 alkyl, phenyl(C_1-C_3)alkyl, mono(C_1-C_6)alkyl substituted phenyl(C_1-C_3)alkyl, mono(C_1-C_6)alkoxy substituted phenyl(C_1-C_3)alkyl, or the unsubstituted, mono- or di-substituted aryl groups phenyl or naphthyl, or R_2 may be the group, $-CH(R_6)Y$, wherein R_6 is hydrogen, C_1-C_6 alkyl or the unsubstituted, mono- or di-substituted aryl groups phenyl or

naphthyl, and Y is $-COOR_5$, $-COR_7$, or $-CH_2OR_{11}$, wherein R_7 is hydrogen, C_1-C_6 alkyl, the unsubstituted, mono- or di-substituted aryl groups phenyl or naphthyl, amino, mono(C_1-C_6)alkylamino, di(C_1-C_6)alkylamino, e.g. dimethyl amino, methyl propyl amino, etc., phenylamino, mono- or di-(C_1-C_6)alkyl substituted phenylamino, mono- or di-(C_1-C_6)alkoxy substituted phenylamino, diphenylamino, mono- or di(C_1-C_6)alkyl substituted diphenylamino, i.e., each phenyl has one or two C_1-C_6 alkyl substituents, mono- or di-(C_1-C_6)alkoxy substituted diphenylamino, morpholino, or piperidino; R_{11} is hydrogen, $-COR_5$, C_1-C_6 alkyl, C_1-C_3 alkoxy(C_1-C_6)alkyl, phenyl(C_1-C_3)alkyl, mono(C_1-C_6)alkyl substituted phenyl(C_1-C_3)alkyl, mono(C_1-C_6)alkoxy substituted phenyl(C_1-C_3)alkyl, or the unsubstituted, mono- or di-substituted aryl groups phenyl or naphthyl, each of all of the aforedescribed aryl group substituents being C_1-C_6 alkyl or C_1-C_6 alkoxy. Alternatively, R_1 and R_2 together may form the group, $=C(V)_2$ or $=C(R_6)W$, wherein W is $-COOR_5$ or $-COR_7$.

Preferably, R_1 is hydrogen, hydroxy, fluoro or chloro and R_2 is the group, $-CH(V)_2$, wherein V is -CN or $-COOR_5$, and each R_5 is hydrogen, C_1-C_4 alkyl, phenyl(C_1-C_2)alkyl, mono(C_1-C_4)alkyl substituted phenyl(C_1-C_2)alkyl, mono(C_1-C_4)alkoxy substituted phenyl(C_1-C_2)alkyl or the unsubstituted or mono-substituted aryl groups phenyl or naphthyl, or R_2 is the group, $-CH(R_6)Y$, wherein R_6 is hydrogen, C_1-C_4 alkyl or the unsubstituted or mono-substituted aryl groups phenyl or naphthyl, and Y is $-COOR_5$, $-COR_7$ or $-CH_2OR_{11}$, wherein R_7 is hydrogen, C_1-C_4 alkyl, the unsubstituted or mono-substituted aryl groups phenyl or naphthyl, amino, mono(C_1-C_4)alkylamino, di(C_1-C_4)alkylamino, phenylamino, mono- or di-(C_1-C_4)alkyl substituted phenylamino, mono- or di-(C_1-C_4)alkoxy substituted phenylamino, diphenylamino, mono- or di-(C_1-C_4)alkyl substituted diphenylamino, mono- or di-(C_1-C_4)alkoxy substituted diphenylamino, morpholino, or piperidino; R_{11} is hydrogen, $-COR_5$, C_1-C_4 alkyl, C_1-C_2 alkoxy(C_1-C_4)alkyl,

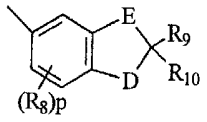
phenyl(C_1-C_2)alkyl, mono(C_1-C_4)alkyl substituted phenyl(C_1-C_2)alkyl, mono(C_1-C_4)alkoxy substituted phenyl(C_1-C_2)alkyl or the unsubstituted or mono-substituted aryl groups phenyl or naphthyl, each of all of the aforedescribed aryl group substituents being C_1-C_4 alkyl or C_1-C_4 alkoxy.

More preferably, R_1 is hydrogen, hydroxy or chloro and R_2 is the group, $-CH(V)_2$, wherein V is CN, or R_2 is the group, $-CH(R_6)Y$, wherein R_6 is hydrogen or C_1-C_4 alkyl, and Y is $-COOR_5$ or $-CH_2OR_{11}$, wherein R_5 is hydrogen or C_1-C_4 alkyl, and R_{11} is hydrogen, $-COR_5$ or C_1-C_4 alkyl. Alternatively, R_1 and R_2 together form the group, $=C(V)_2$ or $=C(R_6)W$, wherein W is $-COOR_5$.

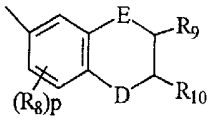
In graphic formulae I and I', R_3 and R_4 may each be C_1-C_6 alkyl, C_1-C_6 alkoxy, bromo, chloro or fluoro, and m and n are each the integers 0, 1 or 2. Preferably, R_3 and R_4 are each C_1-C_4 alkyl, C_1-C_4 alkoxy, chloro or fluoro, and m and n are each the integers 0 or 1. Most preferably, R_3 and R_4 are each C_1-C_3 alkyl or C_1-C_3 alkoxy, and m and n are each the integers 0 or 1.

B and B' in graphic formulae I and I' may each be selected from the group consisting of: (i) the unsubstituted, mono-, di- and tri-substituted aryl groups, phenyl and naphthyl; (ii) the unsubstituted, mono- and di-substituted aromatic heterocyclic groups pyridyl, furanyl, benzofuran-2-yl, benzofuran-3-yl, thienyl, benzothien-2-yl, benzothien-3-yl, dibenzofuranyl, dibenzothienyl, carbazolyl and fluorenyl, each of said aryl and aromatic heterocyclic substituents in parts (i) and (ii) being selected from the group consisting of hydroxy, aryl, mono(C_1-C_6)alkoxyaryl, di(C_1-C_6)alkoxyaryl, mono(C_1-C_6)alkylaryl, di(C_1-C_6)alkylaryl, bromoaryl, chloroaryl, fluoroaryl, C_3-C_7 cycloalkylaryl, C_3-C_7 cycloalkyl, C_3-C_7 cycloalkyloxy, C_3-C_7 cycloalkyloxy(C_1-C_6)alkyl, C_3-C_7 cycloalkyloxy(C_1-C_6)alkyl, C_3-C_7 cycloalkyloxy(C_1-C_6)alkoxy, aryl(C_1-C_6)alkyl,

aryl(C_1-C_6)alkoxy, aryloxy, aryloxy(C_1-C_6)alkyl, aryloxy(C_1-C_6)alkoxy, mono- and di(C_1-C_6)alkylaryl(C_1-C_6)alkyl, mono- and di(C_1-C_6)alkoxyaryl(C_1-C_6)alkyl, mono- and di(C_1-C_6)alkylaryl(C_1-C_6)alkoxy, mono- and di(C_1-C_6)alkoxyaryl(C_1-C_6)alkoxy, amino, mono(C_1-C_6)alkylamino, di(C_1-C_6)alkylamino, diarylamino, N-(C_1-C_6)alkylpiperazino, N-arylpiperazino, aziridino, indolino, piperidino, arylpiperidino, morpholino, thiomorpholino, tetrahydroquinolino, tetrahydroisoquinolino, pyrryl, C_1-C_6 alkyl, C_1-C_6 bromoalkyl, C_1-C_6 chloroalkyl, C_1-C_6 fluoroalkyl, C_1-C_6 alkoxy, mono(C_1-C_6)alkoxy(C_1-C_4)alkyl, acryloxy, methacryloxy, bromo, chloro and fluoro; (iii) the groups represented by the following graphic formulae:

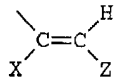


IIA



IIB

wherein E may be carbon or oxygen and D may be oxygen or substituted nitrogen, provided that when D is substituted nitrogen, E is carbon, said nitrogen substituents being selected from the group consisting of hydrogen, C_1-C_6 alkyl and C_2-C_6 acyl; each R_8 is C_1-C_6 alkyl, C_1-C_6 alkoxy, hydroxy, bromo, chloro or fluoro; R_9 and R_{10} are each hydrogen or C_1-C_6 alkyl; and p is the integer 0, 1 or 2; (iv) C_1-C_6 alkyl, C_1-C_6 bromoalkyl, C_1-C_6 chloroalkyl, C_1-C_6 fluoroalkyl, C_1-C_6 alkoxy(C_1-C_4)alkyl, C_3-C_6 cycloalkyl, mono(C_1-C_6)alkoxy(C_3-C_6)cycloalkyl, mono(C_1-C_6)alkyl(C_3-C_6)cycloalkyl, bromo(C_3-C_6)cycloalkyl, chloro(C_3-C_6)cycloalkyl and fluoro(C_3-C_6)cycloalkyl; and(v) the group represented by the following graphic formula:



IIC

wherein X in graphic formula IIC may be hydrogen or C_1-C_4 alkyl and Z in graphic formula IIC may be selected from the unsubstituted, mono-, and di-substituted members of the group consisting of naphthyl, phenyl, furanyl and thienyl, each of said group substituents in this part (v) being C_1-C_4 alkyl, C_1-C_4 alkoxy, bromo, fluoro or chloro; or (vi) B and B' taken together form fluoren-9-ylidene, mono- or di-substituted fluoren-9-ylidene or form a member selected from the group consisting of saturated C_3-C_{12} spiro-monocyclic hydrocarbon rings, e.g., cyclopropylidene, cyclobutylidene, cyclopentylidene, cyclohexylidene, cycloheptylidene, cyclooctylidene, cyclononylidene, cyclodecylidene cycloundecylidene and cyclododecylidene; saturated C_7-C_{12} spiro-bicyclic hydrocarbon rings, e.g., bicyclo[2.2.1]heptylidene, i.e., norbornylidene, 1,7,7-trimethyl bicyclo[2.2.1]heptylidene, i.e., bornylidene, bicyclo[3.2.1]octylidene, bicyclo[3.3.1]nonan-9-ylidene and bicyclo[4.3.2]undecane and saturated C_7-C_{12} spiro-tricyclic hydrocarbon rings, e.g., tricyclo[2.2.1.$0^{2,6}$]heptylidene and tricyclo[3.3.1.$1^{3,7}$]decylidene, i.e., adamantylidene, and tricyclo[5.3.1.$1^{2,6}$]dodecylidene, each of said fluoren-9-ylidene substituents being selected from the group consisting of C_1-C_4 alkyl, C_1-C_4 alkoxy, bromo, fluoro and chloro.

More preferably, B and B' are each selected from the group consisting of: (i) phenyl, mono-substituted phenyl and di-substituted phenyl, preferably substituted in the meta and/or para positions; (ii) the unsubstituted, mono- and di-substituted aromatic heterocyclic groups furanyl, benzofuran-2-yl, thienyl, benzothien-2-yl, dibenzofuran-2-yl and dibenzothien-2-yl, each of said phenyl and aromatic heterocyclic substituents in (i) and (ii) being selected from

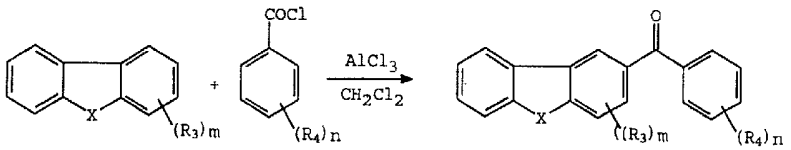
the group consisting of hydroxy, aryl, aryloxy, aryl(C_1-C_3)alkyl, amino, mono(C_1-C_3)alkylamino, di(C_1-C_3)alkylamino, N-(C_1-C_3)alkylpiperazino, indolino, piperidino, morpholino, pyrryl, C_1-C_3 alkyl, C_1-C_3 chloroalkyl, C_1-C_3 fluoroalkyl, C_1-C_3 alkoxy, mono(C_1-C_3)alkoxy(C_1-C_3)alkyl, fluoro and chloro; (iii) the groups represented by the graphic formulae IIA and IIB, wherein E is carbon and D is oxygen, R_8 is C_1-C_3 alkyl or C_1-C_3 alkoxy, R_9 and R_{10} are each hydrogen or C_1-C_4 alkyl; and p is the integer 0 or 1; (iv) C_1-C_4 alkyl; and (v) the group represented by the graphic formula IIC wherein X is hydrogen or methyl and Z is phenyl or mono-substituted phenyl, said phenyl substituent being selected from the group consisting of C_1-C_3 alkyl, C_1-C_3 alkoxy and fluoro; or (vi) B and B' taken together form fluoren-9-ylidene, mono-substituted fluoren-9-ylidene or a member selected from the group consisting of saturated C_3-C_8 spiro-monocyclic hydrocarbon rings, saturated C_7-C_{10} spiro-bicyclic hydrocarbon rings and saturated C_7-C_{10} spiro-tricyclic hydrocarbon rings, said fluoren-9-ylidene substituent being selected from the group consisting of C_1-C_3 alkyl, C_1-C_3 alkoxy, fluoro and chloro.

Most preferably, B and B' are each selected from the group consisting of (i) phenyl, mono- and di-substituted phenyl; (ii) the unsubstituted, mono- and di-substituted aromatic heterocyclic groups furanyl, benzofuran-2-yl, thienyl and benzothien-2-yl, each of said phenyl and aromatic heterocyclic substituents in (i) and (ii) being selected from the group consisting of hydroxy, C_1-C_3 alkyl, C_1-C_3 alkoxy, aryl, indolino, fluoro and chloro; and (iii) the group represented by graphic formula IIA, wherein E is carbon and D is oxygen, R_8 is C_1-C_3 alkyl or C_1-C_3 alkoxy, R_9 and R_{10} are each hydrogen or C_1-C_3 alkyl, and p is the integer 0 or 1; or (iv) B and B' taken together form fluoren-9-ylidene, adamantylidene, bornylidene, norbornylidene or bicyclo[3.3.1]nonan-9-ylidene.

Compounds represented by graphic formulae I and I' having the substituents R_3 and R_4, as described hereinbefore, may be prepared by the following described Reactions A through E. Compounds represented by graphic formula V or VA (as shown in Reactions A and B, respectively) are prepared by Friedel-Crafts methods shown in Reaction A using an appropriately substituted or unsubstituted benzoyl chloride of graphic formula IV with a commercially available substituted or unsubstituted heterocyclic compound of graphic formula III. See the publication Friedel-Crafts and Related Reactions, George A. Olah, Interscience Publishers, 1964, Vol. 3, Chapter XXXI (Aromatic Ketone Synthesis), and "Regioselective Friedel-Crafts Acylation of 1,2,3,4-Tetrahydroquinoline and Related Nitrogen Heterocycles: Effect on NH Protective Groups and Ring Size" by Ishihara, Yugi et al, J. Chem. Soc., Perkin Trans. 1, pages 3401 to 3406, 1992.

In Reaction A, the compounds represented by graphic formulae III (wherein X is oxygen, nitrogen or sulfur) and IV are dissolved in a solvent, such as carbon disulfide or methylene chloride, and reacted in the presence of a Lewis acid, such as aluminum chloride or tin tetrachloride, to form the corresponding substituted benzophenone represented by graphic formula V.

REACTION A

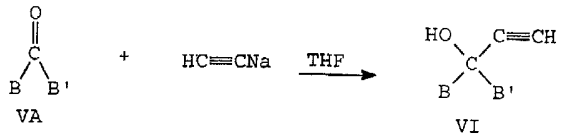


III IV V

In Reaction B, the substituted or unsubstituted ketone represented by graphic formula VA is reacted with sodium acetylide in a suitable solvent, such as anhydrous tetrahydrofuran (THF), to form the corresponding propargyl

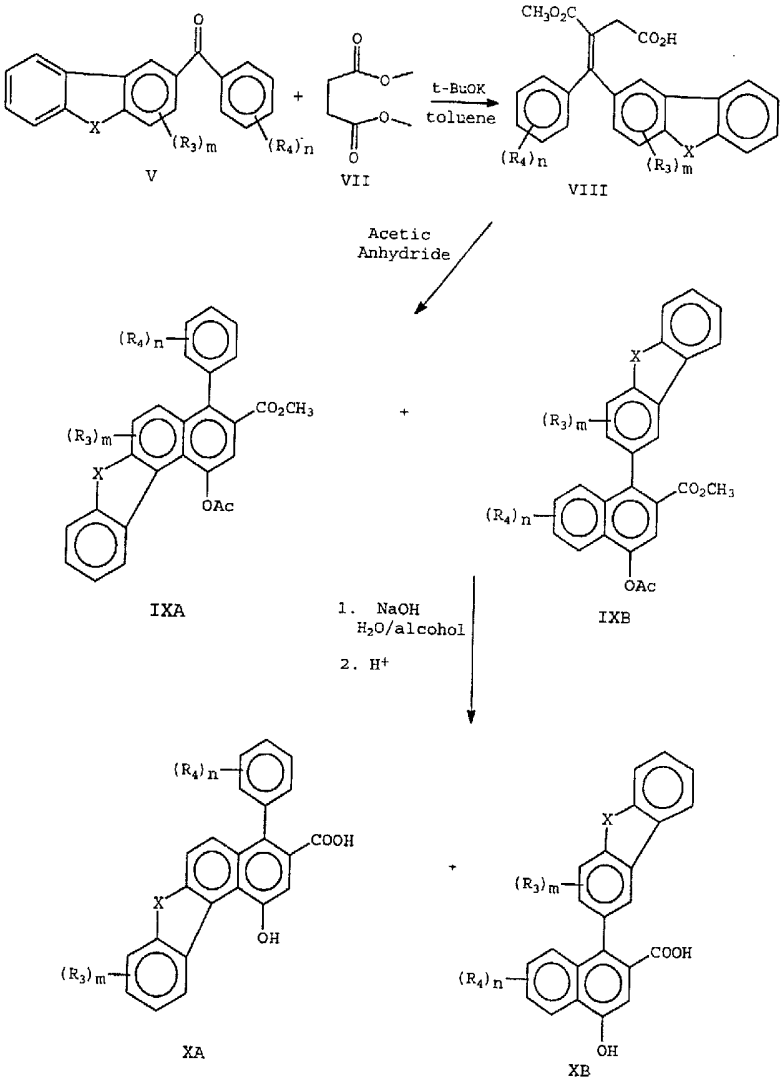
alcohol represented by graphic formula VI. Propargyl alcohols having B or B' groups other than substituted and unsubstituted phenyl may be prepared from commercially available ketones or ketones prepared via reaction of an acyl halide with a substituted or unsubstituted benzene, naphthalene or heteroaromatic compound. Propargyl alcohols having a B or B' group represented by graphic formula IIC may be prepared by the methods described in U.S. Patent 5,274,132, column 2, lines 40 to 68.

REACTION B



In Reaction C, the substituted or unsubstituted ketone represented by graphic formula V is reacted with an ester of succinic acid such as dimethyl succinate represented by graphic formula VII. Addition of the reactants to a solvent, e.g., toluene, containing potassium t-butoxide or sodium hydride as the base yields the Stobbe condensation half ester represented by graphic formula VIII. The half ester (VIII) undergoes cyclodehydration in the presence of acetic anhydride to form the heterofused acetoxynaphthalenes represented by graphic formulae IXA and IXB. Compounds IXA and IXB may be separated by crystallization, hydrolyzed in an aqueous alcoholic solution of a base, such as sodium hydroxide, followed by treatment with aqueous hydrochloric acid (H^+) to form the carboxynaphthols represented by graphic formula XA or XB, respectively.

REACTION C



V VII VIII

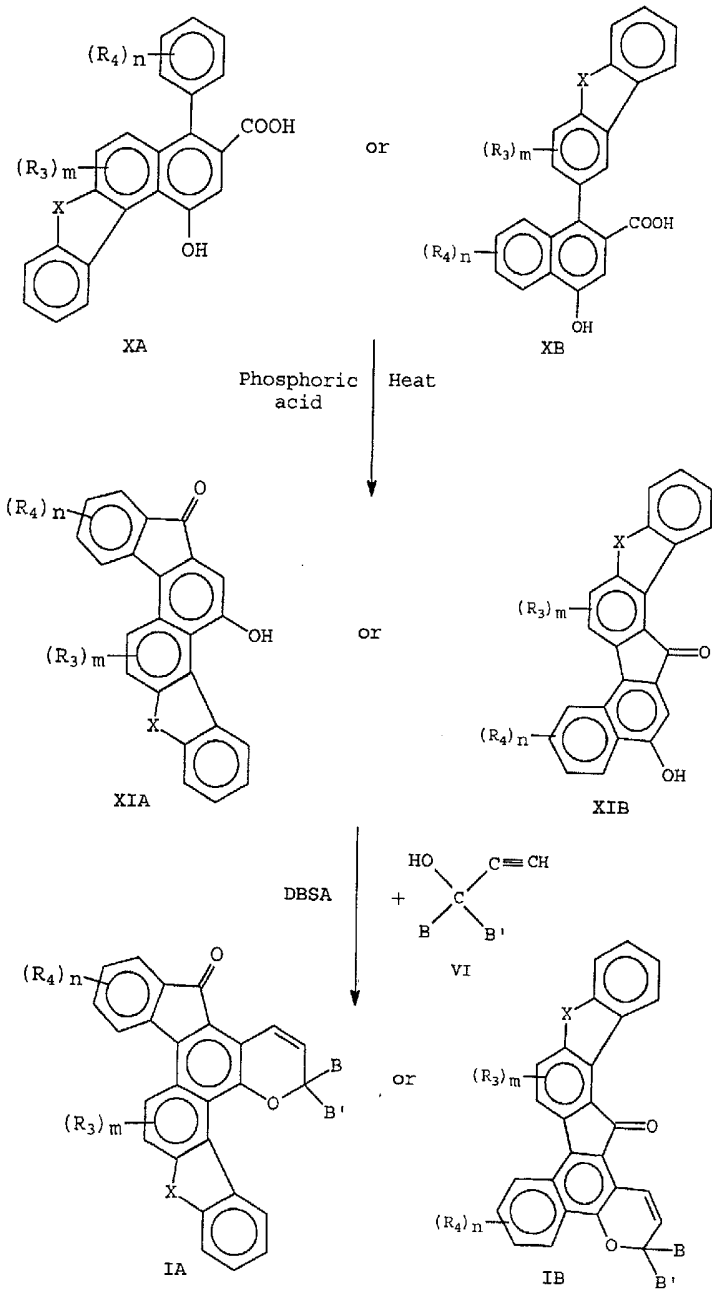
IXA IXB

XA XB

In Reaction D, the carboxynaphthols represented by graphic formulae XA and XB are cyclized by heating, e.g., from about 160 to about 220°C, in the presence of an acid, such as phosphoric acid, to form a hydroxy-substituted benz-fused fluorenone represented by graphic formulae XIA and XIB. See the article by F.G. Baddar et al, in the J. Chem. Soc., page 986, 1958. An alternate method of synthesizing the compound represented by graphic formula XIB is described by C.F. Koelsch in the Journal of Organic Chemistry, volume 26, page 2590, 1961.

Coupling of the compounds represented by graphic formulae XIA and XIB with propargyl alcohol represented by graphic formula VI in the presence of a catalytic amount of an acid, e.g., dodecylbenzene sulfonic acid (DBSA), results in the indeno-fused naphthopyran represented by graphic formulae IA and IB.

REACTION D

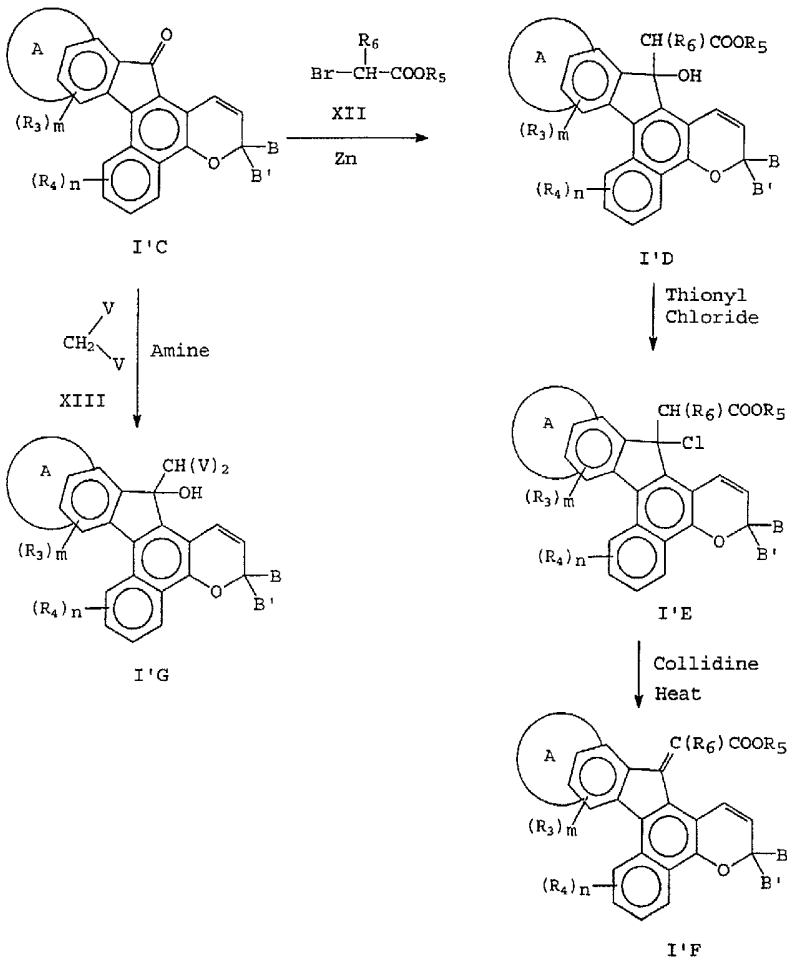

(R4)n
COOH
(R3)m
X
OH
or
XA
XB
Phosphoric acid
Heat
O
XIA
XIB
DBSA
HO
C≡CH
C
B
B'
VI
IA
IB

In Reaction E, further methods for preparing compounds represented by graphic formula I' having a variety of R_1 and R_2 substituents are described. Starting with the compound represented by graphic formula I'C, treatment with an α-bromoester of graphic formula XII in the presence of activated zinc dust results in the compound represented by graphic formula I'D. This reaction, referred to as the Reformatsky Reaction, is reviewed by R. L. Shriner in Organic Reactions Vol.1, pp 1-37, 1942. The compound represented by graphic formula I'D can be further reacted with chlorinating reagents, for example thionyl chloride, to produce derivatives represented by graphic formula I'E. The compound represented by graphic formula I'E can be dehydrohalogenated by heating in the presence of a tertiary amine, for example collidine, to yield α,β-unsaturated esters of graphic formula I'F.

Alternatively the compound represented by graphic formula I'C can be condensed with a compound containing an active methylene represented by graphic formula XIII in the presence of an amine to produce the compound represented by graphic formula I'G. This reaction, referred to as the Knoevenagel Condensation, is reviewed by G. Jones in Organic Reactions Vol. 15, pp 204-599, 1967.

All of the steps of Reaction E may also be conducted with a compound analogous to the compound represented by graphic formula I'C but having the A group in the position represented in graphic formula I.

REACTION E



Compounds represented by graphic formula I, I', IA, IB, I'C, I'D, I'E, I'F and I'G may be used in those applications in which organic photochromic substances may be employed, such as optical lenses, e.g., vision correcting ophthalmic lenses and plano lenses, face shields, goggles, visors, camera lenses, windows, automotive windshields,

aircraft and automotive transparencies, e.g., T-roofs, sidelights and backlights, plastic films and sheets, textiles and coatings, e.g., coating compositions such as paints, and verification marks on security documents, e.g., documents such as banknotes, passports and drivers' licenses for which authentication or verification of authenticity may be desired. Heterocyclic fused indenonaphthopyrans represented by the aforedescribed graphic formulae exhibit color changes from colorless to colors ranging from orange to blue/gray.

Examples of contemplated indenonaphthopyran compounds within the scope of the invention include the following:

(a) 3,3-di(4-methoxyphenyl)-16-(ethoxycarbonyl) methyl-16-hydroxy-3,16-di[H]-benzofuro[2',3':7,8]indeno [2',3':3,4]naphtho[1,2-b]pyran;

(b) 3-(4-methoxyphenyl)-3-(4-morpholinophenyl)-16-(ethoxycarbonyl)methyl-16-hydroxy-3,16-di[H]-benzofuro [2',3':7,8]indeno[2',3':3,4]naphtho[1,2-b]pyran;

(c) 3-phenyl-3-(4-methoxyphenyl)-16-(ethoxycarbonyl)methyl-16-hydroxy-3,16-di[H]-benzofuro [2",3":6',7']indeno[3',2':4,3]naphtho[1,2-b]pyran; and

(d) 3-phenyl-3-(4-morpholinophenyl)-16-(ethoxycarbonyl)methyl-16-hydroxy-3,16-di[H]-benzofuro [2",3":6',7']indeno[3',2':4,3]naphtho[1,2-b]pyran.

It is contemplated that the organic photochromic indenonaphthopyrans of the present invention may be used alone, in combination with other indenonaphthopyrans of the present invention, or in combination with one or more other appropriate complementary organic photochromic materials, i.e., organic photochromic compounds having at least one activated absorption maxima within the range of between about 400 and 700 nanometers, or substances containing same, and may be incorporated, e.g., dissolved or dispersed, in a polymeric organic host material used to prepare photochromic articles and which color when activated to an appropriate hue.

Other than where otherwise indicated, all numbers expressing wavelengths, quantities of ingredients or reaction conditions used herein are to be understood as modified in all instances by the term "about".

Examples of complementary organic photochromic compounds include other indenonaphthopyrans, chromenes and oxazines, e.g., naphthopyrans having the 2,1 positions of an indeno group fused to the f side of the naphtho portion, and certain substituents at the 3 position of the pyran ring, substituted 2H-phenanthro[4,3-b]pyran and 3H-phenanthro[1,2-b]pyran compounds, benzopyran compounds having substituents at the 2-position of the pyran ring including a dibenzo-fused 5 member heterocyclic compound and a substituted or unsubstituted heterocyclic ring, such as a benzothieno or benzofurano ring fused to the benzene portion of the benzopyrans, spiro(benzindoline)naphthopyrans, spiro(indoline)benzopyrans, spiro(indoline)naphthopyrans, spiro(indoline)quinopyrans, spiro(indoline)pyrans, spiro(indoline)napthoxazines, spiro(indoline)pyridobenzoxazines, spiro(benzindoline)pyridobenzoxazines, spiro(benzindoline)naphthoxazines, spiro(indoline)benzoxazines, and mixtures of such photochromic compounds. Many of such photochromic compounds are described in the open literature, e.g., U.S. Patents 3,562,172; 3,567,605; 3,578,602; 4,215,010; 4,342,668; 4,816,584; 4,818,096; 4,826,977; 4,880,667; 4,931,219; 5,066,818; 5,238,931; 5,274,132; 5,384,077; 5,405,958; 5,429,774; 5,466,398; 5,514,817; 5,552,090; 5,552,091; 5,565,146; 5,573,712; 5,578,252; WO 96 14596 and Japanese Patent Publication 62/195383. Spiro(indoline)pyrans are also described in the text, Techniques in Chemistry, Volume III, "Photochromism", Chapter 3, Glenn H. Brown, Editor, John Wiley and Sons, Inc., New York, 1971.

Other photochromic substances contemplated are photochromic metal-dithizonates, e.g. mercury dithizonates

which are described in, for example, U.S. Patent 3,361,706, fulgides and fulgimides, e.g. the 3-furyl and 3-thienyl fulgides and fulgimides which are described in U.S. Patent 4,931,220 at column 20, line 5 through column 21, line 38.

The disclosures relating to such photochromic compounds in the aforedescribed patents are incorporated herein, *in toto*, by reference. The photochromic articles of the present invention may contain one photochromic compound or a mixture of photochromic compounds, as desired.

Each of the photochromic substances described herein may be used in amounts (or in a ratio) such that an organic host material to which the photochromic compounds or mixture of compounds is applied or in which they are incorporated exhibits a desired resultant color, e.g., a substantially neutral color when activated with unfiltered sunlight, i.e., as near a neutral color as possible given the colors of the activated photochromic compounds. Neutral gray and neutral brown colors are preferred.

A neutral gray color exhibits a spectrum that has relatively equal absorption in the visible range between 400 and 700 nanometers. A neutral brown color exhibits a spectrum in which the absorption in the 400-550 nanometer range is moderately larger than in the 550-700 nanometer range. An alternative way of describing color is in terms of its chromaticity coordinates, which describe the qualities of a color in addition to its luminance factor, i.e., its chromaticity. In the CIE system, the chromaticity coordinates are obtained by taking the ratios of the tristimulus values to their sum, e.g., $x=X/(X+Y+Z)$ and $y=Y/(X+Y+Z)$. Color as described in the CIE system can be plotted on a chromaticity diagram, usually a plot of the chromaticity coordinates x and y. See pages 47-52 of Principles of Color Technology, by F. W. Billmeyer, Jr., and Max Saltzman, Second Edition, John Wiley and Sons, N.Y. (1981). As used herein, a near neutral color is one in which the chromaticity coordinate values of "x" and "y" for the color are within the following ranges (D65

illuminant): x = 0.260 to 0.400, y = 0.280 to 0.400 following activation to 40 percent luminous transmission by exposure to solar radiation (Air Mass 1 or 2).

The amount of photochromic substance or composition containing same applied to or incorporated into a host material is not critical provided that a sufficient amount is used to produce a photochromic effect discernible to the naked eye upon activation. Generally such amount can be described as a photochromic amount. The particular amount used depends often upon the intensity of color desired upon irradiation thereof and upon the method used to incorporate or apply the photochromic substances. Typically, the more photochromic substance applied or incorporated, the greater is the color intensity up to a certain limit.

The relative amounts of the aforesaid photochromic compounds used will vary and depend in part upon the relative intensities of the color of the activated species of such compounds, and the ultimate color desired. Generally, the amount of total photochromic substance incorporated into or applied to a photochromic optical host material may range from 0.05 to 1.0, e.g., from 0.1 to 0.45, milligrams per square centimeter of surface to which the photochromic substance(s) is incorporated or applied.

The photochromic substances of the present invention may be applied to or incorporated into a host material such as a polymeric organic host material by various methods described in the art. Such methods include dissolving or dispersing the photochromic substance within the host material, e.g., casting it in place by adding the photochromic substance to the monomeric host material prior to polymerization; imbibition of the photochromic substance into the host material by immersion of the host material in a hot solution of the photochromic substance or by thermal transfer; providing the photochromic substance as a separate layer between adjacent layers of the host material, e.g., as a part of a polymeric film; and applying the photochromic substance

as part of a coating or film placed on the surface of the host material. The term "imbibition" or "imbibe" is intended to mean and include permeation of the photochromic substance alone into the host material, solvent assisted transfer of the photochromic substance into a porous polymer, vapor phase transfer, and other such transfer mechanisms.

Compatible (chemically and color-wise) tints, i.e., dyes, may be applied to the host material to achieve a more aesthetic result, for medical reasons, or for reasons of fashion. The particular dye selected will vary and depend on the aforesaid need and result to be achieved. In one embodiment, the dye may be selected to complement the color resulting from the activated photochromic substances, e.g., to achieve a more neutral color or absorb a particular wavelength of incident light. In another embodiment, the dye may be selected to provide a desired hue to the host matrix when the photochromic substances is in an unactivated state.

The host material will usually be transparent, but may be translucent or even opaque. The host material need only be transparent to that portion of the electromagnetic spectrum, which activates the photochromic substance, i.e., that wavelength of ultraviolet (UV) light that produces the open form of the substance and that portion of the visible spectrum that includes the absorption maximum wavelength of the substance in its UV activated form, i.e., the open form. Preferably, the host color should not be such that it masks the color of the activated form of the photochromic substance, i.e., so the change in color is readily apparent to the observer. More preferably, the host material article is a solid transparent or optically clear material, e.g., materials suitable for optical applications, such as plano and ophthalmic lenses, windows, automotive transparencies, e.g., windshields, aircraft transparencies, plastic sheeting, polymeric films, etc.

Examples of polymeric organic host materials which may be used with the photochromic substances or compositions

described herein include: polymers, i.e., homopolymers and copolymers, of polyol(allyl carbonate) monomers, diethylene glycol dimethacrylate monomers, diisopropenyl benzene monomers, ethoxylated bisphenol A dimethacrylate monomers, ethylene glycol bismethacrylate monomers, poly(ethylene glycol) bismethacrylate monomers, ethoxylated phenol methacrylate monomers and alkoxylated polyhydric alcohol acrylate monomers, such as ethoxylated trimethylol propane triacrylate monomers; polymers, i.e., homopolymers and copolymers, of polyfunctional, e.g., mono-, di- or multi-functional, acrylate and/or methacrylate monomers, poly(C_1-C_{12} alkyl methacrylates), such as poly(methyl methacrylate), poly(oxyalkylene dimethacrylates), poly(alkoxylated phenol methacrylates), cellulose acetate, cellulose triacetate, cellulose acetate propionate, cellulose acetate butyrate, poly(vinyl acetate), poly(vinyl alcohol), poly(vinyl chloride), poly(vinylidene chloride), polyurethanes, thermoplastic polycarbonates, polyesters, poly(ethylene terephthalate), polystyrene, poly(alpha methylstyrene), copoly(styrene-methyl methacrylate), copoly(styrene-acrylonitrile), polyvinylbutyral and polymers, i.e., homopolymers and copolymers, of diallylidene pentaerythritol, particularly copolymers with polyol (allyl carbonate) monomers, e.g., diethylene glycol bis(allyl carbonate), and acrylate monomers.

Transparent copolymers and blends of transparent polymers are also suitable as host materials. Preferably, the host material is an optically clear polymerized organic material prepared from a thermoplastic polycarbonate resin, such as the carbonate-linked resin derived from bisphenol A and phosgene, which is sold under the trademark, LEXAN; a polyester, such as the material sold under the trademark, MYLAR; a poly(methyl methacrylate), such as the material sold under the trademark, PLEXIGLAS; polymerizates of a polyol(allyl carbonate) monomer, especially diethylene glycol bis(allyl carbonate), which monomer is sold under the

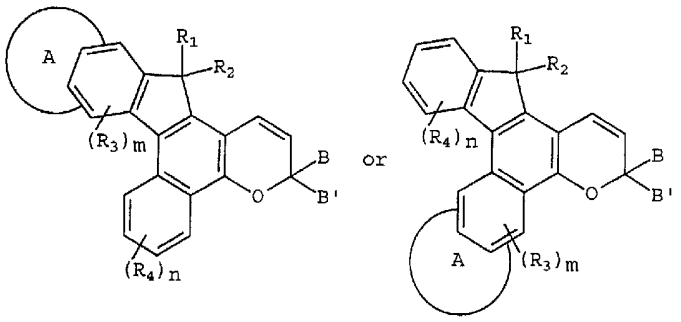
trademark CR-39, and polymerizates of copolymers of a polyol (allyl carbonate), e.g., diethylene glycol bis(allyl carbonate), with other copolymerizable monomeric materials, such as copolymers with vinyl acetate, e.g., copolymers of from 80-90 percent diethylene glycol bis(allyl carbonate) and 10-20 percent vinyl acetate, particularly 80-85 percent of the bis(allyl carbonate) and 15-20 percent vinyl acetate, and copolymers with a polyurethane having terminal diacrylate functionality, as described in U.S. patents 4,360,653 and 4,994,208; and copolymers with aliphatic urethanes, the terminal portion of which contain allyl or acrylyl functional groups, as described in U.S. Patent 5,200,483; poly(vinyl acetate), polyvinylbutyral, polyurethane, polymers of members of the group consisting of diethylene glycol dimethacrylate monomers, diisopropenyl benzene monomers, ethoxylated bisphenol A dimethacrylate monomers, ethylene glycol bismethacrylate monomers, poly(ethylene glycol) bismethacrylate monomers, ethoxylated phenol methacrylate monomers and ethoxylated trimethylol propane triacrylate monomers; cellulose acetate, cellulose propionate, cellulose butyrate, cellulose acetate butyrate, polystyrene and copolymers of styrene with methyl methacrylate, vinyl acetate and acrylonitrile.

More particularly contemplated is use of the photochromic indenonaphthopyrans of the present invention with optical organic resin monomers used to produce optically clear polymerizates, i.e., materials suitable for optical applications, such as for example plano and ophthalmic lenses, windows, and automotive transparencies. Such optically clear polymerizates may have a refractive index that may range from about 1.48 to about 1.75, e.g., from about 1.495 to about 1.66. Specifically contemplated are optical resins sold by PPG Industries, Inc. under the designation CR-307 and CR-407.

Although the present invention has been described with reference to the specific details of particular embodiments thereof, it is not intended that such details be regarded as limitations upon the scope of the invention except as and to the extent that they are included in the accompanying claims.

We claim:

1. An indenonaphthopyran compound represented by the following graphic formulae:



wherein,

(a) A is an unsubstituted, mono-substituted or di-substituted heterocyclic ring selected from the group consisting of benzothieno, benzofurano and indolo, the 2,3 or 3,2 positions of said heterocyclic ring being fused to the g, h, i, n, o or p side of said indenonaphthopyran, said heterocyclic ring substituents being C_1-C_6 alkyl, C_5-C_7 cycloalkyl, C_1-C_6 alkoxy, bromo, chloro or fluoro;

(b) R_1 is hydrogen, hydroxy, bromo, fluoro or chloro and R_2 is the group, $-CH(V)_2$, wherein V is -CN or $-COOR_5$, and each R_5 is hydrogen, C_1-C_6 alkyl, phenyl(C_1-C_3)alkyl, mono(C_1-C_6)alkyl substituted phenyl(C_1-C_3)alkyl, mono(C_1-C_6)alkoxy substituted phenyl(C_1-C_3)alkyl or the unsubstituted, mono- or di-substituted aryl groups phenyl or naphthyl, or R_2 is the group, $-CH(R_6)Y$, wherein R_6 is hydrogen, C_1-C_6 alkyl or the unsubstituted, mono- or di-substituted aryl groups phenyl or naphthyl, and Y is $-COOR_5$, $-COR_7$, or $-CH_2OR_{11}$, wherein R_7 is hydrogen, C_1-C_6 alkyl, the unsubstituted, mono- or di-substituted aryl groups phenyl or naphthyl, amino,

mono(C_1-C_6)alkylamino, di(C_1-C_6)alkylamino, phenylamino, mono- or di-(C_1-C_6)alkyl substituted phenylamino, mono- or di-(C_1-C_6)alkoxy substituted phenylamino, diphenylamino, mono- or di-(C_1-C_6)alkyl substituted diphenylamino, mono- or di-(C_1-C_6)alkoxy substituted diphenylamino, morpholino, or piperidino; R_{11} is hydrogen, -COR_5, C_1-C_6 alkyl, C_1-C_3 alkoxy(C_1-C_6)alkyl, phenyl(C_1-C_3)alkyl, mono(C_1-C_6)alkyl substituted phenyl(C_1-C_3)alkyl, mono(C_1-C_6)alkoxy substituted phenyl(C_1-C_3)alkyl, or the unsubstituted, mono- or di-substituted aryl groups phenyl or naphthyl, each of all of said aryl group substituents being C_1-C_6 alkyl or C_1-C_6 alkoxy; or

(c) R_1 and R_2 together form the group, $=C(V)_2$ or $=C(R_6)W$, wherein W is -$COOR_5$ or -COR_7;

(d) R_3 and R_4 are each C_1-C_6 alkyl, C_1-C_6 alkoxy, bromo, chloro or fluoro, and m and n are each the integers 0, 1 or 2; and

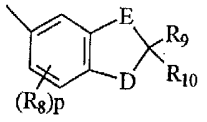
(e) B and B' are each selected from the group consisting of:

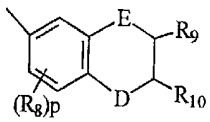
(i) the unsubstituted, mono-, di- and tri-substituted aryl groups, phenyl and naphthyl;

(ii) the unsubstituted, mono- and di-substituted aromatic heterocyclic groups pyridyl, furanyl, benzofuran-2-yl, benzofuran-3-yl, thienyl, benzothien-2-yl, benzothien-3-yl, dibenzofuranyl, dibenzothienyl, carbazolyl and fluorenyl, each of said aryl and aromatic heterocyclic substituents in (e)(i) and (ii) being selected from the group consisting of hydroxy, aryl, mono(C_1-C_6)alkoxyaryl, di(C_1-C_6)alkoxyaryl, mono(C_1-C_6)alkylaryl, di(C_1-C_6)alkylaryl, bromoaryl, chloroaryl, fluoroaryl, C_3-C_7 cycloalkylaryl, C_3-C_7 cycloalkyl, C_3-C_7 cycloalkyloxy, C_3-C_7 cycloalkyloxy(C_1-C_6)alkyl, C_3-C_7 cycloalkyloxy(C_1-C_6)alkyl, C_3-C_7 cycloalkyloxy(C_1-C_6)alkoxy, aryl(C_1-C_6)alkyl, aryl(C_1-C_6)alkoxy, aryloxy, aryloxy(C_1-C_6)alkyl, aryloxy(C_1-C_6)alkoxy, mono- and di-(C_1-C_6)alkylaryl(C_1-C_6)alkyl,

mono- and di-(C_1-C_6)alkoxyaryl(C_1-C_6)alkyl, mono- and di-(C_1-C_6)alkylaryl(C_1-C_6)alkoxy, mono- and di-(C_1-C_6)alkoxyaryl(C_1-C_6)alkoxy, amino, mono(C_1-C_6)alkylamino, di(C_1-C_6)alkylamino, diarylamino, N-(C_1-C_6)alkylpiperazino, N-arylpiperazino, aziridino, indolino, piperidino, arylpiperidino, morpholino, thiomorpholino, tetrahydroquinolino, tetrahydroisoquinolino, pyrryl, C_1-C_6 alkyl, C_1-C_6 bromoalkyl, C_1-C_6 chloroalkyl, C_1-C_6 fluoroalkyl, C_1-C_6 alkoxy, mono(C_1-C_6)alkoxy(C_1-C_4)alkyl, acryloxy, methacryloxy, bromo, chloro and fluoro;

(iii) the groups represented by the following graphic formulae:

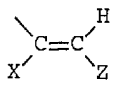




wherein E is carbon or oxygen and D is oxygen or substituted nitrogen, provided that when D is substituted nitrogen, E is carbon, said nitrogen substituents being selected from the group consisting of hydrogen, C_1-C_6 alkyl and C_2-C_6 acyl; each R_8 is C_1-C_6 alkyl, C_1-C_6 alkoxy, hydroxy, bromo, chloro or fluoro; R_9 and R_{10} are each hydrogen or C_1-C_6 alkyl; and p is the integer 0, 1 or 2;

(iv) C_1-C_6 alkyl, C_1-C_6 bromoalkyl, C_1-C_6 chloroalkyl, C_1-C_6 fluoroalkyl, C_1-C_6 alkoxy(C_1-C_4)alkyl, C_3-C_6 cycloalkyl, mono(C_1-C_6) alkoxy(C_3-C_6)cycloalkyl, mono(C_1-C_6)alkyl(C_3-C_6)-cycloalkyl, bromo(C_3-C_6)cycloalkyl, chloro(C_3-C_6)cycloalkyl and fluoro(C_3-C_6)cyclo-alkyl; and

(v) the group represented by the following graphic formula:



wherein X is hydrogen or C_1-C_4 alkyl and Z is selected from the unsubstituted, mono-, and di-substituted members of the group consisting of naphthyl, phenyl, furanyl and thienyl, each of said group substituents being C_1-C_4 alkyl, C_1-C_4 alkoxy, bromo, fluoro or chloro; or

(vi) B and B' taken together form fluoren-9-ylidene, mono- or di-substituted fluoren-9-ylidene or a member selected from the group consisting of saturated C_3-C_{12} spiro-monocyclic hydrocarbon rings, saturated C_7-C_{12} spiro-bicyclic hydrocarbon rings, and saturated C_7-C_{12} spiro-tricyclic hydrocarbon rings, each of said fluoren-9-ylidene substituents being selected from the group consisting of C_1-C_4 alkyl, C_1-C_4 alkoxy, bromo, fluoro and chloro.

2. The indenonaphthopyran of claim 1 wherein:

(a) the heterocyclic ring A is unsubstituted or mono-substituted, and said heterocyclic ring substituents are C_1-C_4 alkyl or C_1-C_4 alkoxy;

(b) R_1 is hydrogen, hydroxy, fluoro or chloro and R_2 is the group, $-CH(V)_2$, wherein V is -CN or $-COOR_5$, and each R_5 is hydrogen, C_1-C_4 alkyl, phenyl(C_1-C_2)alkyl, mono(C_1-C_4)alkyl substituted phenyl(C_1-C_2)alkyl, mono(C_1-C_4)alkoxy substituted phenyl(C_1-C_2)alkyl or the unsubstituted or mono-substituted aryl groups phenyl or naphthyl, or R_2 is the group, $-CH(R_6)Y$, wherein R_6 is hydrogen, C_1-C_4 alkyl or the unsubstituted or mono-substituted aryl groups phenyl or naphthyl, and Y is $-COOR_5$, $-COR_7$, or $-CH_2OR_{11}$, wherein R_7 is hydrogen, C_1-C_4 alkyl, the unsubstituted or mono-substituted aryl groups phenyl or naphthyl, amino, mono(C_1-C_4)alkylamino, di(C_1-C_4)alkylamino, phenylamino, mono- or di-(C_1-C_4)alkyl substituted phenylamino,

mono- or di-(C_1-C_4)alkoxy substituted phenylamino, diphenylamino, mono- or di-(C_1-C_4)alkyl substituted diphenylamino, mono- or di-(C_1-C_4)alkoxy substituted diphenylamino, morpholino or piperidino; R_{11} is hydrogen, -COR_5, C_1-C_4 alkyl, C_1-C_2 alkoxy(C_1-C_4)alkyl, phenyl(C_1-C_2)alkyl, mono(C_1-C_4)alkyl substituted phenyl(C_1-C_2)alkyl, mono(C_1-C_4)alkoxy substituted phenyl(C_1-C_2)alkyl or the unsubstituted or mono-substituted aryl groups phenyl or naphthyl, each of all of said aryl group substituents being C_1-C_4 alkyl or C_1-C_4 alkoxy; or

(c) R_1 and R_2 together form the group, $=C(V)_2$ or $=C(R_6)W$, wherein W is -$COOR_5$ or -COR_7;

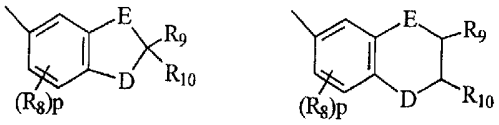
(d) R_3 and R_4 are each C_1-C_4 alkyl, C_1-C_4 alkoxy, chloro or fluoro, and m and n are each the integers 0 or 1; and

(e) B and B.' are each selected from the group consisting of:

(i) phenyl, mono-substituted phenyl and di-substituted phenyl;

(ii) the unsubstituted, mono-substituted and di-substituted aromatic heterocyclic groups furanyl, benzofuran-2-yl, thienyl, benzothien-2-yl, dibenzofuran-2-yl, and dibenzothien-2-yl, each of said phenyl and aromatic heterocyclic substituents in (e)(i) and (ii) being selected from the group consisting of hydroxy, aryl, aryloxy, aryl(C_1-C_3)alkyl, amino, mono(C_1-C_3)alkylamino, di(C_1-C_3)alkylamino, N-(C_1-C_3)alkylpiperazino, indolino, piperidino, morpholino, pyrryl, C_1-C_3 alkyl, C_1-C_3 chloroalkyl, C_1-C_3 fluoroalkyl, C_1-C_3 alkoxy, mono(C_1-C_3)alkoxy(C_1-C_3)alkyl, fluoro and chloro;

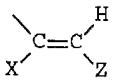
(iii) the groups represented by the following graphic formulae:



wherein E is carbon and D is oxygen, R_8 is C_1-C_3 alkyl or C_1-C_3 alkoxy, R_9 and R_{10} are each hydrogen or C_1-C_4 alkyl; and p is the integer 0 or 1;

(iv) C_1-C_4 alkyl; and

(v) the group represented by the following graphic formula:



wherein X is hydrogen or methyl and Z is phenyl or mono-substituted phenyl, said phenyl substituent being selected from the group consisting of C_1-C_3 alkyl, C_1-C_3 alkoxy and fluoro; or

(vi) B and B' taken together form a fluoren-9-ylidene, mono-substituted fluoren-9-ylidene or a member selected from the group consisting of saturated C_3-C_8 spiro-monocyclic hydrocarbon rings, saturated C_7-C_{10} spiro-bicyclic hydrocarbon rings and saturated C_7-C_{10} spiro-tricyclic hydrocarbon rings, said fluoren-9-xylidene substituent being selected from the group consisting of C_1-C_3 alkyl, C_1-C_3 alkoxy, fluoro and chloro.

3. The indenonaphthopyran of claim 2 wherein:

(a) the heterocyclic ring A is unsubstituted or mono-substituted, the 2,3 or 3,2 position of said heterocyclic ring being fused to the g or p side of said indenonaphthopyran, and said heterocyclic ring substituents being C_1-C_3 alkyl or C_1-C_3 alkoxy;

(b) R_1 is hydrogen, hydroxy or chloro and R_2 is the group, $-CH(V)_2$, wherein V is -CN, or R_2 is the group,

$-CH(R_6)Y$, wherein R_6 is hydrogen or C_1-C_4 alkyl, and Y is $-COOR_5$ or $-CH_2OR_{11}$, wherein R_5 is hydrogen or C_1-C_4 alkyl, R_{11} is hydrogen, $-COR_5$ or C_1-C_4 alkyl; or

(c) R_1 and R_2 together form the group $=C(V)_2$ or $=C(R_6)W$, wherein W is $-COOR_5$;

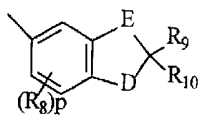
(d) R_3 and R_4 are each C_1-C_3 alkyl or C_1-C_3 alkoxy, and m and n are each the integers 0 or 1; and

(e) B and B' are each selected from the group consisting of:

(i) phenyl, mono-substituted and di-substituted phenyl;

(ii) the unsubstituted, mono-, and di-substituted aromatic heterocyclic groups furanyl, benzofuran-2-yl, thienyl and benzothien-2-yl, each of said phenyl and aromatic heterocyclic substituents in (e)(i) and (ii) being selected from the group consisting of hydroxy, C_1-C_3 alkyl, C_1-C_3 alkoxy, aryl, indolino, fluoro and chloro; and

(iii) the group represented by the following graphic formula:



wherein E is carbon and D is oxygen, R_8 is C_1-C_3 alkyl or C_1-C_3 alkoxy, R_9 and R_{10} are each hydrogen or C_1-C_3 alkyl, and p is the integer 0 or 1; or

(iv) B and B' taken together form fluoren-9-ylidene, adamantylidene, bornylidene, norbornylidene or bicyclo(3.3.1)nonan-9-ylidene.

4. An indenonaphthopyran compound selected from the group consisting of:

(a) 3,3-di(4-methoxyphenyl)-16-(ethoxycarbonyl) methyl-16-hydroxy-3,16-di[H]-benzofuro[2',3':7,8]indeno [2',3':3,4]naphtho[1,2-b]pyran;

(b) 3-(4-methoxyphenyl)-3-(4-morpholinophenyl)-16-(ethoxycarbonyl)methyl-16-hydroxy-3,16-di[H]-benzofuro [2',3':7,8]indeno[2',3':3,4]naphtho[1,2-b]pyran;

(c) 3-phenyl-3-(4-methoxyphenyl)-16-(ethoxycarbonyl)methyl-16-hydroxy-3,16-di[H]-benzofuro [2",3":6',7']indeno[3',2':4,3]naphtho[1,2-b]pyran; and

(d) 3-phenyl-3-(4-morpholinophenyl)-16-(ethoxycarbonyl)methyl-16-hydroxy-3,16-di[H]-benzofuro [2",3":6',7']indeno[3',2':4,3]naphtho[1,2-b]pyran.

5. A photochromic article comprising a polymeric organic host material and a photochromic amount of the indenonaphthopyran compound of claim 1.

6. The photochromic article of Claim 5 wherein the polymeric organic host material is selected from the group consisting of poly(C_1-C_{12} alkyl methacrylates), poly(oxyalkylene dimethacrylates), poly(alkoxylated phenol methacrylates), cellulose acetate, cellulose triacetate, cellulose acetate propionate, cellulose acetate butyrate, poly(vinyl acetate), poly(vinyl alcohol), poly(vinyl chloride), poly(vinylidene chloride), thermoplastic polycarbonates, polyesters, polyurethanes, poly(ethylene terephthalate), polystyrene, poly(alpha methylstyrene), copoly(styrene-methylmethacrylate), copoly(styrene-acrylonitrile), polyvinylbutyral and polymers of members of the group consisting of polyol(allyl carbonate) monomers, polyfunctional acrylate monomers, polyfunctional methacrylate monomers, diethylene glycol dimethacrylate monomers, diisopropenyl benzene monomers, ethoxylated bisphenol A

dimethacrylate monomers, ethylene glycol bismethacrylate monomers, poly(ethylene glycol) bismethacrylate monomers, ethoxylated phenol methacrylate monomers, alkoxylated polyhydric alcohol acrylate monomers and diallylidene pentaerythritol monomers.

7. The photochromic article of Claim 6 wherein the polymeric organic host material is a solid transparent polymer selected from the group consisting of poly(methyl methacrylate), poly(ethylene glycol bismethacrylate), poly(ethoxylated bisphenol A dimethacrylate), thermoplastic polycarbonate, poly(vinyl acetate), polyvinylbutyral, polyurethane and polymers of members of the group consisting of diethylene glycol bis(allyl carbonate) monomers, diethylene glycol dimethacrylate monomers, ethoxylated phenol methacrylate monomers, diisopropenyl benzene monomers and ethoxylated trimethylol propane triacrylate monomers.

8. The photochromic article of Claim 7 wherein the photochromic compound is present in an amount of from 0.05 to 1.0 milligram per square centimeter of organic host material surface to which the photochromic substance(s) is incorporated or applied.

9. The photochromic article of Claim 8 wherein the article is a lens.

10. A photochromic article comprising a polymeric organic host material selected from the group consisting of poly(methyl methacrylate), poly(ethylene glycol bismethacrylate), poly(ethoxylated bisphenol A dimethacrylate), thermoplastic polycarbonate, poly(vinyl acetate), polyvinylbutyral, polyurethane and polymers of members of the group consisting of diethylene glycol bis(allyl carbonate) monomers, diethylene glycol dimethacrylate monomers, ethoxylated phenol methacrylate monomers,

diisopropenyl benzene monomers and ethoxylated trimethylol propane triacrylate monomers and a photochromic amount of the naphthopyran compound of claim 2.

11. A photochromic article comprising a polymeric organic host material selected from the group consisting of poly(methyl methacrylate), poly(ethylene glycol bismethacrylate), poly(ethoxylated bisphenol A dimethacrylate), thermoplastic polycarbonate, poly(vinyl acetate), polyvinylbutyral, polyurethane and polymers of members of the group consisting of diethylene glycol bis(allyl carbonate) monomers, diethylene glycol dimethacrylate monomers, ethoxylated phenol methacrylate monomers, diisopropenyl benzene monomers and ethoxylated trimethylol propane triacrylate monomers, and a photochromic amount of the naphthopyran compound of claim 3.

12. A photochromic article comprising a polymerizate of an optical organic resin monomer and a photochromic amount of the indenonaphthopyran compound of claim 1.

13. The photochromic article of claim 12 wherein the refractive index of the polymerizate is from about 1.48 to about 1.75.

14. The photochromic article of claim 13 wherein the refractive index of the polymerizate is from about 1.495 to about 1.66.

15. A photochromic article comprising, in combination, a solid transparent polymeric organic host material, and a photochromic amount of each of (a) at least one indenonaphthopyran compound of claim 1, and (b) at least one other organic photochromic compound having at least one

activated absorption maxima within the range of between about 400 and 700 nanometers.

16. The photochromic article of Claim 15 wherein the polymeric organic host material is selected from the group consisting of poly(C_1-C_{12} alkyl methacrylates), poly(oxyalkylene dimethacrylates), poly(alkoxylated phenol methacrylates), cellulose acetate, cellulose triacetate, cellulose acetate propionate, cellulose acetate butyrate, poly(vinyl acetate), poly(vinyl alcohol), poly(vinyl chloride), poly(vinylidene chloride), thermoplastic polycarbonates, polyesters, polyurethanes, poly(ethylene terephthalate), polystyrene, poly(alpha methylstyrene), copoly(styrene-methylmethacrylate), copoly(styrene-acrylonitrile), polyvinylbutyral and polymers of members of the group consisting of polyol(allyl carbonate) monomers, polyfunctional acrylate monomers, polyfunctional methacrylate monomers, diethylene glycol dimethacrylate monomers, ethoxylated bisphenol A dimethacrylate monomers, diisopropenyl benzene monomers, ethylene glycol bismethacrylate monomers, poly(ethylene glycol) bismethacrylate monomers, ethoxylated phenol methacrylate monomers, alkoxylated polyhydric alcohol acrylate monomers and diallylidene pentaerythritol monomers.

17. The photochromic article of Claim 16 wherein the polymeric organic host material is a solid transparent homopolymer or copolymer selected from the group consisting of poly(methyl methacrylate), poly(ethylene glycol bis methacrylate), poly(ethoxylated bisphenol A dimethacrylate), thermoplastic polycarbonate, poly(vinyl acetate), polyvinylbutyral, polyurethane and polymers of members of the group consisting of diethylene glycol bis(allyl carbonate) monomers, diethylene glycol dimethacrylate monomers, ethoxylated phenol methacrylate monomers, diisopropenyl benzene monomers and ethoxylated trimethylol propane triacrylate monomers.

18. The photochromic article of claim 15 wherein the organic photochromic compound (b) is selected from the group consisting of other indenonaphthopyrans, chromenes, oxazines, metal-dithizonates, fulgides and fulgimides.

19. The photochromic article of claim 18 wherein the organic photochromic compound is selected from the group consisting of naphthopyrans, benzopyrans, phenanthropyrans, indenonaphthopyrans, spiro(benzindoline)naphthopyrans, spiro(indoline)benzopyrans, spiro(indoline)naphthopyrans, spiro(indoline)quinopyrans, spiro(indoline)pyrans, spiro(indoline)naphthoxazines, spiro(indoline)pyrido-benzoxazines, spiro(benzindoline)pyridobenzoxazines, spiro(benzindoline)naphthoxazines, spiro(indoline)-benzoxazines and mixtures of such photochromic compounds.

20. The photochromic article of Claim 18 wherein the total amount of photochromic compound present is from 0.05 to 1.0 milligram per square centimeter of organic host material surface to which the photochromic substance(s) is incorporated or applied.

21. The photochromic article of Claim 19 wherein the article is a lens.

22. A photochromic article comprising, in combination, a polymeric organic host material selected from the group consisting of poly(methyl methacrylate), poly(ethylene glycol bismethacrylate), poly(ethoxylated bisphenol A dimethacrylate), thermoplastic polycarbonate, poly(vinyl acetate), polyvinylbutyral, polyurethane and polymers of members of the group consisting of diethylene glycol bis(allyl carbonate) monomers, diethylene glycol dimethacrylate monomers, ethoxylated phenol methacrylate monomers, diisopropenyl benzene monomers and ethoxylated

trimethylol propane triacrylate monomers, and a photochromic amount of each of (a) at least one indenonaphthopyran compound of claim 2, and (b) at least one other organic photochromic compound having at least one activated absorption maxima within the range of between about 400 and 700 nanometers.

23. A photochromic article comprising, in combination, a polymeric organic host material selected from the group consisting of poly(methyl methacrylate), poly(ethylene glycol bismethacrylate), poly(ethoxylated bisphenol A dimethacrylate), thermoplastic polycarbonate, poly(vinyl acetate), polyvinylbutyral, polyurethane and polymers of members of the group consisting of diethylene glycol bis(allyl carbonate) monomers, diethylene glycol dimethacrylate monomers, ethoxylated phenol methacrylate monomers, diisopropenyl benzene monomers and ethoxylated trimethylol propane triacrylate monomers, and a photochromic amount of each of (a) at least one indenonaphthopyran compound of claim 3, and (b) at least one other organic photochromic compound having at least one activated absorption maxima within the range of between about 400 and 700 nanometers.