



(19) **United States**

(12) **Patent Application Publication** (10) **Pub. No.: US 2003/0091859 A1**

Cho et al. (43) **Pub. Date: May 15, 2003**

(54) **FLUORENE COMPOUNDS CONTAINING VARIOUS FUNCTIONAL GROUPS, POLYMERS THEREOF AND EL ELEMENT USING THE SAME**

Publication Classification

(76) Inventors: **Hyun-Nam Cho**, Seoul (KR); **Sung Hyun Jung**, Seoul (KR); **Sang Won Son**, Jeollabuk-do (KR)

(51) **Int. Cl.⁷** **C09B 27/00**; C09B 31/00; C09B 33/00; C09B 35/00; C09B 37/00; C09B 39/00; C09B 41/00; C07C 245/00; C07C 321/00; C07C 323/00; C07C 381/00; B32B 9/00; B32B 19/00

Correspondence Address:

Raj S. Dave
Morrison & Foerster LLP
Suite 5500
2000 Pennsylvania Avenue N.W.
Washington, DC 20006-1888 (US)

(52) **U.S. Cl.** **428/690**; 534/573

(57) **ABSTRACT**

(21) Appl. No.: **10/135,728**

(22) Filed: **May 1, 2002**

(30) **Foreign Application Priority Data**

May 22, 2001 (KR) 28020/2001

The present invention relates to fluorene compounds and polymers thereof, having various structures and functional groups, and capable of being used as a luminescent material for organic and polymer-based electro-luminescence (EL) element and other optical element, and to an EL element using the same as a luminescent material.

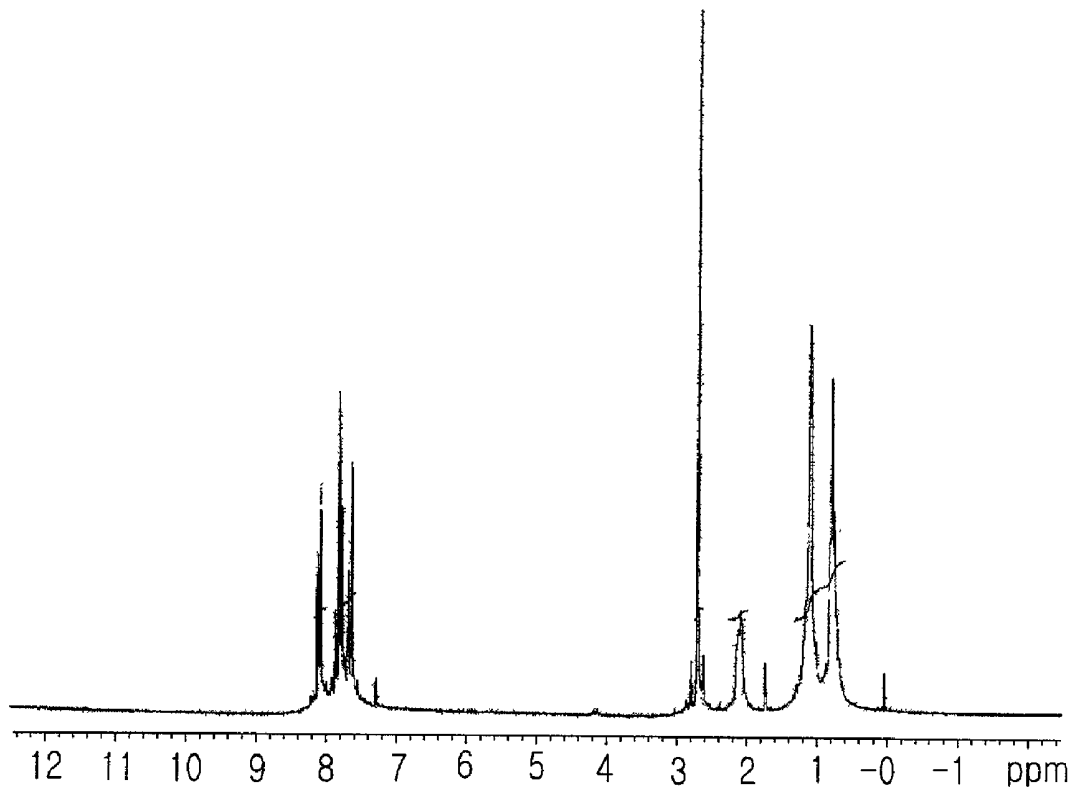


FIG. 1

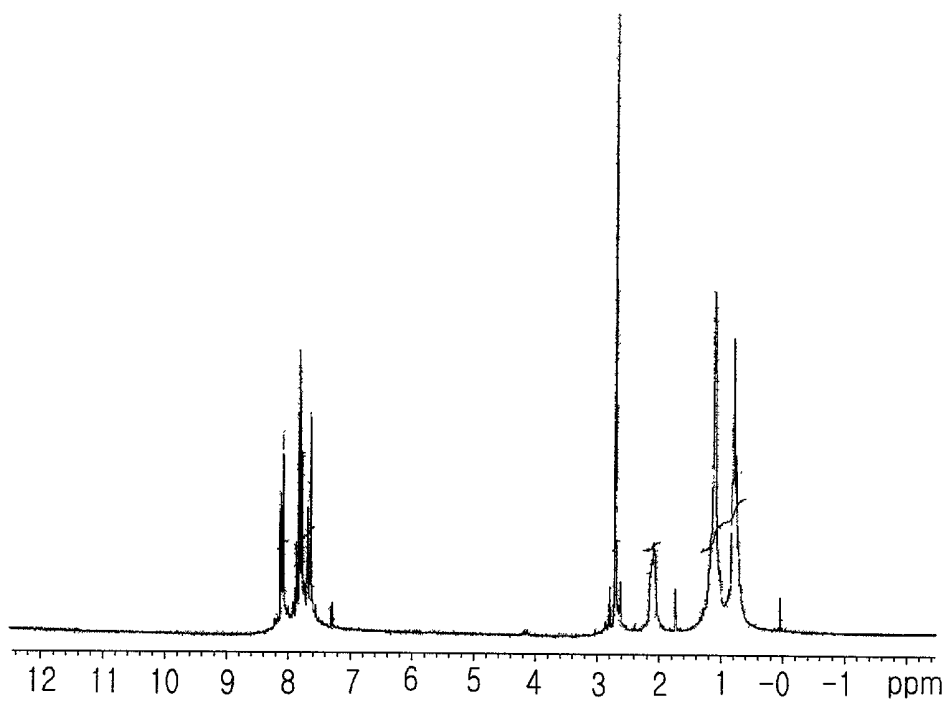


FIG. 2

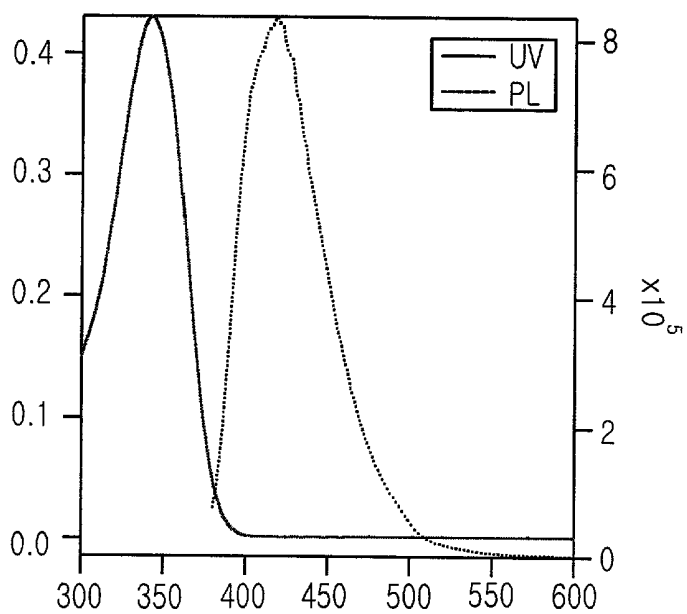


FIG. 3

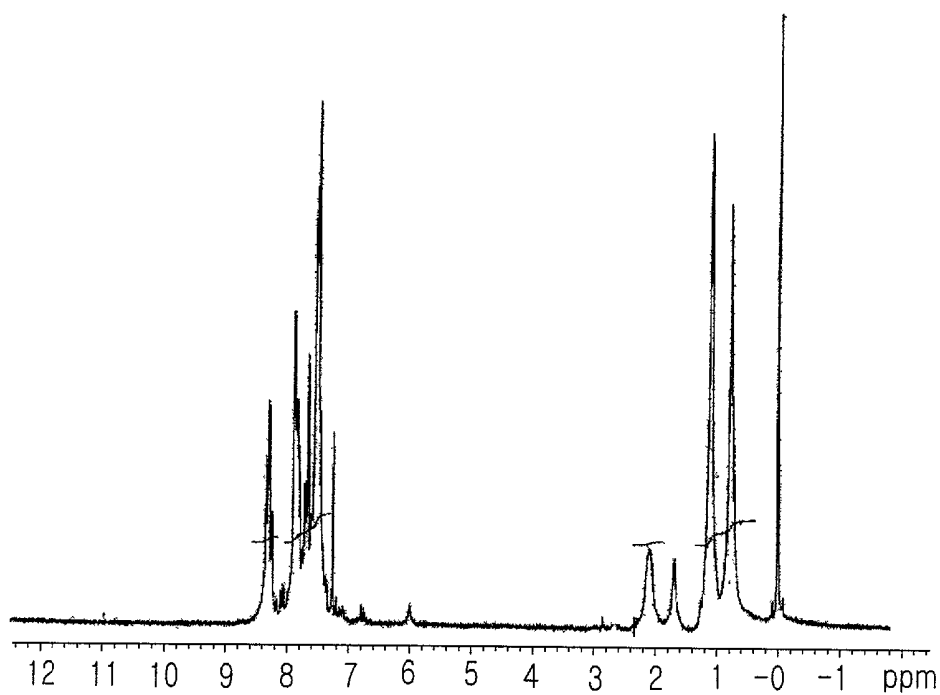


FIG. 4

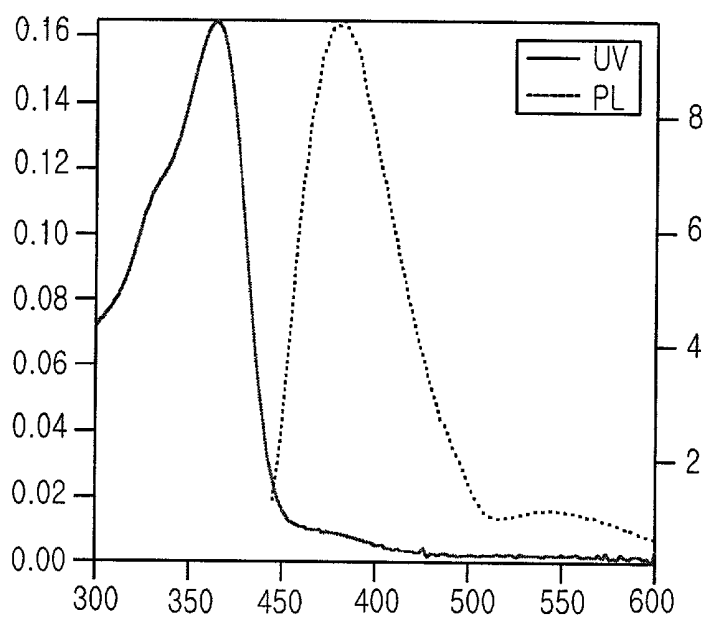


FIG. 5

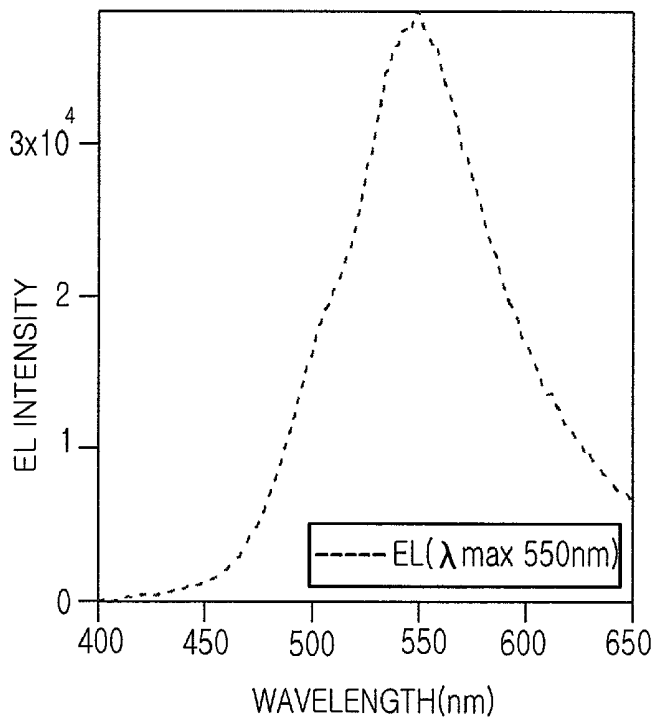
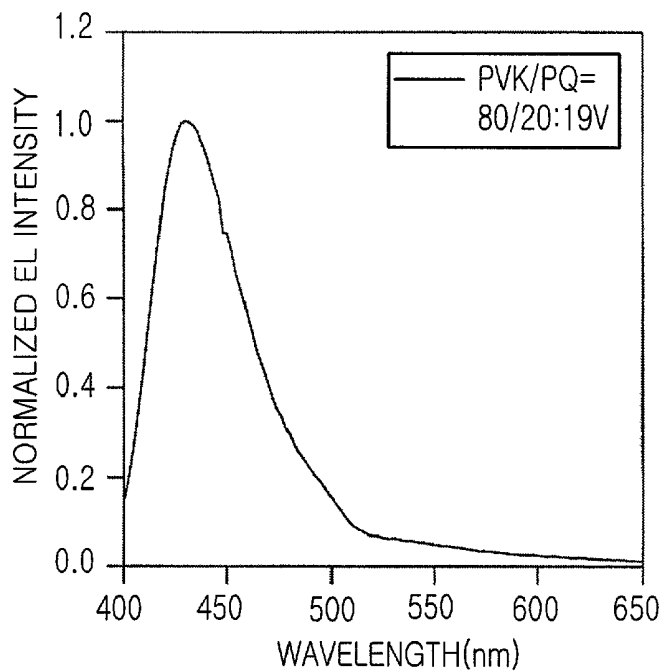


FIG. 6



FLUORENE COMPOUNDS CONTAINING VARIOUS FUNCTIONAL GROUPS, POLYMERS THEREOF AND EL ELEMENT USING THE SAME

BACKGROUND OF THE INVENTION

[0001] 1. Field of the Invention

[0002] The present invention relates to a new fluorene compounds containing various functional groups and polymers thereof which can be used as organic polymer semiconductor and photo-electronic materials, and especially as a material for electro-luminescence (hereinafter, referred to as "EL"), and to an EL element using the same.

[0003] 2. Description of the Background Art

[0004] Generally, polymers of a polyphenylene vinylene (hereinafter, referred to as "PPV"), of a polythiophene (hereinafter, referred to as "PTh") and of a polyphenylene (refer to *Synth. Met.*, 50 (1-3), P491 (1992) and *Adv Mater.*, 4, p.36 (1992)) are known as organic polymer semiconductor and photoelectronic materials (refer to *Semiconducting Polymers: Chemistry, Physics and Engineering*, Edited by G. Hadziioannou and P. F. van Hutten) WILEY-VCH (2000) or as a material for polymer EL (refer to *Angew. Chem. Int. Ed.*, 37, p.402 (1998), *Prog. Polym. Sci.*, 25, p.1089 (2000) and *Adv. Mater.*, 12, p.1737 (2000)). At present, studies for these polymer materials have been made, however, these materials have disadvantages in that the final product is not dissolved in an organic solvent. Also, PPV or PTh derivatives which are improved its processability by introducing an appropriate substituent and illuminate lights of blue, green and red colors are known as the materials (refer to *Synth. Met.*, 62, p.35 (1994), *Adv. Mater.*, 4, p.36 (1992), and *Macromolecules*, 28, p.7525 (1995)). However, the fabrication processes for these derivatives are very complex, and they have a problem in stability.

[0005] Polymers having an acetylene group are also disclosed (refer to *Macromol. Chem.*, 191, p.857 (1990), *Macromolecules*, 27, p.562 (1994), *J. Chem. Soc., Chem. Commun.*, p.1433 (1995), and *Macromolecules*, 29, P5157 (1996)), and applications for nonlinear optics or for light conductivity, and photoluminescence (hereinafter referred to as "PL") are reported (refer to *Science*, 279, p.835 (1998)). Also, polymers having a diacetylene group are disclosed (refer to *Prog. Polym. Sci.*, 20, p.943 (1995), *CHEMTECH*, October, p.32, (1993)), and *Macromolecules*, 29, p.2885 (1996)). These polymers are more sensitive to heat or light than the polymers of acetylene group and therefore a cross-link reaction can be easily taken place. These polymers can be applied for a material of nonlinear optics, a heat resistant polymer, a polarized PL polymer, and an electric or optically active polymer. Applying the polymers having a novel acetylene or diacetylene group to a material for the EL was patented by the present inventors (U.S. Pat. No. 5,876,864 and Japanese Patent No. 3,046,814).

[0006] A fluorene-based polymer emitting blue light has also been reported (refer to *Jpn. J. Appl. Phys.*, 30, p.L1941 (1991)). However, it uses a preparation method that can not be applied to a preparation of a polymer having various conjugated double bonds. The present inventors has solved the above problem and disclosed fluorene-based alternating copolymers for EL element having conjugated double bond (U.S. Pat. No. 5,801,974. However, there are few examples of preparing or applying fluorene-based polymers having various functional groups as polymeric EL materials.

SUMMARY OF THE INVENTION

[0007] Therefore, an object of the present invention is to provide fluorene-based compounds containing various func-

tional groups and polymers thereof which can be dissolved in an organic solvent and can be applied for EL and photo-electronic materials, and to provide EL elements using the same.

[0008] The object of the present invention will become more apparent from the following detailed description of the present invention when taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] The accompanying drawings, which are included to provide a further understanding of the invention and are incorporated in and constitute a part of this specification, illustrate embodiments of the invention and together with the description serve to explain the principles of the invention.

[0010] In the drawings:

[0011] FIG. 1 shows a ¹H NMR spectrum of the monomer M-34 of Example 34;

[0012] FIG. 2 shows UV-Vis and PL spectra of the monomer M-34 of Example 34;

[0013] FIG. 3 shows a ¹H NMR spectrum of the polymer P-18 of Example 54;

[0014] FIG. 4 shows UV-Vis and PL spectra of the polymer P-18 of Example 54;

[0015] FIG. 5 shows an EL spectrum of the polymer P-18 of Example 54; and

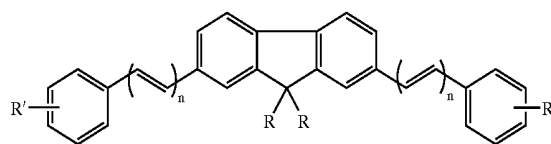
[0016] FIG. 6 shows an EL spectrum of the polymer P-18 of Example 54 which is blended with polyvinylcarbazole (polyvinylcarbazole: P-18=8:2)

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0017] Reference will now be made in detail to the preferred embodiments of the present invention, examples of which are illustrated in the accompanying drawings.

[0018] The fluorene compound according to the present invention have the following general formula (I):

(I)



[0019] wherein,

[0020] R represents hydrogen, C₁-C₂₂ aliphatic alkyl or alkoxy, C₁-C₂₂ alicyclic alkyl or alkoxy, C₆-C₁₈ aryl or aryloxy, or alkyl or aryl derivatives of silicon, tin, germanium or the like;

[0021] R' means a functional group which presents in meta- or para-position of the phenyl group and is not limited to a certain group, and any functional groups can be included if it is easy to be prepared and has good properties; and

[0022] n represents 0 or 1.

[0023] For example, R may be a hydrogen, methyl, ethyl, propyl, isopropyl, butyl, isobutyl, pentyl, hexyl, ethylhexyl, heptyl, octyl, isooctyl, nonyl, decyl, dodecyl, hexadecyl,

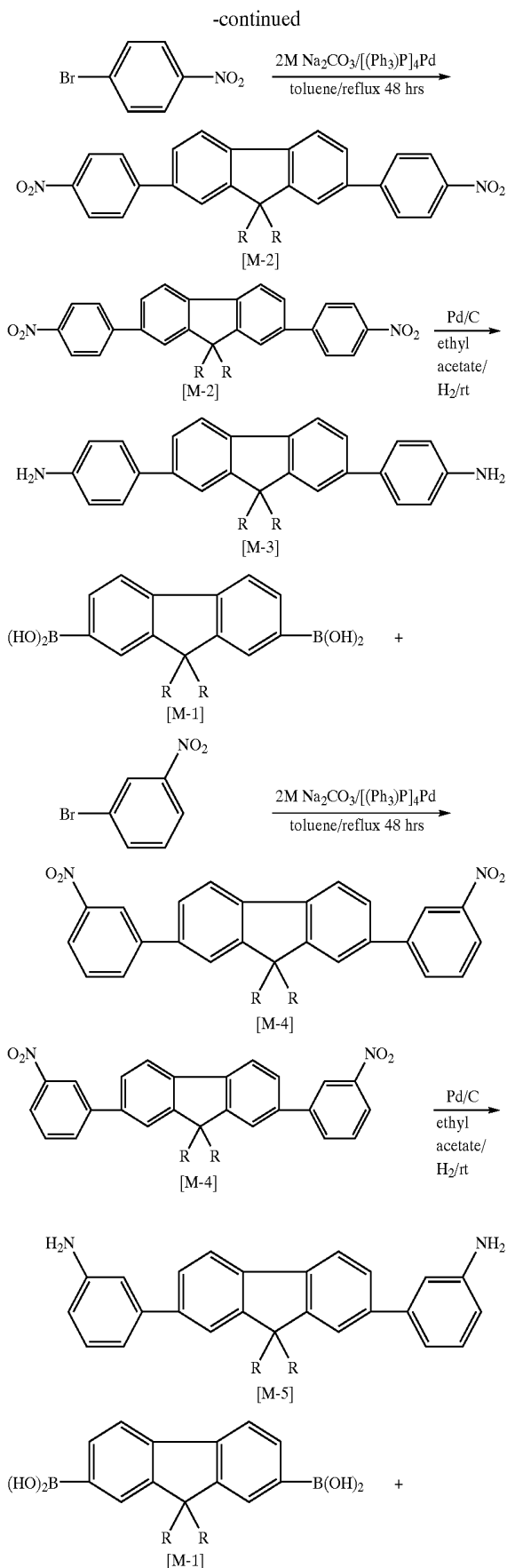
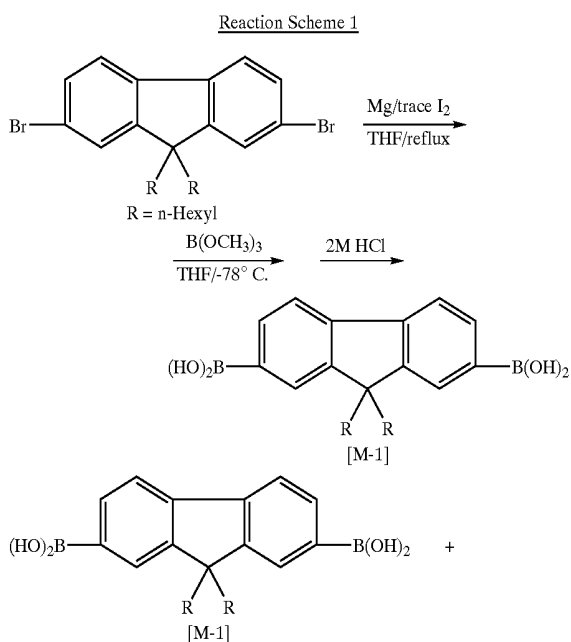
octadecyl, dodecyl, cyclopropyl, cyclopentyl, cyclohexyl, methoxy, ethoxy, butoxy, hexyloxy, methoxyethoxyethyl, methoxyethoxyethoxyethyl, phenyl, phenoxy, tolyl, benzyl, naphthyl, anthracene group, trimethylsilyl, triphenylsilyl, tributyltin or triethylgermanium; and

[0024] R' may be an ether, ester, amine, amide, imide, aldehyde, ketone, sulfone, sulfide, nitro, nitrile, acetylene, halogen, carboxylic acid, boronic acid, vinyl, hydrazide, isocyanate, urethane, carbonate, chloromethyl, hydroxy, anhydride, cyanate, azometine, quinoline, oxadiazole, azo or the like.

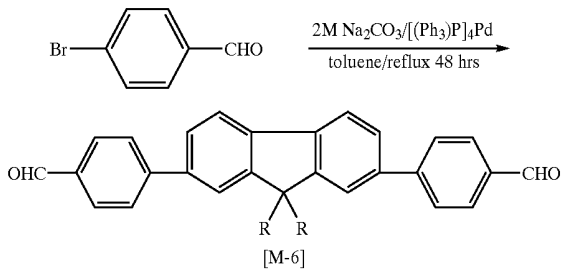
[0025] The fluorene-based polymer according to the present invention includes polymerization products of the same or different fluorene compounds according to the present invention and polymerization products of the fluorene compounds of the present invention with another organic compound.

[0026] The functional groups included in the polymer according to the present invention are not specifically limited, and any functional group can be included if the compound having those functional groups can be prepared easily and has a good EL properties. There may be an ether, ester, amide, imide, ketone, sulfone, sulfides, acetylene, diacetylene, vinyl, hydrazide, urea, urethane, carbonate, azometine, quinoline, oxadiazole, azo group, etc., but it is not limited thereto. To a polymer having a functional group with an atom such as nitrogen (for example, azometine, quinoline, etc.), if an inorganic or organic acid is added, its salt is generated and thereby its UV and maximum PL wavelengths are changed. For example, when hydrochloric acid is added to [P-1] which is an azometine polymer as shown in Reaction Scheme 8, the UV maximum wavelength is changed from 370 nm to 355 nm, and light is emitted at a maximum PL wavelength of 411 nm although the pure [P-1] polymer does not originally show maximum PL wavelength.

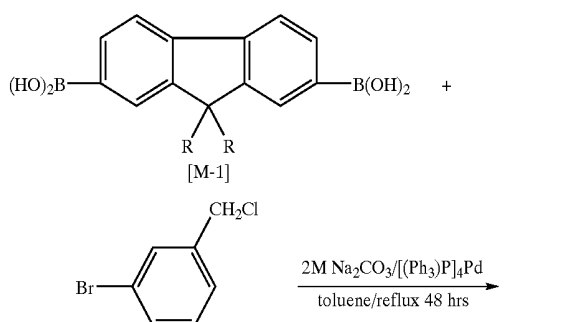
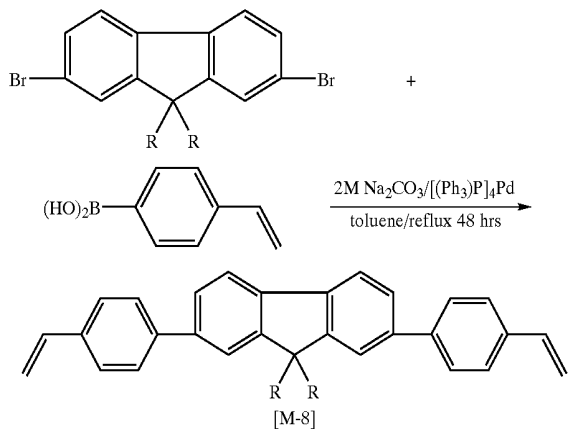
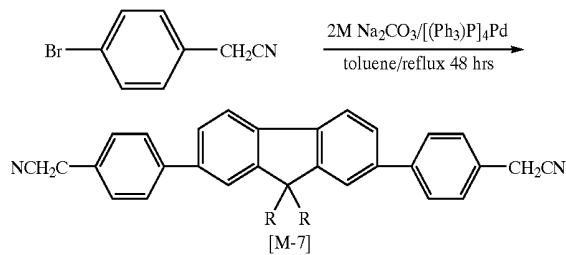
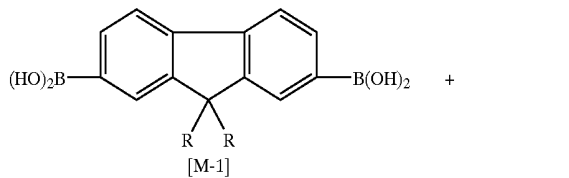
[0027] The fluorene compounds and polymers thereof of the present invention can be prepared by the following Reaction Schemes 1 to 14:



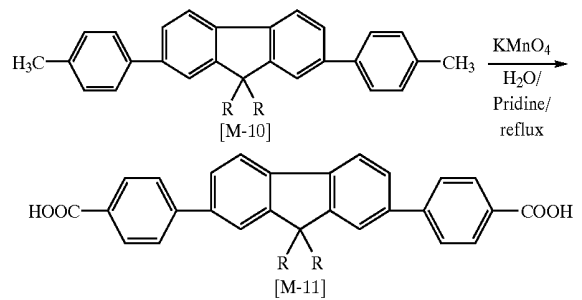
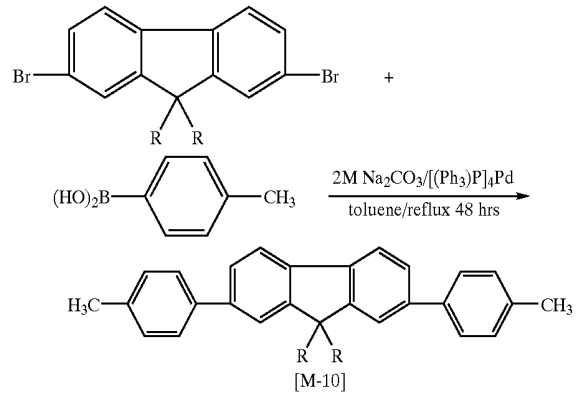
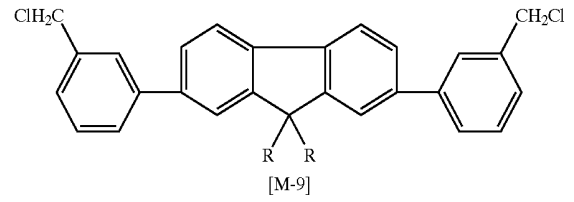
-continued



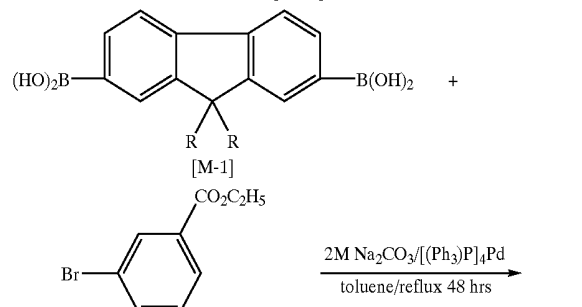
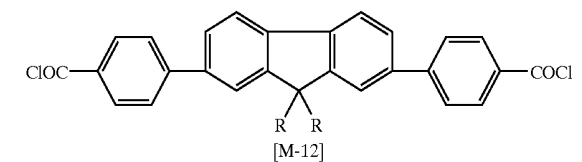
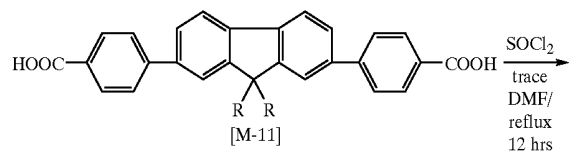
Reaction Scheme 2

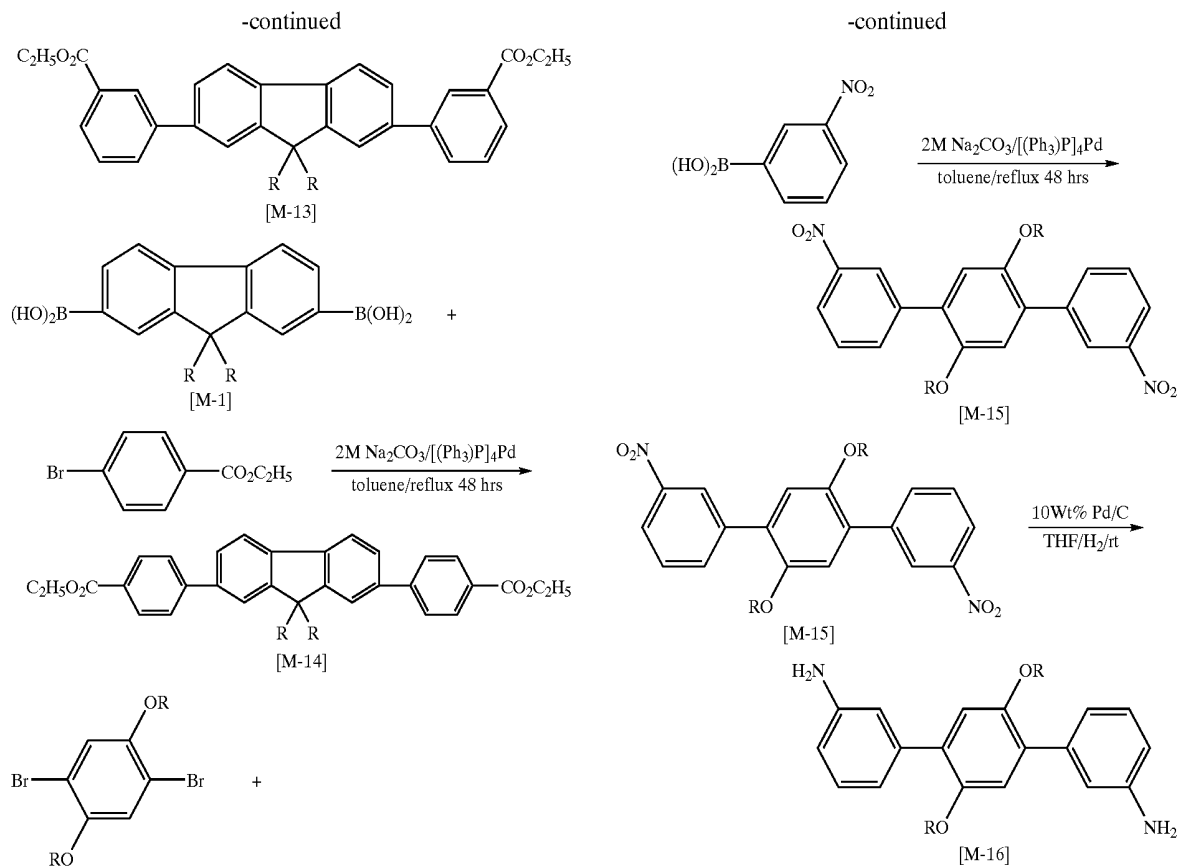


-continued

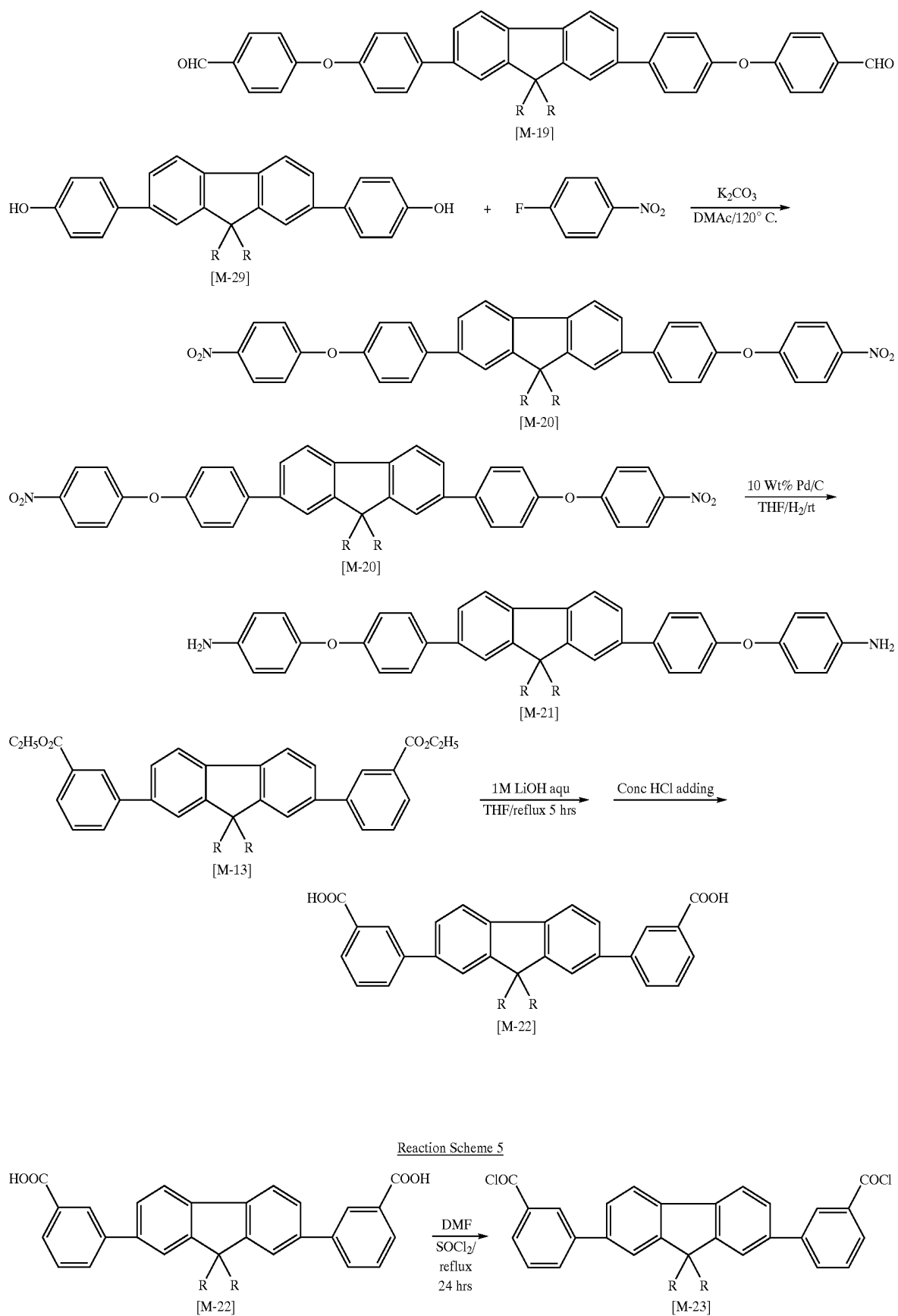


Reaction Scheme 3

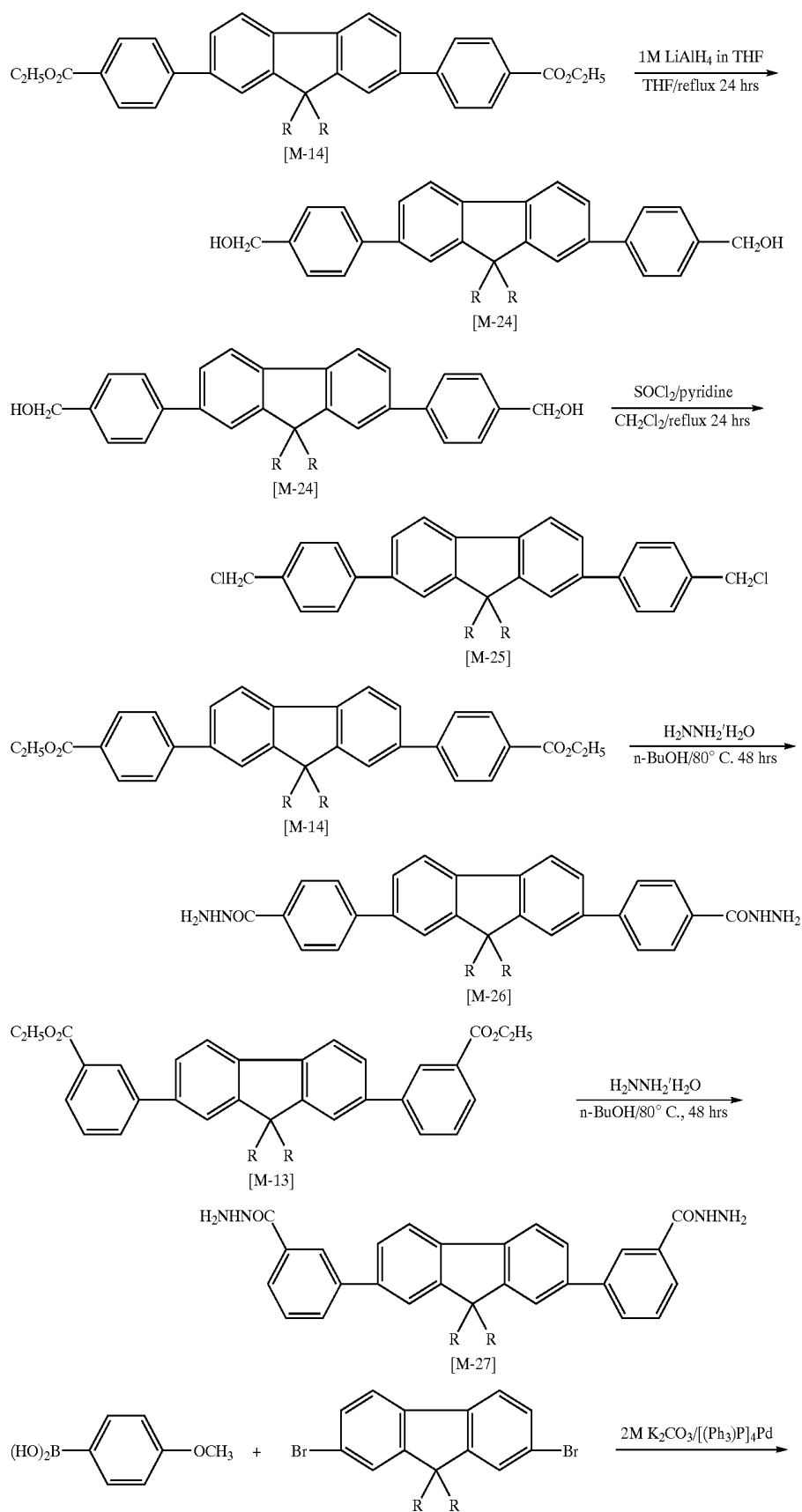




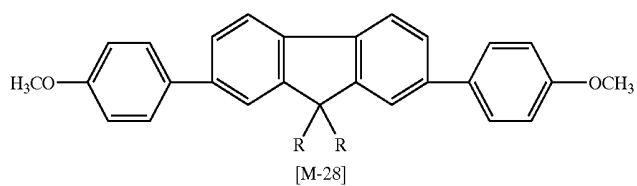
-continued



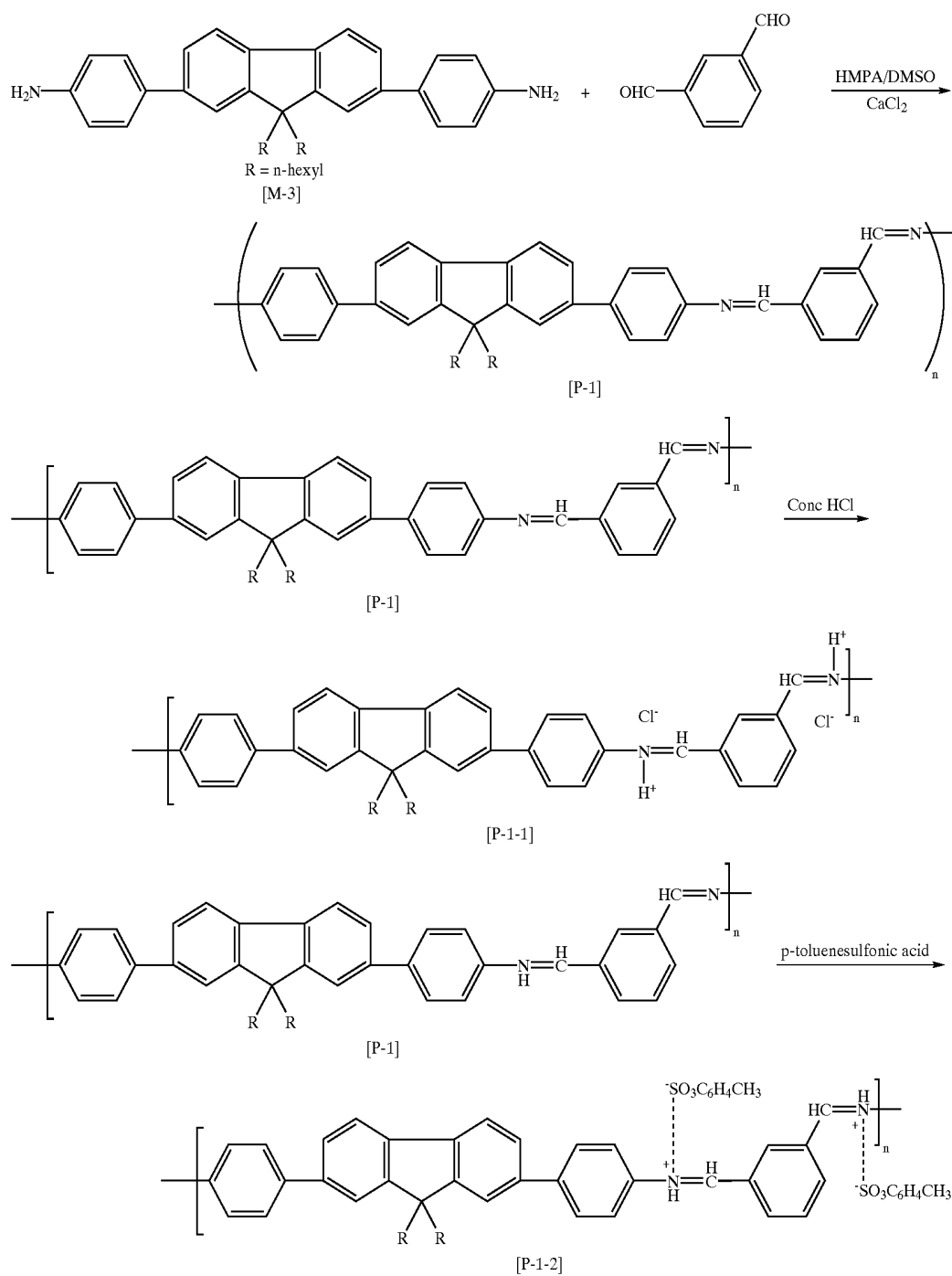
-continued



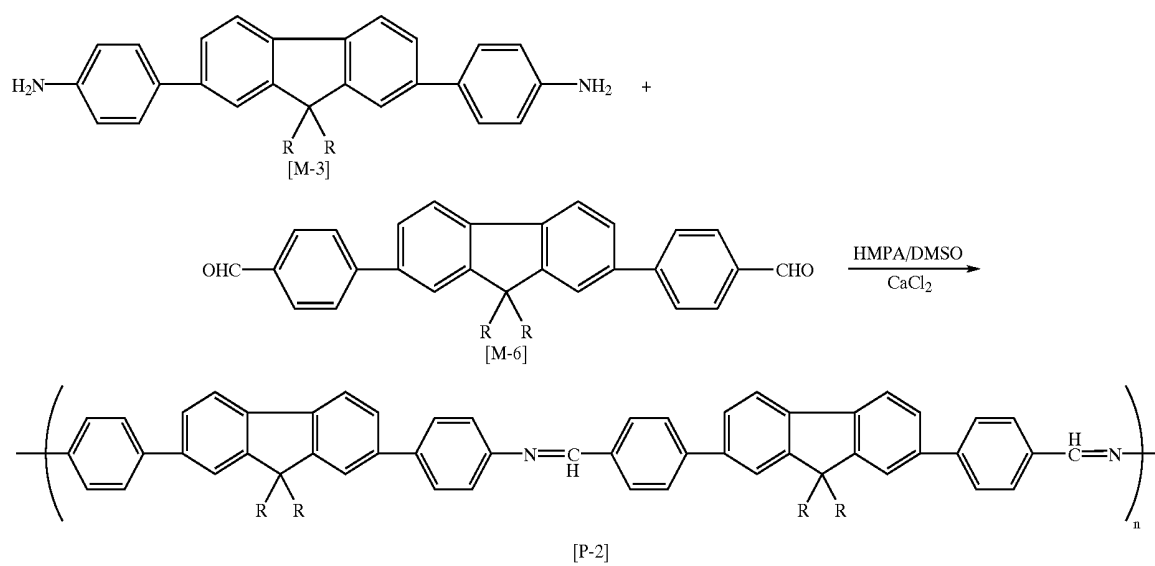
-continued



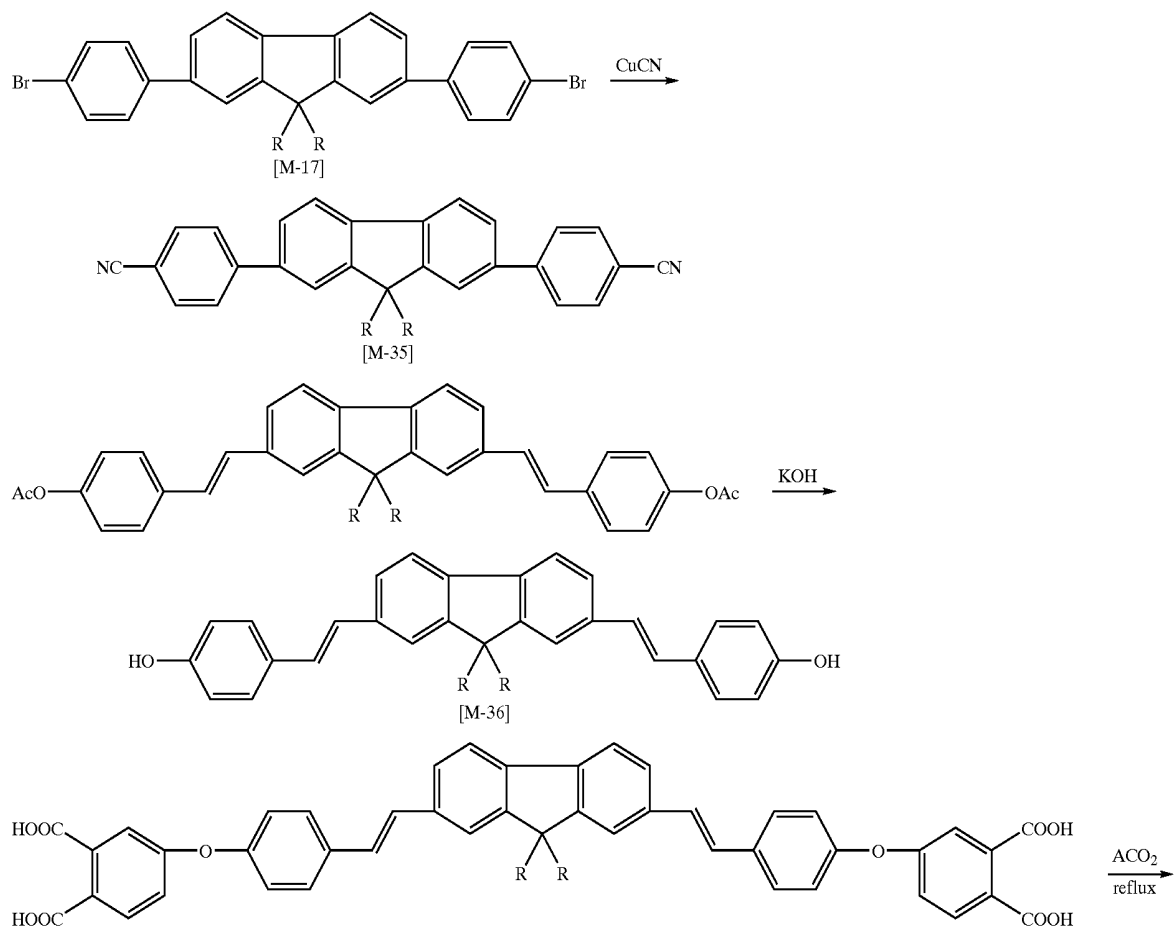
Reaction Scheme 6



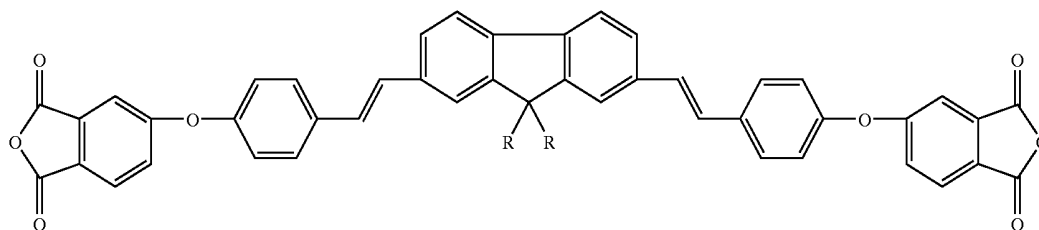
-continued



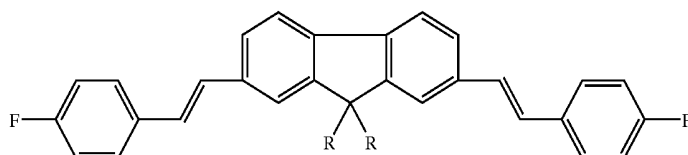
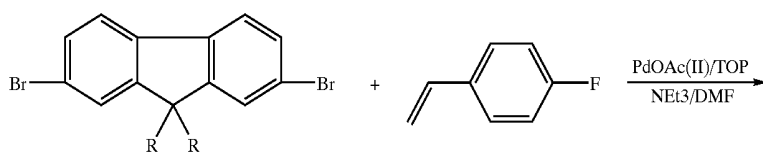
Reaction Scheme 7



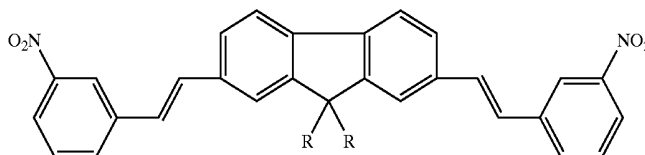
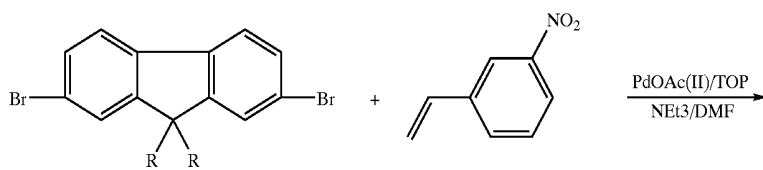
-continued



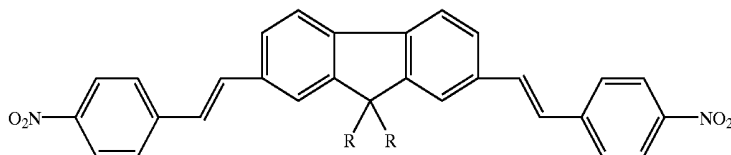
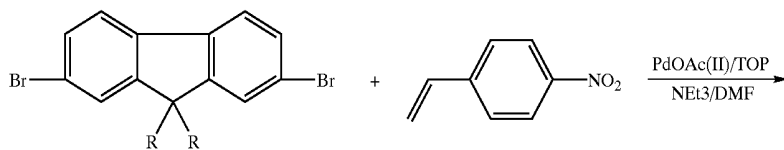
[M-37]



[M-38]

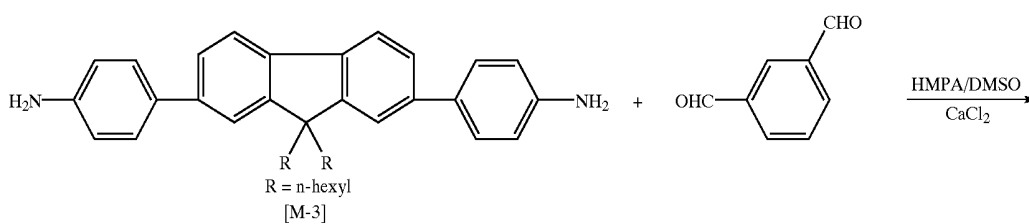


[M-39]

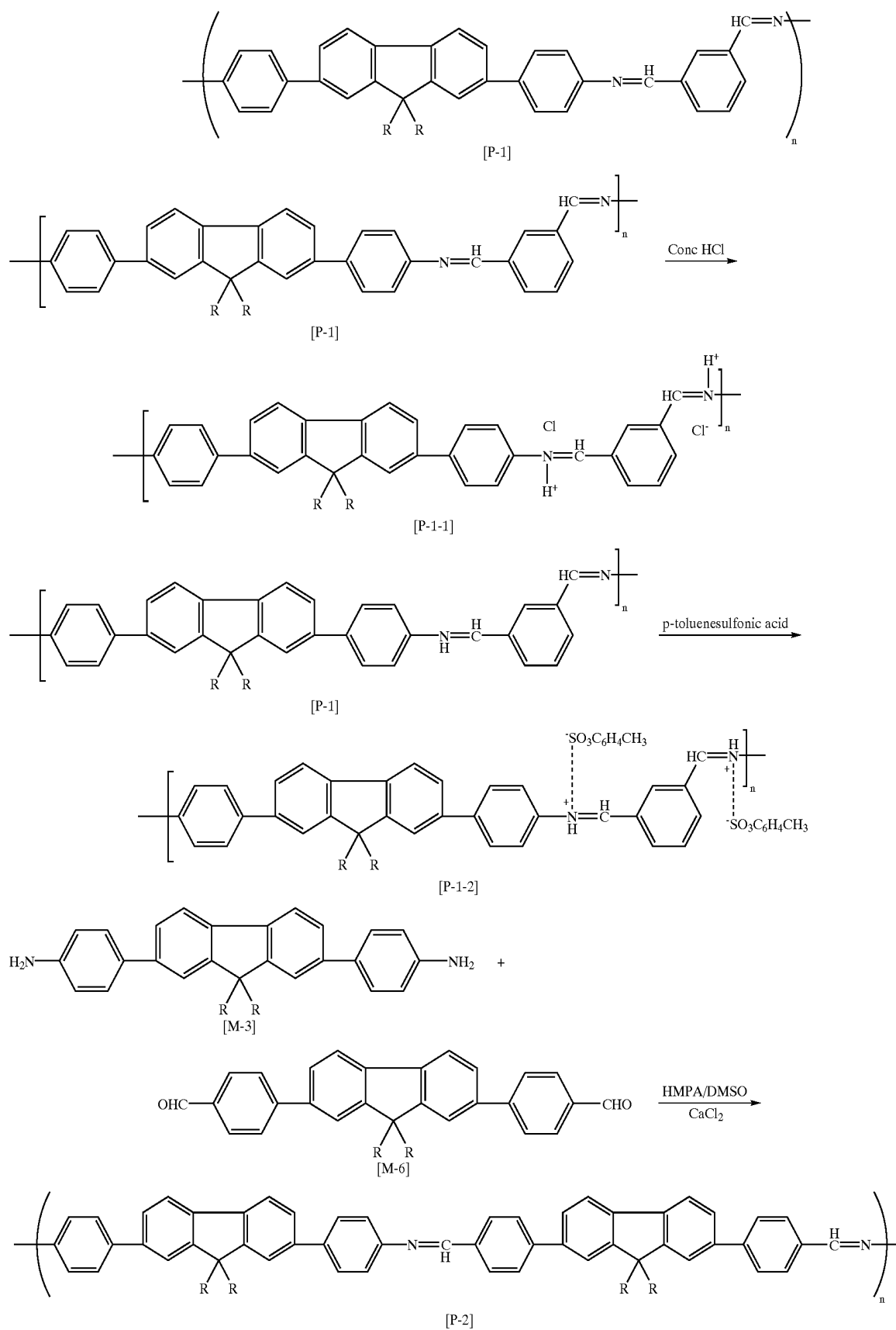


[M-40]

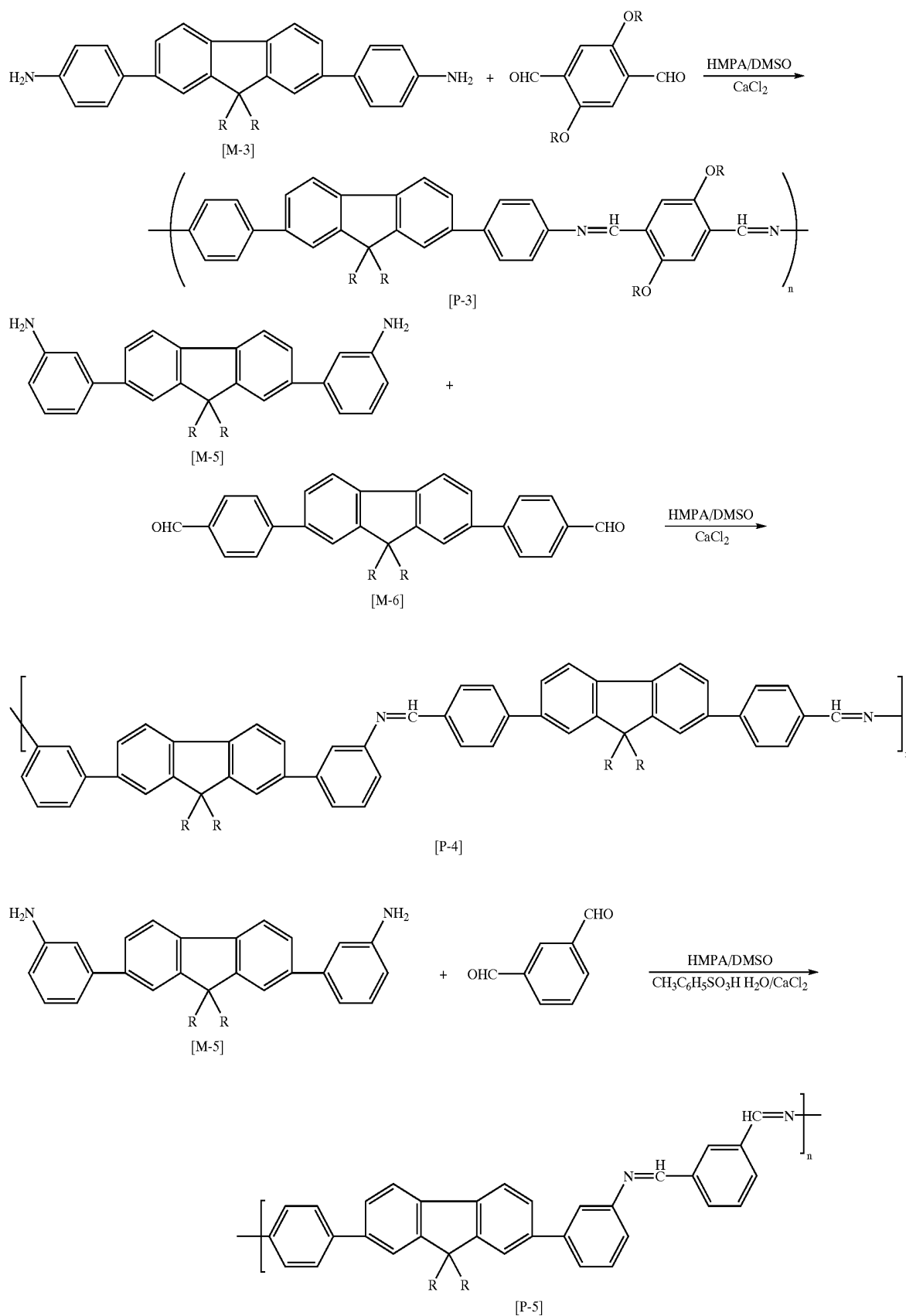
Reaction Scheme 8

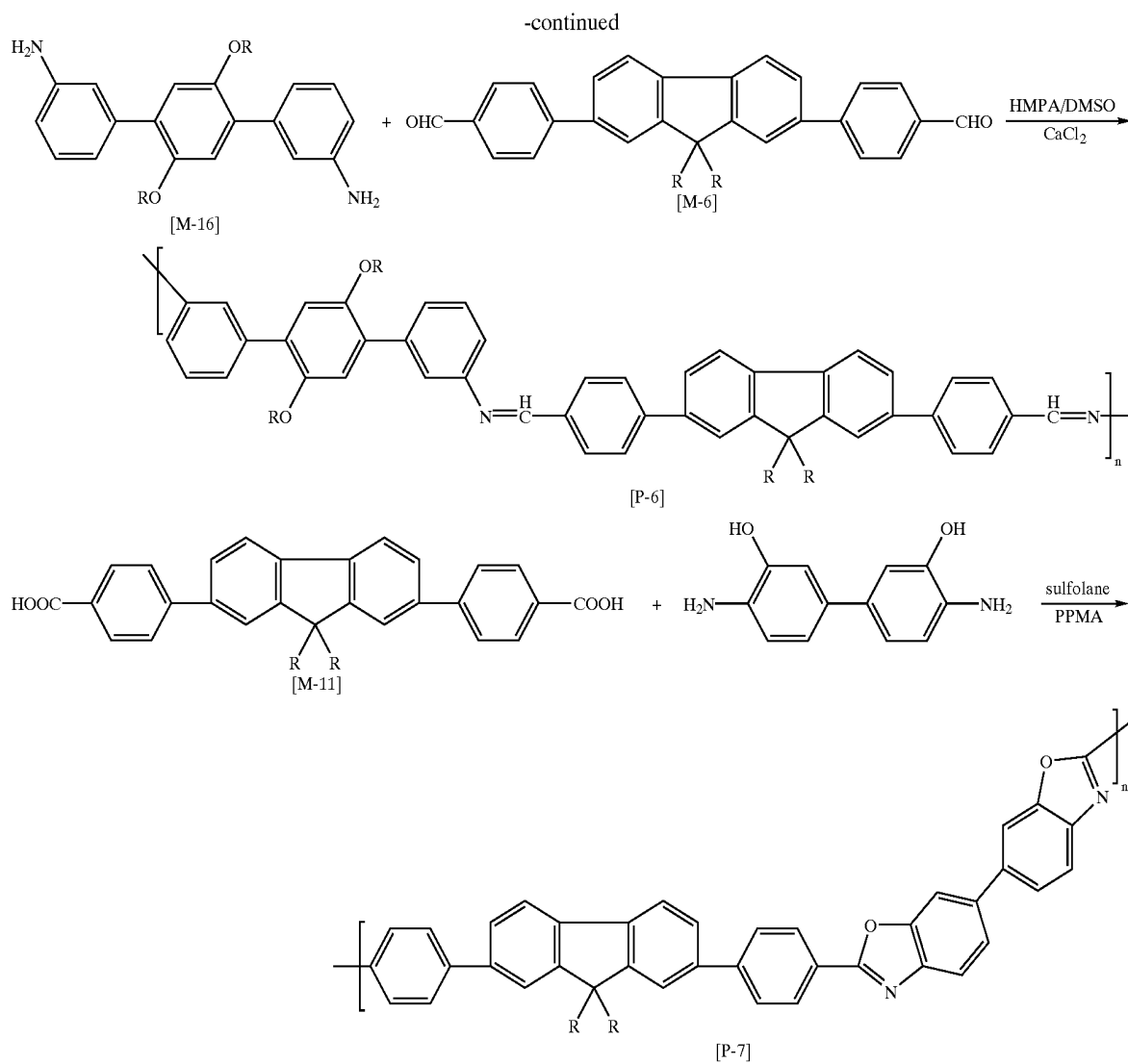
R = n-hexyl
[M-3]

-continued

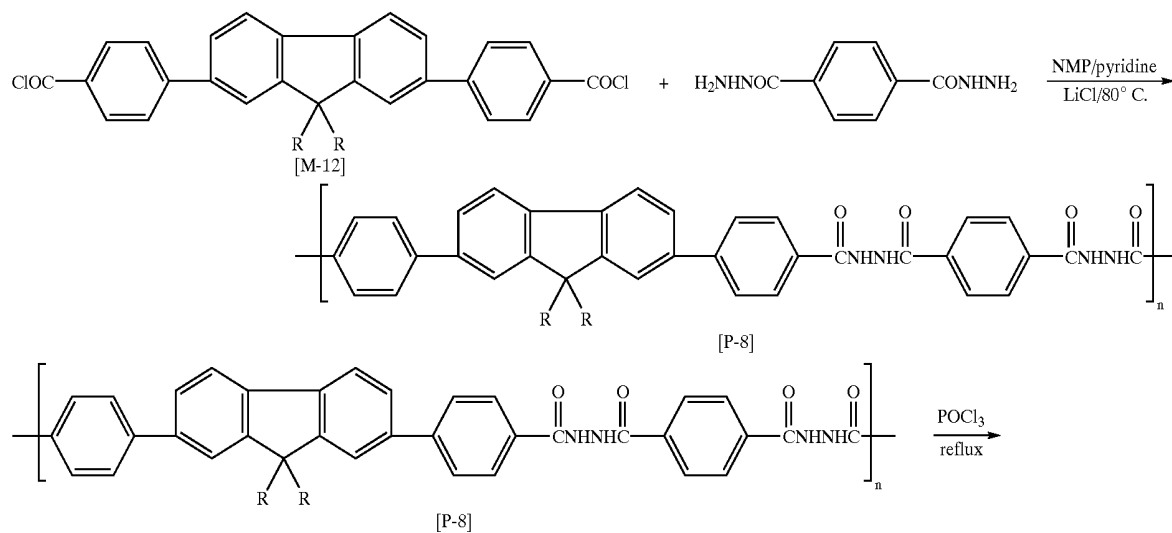


Reaction Scheme 9

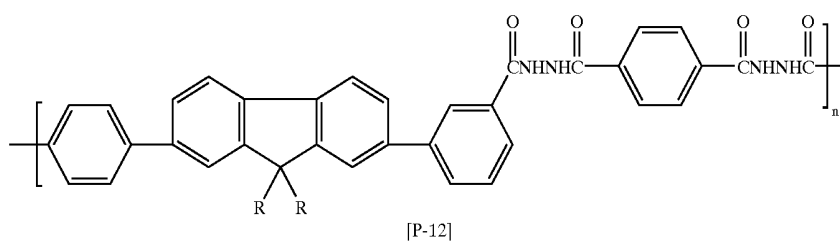
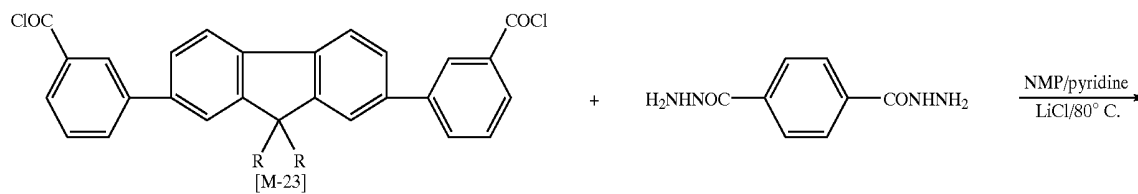
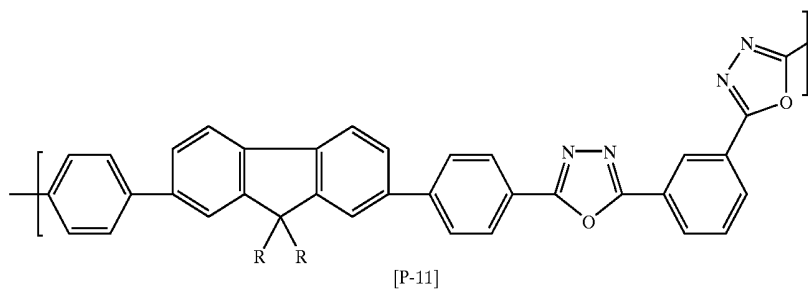
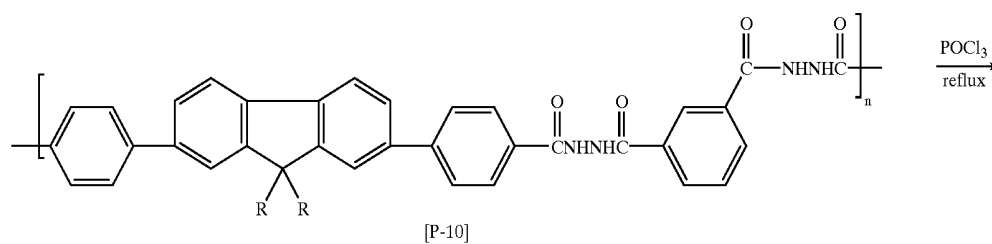
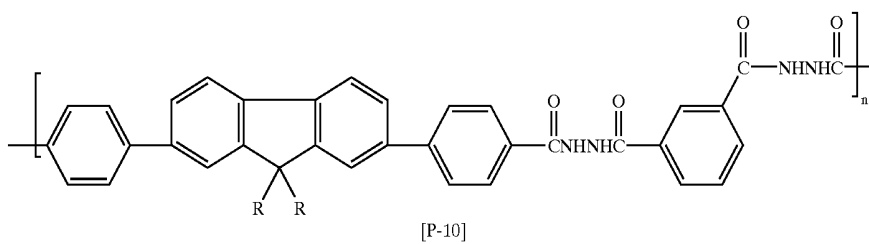
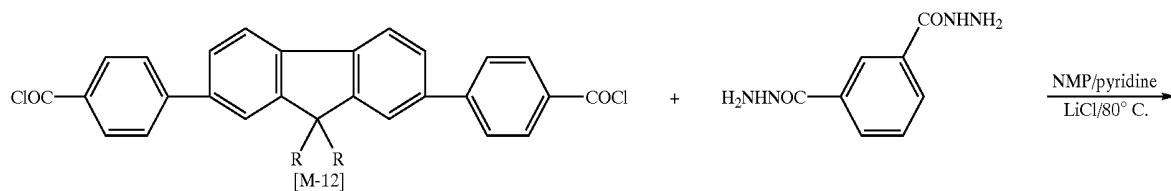
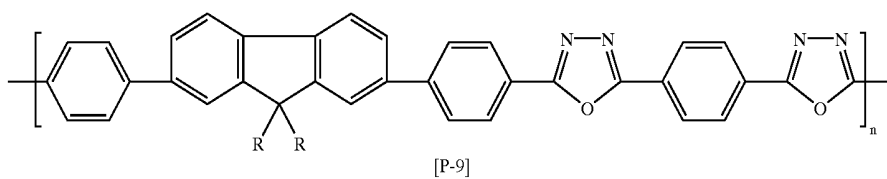


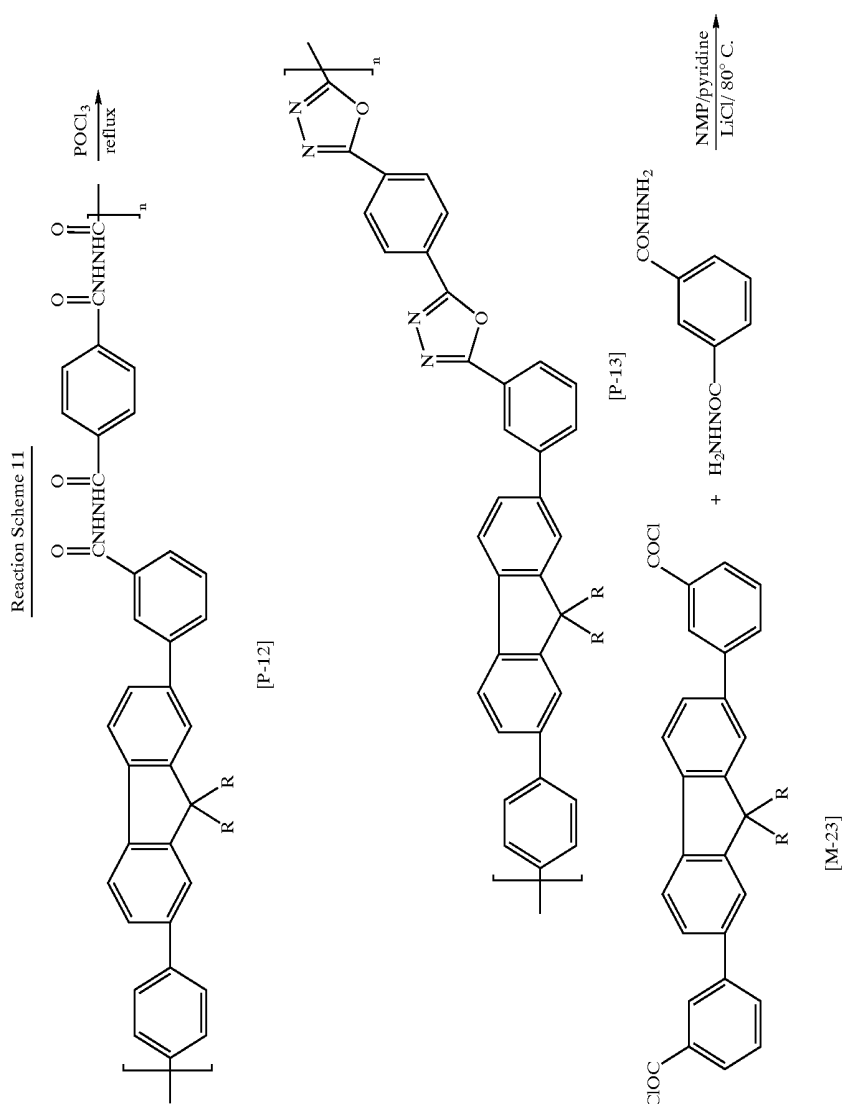


Reaction Scheme 10

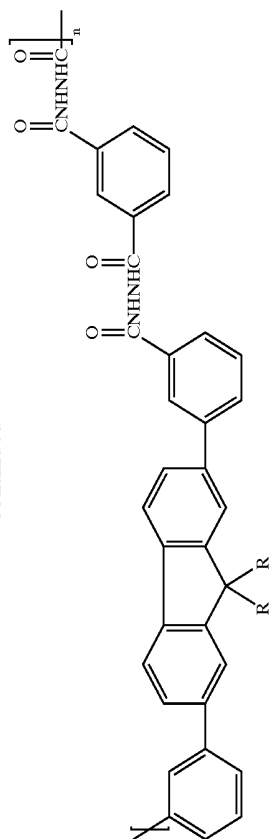


-continued

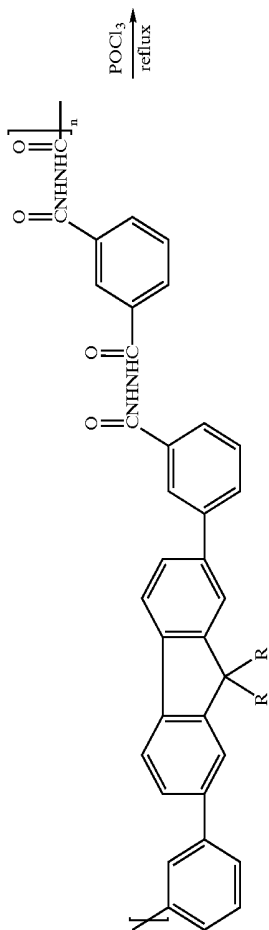




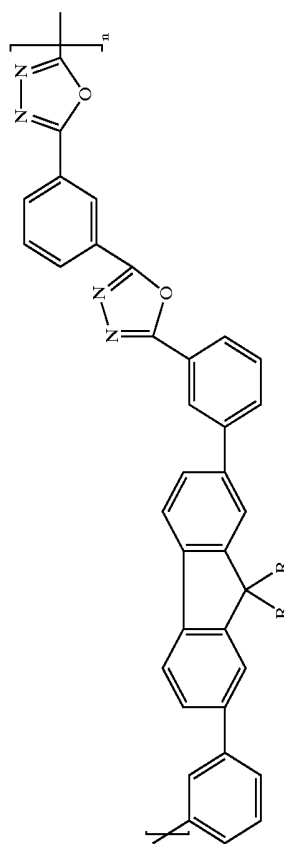
-continued



[P-14]

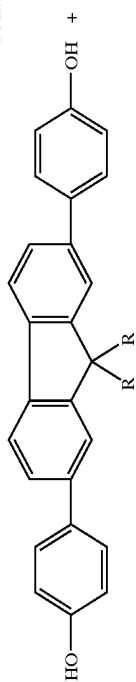


[P-14]

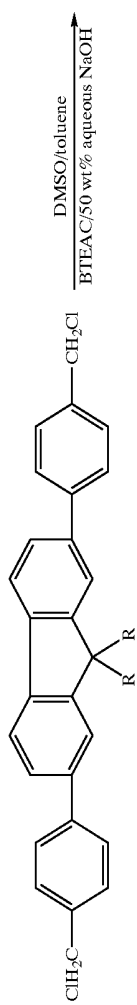


[P-15]

-continued

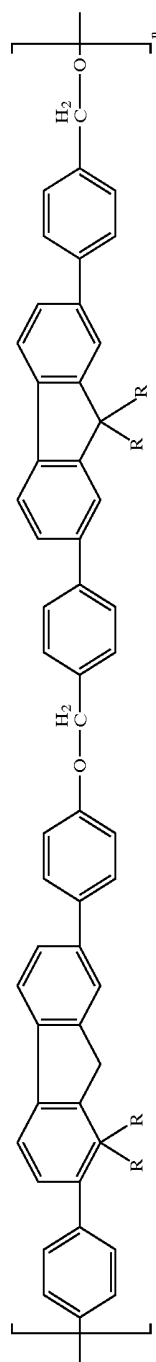


[M-29]



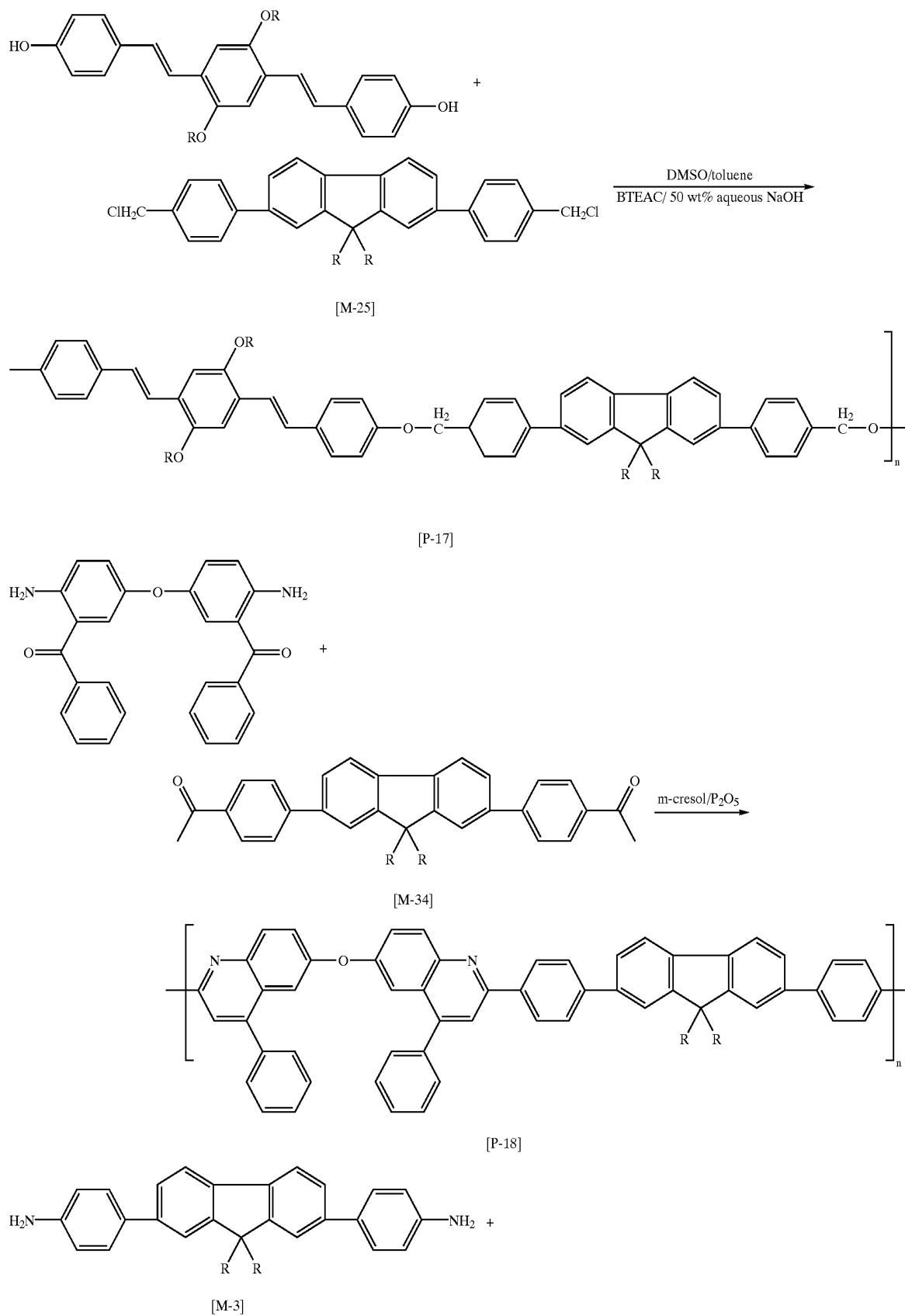
DMSO/toluene
BTEAC/50 wt% aqueous NaOH

[M-25]

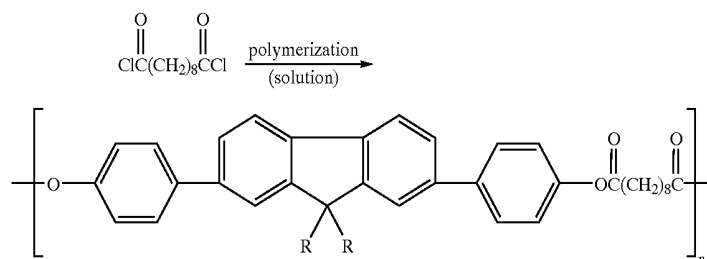
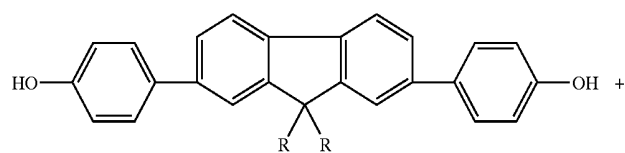
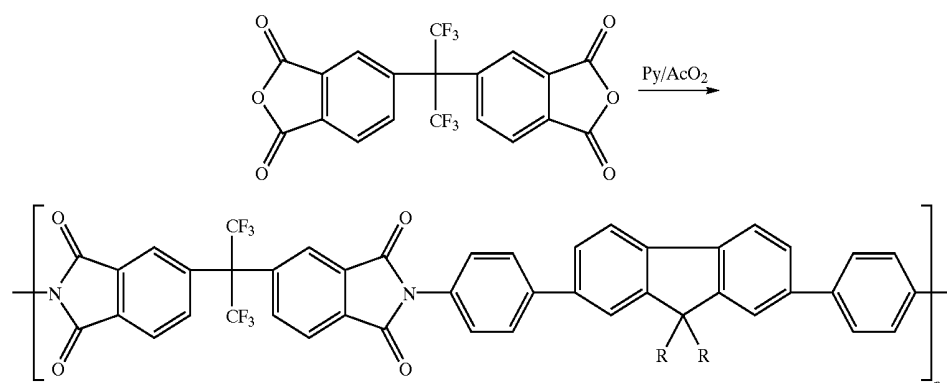


[P-16]

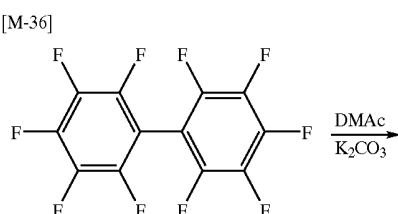
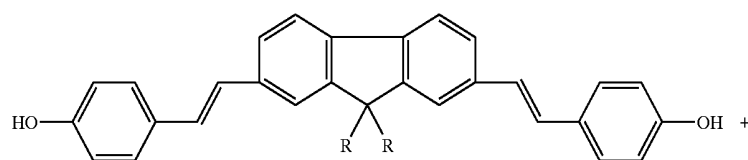
Reaction Scheme 12



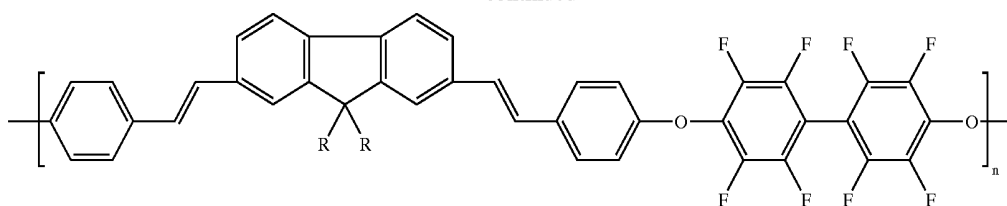
-continued



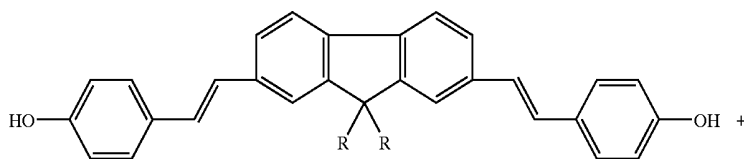
Reaction Scheme 13



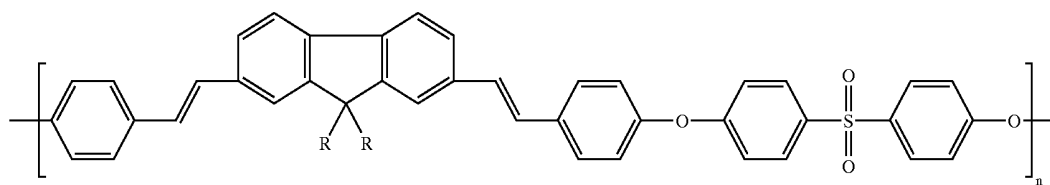
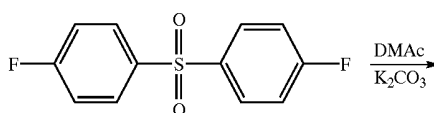
-continued



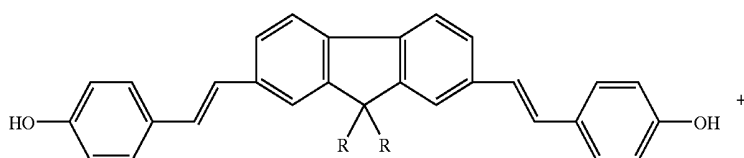
[P-21]



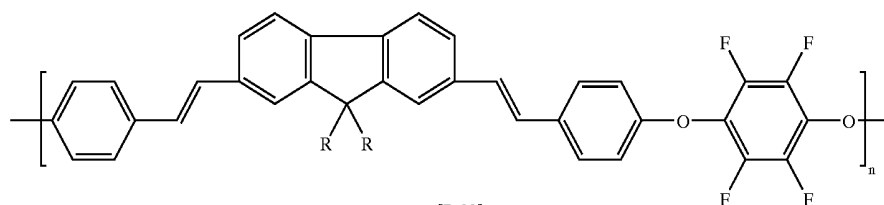
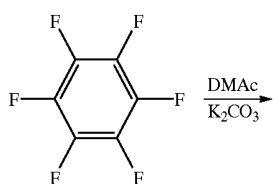
[M-36]



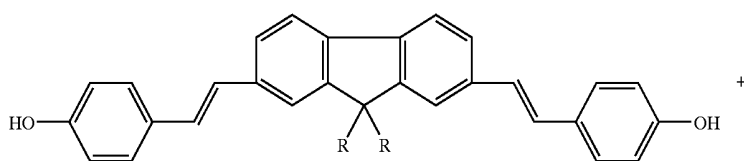
[P-22]



[M-36]

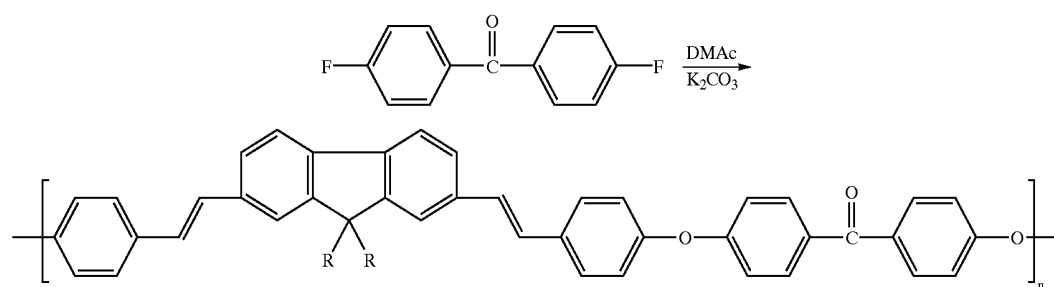


[P-23]

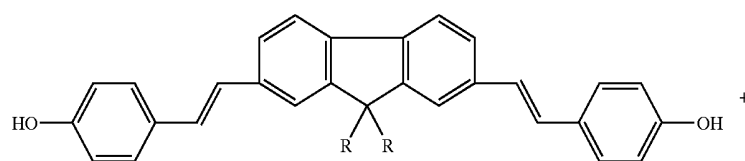


[M-36]

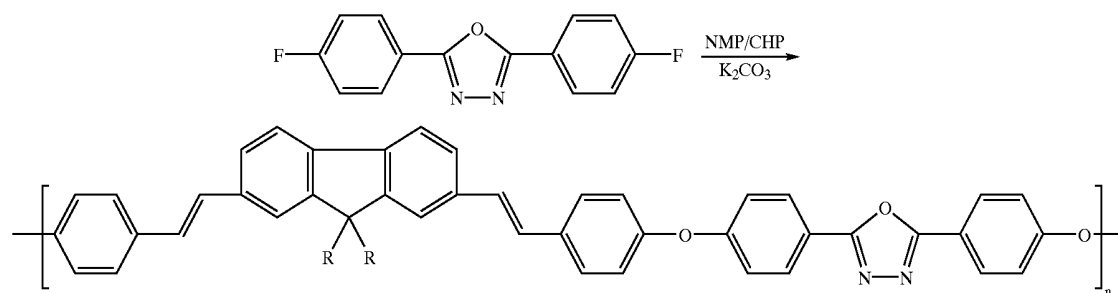
-continued



[P-24]

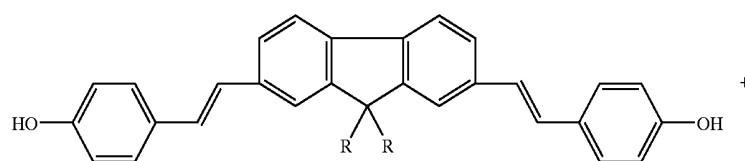


[M-36]

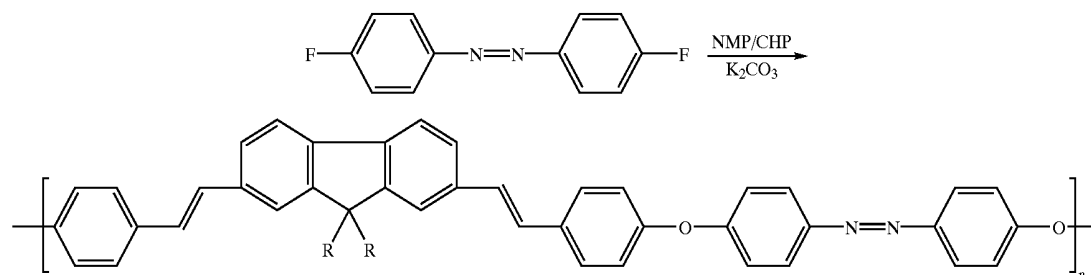


[P-25]

Reaction Scheme 14

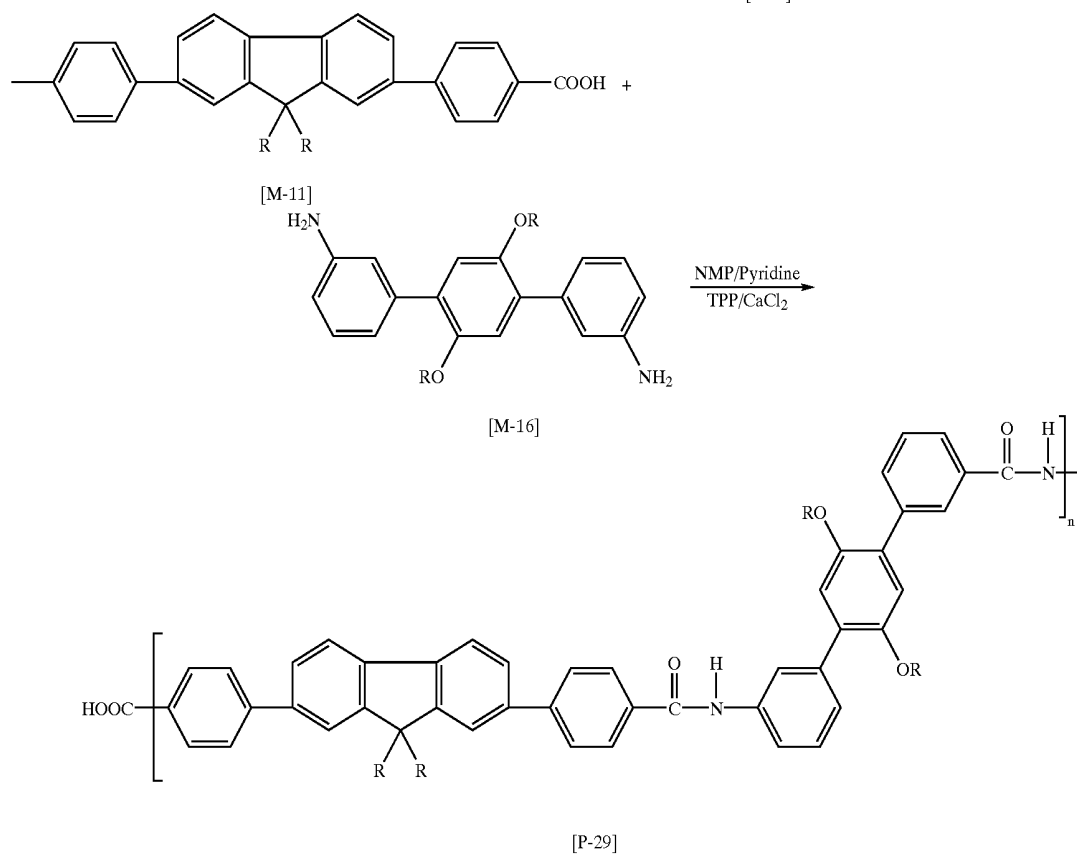
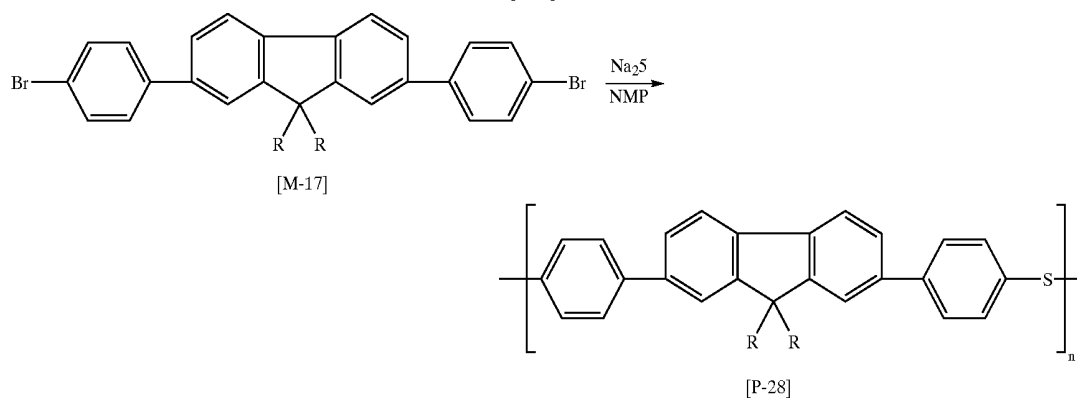
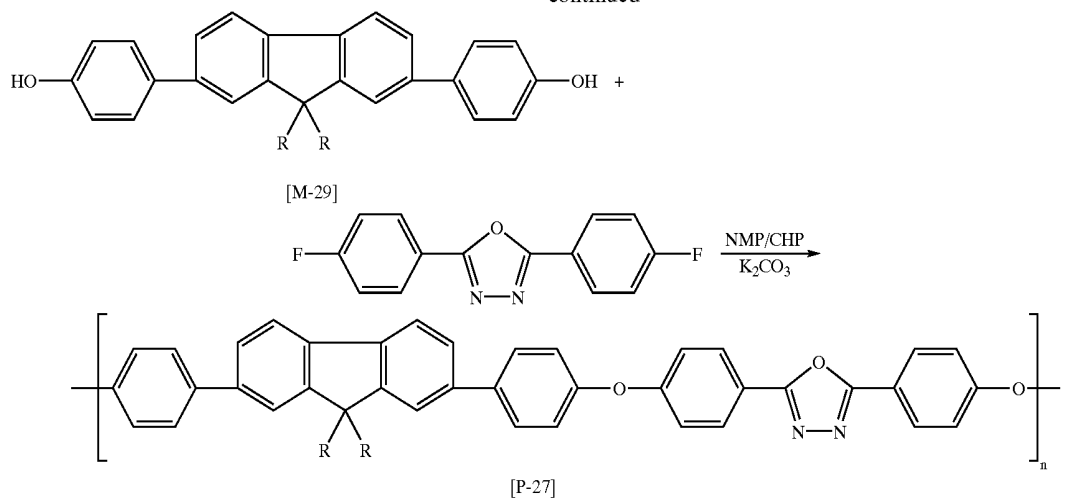


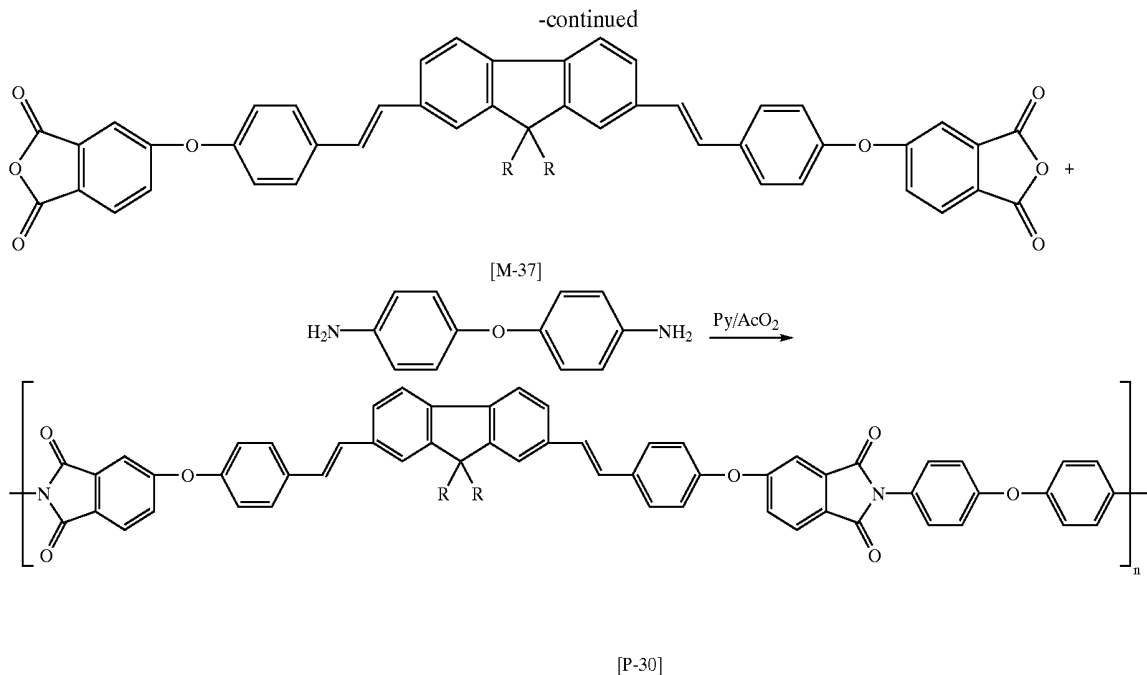
[M-26]



[P-26]

-continued





[0028] In addition to the above reaction procedures as described in Reaction Schemes 1 to 14, the fluorene compounds and/or the polymers thereof of the present invention can be prepared by using any known reactions if the final product has the same structure. That is, there is no need to limit a solvent, reaction temperature, concentration or catalyst used for preparing the fluorene compounds and/or

polymers thereof of the present invention, and further it is regardless of a yield of the product.

[0029] The following Table 1 shows structures of the fluorene and other monomers M-1 to M-40 of the present invention, wherein the R is n-hexyl, and the light emitting properties thereof. The preparation and structures thereof will be described in more detail in Examples 1 to 40.

TABLE 1

Monomers	Structure (R = n-Hexyl)	UV(λ_{max}) (nm)	PL(λ_{max}) (nm)	M.P.(° C.)
[M-1]	<p>R = n-hexyl</p>	290/316	334	188-191
[M-2]		374	—	134-136
[M-3]		344	397	79-80

TABLE 1-continued

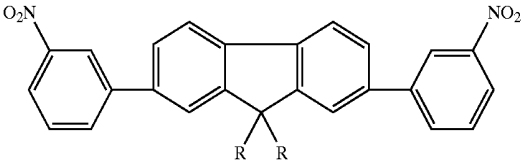
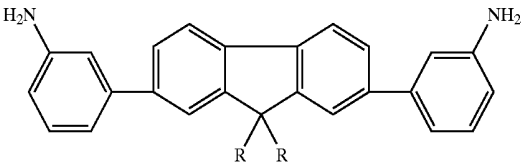
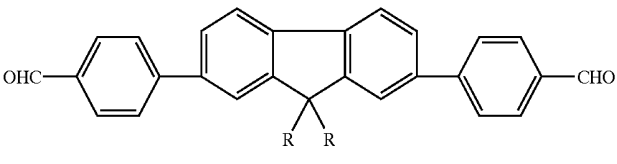
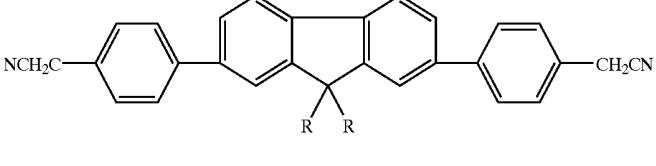
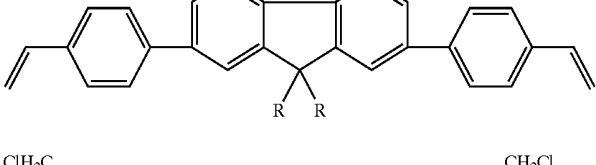
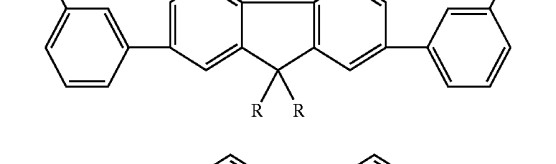
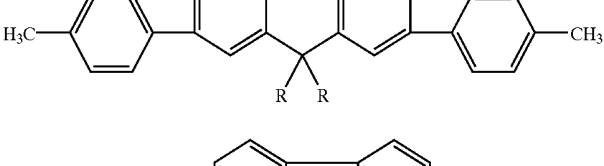
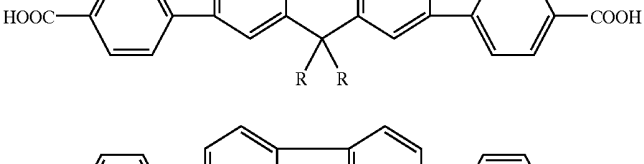
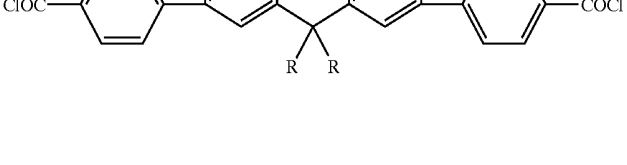
Monomers	Structure (R = n-Hexyl)	UV(λ_{\max}) (nm)	PL(λ_{\max}) (nm)	M.P.(° C.)
[M-4]		362	—	128–129
[M-5]		333	386	135–136
[M-6]		354	428	120–121
[M-7]		330	367/383	104–105
[M-8]		344	388/407	106–107
[M-9]		328	386/405	97–98
[M-10]		332	374	88–89
[M-11]		344	394	290–293
[M-12]		364	432	130–131

TABLE 1-continued

Monomers	Structure (R = n-Hexyl)	UV(λ_{\max}) (nm)	PL(λ_{\max}) (nm)	M.P.(° C.)
[M-13]		330	368/382	94-95
[M-14]		344	390/406	100-101
[M-15]		328	—	126-127
[M-16]		320	390	105-106
[M-17]		332	368/386	12-123
[M-18]		340	382	101-102
[M-19]		334	376/482	86-88
[M-20]		334	—	102-103

TABLE 1-continued

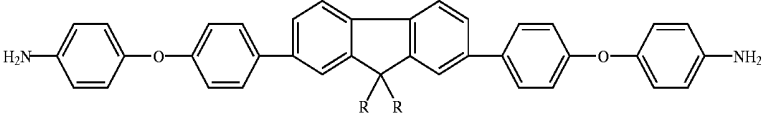
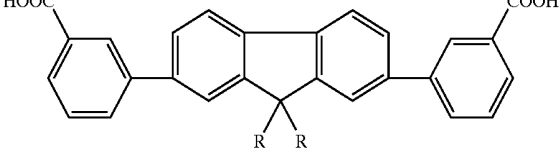
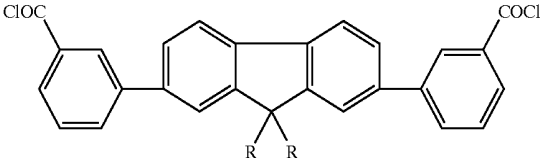
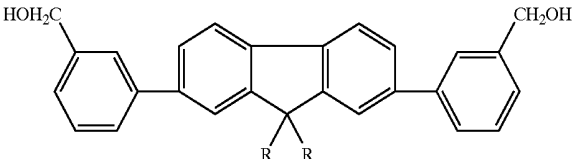
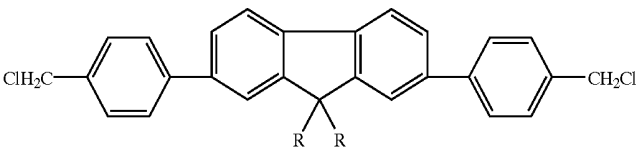
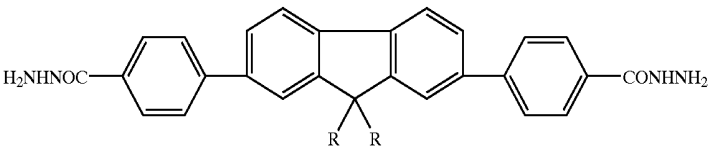
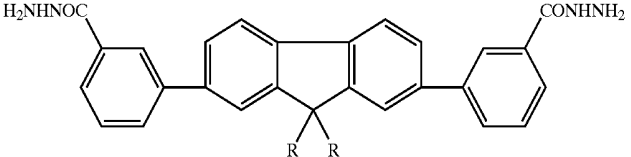
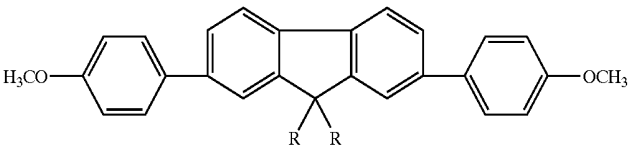
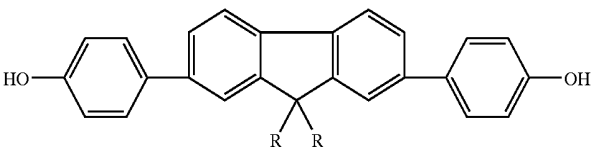
Monomers	Structure (R = n-Hexyl)	UV(λ_{\max}) (nm)	PL(λ_{\max}) (nm)	M.P.(° C.)
[M-21]		335	375/393	57-58
[M-22]		330	404	227-229
[M-23]		326	445	113-114
[M-24]		330	368/386	58-59
[M-25]		334	438	104-105
[M-26]		343	406	134-136
[M-27]		332	370/386	106-108
[M-28]		334	372/388	104-105
[M-29]		340	397	142-143

TABLE 1-continued

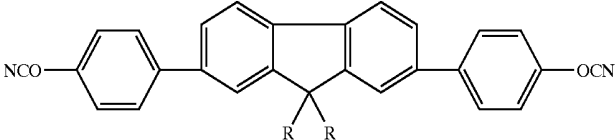
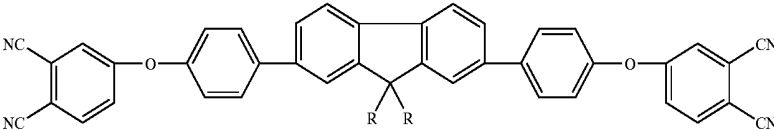
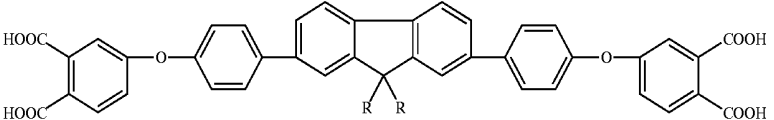
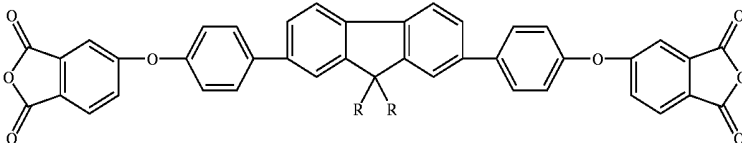
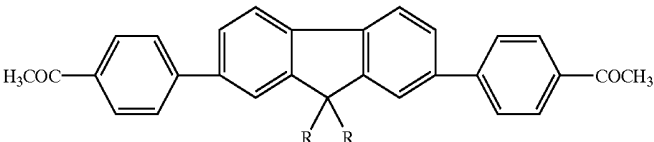
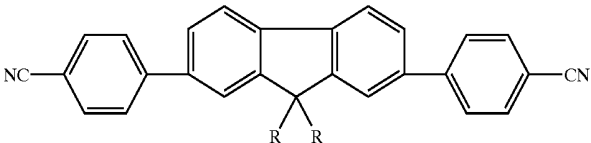
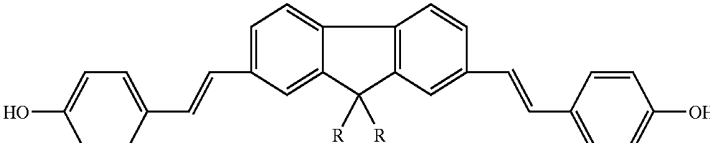
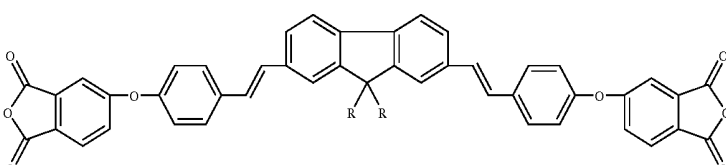
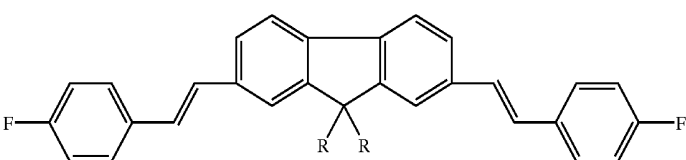
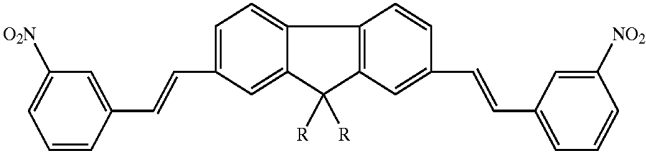
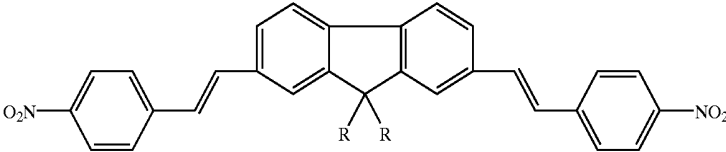
Monomers	Structure (R = n-Hexyl)	UV(λ_{\max}) (nm)	PL(λ_{\max}) (nm)	M.P.(° C.)
[M-30]		330	365/380	125-126
[M-31]		332	364	183-184
[M-32]		350	414	214-215
[M-33]		332	374	187-188
[M-34]		350	414	130-131
[M-35]		342	389/404	113-115
[M-36]		378	415/438	96-97
[M-37]		380	429	190-193
[M-38]		372	407/430	110-111

TABLE 1-continued

Monomers	Structure (R = n-Hexyl)	UV(λ_{max}) (nm)	PL(λ_{max}) (nm)	M.P.(° C.)
[M-39]		376	—	189–192
[M-40]		374	—	164–166

[0030] The following Table 2 shows the structures of the fluorene-based polymers P-1 to P-30, wherein the R represents n-hexyl group, and the light emitting properties thereof. The preparation and structures thereof will be described in more detail in Examples 41 to 66.

TABLE 2

Polymers	Structures (R = n-Hexyl)	UV(λ_{max}) (nm)	PL(λ_{max}) (nm)	$M_w \times 10^{-3}$	P.D.I.
[P-1]		370	—	19.9	2.54
[P-1-1]		355	411	—	—
[P-1-2]		348	418	—	—
[P-2]		380	—	10.7	2.49
[P-3]		333	375	9.6	1.82

TABLE 2-continued

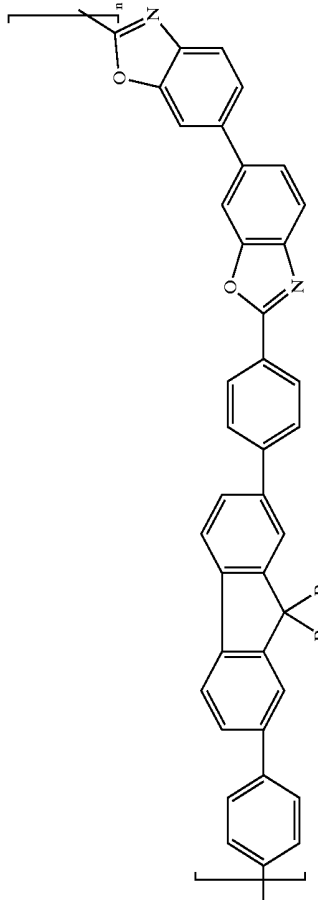
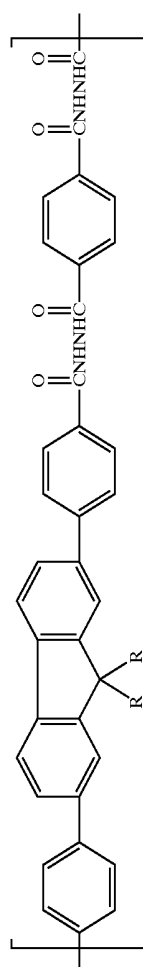
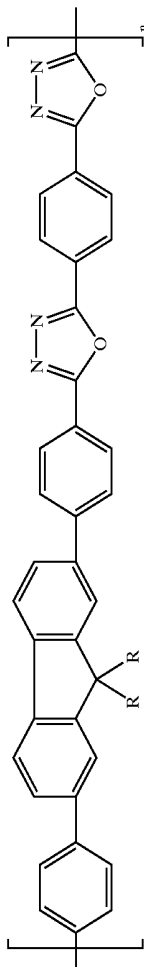
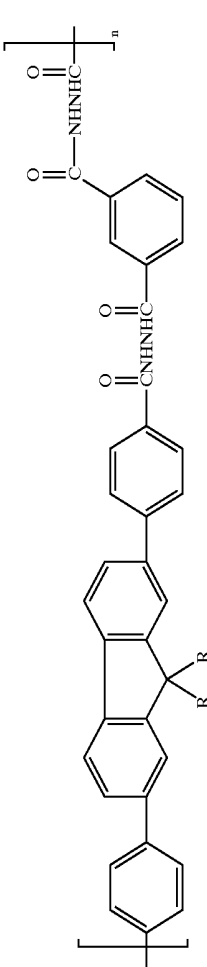
Polymers	Structures (R = n-Hexyl)	UV(λ_{max}) (nm)	PL(λ_{max}) (nm)	$M_w \times 10^{-3}$	P.D.I.
[P-7]		—	—	—	—
[P-8]		344	400	10.5	1.9
[P-9]		366	454	—	—
[P-10]		344	407	11.7	2.0

TABLE 2-continued

Polymers	Structures (R = n-Hexyl)	UV(λ_{max}) (nm)	PL(λ_{max}) (nm)	$M_w \times 10^{-3}$	P.D.I.
[P-11]		358	432	—	—
[P-12]		334	386	12.3	2.1
[P-13]		333	490	—	—

TABLE 2-continued

Polymers	Structures (R = n-Hexyl)	UV(λ_{max}) (nm)	PL(λ_{max}) (nm)	$M_w \times 10^{-3}$	P.D.I.
[P-14]		334	379	12.7	1.7
[P-15]		326	398	—	—
[P-16]		338	378/392	89.0	2.6
[P-17]		334	448/475	76.2	2.4

TABLE 2-continued

Polymers	Structures (R = n-Hexyl)	UV(λ_{max}) (nm)	PL(λ_{max}) (nm)	$M_w \times 10^{-3}$	P.D.I.
[P-18]		374	431	40.3	3.38
[P-19]		334	367	$\eta_{inh} = 1.2 \text{ dl/g}$ (30° C., 0.5 g/dl, NMP)	—
[P-20]		330	366/383	29.9	2.53
[P-21]		378	415/438	258.8	3.57
[P-22]		380	417/443	100.9	3.8

TABLE 2-continued

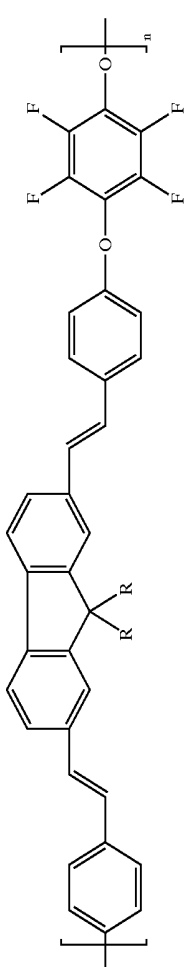
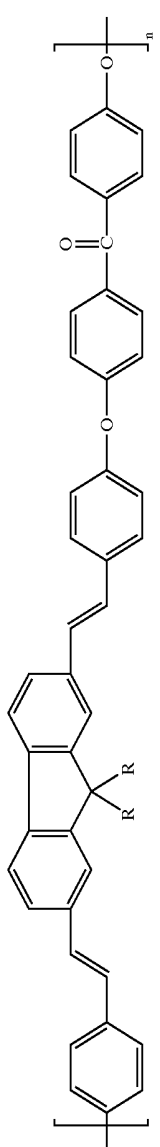
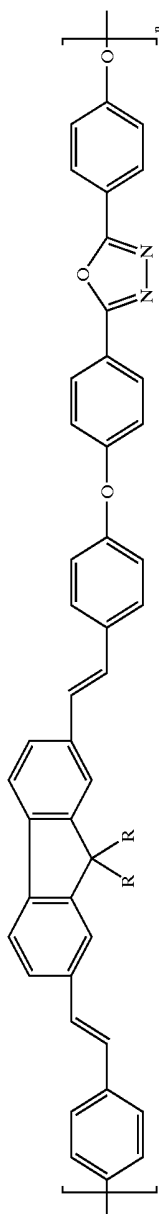
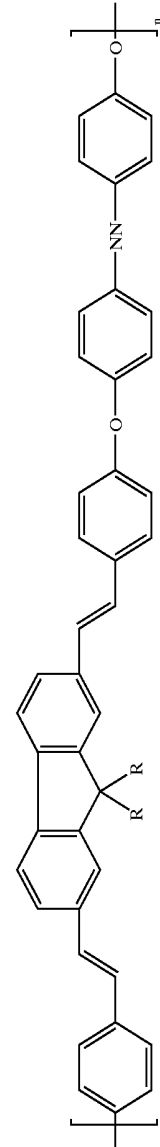
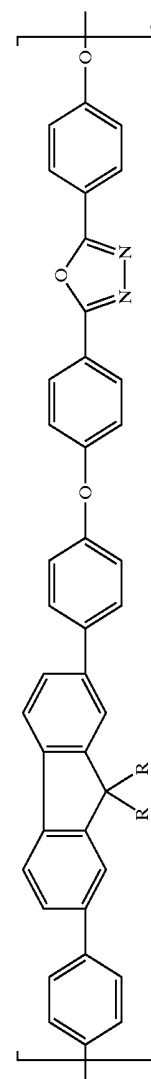
Polymers	Structures (R = n-Hexyl)	UV(λ_{max}) (nm)	PL(λ_{max}) (nm)	$M_w \times 10^{-3}$	P.D.I.
[P-23]		378	417/438	98.8	6.24
[P-24]		380	418/442	28.2	2.66
[P-25]		380	417/440	235.3	3.95
[P-26]		384	418/443	13.7	2.28
[P-27]		356	373/389	185.2	3.34

TABLE 2-continued

Polymers	Structures (R = n-Hexyl)	UV(λ_{max}) (nm)	PL(λ_{max}) (nm)	$M_w \times 10^{-3}$	P.D.I.
[P-28]		346	395	5.8	1.86
[P-29]		342	407	$\eta_{inh} = 0.6 \text{ dl/g}$ (30° C., 0.5 g/dl, DMAc)	—
[P-30]		382	—	$\eta_{inh} = 1.07 \text{ dl/g}$ (30° C., 0.5 g/dl, NMP)	—

[0031] The light emitting properties shown in the Tables 1 and 2 are measured using the method described in Example 67.

[0032] The organic and polymeric EL element and/or other optical elements according to the present invention can be fabricated using the fluorene compounds having various structures and functional groups and the polymers thereof as shown in the Table 1 and 2, as core materials for light emitting.

[0033] The fluorene compounds and/or polymers thereof can be made a film using known methods such as vacuum deposition, spin coating, role coating, bar coating, ink jet coating and the like, and can be directly used as EL materials.

[0034] The structure of the EL element can include a typical element constitution in which the material for the light emitting layer is inserted between an anode and a cathode, that is, an element constitution of anode/light emitting layer/cathode. Further, an element constitution in which uses together with a hole and electron transporting layer materials (Japanese Laid-open patent publications 2-135361, 3-152184 and 6-207170), that is, an element constitution of anode/hole transporting layer/light emitting layer/electron transporting layer/cathode can also be included. However, the constitution of the EL element of the present invention is not particularly limited.

[0035] The anode ordinarily comprises a transparent supporting substrate such as glass, transparent plastics, quartz, etc., coated with a metal or metal oxide such as ITO, gold, copper, tin oxide, zinc oxide, etc., or an organic semiconductor compound such as polypyrrole, polyaniline or polythiophene in the thickness of 10 nm to 1 μ m thereon as electrode materials. The cathode is usually made of a metal such as sodium, magnesium, calcium, aluminum, indium, silver, gold, copper, or the like, or alloys thereof. In an embodiment of the present invention, the hole transporting layer can be formed by coating with polyvinylcarbazole, 2,5-bis(4'-diethylaminophenyl)-1,3,4-oxadiazole, N,N'-diphenyl-N,N'-(3-methylphenyl)-1,1'-biphenyl-4,4'-diamine (TPD) or the like, while the electron transporting layer can be formed by coating with known compounds such as tris(8-hydroxyquinolinato)aluminum, 2-(4'-t-butylphenyl)-5-(4''-biphenyl)-1,3,4-oxadiazole, 2,4,7-trinitro-9-fluorenone or the like, by employing known thin film formation methods such as vacuum deposition, spin-coating, casting, LB method, or the like.

[0036] The luminescent materials of the present invention can also be used by blending with the above hole or electron transporting layers, or other mutually different polymers of the present invention, and known luminescent polymers such as soluble PPV or PTh derivatives. For instance, polyvinylcarbazole, poly(1,4-hexyloxy-2,5-phenylenevinylene), poly(3-hexylthiophene), or the like and the fluorene-based polymers of the present invention can be dissolved in an organic solvent such as chloroform, and then coated them by spin coating, casting method, or the like. Although no particular restrictions are required, the concentration of the fluorene-based luminescent polymers of the present invention is in the range of 0.001 to 99%, preferably 0.1 to 50% of the polyvinylcarbazole, and the thickness of the film is from 5 nm to 5 μ m, preferably from 50 nm to 1 μ m.

[0037] Also, polymers that are soluble in any typical organic solvent and can be formed into a film may be used by blending with the luminescent material of the present invention in the same concentration and thickness as described above. Such polymers can include thermoplastics such as polymethylmethacrylate, polyacrylate, polystyrene, polycarbonate, polyvinylchloride, polyethylene, polypropylene, polyacrylonitrile, polyvinylpyrrolidone, polyvinylalcohol, polyvinylacetate, polyvinylbutyral, polyvinylamine, polycaprolacton, polyethyleneterephthalate, polybutyleneterephthalate, polyurethan, ABS, polysulfone, polyvinylfluoride, or the like, or resins for general use such as acetal, polyamides, polyimides, polyesters, alkyd, urea, furan, nylons, melamine, phenol, silicone, epoxy, or the like.

EXAMPLE

[0038] The present invention will now be described in more detail by examples which are not limited.

[0039] Synthesis of Monomers:

Example 1

[0040] Synthesis of 9,9'-di-n-hexylfluorene-2,7-diboranic acid (M-1)

[0041] Under an argon atmosphere, 2,7-dibromo-9,9'-dihexylfluorene 60.0 g (0.12 mol) and magnesium 11.9 g (0.49 mol) were introduced into a 1 L three-necked flask equipped with a stirrer, a thermometer and a reflux condenser and dissolved in 40 ml of anhydrous tetrahydrofuran (THF). After adding small amount of iodine to the above mixture, it was refluxed for 6 hours at 70° C., to obtain Grynard Reagent of pure brown color. Into a separate 2 L three-necked flask equipped with a mechanical stirrer, trimethyl borate [B(OCH₃)₃] 38.0 g (0.36 mol) was introduced, cooled with dry-ice and dissolved in 300 ml of anhydrous THF. To this solution, the Grynard Reagent obtained above was added, and the resulting solution was stirred for two hours at -78° C. and two days at room temperature. 500 ml of 2M hydrochloric acid was added gradually to the reaction mixture, and then the mixture was stirred for three hours, whereby pure yellow solution was obtained. The solution was extracted three times with diethyl ether, and combined extract was dried with anhydrous magnesium sulfate, filtered to remove drying agent, and then the solvent was removed, thereby to give pale brown solid. By recrystallizing in a mixture of acetone/hexane (20/80), white solid was obtained. The solid was filtered and dried in a vacuum oven at 40° C., to give 30 g of the desired product (yield 58.8%).

[0042] Mp: 188-189° C.; ¹H NMR (DMSO-d₆): δ 0.42 (br, 6H, CH₃), 0.61-0.91 (t, 16H, CH₂), 1.9 (br, s, 4H, CCH₂), 7.73-7.81 (d, 6H, aromatic), 8.04 (s, 4H, OH).

Example 2

[0043] Synthesis of 2,7-bis(4-nitrophenyl)-9,9'-di-n-hexylfluorene (M-2)

[0044] Under an argon atmosphere, 9,9'-di-n-hexylfluorene-2,7-diboranic acid 5.0 g (11.8 mmol), 4-bromonitrobenzene 5.26 g (26.0 mmol) and tetrakis(triphenyl)phosphine palladium [(PPh₃)₄]Pd(0) 0.3 g (0.26 mmol) were introduced into a 500 ml three-necked flask equipped with a stirrer, a thermometer and a reflux condenser and dissolved

in 140 ml of toluene. In addition, 65 ml of 2M sodium carbonate solution was added to the mixture, and then the reaction mixture was refluxed for 48 hours. After the reaction was completed, the reaction mixture was cooled to be room temperature, and then the mixture was extracted three times with toluene. Combined extract was washed with water and dried with anhydrous magnesium sulfate. When the solvent was removed, visco-elastic liquid was obtained. The liquid was purified by performing chromatography on silica gel column using a mixture of hexane/methylenechloride (1/1) as an eluent. By performing recrystallization in a mixture of ethyl acetate/hexane, fine yellow crystal was obtained. By drying the obtained solid in a vacuum oven at 40° C., 5 g of the desired product (yield: 73.2%) was obtained.

[0045] Mp: 134-136° C.; ¹H NMR (CDCl₃): δ 0.72-1.12 (m, 22H, CH₂ and CH₃), 2.04-2.12 (m, 4H, CCH₂), 7.62-7.81 (m, 14H, aromatic).

Example 3

[0046] Synthesis of 2,7-bis(4-aminophenyl)-9,9'-di-n-hexylfluorene (M-3)

[0047] 2,7-bis(4-nitrophenyl)-9,9'-di-n-hexylfluorene 4.0 g (6.9 mmol) and 10 wt % palladium activated carbon (Pd/C) 1 g were introduced into a 500 ml two-necked flask equipped with a stirrer and dissolved in 50 ml of ethyl acetate, and then the mixture was reacted at room temperature for 24 hours while filling hydrogen gas. When the reaction was completed, anhydrous magnesium sulfate was added to the reaction mixture to dry, the reaction mixture was filtered to remove the drying agent, and the solvent was then removed, to give viscous liquid. The liquid was purified by performing chromatography on silica gel column using methylenechloride as an eluent. By performing recrystallization in methanol, white fine crystal was obtained. The obtained solid was dried in a vacuum oven at 40° C., to give 2.2 g of the desired product (yield: 65.0%).

[0048] Mp: 79-81° C.; ¹H NMR (CDCl₃): δ 0.72-1.15 (m, 22H, CH₂ and CH₃), 1.96-2.04 (m, 4H, CCH₂), 3.67 (br, s, 4H, NH₂), 6.76-7.72 (m, 14H, aromatic).

Example 4

[0049] Synthesis of 2,7-bis(3-nitrophenyl)-9,9'-di-n-hexylfluorene (M-4)

[0050] Under an argon atmosphere, 2,7-dibromo-9,9'-di-n-hexylfluorene 40.0 g (81.3 mmol), 3-nitrobenzenboronic acid [(O₂NC₆H₄B(OH)₂] 29.8 g (0.178 mol) and tetrakis(triphenyl)phosphine palladium 0.93 g (0.81 mmol) were introduced into a 1 L three-necked flask equipped with a thermometer, a mechanical stirrer and a reflux condenser and dissolved in 300 ml of toluene. In addition, 150 ml of 2M sodium carbonate was added to the mixture, and then the reaction mixture was refluxed for 48 hours. After the reaction was completed, the reaction mixture was cooled to be room temperature, and the reaction mixture was extracted with toluene three times. Combined extract was washed with water and dried with anhydrous magnesium sulfate. After filtering to remove the drying agent, solvent was removed, to give viscous liquid. The liquid was purified by performing chromatography on silica gel column using a mixture of ethyl acetate/hexane (1/3) as an eluent and then recrystal-

lized in a mixture of ethyl acetate/hexane, to give fine yellow crystal. By drying the obtained solid in a vacuum oven at 40° C., 25 g of the desired product (yield: 53.3%) was obtained.

[0051] Mp: 135-136° C.; ¹H NMR (CDCl₃): δ 0.72-1.13 (m, 22H, CH₂ and CH₃), 2.06-2.14 (m, 4H, CCH₂), 7.62-8.56 (m, 14H, aromatic).

Example 5

[0052] Synthesis of 2,7-bis(3-aminophenyl)-9,9'-di-n-hexylfluorene (M-5)

[0053] 2,7-bis(3-nitrophenyl)-9,9'-di-n-hexylfluorene 9.0 g (15.6 mmol) and 10 wt % palladium activated carbon (Pd/C) 1.5 g were introduced into a 500 ml two necked flask equipped with a stirrer and dissolved in 100 ml of ethyl acetate, and then the reaction mixture was reacted at room temperature for 24 hours while filling hydrogen gas. When the reaction was completed, anhydrous magnesium sulfate was added to dry and removed by filtering, and then solvent was removed to give viscous liquid. The liquid was purified by performing chromatography on silica gel column using a mixture of ethyl acetate/hexane (1/1). By performing recrystallization in a mixture of diethyl ether/methanol, white crystal was obtained. The white crystal was dried in a vacuum oven at 40° C. to give 6.5 g of the desired product (yield: 80%).

[0054] Mp: 120-121° C.; ¹H NMR (CDCl₃): δ 0.76-1.16 (m, 22H, CH₂ and CH₃), 2.02-2.10 (m, 4H, CCH₂), 3.77 (br, s, 4H, NH₂), 6.72-7.79 (m, 14H, aromatic).

Example 6

[0055] Synthesis of 2,7-bis(4-aldehydephenyl)-9,9'-di-n-hexylfluorene (M-6)

[0056] Under an argon atmosphere, 9,9'-di-n-hexylfluorene-2,7-diboronic acid 5.0 g (11.8 mmol), 4-bromobenzaldehyde (BrC₆H₄CHO) 4.8 g (26.0 mmol) and tetrakis(triphenyl)phosphine palladium 0.3 g (0.26 mmol) were introduced into a 500 ml three-necked flask equipped with a thermometer, a stirrer and a reflux condenser, and then the mixture was refluxed for 48 hours. After the reaction was completed, the reaction mixture was cooled to be room temperature and extracted with toluene three times. Combined extract was washed with water several times and then dried with anhydrous magnesium sulfate. Solvent was removed to give viscous liquid. The liquid was purified by performing chromatography on silica gel column using methylenechloride as an eluent. By performing recrystallization in a mixture of ethyl acetate/hexane, yellow crystal was obtained. The crystal was dried in a vacuum oven at 40° C. to give 5.0 g of desired product (yield: 77.8%).

[0057] Mp: 128-129° C.; ¹H NMR (CDCl₃): δ 0.71-1.12 (m, 22H, CH₂ and CH₃), 2.03-2.11 (m, 4H, CCH₂), 7.62-8.02 (m, 14H, aromatic), 10.08 (s, 2H, CHO).

Example 7

[0058] Synthesis of 2,7-bis(4-acetonitrylphenyl)-9,9'-di-n-hexylfluorene (M-7) Under an argon atmosphere, 9,9'-di-n-hexylfluorene-2,7-diboronic acid 9.0 g (16.58 mmol), 4-bromophenylacetonitril (BrC₆H₄CH₂CN) 7.15 g (36.47 mmol) and tetrakis(triphenyl)phosphine palladium 0.42 g (0.36 mmol) were introduced into a 500 ml three-necked

flask equipped with a thermometer, a stirrer and a reflux condenser and dissolved 180 ml of in toluene. In addition, 90 ml of 2M sodium carbonate solution was added to the mixture and the reaction mixture was refluxed for 48 hours. After the reaction was completed, the reaction mixture was cooled down to room temperature, and the above solution was extracted with toluene three times. Combined extract was washed several times, and dried to anhydrous magnesium sulfate. In addition, the resultant was filtered and the solvent was removed to give viscous liquid. The liquid was purified by performing chromatography on silica gel column using ethyl acetate (1:2) mixture, after that recrystallized in a mixture of ethanol/chloroform to give yellow crystal. The crystal was dried in a vacuum oven at 40° C. and of desired product 4.7 g of desired product (yield: 50%). Mp: 104-105° C.; ¹H NMR (CDCl₃), δ 0.72-1.07 (m, 22H, CH₂ and CH₃), 2.01-2.18 (m, 4H, CCH₂), 3.83 (s, 4H, NH₂), 7.42-7.81 (m, 14H, aromatic).

Example 8

[0059] Synthesis of 2,7-bis(4-vinylphenyl)-9,9'-di-n-hexylfluorene (M-8)

[0060] In 500 ml three-necked flask equipped with a thermometer, a stirrer and a reflux condenser under nitrogen argon atmosphere, 2,7-dibromo-9,9'-di-n-hexylfluorene 20.0 g (40.6 mmol), 4-vinylphenylboron acid [H₂C=CHC₆H₄B(OH)₂] 13.3 g (89.4 mmol) and tetrakis(triphenylphosphine) palladium 0.46 g (0.4 mmol) were introduced and dissolved in toluene 200 ml, and 2M sodium carbonate 100 ml was added and refluxed for 48 hours. After the reaction was completed, the reaction mixture was cooled down to room temperature, and the mixture was extracted with toluene three times. Combined extract was washed with water several times and then dried with anhydrous magnesium sulfate. Solvent was removed to give viscous liquid. The obtained liquid was purified by performing chromatography on silica gel column using a mixture of ethyl acetate/hexane (1/3) and then crystallized in a mixture of ethyl acetate/hexane to give yellow crystal. The crystal was dried in vacuum oven at 40° C. to give 16.0 g of desired product (yield: 73%).

[0061] Mp: 106-107° C.; ¹H NMR (CDCl₃): δ 0.75-1.16 (m, 22H, CH₂ and CH₃), 2.04-2.12 (m, 4H, CCH₂), 5.29-6.86 (m, 6H, vinyl), 7.53-7.82 (m, 14H, aromatic).

Example 9

[0062] Synthesis of 2,7-bis(3-chloromethylphenyl)-9,9'-di-n-hexylfluorene (M-9)

[0063] Under an argon atmosphere, 9,9'-di-n-hexylfluorene-2,7-diboron acid 2.0 g (4.7 mmol), 3-bromobenzylchloride (BrC₆H₄CH₂Cl) 2.14 g (10.4 mmol) and tetrakis(triphenylphosphine) palladium 0.12 g (0.104 mmol) were introduced into a 250 ml three-necked flask equipped with a thermometer, a stirrer and a reflux condenser and dissolved in 50 ml of toluene. In addition, 25 ml of 2M sodium carbonate was added to the mixture and the reaction mixture was refluxed for 48 hours. After the reaction was completed, the reaction mixture was cooled down to room temperature and then extracted with toluene three times. Combined extract was washed with water several times and then dried with anhydrous magnesium sulfate. When the solvent was removed, viscous liquid was obtained. The liquid was purified

by performing chromatography on silica gel column using a mixture of ethyl acetate/hexane (1:3) and then recrystallized in a mixture of ethyl acetate/hexane to give pale yellow crystal. The crystal was dried in a vacuum oven at 40° C. to give 1.2 g of desired product (yield: 43.5%).

[0064] Mp: 97-98° C.; ¹H NMR (CDCl₃): δ 0.75-1.11 (m, 22H, CH₂ and CH₃), 2.05-2.13 (m, 4H, CCH₂), 4.73 (s, 4H, CH₂Cl), 7.41-7.84 (m, 14H, aromatic).

Example 10

[0065] Synthesis of 2,7-bis(toryl)-9,9'-di-n-hexylfluorene (M-10)

[0066] Under a nitrogen atmosphere, 2,7-dibromo-9,9'-di-n-hexylfluorene 40.0 g (81.3 mmol), 4-tolylboron acid [CH₃C₆H₄B(OH)₂] 24.4 g (0.18 mmol) and tetrakis(triphenylphosphine) palladium 0.94 g (0.81 mmol) were introduced into a 1 L three-necked flask equipped with a thermometer, a stirrer and a reflux condenser and dissolved in 400 ml of toluene. In addition, 200 ml of 2M sodium carbonate was added to the mixture, and the reaction mixture was then refluxed for 48 hours. After the reaction was completed, the reaction mixture was cooled down to room temperature and extracted with toluene three times. Combined extract was washed with water several times and dried with anhydrous magnesium sulfate, and then solvent was removed, to give viscous liquid. The liquid was purified by performing chromatography on silica gel column using a mixture of ethyl acetate/hexane (1/2) as an eluent and then recrystallized in a mixture of ethyl acetate/hexane, to give pale yellow crystal. The crystal was dried in a vacuum oven at 40° C. to give 36.1 g of desired product (yield: 86%).

[0067] Mp: 88-89° C.; ¹H NMR (CDCl₃): δ 0.76-1.10 (m, 22H, CH₂ and CH₃), 2.03-2.11 (m, 4H, CCH₂), 2.46 (s, 6H, CH₃), 7.31-7.82 (m, 14H, aromatic).

Example 11

[0068] Synthesis of 2,7-bis(4-carboxyphenyl)-9,9'-di-n-hexylfluorene (M-11)

[0069] Into a 1 L three-necked flask equipped with a thermometer, a stirrer and a reflux condenser, 2,7-bis(toryl)-9,9'-di-n-hexylfluorene 15.0 g (29.1 mmol) was introduced and dissolved in 270 ml of pyridine, and the resulting mixture was refluxed. After 50 ml of boiling water was added to the above solution, potassium permanganate (KmnO₄) 13.8 g (87.4 mmol) was also added for 4 hours. The mixture was then refluxed for 8 hours to give brown colored solution. To this solution, 350 ml of boiling water was added, and then the potassium permanganate 27.6 g was added for 6 hours. The resulting mixture was refluxed for 12 hours to give brown colored solution. The solution was filtered in a hot state and washed with boiling water several times, to give yellow colored solution. Concentrated hydrochloric acid was added to the solution to form white precipitate. The precipitate was filtered, washed with water and then dried in a vacuum oven at 50° C., to give 11.7 g of white solid (yield: 70%).

[0070] Mp: 290-2930C; ¹H NMR (DMSO-d₆), δ 0.53-0.96 (m, 22H, CH₂ and CH₃), 0.96-2.11 (m, 4H, CCH₂), 7.71-8.05 (m, 14H, aromatic), 12.96 (br, s, 2H, COOH).

Example 12

[0071] Synthesis of 2,7-bis(4-chlorocarbonylphenyl)-9,9'-di-n-hexylfluorene (M-12)

[0072] Under an argon atmosphere, 2,7-bis(carboxylphenyl)-9,9'-di-n-hexylfluorene 6.0 g (10.4 mmol) and thionyl chloride (SOCl₂) 30 ml were introduced into a 50 ml three-necked flask equipped with a thermometer, a stirrer and a reflux condenser, and the mixture was heated to dissolve the starting material. Dimethylformamide 1 ml was then added to the mixture, and the resulting mixture was refluxed for 12 hours. The reaction mixture was cooled down to room temperature, the solvent was entirely removed under a reduced pressure, and then diethyl ether was added to the residue. Dissolved part in diethyl ether was separated from undissolved part and concentrated by removing solvent. The residue was recrystallized in a mixture of petroleum ether/diethyl ether to give yellow crystal. The obtained solid was filtered and dried in a vacuum oven at 40° C. to give 4.3 g of desired product (yield: 67%).

[0073] Mp: 130-131° C.; ¹H NMR (CDCl₃), δ 0.71-1.12 (m, 22H, CH₂ and CH₃), 2.03-2.11 (m, 4H, CCH₂), 7.61-8.25 (m, 14H, aromatic).

Example 13

[0074] Synthesis of 2,7-bis(3-ethylformatylphenyl)-9,9'-di-n-hexylfluorene (M-13)

[0075] Under an argon atmosphere, 9,9'-di-n-hexylfluorene-2,7-diboron acid 10.0 g (23.7 mmol), ethyl 3-bromobenzoate 11.9 g (52.1 mmol) and tetrakis(triphenyl)phosphine palladium 0.6 g (0.52 mmol) were introduced into a 500 ml three-necked flask equipped with a thermometer, a stirrer and a reflux condenser, and dissolved in 260 ml of toluene. 130 ml of 2M sodium carbonate solution was added to the mixture, and the resulting mixture was refluxed for 48 hours. After the reaction was completed, the reaction mixture was cooled down to room temperature and extracted with toluene three times. Combined extract was washed with water several times and dried with anhydrous magnesium sulfate, and then solvent was removed, to give viscous liquid. The liquid was purified by performing chromatography on silica gel column using a mixture of ethyl acetate/hexane (1/3) as an eluent and then recrystallized in a mixture of ethanol/acetone to give white crystal. The crystal was dried in a vacuum oven at 40° C. to give 11 g of desired product (yield: 73.8%).

[0076] Mp: 94-95° C.; ¹H NMR (CDCl₃), δ 0.70-1.06 (m, 22H, CH₂ and CH₃), 1.39-1.46 (t, 6H, CH₃), 2.00-2.08 (m, 4H, CCH₂), 4.37-4.48 (q, 4H, OCH₂), 7.50-8.35 (m, 14H, aromatic).

Example 14

[0077] Synthesis of 2,7-bis(4-ethylformatylephenyl)-9,9'-di-n-hexylfluorene (M-14)

[0078] Under an argon atmosphere, 9,9'-di-n-hexylfluorene-2,7-diboron acid 10.0 g (23.7 mmol), ethyl 4-bromobenzoate 11.9 g (52.1 mmol) and tetrakis(triphenyl)phosphine palladium 0.6 g (0.52 mmol) were introduced into a 500 ml three-necked flask equipped with a thermometer, a stirrer and a reflux condenser and dissolved in 260 ml of toluene. 130 ml of 2M sodium carbonate solution was then

added to the mixture, and the resulting mixture was refluxed for 48 hours. After the reaction was completed, the reaction mixture was cooled down to room temperature and extracted with toluene three times. Combined extract was washed with water several times and dried with anhydrous magnesium sulfate, and then solvent was removed to give viscous liquid. The liquid was purified by performing chromatography on silica gel column using a mixture of ethyl acetate/hexane (1:3) as an eluent and then recrystallized in a mixture of ethanol/acetone to give white crystal. The crystal was dried in a vacuum oven at 40° C. to give 9 g of desired product (yield: 60%).

[0079] Mp: 100° C.; ¹H NMR (CDCl₃), δ 0.72-1.05 (m, 22H, CH₂ and CH₃), 1.40-1.44 (t, 6H, CH₃), 2.00-2.08 (m, 4H, CCH₂), 4.38-4.45 (q, 4H, OCH₂), 7.58-8.14 (m, 14H, aromatic).

Example 15

[0080] Synthesis of 1,4-bis(3-nitrophenyl)-3,6-di-hexyloxybenzen (M-15)

[0081] Under an argon atmosphere, 1,4-dibromo-3,6-di-hexyloxybenzen 20.0 g (45.8 mmol), 3-nitrobenzenboron acid [(O₂NC₆H₄B(OH)₂)] 16.8 g (0.1 mol) and tetrakis(triphenyl)phosphine palladium 0.53 g (0.46 mmol) were introduced into a 500 ml three-necked flask equipped with a thermometer, a stirrer and a reflux condenser, and dissolved in 200 ml of toluene. After adding 100 ml of 2M sodium carbonate solution to the mixture, the resulting mixture was refluxed for 48 hours. After the reaction was completed, the reaction mixture was cooled down to room temperature and extracted with toluene three times. Combined extract was washed with water several times and dried with anhydrous magnesium sulfate, and then solvent was removed to give viscous liquid. The liquid was purified by performing chromatography on silica gel column using a mixture of ethyl acetate/hexane (1/3) as an eluent and then recrystallized in a mixture of ethyl acetate/hexane to give yellow fine crystal. The crystal was dried in a vacuum oven at 40° C. to give 12 g of desired product (yield: 50%).

[0082] Mp: 126-127° C.; ¹H NMR (CDCl₃), δ 0.87-1.77 (m, 22H, CH₂ and CH₃), 3.91-3.98 (m, 4H, OCH₂), 7.01-8.51 (m, 10H, aromatic).

Example 16

[0083] Synthesis of 1,4-bis(3-aminophenyl)-3,6-di-hexyloxybenzen (M-16)

[0084] Into a 500 ml three-necked flask equipped with a stirrer, 1,4-bis(3-nitrophenyl)-3,6-di-hexyloxybenzene 9.0 g (17.3 mmol) and 10 wt % palladium activated carbon (Pd/C) 2 g were introduced and dissolved in 200 ml of THF, and then the resulting mixture was reacted for 24 hours at room temperature while filling hydrogen gas therein. After the reaction was completed, the reaction mixture was dried with anhydrous magnesium sulfate, and then solvent was removed to give white crystal. The crystal was dried in a vacuum oven at 40° C. to give 7.0 g of desired product (yield: 88%).

[0085] Mp: 105-106° C.; ¹H NMR (CDCl₃), δ 0.81-1.69 (m, 22H, CH₂ and CH₃), 3.57 (br, s, 4H, NH₂) 3.83-3.89 (m, 4H, OCH₂), 6.62-7.24 (m, 10H, aromatic).

Example 17

[0086] Synthesis of 2,7-bis(4-bromophenyl)-9,9-(di-n-hexylfluorene (M-17)

[0087] Into a 1 L three-necked flask equipped with a thermometer, a stirrer and a reflux condenser, 2,7-diphenyl-9,9-(di-n-hexylfluorene 50.0 g (0.1 mol) was introduced and dissolved in 400 ml of methylenechloride, and then the solution was cooled down to -5° C. using ice-salt bath. Bromine 33.6 g (0.21 mol) which was diluted in 100 ml of methylenechloride was added dropwise to the solution, and then the resulting mixture was reacted for 24 hours at 25° C. After the reaction was completed, 20% aqueous potassium hydroxide solution was gradually added to the solution until red color of the solution was disappeared, and then an organic layer was separated and washed with water several times. The solution was dried with anhydrous magnesium sulfate, and then solvent was removed to give viscous liquid. The liquid was dissolved in hexane and cooled down to -40° C., to give solid. The obtained solid was recrystallized in hexane two times to obtain pure white crystal. The crystal was filtered and dried in a vacuum oven at 40° C. to give 55 g of desired product (yield: 83.66%).

[0088] Mp: $121-123^{\circ}$ C.; $^1\text{H NMR}$ (CDCl_3), δ 0.71-1.06 (m, 22H, CH_2 and CH_3), 1.99-2.06 (m, 4H, CCH_2), 7.45-7.78 (m, 16H, aromatic).

Example 18

[0089] Synthesis of 2,7-bis(4-ethinylphenyl)-9,9'-di-n-hexylfluorene (M-18)

[0090] Into a 250 ml flask equipped with a thermometer and a stirrer, 2,7-bis[4-((trimethylsilyl)ethinyl)phenyl]-9,9'-di-n-hexylfluorene 4.0 g (5.8 mmol) and 20 wt % potassium fluoride 6 ml were introduced and dissolved in 100 ml of methanol, and then the resulting mixture was reacted for 6 hours at room temperature. After the reaction was completed, methanol 50 ml was added, and the solvent was removed under a vacuum condition. The residue was extracted with ether three times, and combined extract was washed with water several times and dried with magnesium sulfate. After removing solvent, the residue was purified by performing chromatography on silica gel column using a mixture of hexane/methylenechloride (4/1) as an eluent and then recrystallized in hexane to give 2.8 g of desired product as pale yellow solid (yield: 90%).

[0091] Mp: $101-102^{\circ}$ C.; $^1\text{H NMR}$ (CDCl_3), δ 0.78-1.42 (m, 22H, CH_2 and CH_3), 2.02-2.1 (m, 4H, CCH_2), 3.19 (s, 2H, CH), 7.42-7.78 (m, 14H, aromatic).

Example 19

[0092] Synthesis of 2,7-bis(4-aldehydephenyloxyphenyl)-9,9'-di-n-hexylfluorene (M-19)

[0093] Under an argon atmosphere, 2,7-bis(4-hydroxyphenyl)-9,9'-di-n-hexylfluorene 4.0 g (7.7 mmol), 4-fluorobenzaldehyde 1.96 g (15.8 mmol) and potassium carbonate 2.13 g (15.4 mmol) were introduced into a 100 ml three-necked flask equipped with a thermometer, a stirrer and a reflux condenser and dissolved in 25 ml of dimethyl acetamide (DMAc), and the resulting mixture was refluxed for 8 hours at 120° C. After the reaction was completed, the reaction mixture was cooled down to room temperature and

then gradually dropped into 400 ml of water to form solid. The solid was filtered and dissolved in diethyl ether, and then the solution was washed with water several times and dried with anhydrous magnesium sulfate. After removing solvent the residue was recrystallized in a mixture of ethyl acetate/hexane to give white solid. The solid was dried in a vacuum oven at 40° C. to give 4.3 g of desired product (yield: 76.7%).

[0094] Mp: $86-88^{\circ}$ C.; $^1\text{H NMR}$ (CDCl_3), δ 0.73-1.09 (m, 22H, CH_2 and CH_3), 2.03-2.10 (m, 4H, CCH_2), 7.13-7.91 (m, 22H, aromatic), 9.95 (s, 2H, CHO).

Example 20

[0095] Synthesis of 2,7-bis(4-nitrophenyloxyphenyl)-9,9'-di-n-hexylfluorene (M-20)

[0096] Under an argon atmosphere, 2,7-bis(4-hydroxyphenyl)-9,9'-di-n-hexylfluorene 6.0 g (11.6 mmol), 1-fluoro-4-nitrobenzene 3.3 g (23.7 mmol) and potassium carbonate 3.2 g (23.1 mmol) were introduced into a 100 ml three-necked flask equipped with a thermometer, a stirrer and a reflux condenser and dissolved in 35 ml of dimethyl acetamide, and the resulting mixture was refluxed for 8 hours at 120° C. After the reaction was completed, the reaction mixture was cooled down to room temperature and gradually dropped into 400 ml of water to form solid. The solid was filtered and dissolved in diethyl ether, and then the solution was washed with water several times and dried with anhydrous magnesium sulfate. After removing solvent, the residue was recrystallized in a mixture of ethyl acetate/hexane to give pale yellow solid. The solid was dried in a vacuum oven at 40° C. to give 7.2 g of desired product (yield: 79.8%).

[0097] Mp: $102-103^{\circ}$ C.; $^1\text{H NMR}$ (CDCl_3), δ 0.73-1.09 (m, 22H, CH_2 and CH_3), 2.03-2.11 (m, 4H, CCH_2), 7.06-8.28 (m, 22H, aromatic).

Example 21

[0098] Synthesis of 2,7-bis(4-aminophenyloxyphenyl)-9,9'-di-n-hexylfluorene (M-21)

[0099] Into a 500 ml two-necked flask equipped with a stirrer, 2,7-bis(4-nitrophenyloxyphenyl)-9,9'-di-n-hexylfluorene 6.0 g (7.9 mmol) and 10 wt % palladium activated carbon (Pd/C) 2 g were introduced and dissolved in 200 ml of THF, and then the resulting mixture was reacted for 24 hours at room temperature while filling hydrogen gas therein. When the reaction was completed, the reaction mixture was dried with anhydrous magnesium sulfate, and then solvent was removed to give viscous liquid. The liquid was recrystallized in a mixture of ethyl acetate/hexane mixture to give yellow crystal. The crystal was dried in a vacuum oven at 40° C. to give 4.7 g of desired product (yield: 85%).

[0100] Mp: $57-58^{\circ}$ C.; $^1\text{H NMR}$ (CDCl_3), δ 0.71-1.05 (m, 22H, CH_2 and CH_3), 2.01-2.05 (m, 4H, CCH_2), 6.68-7.75 (m, 22H, aromatic).

Example 22

[0101] Synthesis of 2,7-bis(3-carboxyphenyl)-9,9'-di-n-hexylfluorene (M-22) Under an argon atmosphere, 2,7-bis(3-ethylformatylephenyl)-9,9'-di-n-hexylfluorene 15.0 g

(23.8 mmol) was introduced into a 500 ml three-necked flask equipped with a thermometer, a stirrer and a reflux condenser and dissolved in 100 ml of THF. 100 ml of 1M aqueous lithium hydroxide solution was added to the mixture, and the resulting mixture was refluxed for 5 hours. When the reaction was completed, THF was removed, and then concentrated hydrochloric acid solution was gradually added to the residue while stirring to form solid. The solid was filtered, washed with water completely and then put into hexane. The mixture was stirred for two hours and then filtered to obtain pale yellow solid. The solid was dried in a vacuum oven at 40° C. to give 13.1 g of desired product (yield: 95%).

[0102] Mp: 227-229° C.; ¹H NMR (DMSO-d₆), δ 0.58-0.92 (m, 22H, CH₂ and CH₃), 2.05-2.09 (m, 4H, CCH₂), 7.5-8.28 (m, 14H, aromatic).

Example 23

[0103] Synthesis of 2,7-bis(3-chlorocarbonylphenyl)-9,9'-di-n-hexylfluorene (M-23)

[0104] Under an argon atmosphere, 2,7-bis(3-carboxyphenyl)-9,9'-di-n-hexylfluorene 8.0 g (13.9 mmol) was introduced into a 50 ml three-necked flask equipped with a thermometer, a stirrer and a reflux condenser and was dissolved in 40 ml of thionyl chloride by heating. 2 ml of dimethyl formamide (DMF) was added to the solution and the resulting mixture was refluxed for 24 hours. After the reaction was completed, the reaction mixture was cooled down to room temperature, and solvent was totally removed under a reduced pressure. Cyclohexane was added to the residue, and dissolved part in cyclohexane was separated from undissolved part and concentrated by removing solvent. The residue was dissolved and then recrystallized in hexane to give yellow crystal. The crystal was filtered and dried in a vacuum oven at 40° C. to give 6.0 g of desired product (yield: 70%).

[0105] Mp: 113-114° C.; ¹H NMR (CDCl₃), δ 0.72-1.13 (m, 22H, CH₂ and CH₃), 2.04-2.11 (m, 4H, CCH₂), 7.26-8.41 (m, 14H, aromatic).

Example 24

[0106] Synthesis of 2,7-bis(4-hydroxymethylphenyl)-9,9'-di-n-hexylfluorene (M-24)

[0107] Under an argon atmosphere, 2,7-bis(4-ethylformatephenyl)-9,9'-di-n-hexylfluorene 6.0 g (9.5 mmol) was introduced into a 250 ml three-necked flask equipped with a dropping funnel, a stirrer and a reflux condenser and dissolved in 30 ml of anhydrous THF. 1M LiAlH₄ solution in 40 ml of anhydrous THF was prepared and rapidly added to the mixture using the dropping funnel, and the resulting mixture was refluxed for 24 hours. After an ice-bath was installed, to the reaction mixture, water and 16 wt % NaOH solution was gradually added sequentially. The precipitate was filtered and washed with chloroform, and then the filtrate solution was extracted with chloroform and washed with water. Combined extract was dried with anhydrous magnesium sulfate and concentrated by removing chloroform under a reduced pressure. The residue was recrystallized in a mixture of ethyl acetate/hexane to give white solid. The solid was dried in a vacuum oven at 40° C. to give 5.1 g of desired product (yield: 96%).

[0108] Mp: 113-114° C.; ¹H NMR (CDCl₃), δ 0.73-1.07 (m, 22H, CH₂ and CH₃), 1.89 (s, 2H, OH), 2.01-2.09 (m, 4H, CCH₂), 4.78 (s, 4H, CH₂), 7.47-7.80 (m, 14H, aromatic).

Example 25

[0109] Synthesis of 2,7-bis(4-chloromethylphenyl)-9,9'-di-n-hexylfluorene (M-25)

[0110] Under an argon atmosphere, 2,7-bis(4-hydroxymethylphenyl)-9,9'-di-n-hexylfluorene 4.0 g (7.31 mmol) was introduced into a 100 ml three-necked flask equipped with a thermometer, a stirrer and a reflux condenser and dissolved in 50 ml of methylenechloride, and then thionyl chloride 1.4 ml and pyridine 0.05 ml were added to the mixture. The reaction mixture was refluxed for 12 hours and cooled down to room temperature, and then methylenechloride, thionyl chloride and pyridine were removed under a reduced pressure. The residual solid was purified by performing chromatography on silica gel column using a mixture of hexane/ethyl acetate (5/1) as an eluent and then recrystallized in a mixture of chloroform/methanol to give white crystal. The solid was filtered and dried in a vacuum oven at 40° C., to give 4.1 g of desired product (yield: 94%).

[0111] Mp: 104-105° C.; ¹H NMR (CDCl₃), δ 0.73-1.13 (m, 22H, CH₂ and CH₃), 2.00-2.08 (m, 4H, CCH₂), 4.68 (s, 4H, CH₂Cl), 7.49-7.81 (m, 14H, aromatic).

Example 26

[0112] Synthesis of 2,7-bis(4-hydrazidephenyl)-9,9'-di-n-hexylfluorene (M-26)

[0113] Into a 100 ml three-necked flask equipped with a thermometer, a stirrer and a reflux condenser under an argon atmosphere, 2,7-bis(3-ethylformatephenyl)-9,9'-di-n-hexylfluorene 5.0 g (7.92 mmol) was introduced and dissolved in 35 ml of butyl alcohol by heating, and then hydrazine monohydrate 6 ml was added. The resulting mixture was reacted for 48 hours at 80° C., cooled down to room temperature and extracted with ethyl acetate, sequentially. Combined extract was washed with water, and then ethyl acetate was removed except a small amount. The residue was dropped into hexane to form precipitate and washed for one hour, and then the solid was filtered and dried in a vacuum oven at 40° C., to give 2.0 g of desired product (yield: 42%).

[0114] Mp: 134-136° C.; ¹H NMR (CDCl₃), δ 0.72-1.19 (m, 22H, CH₂ and CH₃), 2.03-2.10 (m, 4H, CH₂), 4.21 (br, s, 4H, NH₂), 7.51 (s, 2H, NH), 7.60-7.90 (m, 14H, aromatic).

Example 27

[0115] Synthesis of 2,7-bis(3-hydrazidephenyl)-9,9'-di-n-hexylfluorene (M-27)

[0116] Under an argon atmosphere, 2,7-bis(3-ethylformatephenyl)-9,9'-di-n-hexylfluorene 5.0 g (7.92 mmol) was introduced into a 100 ml three-necked flask equipped with a thermometer, a stirrer and a reflux condenser and dissolved in 35 ml of butyl alcohol by heating, and then hydrazine monohydrate 6 ml was added. The resulting mixture was reacted for 48 hours at 80° C., cooled down to room temperature and then extracted with ethyl acetate. Combined extract was washed with water and dried with anhydrous magnesium sulfate, and then ethyl acetate was

removed except a small amount. The residue was dropped into hexane to form precipitate and washed for one hour. The solid was filtered and dried in a vacuum oven at 40° C. to give 2.5 g of desired product (yield: 52.4%).

[0117] Mp: 106-108° C.; ¹H NMR (CDCl₃), δ 0.72-1.06 (m, 22H, CH₂ and CH₃), 2.03-2.11 (m, 4H, CH₂), 4.21 (br, s, 4H, NH₂), 8.09 (s, 2H, NH), 7.60-7.90 (m, 14H, aromatic).

Example 28

[0118] Synthesis of 2,7-bis(4-methoxyphenyl)-9,9'-di-n-hexylfluorene (M-28)

[0119] Under an argon atmosphere, 2,7-(dibromo)-9,9'-di-n-hexylfluorene 45.1 g (81.4 mmol), p-methoxyphenylboronic acid 32.0 g (0.21 mol) and tetrakis(triphenylphosphine) palladium 1.06 g (1 mmol) were introduced into a round bottom flask equipped with a condenser and a stirrer and dissolved in 600 ml of toluene, and then 400 ml of 2M aqueous potassium carbonate solution was added. The resulting mixture was reacted for 48 hours at 120° C. and extracted with toluene several times. Combined extract was washed with water several times, dried with anhydrous magnesium sulfate, and then solvent was removed. The residue was purified by performing chromatography on silica gel column using ethyl acetate (5/1) as an eluent and then recrystallized in ethyl acetate/hexane, to give 41.5 g of desired product (yield: 83%).

[0120] Mp: 104-105° C.; ¹H NMR (CDCl₃), δ 0.76-1.16 (m, 22H, CH₂ and CH₃), 2.10-2.11 (m, 4H, CCH₂), 3.91 (s, 6H, OCH₃), 7.03-7.75 (m, 14H, aromatic).

Example 29

[0121] Synthesis of 2,7-bis(4-hydroxyphenyl)-9,9'-di-n-hexylfluorene (M-29)

[0122] Into a round bottom flask, 2,7-bis(4-methoxyphenyl)-9,9'-di-n-hexylfluorene 30.0 g (54.9 mmol) was introduced and dissolved in 400 ml of methylenechloride, and then 220 ml of 1 M tribromoborate was added dropwise for one hour at -76° C. The mixture was reacted at -76° C. for one hour, allowed to reach room temperature and then reacted for 24 hours at room temperature. Hydrolysis was carried out by adding water to the reaction mixture, and then organic layer was separated. 2N sodium hydroxide was added to the organic layer to form alkaline solid, and then diluted hydrochloric acid was added to neutralize and to make a clear solution by dissolving the solid. The resulting solution was extracted with ether. Combined extract was washed with distilled water several times and dried with anhydrous magnesium sulfate and then concentrated. The residue was purified by performing chromatography on silica gel column using a mixture of ethyl acetate/hexane (1:10) as an eluent and then recrystallized in ether, to give 21.8 g of desired product (yield: 76.6%).

[0123] Mp: 142-143° C.; ¹H NMR (DMSO-d₆), δ 0.61-1.16 (m, 22H, —CH₂— and —CH₃), 2.10-2.12 (m, 4H, —CCH₂—), 6.89-7.85 (m, 14H, aromatic), 9.57 (s, 2H, —OH).

Example 30

[0124] Synthesis of 2,7-bis(4-cyanatephenyl)-9,9'-di-n-hexylfluorene (M-30) Under an argon atmosphere, 2,7-

bis(4-hydroxyphenyl)-9,9'-di-n-hexylfluorene 10.0 g (19.3 mmol) and bromocyanide 6.1 g (57.9 mmol) were introduced into a round bottom flask and dissolved in 100 ml of acetone by stirring, and then 8 ml of triethylamine was added dropwise for 30 minutes at -30° C. The resulting mixture was reacted for 10 hours while allowing to reach room temperature. The reaction was quenched by adding 500 ml of water, and the reaction mixture was extracted with methylenechloride. Combined organic extract was washed with distilled water several times, dried with anhydrous magnesium sulfate and then concentrated. The residue was recrystallized in ethyl acetate to give 8.7 g of desired product (yield: 79.4%).

[0125] Mp: 125-126° C.; ¹H NMR (CDCl₃), δ 0.74-1.08 (m, 22H, —CH₂— and —CH₃—), 2.03-2.07 (m, 4H, —CCH₂—), 7.40-7.84 (m, 14H, aromatic).

Example 31

[0126] Synthesis of 2,7-bis[4-(3,4-dicyanophenoxy)phenyl]-9,9'-di-n-hexylfluorene (M-31)

[0127] Into a round bottom flask equipped with dean-stark device, 2,7-bis(4-hydroxyphenyl)-9,9'-di-n-hexylfluorene 10.0 g (19.3 mmol) was introduced and dissolved in 50 ml of DMF and 40 ml of toluene, and then potassium carbonate 5.6 g (40.5 mmol) was added. The reaction mixture was refluxed while maintaining the temperature at 140° C. After removing water and toluene completely from the dean-stark device, the temperature was cooled down to 60° C. p-nitrophthalonitrile 6.93 g (40.5 mmol) was added to the mixture, and then the resulting mixture was reacted for 24 hours at the same temperature. The reaction mixture was precipitated in 1000 ml of water, and then the precipitate was filtered and dried at 60° C. under a reduced pressure. The residue was purified by performing chromatography on silica gel column using hexane/ethyl acetate (4/1) as the elution solvent and then recrystallized in ethyl acetate to give 10.2 g of desired product (yield: 69%).

[0128] Mp: 183-184° C.; ¹H NMR (CDCl₃), δ 0.68-0.81 (m, 22H, —CH₂— and —CH₃), 2.06-2.08 (m, 4H, —CCH₂—), 7.14-7.80 (m, 20H, aromatic).

Example 32

[0129] Synthesis of 2,7-bis[4-(3,4-dicarboxyphenoxy)phenyl]-9,9'-di-n-hexylfluorene (M-32)

[0130] Into a round bottom flask, 2,7-bis[4-(3,4-dicyanophenoxy)phenyl]-9,9'-di-n-hexylfluorene 10 g (13 mmol), potassium hydroxide 14.6 g (0.26 mmol), 75 ml of distilled water and 75 ml of ethanol were introduced, and the mixture was refluxed for 3 days with stirring. After the hot reaction mixture was filtered to remove impurities which were not dissolved, the pH of the solution was adjusted to be 2-3 by adding hydrochloric acid to give solid. The solid was filtered, washed with water several times, neutralized, dried at 60° C. for 24 hours under a reduced pressure and recrystallized in a mixture of ethyl acetate and normal hexane, sequentially, thereby to obtain 8.6 g of desired product as white crystal (yield 78.3%).

[0131] Mp: 214-215° C.; ¹H NMR (DMSO-d₆), δ 0.58-1.20 (m, 22H, CH₂ and CH₃), 2.16-2.20 (m, 4H, CCH₂), 7.16-7.92 (m, 20H, aromatic).

Example 33

[0132] Synthesis of 2,7-bis[4-(3,4-dicarboxyphenoxy)phenyl]-9,9'-di-n-hexylfluorene dianhydride (M-33)

[0133] Into a round bottom flask, 2,7-bis[4-(3,4-dicarboxyphenoxy)phenyl]-9,9'-di-n-hexylfluorene 5.0 g (5.9 ml) and acetic anhydride 50 ml were introduced, and the resulting mixture was refluxed for 24 hours. After the hot solution was filtered to remove impurities which were not dissolved, the solution was cooled down slowly to give 3.75 g of desired product (yield: 78%).

[0134] Mp: 187-188° C.; ¹H NMR (CDCl₃), δ 0.76-1.12 (m, 22H, CH₂ and CH₃), 2.13-2.15 (m, 4H, CCH₂—), 7.24-8.04 (m, 20H, aromatic).

Example 34

[0135] Synthesis of 2,7-bis(4-acetyphenyl)-9,9'-di-n-hexylfluorene (M-34)

[0136] Into a 1.0 L round bottom flask equipped with a condenser and a dripping funnel, after 2,7-bis(diphenyl)-9,9'-di-n-hexylfluorene 30.0 g (61.6 mmol) was introduced and dissolved in 500 ml of carbon disulfide with stirring at room temperature, aluminum trichloride 24.66 g (185 mmol) was added at 0° C. Acetyl chloride 14.5 g (185 mmol) was added dropwise to the resulting solution for an hour using the dripping funnel, and then the reaction mixture was refluxed for 24 hours. The reaction mixture was poured into a mixture of 2M hydrochloric acid and ice to quench the reaction and extracted with methylenechloride. Combined organic extract was washed with water, dried with anhydrous magnesium sulfate and then concentrated. The residue was purified by performing chromatography on silica gel column using methylenechloride/hexane (1/10) as an elution solvent and then recrystallized in methylenechloride/hexane, thereby to obtain 23.5 g of desired product (yield: 66.8%).

[0137] Mp: 130-131° C.; ¹H NMR (CDCl₃), δ 0.73-0.79 (m, 22H, CH₂ and CH₃), 2.07 (m, 4H, CCH₂—), 2.68 (s, 6H, COCH₃), 7.63-8.12 (m, 14H, aromatic).

Example 35

[0138] Synthesis of 2,7-bis(4-cyanophenyl)-9,9'-di-n-hexylfluorene (M-35)

[0139] After 2,7-bis(4-bromophenyl)-9,9'-di-n-hexylfluorene 10.0 g (15.5 mmol) and cyanide copper 4 g (46.5 mmol) were introduced into a round bottom flask equipped with a condenser and dissolved in 60 ml of dimethylformamide (DMF), the reaction mixture was refluxed for 48 hours with stirring. The reaction mixture was poured into 1.0 L of 15% aqueous ammonia solution to generate precipitate. The precipitate was collected with filtering, washed with 15% and 10% aqueous ammonia solution and distilled water, and then dried to remove moisture under a reduced pressure at 60° C. The residue was dissolved in hot acetone, and the solution was filtered to remove impurities which were not dissolved in acetone and concentrated. The residue was purified by performing chromatography on silica gel column using a mixture of ethyl acetate/hexane (1/1) as the elution solvent and then recrystallized in a mixture of ethyl acetate/hexane, thereby to obtain 6.6 g of desired product (yield: 79.4%).

[0140] Mp: 113-115° C.; ¹H NMR (CDCl₃), δ 0.71-1.58 (m, 22H, CH₂ and CH₃), 2.01-2.08 (m, 4H, CCH₂), 7.56-7.85 (m, 14H, aromatic).

Example 36

[0141] Synthesis of 2,7-bis(p-hydroxystyryl)-9,9'-di-n-hexylfluorene (M-36)

[0142] Under a nitrogen atmosphere, 2,7-bis(p-acetoxystyryl)-9,9'-di-n-hexylfluorene 32.7 g (0.05 mol) and KOH 28.0 g (0.5 mol) were introduced into a 500 ml three-necked flask equipped with a stirrer, a thermometer and a reflux condenser and dissolved in 200 ml of methanol, and then the resulting mixture was refluxed for 12 hours. The reaction mixture was cooled down to room temperature and then dropped into 2.0 L of 2.0N aqueous hydrochloric acid to generate solid. The generated solid was filtered, washed with water and dissolved in toluene. The solution was distilled to remove water with toluene from the crude solid product. The solid was recrystallized in toluene two times to give 27.1 g of desired product as pure yellow solid (yield: 95%).

[0143] Mp: 96-97° C.; ¹H NMR (CDCl₃), δ 0.56-1.15 (m, 22H, CH₂ and CH₃), 2.00 (br, 4H, CH₂), 5.10 (br, s, 2H, OH), 6.82-6.86 (d, 4H, vinyl), 7.08-7.64 (m, 14H, aromatic).

Example 37

[0144] Synthesis of 2,7-bis[4-(3,4-dicarboxyphenoxy)phenylenevinyl]-9,9'-di-n-hexylfluorene dianhydride (M-37)

[0145] After 2,7-bis[4-(3,4-dicarboxyphenoxy)phenylenevinyl]-9,9'-di-n-hexylfluorene 3.0 g (3.3 mmol), acetic anhydride 15 ml, and acetic acid 15 ml were introduced into a 250 ml three-necked flask equipped with a thermometer, a stirrer and a reflux condenser, the resulting mixture was refluxed for 24 hours. The hot solution was filtered to remove the undissolved impurities and slowly cooled down, to give 1.9 g of desired product (yield: 67%).

[0146] Mp: 190-193° C.; ¹H NMR (CDCl₃), δ 0.71-1.25 (m, 22H, CH₂ and CH₃), 2.00 (br, 4H, CH₂), 6.82-6.86 (d, 4H, vinyl), 7.09-7.65 (m, 20H, aromatic).

Example 38

[0147] Synthesis of 2,7-bis(4-fluorostyryl)-9,9'-di-n-hexylfluorene (M-38)

[0148] Under an argon atmosphere, 2,7-dibromo-9,9'-di-n-hexylfluorene 17.7 g (36 mmol), 4-fluorostyrene 82 mmol, palladium (II) acetate 0.113 g, tri-*o*-tolylphosphine 1.13 g, tri-*n*-butylamine 17 ml and 60 ml of DMF were introduced into a 250 ml three-necked flask equipped with a thermometer, a stirrer and a reflux condenser, and then the resulting mixture was reacted for 24 hours at 100° C. The reaction mixture was cooled down to room temperature, extracted with diethyl ether and washed with water. Combined organic extract was dried with anhydrous magnesium sulfate and concentrated under a reduced pressure. The residue was recrystallized using hexane/ethyl acetate to give yellow solid. The solid was dried in a vacuum oven at 40° C. to give 11.1 g of desired product (yield: 53%).

[0149] Mp: 110-111° C.; ¹H NMR (CDCl₃), δ 0.66-1.15 (m, 22H, CH₂ and CH₃), 1.95-2.00 (br, 4H, CH₂), 7.08-7.65 (m, 14H, aromatic, 4H, vinyl).

Example 39

[0150] Synthesis of 2,7-bis(3-nitrostyryl)-9,9'-di-n-hexylfluorene (M-39)

[0151] Under an argon atmosphere, after 2,7-dibromo-9,9'-di-n-hexylfluorene 33.0 g (67 mmol), 3-nitrostyrene 25 g (168 mmol), palladium (II) acetate 0.151 g, tri-*o*-tolylphosphine 1.232 g and triethylamine 15 g were introduced into a 250 ml three-necked flask equipped with a thermometer, a stirrer and a reflux condenser, 100 ml of DMF was added, and then the resulting mixture was reacted for 24 hours at 100° C. The reaction mixture was then cooled down to room temperature and then dropped into 1 L of methanol containing small amount of hydrochloride acid, to generate solid. The solid was filtered, washed with methanol and then dried in a vacuum oven at 40° C., to give 31.5 g of desired product (yield: 75%).

[0152] Mp: 189-192° C.; ¹H NMR (CDCl₃), δ 0.66-1.15 (m, 22H, CH₂ and CH₃), 1.95-2.00 (m, 4H, CH₂), 7.15-8.48 (m, 14H, aromatic, 4H, vinyl).

Example 40

[0153] Synthesis of 2,7-bis(4-nitrostyryl)-9,9'-di-n-hexylfluorene (M-40)

[0154] Under an argon atmosphere, after 2,7-dibromo-9,9'-di-n-hexylfluorene 33.0 g (67 mmol), 4-nitrostyrene 25 g (168 mmol), palladium (II) acetate 0.151 g, tri-*o*-tolylphosphine 1.232 g and triethylamine 15 g were introduced into a 250 ml three-necked flask equipped with a thermometer and a reflux condenser, 100 ml of DMF was added, and then the resulting mixture was reacted for 24 hours at 100° C. The reaction mixture was then cooled down to room temperature and then dropped into 1 L of methanol containing small amount of hydrochloride acid, thereby to generate solid. The solid was filtered, washed with methanol and then dried in a vacuum oven at 40° C., to give 33 g of desired product (yield: 78%).

[0155] Mp: 164-166° C.; ¹H NMR (CDCl₃), δ 0.66-1.15 (m, 22H, CH₂ and CH₃), 1.95-2.00 (m, 4H, CH₂), 7.15-7.81 (m, 14H, aromatic, 4H, vinyl).

[0156] Synthesis of Polymers

Example 41

[0157] Polymerization of 2,7-bis(4-aminophenyl)-9,9'-di-n-hexylfluorene (M-3) and isophthalaldehyde (P-1, P-1-1 and P-1-2)

[0158] Under a nitrogen atmosphere, 2,7-bis(4-aminophenyl)-9,9'-di-n-hexylfluorene 0.516 g (1 mmol), isophthalaldehyde 0.134 g (1 mmol), *p*-toluenesulfonic acid monohydrate 3.0 mg (0.016 mmol) and calcium chloride 0.224 g were introduced into a 50 ml flask equipped with a stirrer and dissolved in 3 ml of hexamethylphosphoramide and 3 ml of dimethyl sulfoxide, and then the resulting mixture was reacted for 24 hours at room temperature. The reaction mixture was slowly dropped into 1 L of methanol to deposit the produced polymer. The polymer was filtered, dissolved again in chloroform and then reprecipitated in methanol. The reprecipitated polymer was filtered, washed thoroughly with methanol and then dried in a vacuum oven at 40° C., thereby to obtain 0.57 g of yellow-colored polymer (yield: 92.8%).

[0159] ¹H NMR (CDCl₃), δ 0.76-1.1 (CH₂ and CH₃), 2.08 (br, s, CCH₂), 7.39-8.52 (m, aromatic), 8.68 (s, ArCH=NAr).

[0160] When P-1 polymer which has not exhibited photoluminescence was dissolved in chloroform and, to this solution, one drop of an inorganic acid such as concentrated hydrochloric acid, acid-added polymer (P-1-1) was formed, and this acid-added polymer exhibited photoluminescence. In the same manner, when the P-1 polymer was dissolved in chloroform and, to this solution, small amount of an organic acid such as *p*-toluenesulfonic acid was dropped, acid-added polymer (P-1-2) was formed, and this acid-added polymer also exhibited photoluminescence.

Example 42

[0161] Polymerization of 2,7-bis(4-aminophenyl)-9,9'-di-n-hexylfluorene (M-3) and 2,7-bis(4-aldehydephenyl)-9,9'-di-n-hexylfluorene (M-6) (P-2)

[0162] Under a nitrogen atmosphere, 2,7-bis(4-aminophenyl)-9,9'-di-n-hexylfluorene 0.516 g (1 mmol), 2,7-bis(4-aldehyde phenyl)-9,9'-di-n-hexylfluorene 0.542 g (1 mmol), *p*-toluenesulfonic acid monohydrate 0.003 g (0.016 mmol) and calcium chloride 0.336 g were introduced into 50 ml flask equipped with a stirrer and dissolved in 3 ml of hexamethylphosphoramide and 3 ml of dimethyl sulfoxide. The resulting mixture was reacted for 24 hours at room temperature and then dropped slowly into 1 L of methanol to deposit the produced polymer. The polymer was filtered, dissolved again in chloroform and then reprecipitated in methanol. The reprecipitated polymer was filtered, washed thoroughly with methanol and then dried in a vacuum oven at 40° C., thereby to obtain 0.87 g of yellow-colored polymer (yield 85.3%).

[0163] ¹H NMR (CDCl₃), δ 0.79-1.1 (CH₂ and CH₃), 2.11 (br, s, CCH₂), 7.43-8.09 (m, aromatic), 8.64 (s, ArCH=NAr).

Example 43

[0164] Polymerization of 2,7-bis(4-aminophenyl)-9,9'-di-n-hexylfluorene (M-3) and 3,6-di-hexyloxy terephthalaldehyde (P-3)

[0165] Under a nitrogen atmosphere, 2,7-bis(4-aminophenyl)-9,9'-di-n-hexylfluorene 0.258 g (0.5 mmol), 3,6-di-hexyloxy terephthalaldehyde 0.167 g (0.5 mmol), calcium chloride 0.0176 g were introduced into a 50 ml flask equipped with a stirrer and dissolved in 1.5 ml of hexamethylphosphoramide and 1.5 ml of dimethyl sulfoxide. The resulting mixture was reacted for 24 hours at room temperature and then dropped slowly into 1 L of methanol to deposit the produced polymer. The obtained polymer was filtered, dissolved again in chloroform and reprecipitated in methanol. The reprecipitated polymer was filtered, washed thoroughly with methanol and then dried in a vacuum oven at 40° C., thereby to obtain 0.23 g of yellow-colored polymer (yield: 57.5%).

[0166] ¹H NMR (CDCl₃), δ 0.74-1.85 (CH₂ and CH₃), 2.01 (br, s, CCH₂), 4.10 (t, —OCH₂), 7.43-7.80 (m, aromatic), 9.02 (s, ArCH=NAr).

Example 44

[0167] Polymerization of 2,7-bis(3-aminophenyl)-9,9'-di-n-hexylfluorene (M-5) and 2,7-bis(4-aldehydephenyl)-9,9'-di-n-hexylfluorene (M-6) (P-4)

[0168] Under a nitrogen atmosphere, 2,7-bis(3-aminophenyl)-9,9'-di-n-hexylfluorene 0.516 g (1 mmol), 2,7-bis(4-aldehydephenyl)-9,9'-di-n-hexylfluorene 0.542 g (1 mmol), p-toluenesulfonic acid monohydrate 0.003 g (0.016 mmol) and calcium chloride 0.336 g were introduced into a 50 ml flask equipped with a stirrer and dissolved in 3 ml of hexamethylphosphoramide and 3 ml of dimethyl sulfoxide. The resulting mixture was reacted for 24 hours at room temperature and then dropped slowly into 1 L of methanol to deposit the produced polymer. The polymer was filtered, dissolved in chloroform and reprecipitated in methanol. The reprecipitated polymer was filtered, washed thoroughly with methanol and then dried in a vacuum oven at 40° C., thereby to obtain 0.85 g of yellow-colored polymer (yield: 83.3%).

[0169] ¹H NMR (CDCl₃), δ 0.74-1.1 (CH₂ and CH₃), 2.11 (br, s, CCH₂), 4.10 (t, —OCH₂), 7.54-8.09 (m, aromatic), 8.65 (s, ArCH=NAr).

Example 45

[0170] Polymerization of 2,7-bis(3-aminophenyl)-9,9'-di-n-hexylfluorene (M-5) and isophthalaldehyde (P-5)

[0171] Under a nitrogen atmosphere, 2,7-bis(3-aminophenyl)-9,9'-di-n-hexylfluorene 0.516 g (1 mmol), isophthalaldehyde 0.134 g (1 mmol), p-toluenesulfonic acid monohydrate 0.003 g (0.016 mmol) and calcium chloride 0.224 g were introduced into a 50 ml flask equipped with a stirrer and dissolved in 3 ml of hexamethylphosphoramide and 3 ml of dimethyl sulfoxide. The resulting mixture was reacted for 24 hours at room temperature and then dropped slowly into 1 L of methanol to deposit the produced polymer. The polymer was filtered, dissolved in chloroform and then reprecipitated in methanol. The reprecipitated polymer was filtered, washed thoroughly with methanol and then dried in a vacuum oven at 40° C., thereby to obtain 0.53 g of white-colored polymer (yield 86.3%).

[0172] ¹H NMR (CDCl₃), δ 0.76-1.1 (CH₂ and CH₃), 2.09 (br, s, CCH₂), 7.54-8.52 (m, aromatic), 8.68 (s, ArCH=NAr).

Example 46

[0173] Polymerization of 1,4-bis(3-aminophenyl)-3,6-dihexyloxy benzene (M-16) and 2,7-bis(4-aldehydephenyl)-9,9'-di-n-hexylfluorene (M-6) (P-6)

[0174] Under a nitrogen atmosphere, 1,4-bis(3-aminophenyl)-3,6-dihexyloxy benzene 0.46 g (1 mmol) and 2,7-bis(4-aldehydephenyl)-9,9'-di-n-hexylfluorene 0.542 g (1 mmol), p-toluenesulfonic acid monohydrate 0.003 g (0.016 mmol) and calcium chloride 0.224 g were introduced into a 50 ml flask equipped with a stirrer and dissolved in 3 ml of hexamethylphosphoramide and 3 ml of dimethyl sulfoxide. The resulting mixture was reacted for 24 hours at room temperature and then dropped slowly into 1 L of methanol to deposit the produced polymer. The polymer was filtered, dissolved in chloroform and then reprecipitated in methanol. The reprecipitated polymer was filtered, washed thoroughly

with methanol and then dried in a vacuum oven at 40° C., thereby to obtain 0.64 g of yellow-colored polymer (yield: 66.3%).

[0175] ¹H NMR (CDCl₃)₁ 5 0.65-1.75 (CH₂ and CH₃), 2.09 (br, s, CCH₂), 4.10 (t, OCH₂), 6.68-8.02 (m, aromatic), 8.58 (s, ArCH=NAr).

Example 47

[0176] Polymerization of 2,7-bis(4-carboxyphenyl)-9,9'-di-n-hexylfluorene (M-11) and 3,3-dihydro oxybenzidine (P-7)

[0177] Under a nitrogen atmosphere, 2,7-bis(4-carboxyphenyl)-9,9'-di-n-hexylfluorene 1.149 g (2 mmol) and 3,3-dihydro oxybenzidine 0.432 g (2 mmol) were introduced into a 100 ml flask equipped with a stirrer and dissolved in 10 ml of phosphorus pentoxide/methanesulfonic acid (hereinafter referred to as "PPMA") and 20 ml of tetramethylenesulfone. The resulting mixture was reacted for one and a half hour at 140° C. and reacted for 3 hours after further adding 5 ml of PPMA. The reaction mixture was cooled down to room temperature and then dropped into 1 L of water to deposit the produced polymer. The polymer was washed with diluted aqueous sodium bicarbonate solution, washed with water, washed with methanol thoroughly, and then dried in a vacuum oven at 40° C., thereby to obtain 1.4 g of polymer in black (yield: 98%). The polymer was not dissolved in a typical organic solvent well.

Example 48

[0178] Polymerization of 2,7-bis(4-chlorocarbonylphenyl)-9,9'-di-n-hexylfluorene (M-12) and terephthalic dihydrazide (P-8 and P-9)

[0179] Under a nitrogen atmosphere, 2,7-bis(4-chlorocarbonylphenyl)-9,9'-di-n-hexylfluorene 0.4 g (0.65 mmol), terephthalic dihydrazide 0.126 g (0.65 mmol), lithium chloride 0.1 g were introduced into a 50 ml flask equipped with a stirrer and dissolved in 11 ml of NMP. To this mixture, pyridine 0.126 g was added, and then the resulting mixture was reacted for 4 hours at 80° C. The reaction mixture was cooled down to room temperature and then dropped into 1 L of methanol to deposit the produced polymer. The polymer was filtered, washed with water and methanol thoroughly and then dried in a vacuum oven at 40° C., thereby to obtain 0.475 g of ivory-colored polymer P-8).

[0180] ¹H NMR (DMSO-d₆), δ 0.74-1.05 (CH₂ and CH₃), 2.16 (br, s, CCH₂), 6.68-8.02 (br, aromatic), 10.82 (s, CONH).

[0181] The obtained polymer P-8 0.2 g was dissolved in POCl₃ by heating, and then the solution was refluxed for 4 hours while stirring. The reaction mixture was then dropped into 1 L of water to deposit the produced polymer. The polymer was filtered, washed with methanol and then dried in a vacuum oven at 40° C., thereby to obtain yellow-colored polymer P-9. The polymer shows lower solubility, and therefore, only a small amount of the polymer was dissolved in a typical organic solvent.

Example 49

[0182] Polymerization of 2,7-bis(4-chlorocarbonylphenyl)-9,9'-di-n-hexylfluorene (M-12) and isophthalic dihydrazide (P-10 and P-11)

[0183] Under a nitrogen atmosphere, 2,7-bis(4-chlorocarbonylphenyl)-9,9'-di-n-hexylfluorene 0.8 g (1.3 mmol) and isophthalic dihydrazide 0.253 g (1.3 mmol), lithium chloride 0.15 g were introduced into a 30 ml flask equipped with a stirrer and dissolved in NMP 18 ml. Pyridine 0.252 g was added to the solution, and the resulting mixture was reacted for 4 hours at 80° C. The reaction mixture was cooled down to room temperature and then dropped into 1 L of methanol slowly to deposit the produced polymer. The polymer was filtered, washed with water and methanol, and then dried in a vacuum oven at 40° C., thereby to obtain 0.54 g of ivory-colored polymer P-12. (yield: 92%).

[0184] ¹H NMR (DMSO-d₆), δ 0.62-1.03 (CH₂ and CH₃), 2.16 (br, s, CCH₂), 7.65-8.34 (m, aromatic), 10.82 (s, CONH).

[0185] The polymer P-12 0.3 g was dissolved in 10 ml of POCl₃ by heating and refluxed for 4 hours as stirring. The reaction mixture was dropped into 1 L of water to deposit the produced polymer. The polymer was filtered, washed with methanol and then dried in a vacuum oven at 40° C., thereby to obtain ivory-colored polymer P-13. The polymer shows lower solubility, and therefore, only a small amount of the polymer was dissolved in a typical organic solvent.

Example 51

[0186] Polymerization of 2,7-bis(3-chlorocarbonylphenyl)-9,9'-d-n-hexylfluorene (M-23) and isophthalic dihydrazide (P-14 and P-15)

[0187] Under a nitrogen atmosphere, 2,7-bis(3-chlorocarbonylphenyl)-9,9'-d-n-hexylfluorene 1 g (1.63 mmol), isophthalic dihydrazide 0.317 g (1.63 mmol), lithium chloride 0.1 g were introduced into a 50 ml flask equipped with a stirrer and dissolved in 7 ml of NMP. Pyridine 0.256 g was added to the solution, and the resulting mixture was reacted for 4 hours at 80° C. The reaction mixture was cooled down to room temperature and then dropped into 1 L of methanol slowly to deposit the produced polymer. The polymer was filtered, washed with water and methanol, and then dried in a vacuum oven at 40° C., thereby to obtain 1.1 g of ivory-colored polymer P-14. (yield: 92%).

[0188] ¹H NMR (DMSO-d₆), δ 0.62-1.03 (CH₂ and CH₃), 2.16 (br, s, CCH₂), 7.65-8.59 (m, aromatic), 10.82 (s, CONH).

[0189] The polymer P-14 0.4 g was dissolved in 20 ml of POCl₃ by heating and the resulting mixture was refluxed for 24 hours while stirring. The reaction mixture was dropped into 1 L of water to deposit the produced polymer. The polymer was filtered, washed with methanol and then dried in a vacuum oven at 40° C., thereby to obtain 0.38 g of ivory-colored polymer P-13. The polymer shows lower solubility, and therefore, only a small amount of the polymer was dissolved in a typical organic solvent.

Example 52

[0190] Polymerization of 2,7-bis(4-hydroxyphenyl)-9,9'-di-n-hexylfluorene (M-29) and 2,7-bis(4-chloromethylphenyl)-9,9'-di-n-hexylfluorene (M-25) (P-16)

[0191] Under a nitrogen atmosphere, 2,7-bis(4-hydroxyphenyl)-9,9'-di-n-hexylfluorene 0.44 g (0.85 mmol), 2,7-bis(4-chloromethylphenyl)-9,9'-di-n-hexylfluorene 0.50 g (0.85 mmol), benzyltriethylammonium chloride 0.04 g (0.17 mmol) were introduced into a 50 ml three-necked flask equipped with a stirrer and a reflux condenser and dissolved in a mixture of 1.7 ml of DMSO and 5.2 ml of toluene. 7 ml of 50 wt. % aqueous sodium hydroxide solution was then added to the solution. The resulting mixture was then reacted for 7 hours at 100° C. while stirring vigorously and then cooled down to room temperature. After removing aqueous layer, the organic layer was dropped into 1 L of methanol containing small amount of hydrochloric acid, thereby to deposit white-colored polymer. The polymer was filtered, washed with methanol thoroughly, dissolved in chloroform, and then reprecipitated in methanol. The reprecipitated polymer was filtered, washed with methanol and then dried in a vacuum oven at 40° C., thereby to obtain 0.75 g of white-colored polymer (yield: 85.2%).

[0192] ¹H NMR (CDCl₃), δ 0.74-1.1 (CH₂ and CH₃), 2.01 (br, s, CCH₂), 5.09 (s, OCH₂C), 7.08-7.80 (m, aromatic).

Example 53

[0193] Polymerization of 2,7-bis(4-chloromethylphenyl)-9,9'-di-n-hexylfluorene (M-25) and 1,4-bis(4-hydroxystyryl)-3,6-di-hexyloxy benzene (P-17)

[0194] Under a nitrogen atmosphere, 1,4-bis(4-hydroxystyryl)-3,6-di-hexyloxy benzene 0.44 g (0.85 mmol), 2,7-bis(4-chloromethylphenyl)-9,9'-di-n-hexylfluorene 0.50 g (0.85 mmol), benzyltriethylammonium chloride 0.04 g (0.17 mmol) were introduced into a 50 ml three-necked flask equipped with a stirrer and a reflux condenser and dissolved in a mixture of 1.7 ml of DMSO and 5.2 ml of toluene. 7 ml of 50 wt. % aqueous sodium hydroxide solution was then added to the solution. The resulting mixture was reacted for 7 hours at 100° C. while stirring vigorously. The reaction mixture was then cooled down to room temperature and then dropped into 1 L of methanol containing small amount of hydrochloric acid, to deposit yellow-colored polymer. The polymer was filtered, washed with methanol thoroughly, dissolved in chloroform and then reprecipitated in methanol. The reprecipitated polymer was filtered, washed with methanol and then dried in a vacuum oven at 40° C., thereby to obtain 0.7 g of white-colored polymer (yield 79.7%).

[0195] ¹H NMR (CDCl₃), δ 0.75-1.87 (CH₂ and CH₃), 2.00 (br, s, CCH₂), 4.04 (s, OCH₂), 5.09 (s, OCH₂C), 7.03-7.72 (m, aromatic).

Example 54

[0196] Polymerization of 2,7-bis(4-acetylphenyl)-9,9'-dihexylfluorene (M-34) and 4,4'-diamino-3,3'-dibenzoyidiphenyl ether (P-1 8 and P-1 8-1)

[0197] Under an argon atmosphere, phosphorus pentoxide 1.49 g (14.7 mmol) and m-cresol 5 ml were introduced into a round bottom flask at 0° C., and the resulting mixture was reacted for 3 hours at 110° C. to obtain a dehydrating agent.

The temperature of the flask was then cooled down to room temperature, 4,4'-diamino-3,3'-dibenzoyldiphenyl ether 0.5 g (12 mmol) and 2,7-bis(4-acetylphenyl)-9,9'-di-n-hexylfluorene 0.69 g (1.2 mmol) were introduced into the flask, and then 10 ml of m-cresol was further added to wash the wall of the flask and to dilute the reaction mixture. And then, the temperature was rapidly raised to 110° C., and then the mixture was reacted for 11 hours at that temperature. After the reaction was completed, the reaction mixture was precipitated three times in 15% triethylamine/ethanol solution and then filtered. The precipitate was washed with ethanol, water and methanol, several times, and then dried at 40° C. under a reduced pressure, thereby to obtain 0.98 g of polyquinoline P-18 (yield: 89%).

[0198] ¹H NMR (CDCl₃), 10.70-1.38 ppm (m, 22H, CH₂, CH₃), 1.85-2.38 ppm (m, 4H, CCH₂), 7.10-8.60 ppm (m, 32H, aromatic).

[0199] When the P-18 polymer which has a maximum PL wavelength of 431 nm was dissolved in chloroform in a concentration of 10-5M and then concentrated hydrochloric acid was dropped onto the solution, acid-added polymer P-18-1 was formed. The P-18-1 polymer exhibited a maximum PL wavelength of 554 nm and therefore photoluminescence.

Example 55

[0200] Polymerization of 2,7-bis(4-aminophenyl)-9,9'-di-n-hexylfluorene (M-3) and 6-FDA (P-19)

[0201] Under an argon atmosphere, 2,7-bis(4-aminophenyl)-9,9'-di-n-hexylfluorene 0.50 g (0.97 mmol) was introduced into a round bottom flask at room temperature and dissolved in 3 ml of N-methylpyrrolidone. 4,4'-(hexafluoroisopropylidene)diphthalic anhydride (6-FDA) 0.43 g (0.97 mmol) and 5 ml of N-methylpyrrolidone were then added to the solution. After the resulting mixture 7C was then reacted for 24 hours, pyridine 0.47 g (5.83 mmol) and acetic anhydride 0.61 g (5.83 mmol) were added to the reaction mixture, and then the resulting mixture was further reacted for 6 hours at 40° C., to form imide. The reaction mixture was cooled down to room temperature and precipitated in a mixture of water and methanol (1/1). The precipitate was filtered, washed with methanol several times and dried at 60° C. under a reduced pressure, thereby to obtain 0.81 g of pale yellow polyimide (yield: 90.2%).

[0202] ¹H NMR (CDCl₃), δ 0.74-1.45 ppm (m, 22H, CH₂, CH₃), 1.52-2.45 ppm (m, 4H, CCH₂), 7.20-8.40 ppm (m, 20H, aromatic).

Example 56

[0203] Polymerization of 2,7-bis(4-hydroxyphenyl)-9,9'-di-n-hexylfluorene (M-29) and sebacoyl chloride (P-20)

[0204] Under an argon atmosphere, 2,7-bis(4-hydroxyphenyl)-9,9'-di-n-hexylfluorene 1 g (1.9 mmol) and sebacoyl chloride 0.48 g (1.9 mmol) were introduced into a round bottom flask equipped with a reflux condenser and dissolved in toluene, and then the resulting mixture was refluxed for 5 days at 120° C., to perform solution polymerization. The reaction mixture was then cooled down to room temperature, precipitated three times in methanol and then filtered. The precipitate was washed with water and methanol

several times, and dried at 40° C. under a reduced pressure, thereby to obtain 1.3 g of polyester (yield: 98%).

[0205] ¹H NMR (CDCl₃), δ 0.58-2.45 ppm (m, 34H, CH₂, CH₃, CCH₂), 2.50-2.90 ppm (m, 4H, COCH₂), 7.05-8.10 ppm (m, 14H, aromatic).

Example 57

[0206] Polymerization of 2,7-bis(4-hydroxystyryl)-9,9'-di-n-hexylfluorene (M-26) and decafluorobiphenyl (P-21)

[0207] Under a nitrogen atmosphere, 2,7-bis(4-hydroxystyryl)-9,9'-di-n-hexylfluorene 1.36 g (2.38 mmol) and decafluorobiphenyl 0.79 g (2.38 mmol) were introduced into a 100 ml two-necked flask and dissolved in 20 ml of DMAc, and then the resulting mixture was reacted for 17 hours at 120° C. The reaction mixture was cooled down to room temperature, dropped into 1 L of water/methanol (1/1), to give yellow-colored polymer. The polymer was filtered, dissolved in chloroform and then reprecipitated in 1 L of methanol. The reprecipitated polymer was filtered, washed thoroughly with methanol and then dried in a vacuum oven at 40° C., thereby to obtain 1.48 g of pale yellow polymer (yield: 72%).

[0208] ¹H NMR (CDCl₃), δ 0.72-1.06 (CH₂, CH₃), 2.00 (br, s, CCH₂), 7.06-7.65 (m, vinyl, aromatic).

Example 58

[0209] Polymerization of 2,7-bis(4-hydroxystyryl)-9,9'-di-n-hexylfluorene (M-36) and 4,4'-difluorodiphenylsulfone (P-22)

[0210] Under a nitrogen atmosphere, 2,7-bis(4-hydroxystyryl)-9,9'-di-n-hexylfluorene 1.36 g (2.38 mmol), 4,4'-difluorodiphenylsulfone 0.61 g (2.38 mmol) and potassium carbonate 0.871 g (6.30 mmol) were introduced into a 100 ml two-necked flask and dissolved in 20 ml of DMAc. After the temperature was raised to 120° C., and the resulting mixture was reacted for 17 hours at that temperature. After the reaction was completed, the reaction mixture was cooled down to room temperature and then dropped slowly into 1 L of water/methanol (1/1), to give ivory-colored polymer. The polymer was filtered, dissolved in chloroform and then reprecipitated in 1 L of methanol. The reprecipitated polymer was filtered, washed thoroughly with methanol and then dried in a vacuum oven at 40° C., thereby to obtain 1.3 g of ivory-colored polymer (yield: 70%).

[0211] ¹H NMR (CDCl₃), δ 0.72-1.06 (CH₂, CH₃), 2.00 (br, s, CCH₂), 7.04-7.92 (m, vinyl, aromatic).

Example 59

[0212] Polymerization of 2,7-bis(4-hydroxystyryl)-9,9'-di-n-hexylfluorene (M-36) and hexafluorobenzene (P-23)

[0213] Under a nitrogen atmosphere, 2,7-bis(4-hydroxystyryl)-9,9'-di-n-hexylfluorene 1.23 g (2.1 mmol), hexafluorobenzene 0.4 g (2.1 mmol) and potassium carbonate 0.871 g (6.30 mmol) were introduced into a 100 ml two-necked flask and dissolved in 20 ml of DMAc. After the temperature was raised to 120° C., the resulting mixture was reacted for 4 hours at that temperature. After the reaction was completed, the reaction mixture was cooled down to room temperature and then dropped slowly into 1 L of water/methanol (1/1), to give ivory-colored polymer. The polymer

was filtered, dissolved in chloroform and then reprecipitated in 1 L of methanol. The polymer was filtered, washed thoroughly with methanol and then dried in a vacuum oven at 40° C., thereby to obtain 1.38 g of ivory-colored polymer (yield: 89.6%).

[0214] ¹H NMR (CDCl₃), δ 0.55-1.16 (CH₂, CH₃), 2.00 (br, s, CCH₂), 7.10-8.60 (m, vinyl, aromatic).

Example 60

[0215] Polymerization of 2,7-bis(4-hydroxystyryl)-9,9'-di-n-hexylfluorene (M-36) and 4,4'-difluorobenzophenone (P-24)

[0216] Under a nitrogen atmosphere, 2,7-bis(4-hydroxystyryl)-9,9'-di-n-hexylfluorene 1.36 g (2.38 mmol), 4,4'-difluorobenzophenone 0.52 g (2.38 mmol) and potassium carbonate 0.87 g (6.30 mmol) were introduced into a 100 ml two-necked flask and dissolved in 20 ml of DMAc. After the temperature was raised to 120° C., the resulting mixture was reacted for 17 hours at that temperature. After the reaction was completed, the reaction mixture was cooled down to room temperature and then dropped slowly into 1 L of water/methanol (1/1), to give yellow-colored polymer. The polymer was filtered, dissolved in chloroform and then reprecipitated in 1 L of methanol. The polymer was filtered, washed thoroughly with methanol and then dried in a vacuum oven at 40° C., thereby to obtain 1.47 g of yellow-colored polymer (yield: 82%).

[0217] ¹H NMR (CDCl₃), δ 0.60-1.12 (CH₂, CH₃), 2.00 (br, s, CCH₂), 7.04-7.96 (m, vinyl, aromatic).

Example 61

[0218] Polymerization of 2,7-bis(4-hydroxystyryl)-9,9'-di-n-hexylfluorene (M-36) and 2,5-bis(4-fluorophenyl)-1,3,4-oxadiazole (P-25)

[0219] Under a nitrogen atmosphere, 2,7-bis(4-hydroxystyryl)-9,9'-di-n-hexylfluorene 1.36 g (2.38 mmol), 2,5-bis(4-fluorophenyl)-1,3,4-oxadiazole 0.61 g (2.38 mmol) and potassium carbonate 0.6 g (4.34 mmol) were introduced into a 100 ml two-necked flask equipped with a dean-stock trap and dissolved in 20 ml of NMP/CHP (1/1) mixture. After the temperature was raised to 150° C., the solution was refluxed for 6 hours at that temperature to remove the moisture totally in the reaction flask. After the temperature was raised to 180° C., the resulting mixture was reacted for 20 hours. The reaction mixture was then cooled down to room temperature and diluted with NMP and then dropped slowly into 1 L of water/methanol (1/1), to give yellow-colored polymer. The polymer was filtered, washed thoroughly with acetone, hot water and methanol, sequentially, and then dried in a vacuum oven at 40° C., thereby to obtain 1.36 g of yellow-colored polymer (yield: 72.4%).

[0220] ¹H NMR (CDCl₃), δ 0.58-1.24 (CH₂, CH₃), 2.00 (br, s, CCH₂), 7.10-8.60 (m, vinyl, aromatic).

Example 62

[0221] Polymerization of 2,7-bis(4-hydroxystyryl)-9,9'-di-n-hexylfluorene (M-36) and 4,4'-difluoroazobenzene (P-26)

[0222] Under a nitrogen atmosphere, 2,7-bis(4-hydroxystyryl)-9,9'-di-n-hexylfluorene 1.36 g (2.38 mmol), 4,4'-

difluoroazobenzene 0.53 g (2.38 mmol) and potassium carbonate 0.6 g (4.34 mmol) were introduced into a 100 ml two-necked flask equipped with a dean-stock trap and dissolved in 20 ml of NMP/CHP (1/1) mixture. After the temperature was raised to 150° C., the solution was refluxed for 6 hours at that temperature to remove the moisture totally in the reaction flask. After the temperature was raised to 180° C., the resulting mixture was reacted for 20 hours. The reaction mixture was cooled down to room temperature, diluted with NMP and then dropped slowly into 1 L of water/methanol (1/1), to give yellow-colored polymer. The polymer was filtered, washed thoroughly with acetone, hot water and methanol, sequentially, and then dried in a vacuum oven at 40° C., thereby to obtain 0.71 g of yellow-colored polymer (yield: 40%).

[0223] ¹H NMR (CDCl₃), δ 0.58-1.24 (CH₂, CH₃), 2.00 (br, s, CCH₂), 6.98-8.01 (m, vinyl, aromatic).

Example 63

[0224] Polymerization of 2,7-bis(4-hydroxyphenyl)-9,9'-di-n-hexylfluorene (M-29) and 2,5-bis(4-fluorophenyl)-1,3,4-oxadiazole (P-27)

[0225] Under a nitrogen atmosphere, 2,7-bis(4-hydroxyphenyl)-9,9'-di-n-hexylfluorene 1.0 g (1.9 mmol), 2,5-bis(4-fluorophenyl)-1,3,4-oxadiazole 0.49 g (1.9 mmol) and potassium carbonate 0.66 g (4.8 mmol) were introduced into a 100 ml two-necked flask equipped with a dean-stock trap and dissolved in 20 ml of NMP/CHP (1/1) mixture. After the temperature was raised to 150° C., the solution was refluxed for 6 hours at that temperature to remove the moisture totally in the reaction flask. After the temperature was raised to 180° C., the resulting mixture was reacted for 17 hours. The reaction mixture was cooled down to room temperature, diluted with NMP and then dropped slowly into 1 L of water/methanol (1/1), to give yellow-colored polymer. The polymer was filtered, washed thoroughly with acetone, hot water and methanol, sequentially, and then dried in a vacuum oven at 40° C., thereby to obtain 1.15 g of yellow-colored polymer (yield 81.8%).

[0226] ¹H NMR (CDCl₃), δ 0.45-1.42 (CH₂, CH₃), 1.78-2.38 (m, CCH₂), 7.82-8.35 (m, aromatic).

Example 64

[0227] Polymerization of 2,7-bis(4-bromophenyl)-9,9'-di-n-hexylfluorene (M-17) and sodiumsulphide (P-28)

[0228] Into a 100 ml ample flask equipped with a stirrer, 2,7-bis(4-bromophenyl)-9,9'-di-n-hexylfluorene 5 g (7.75 mmol) and sodium sulphide 0.6 g (7.75 mmol) were introduced and dissolved in 65 ml of NMP, and then the ample was sealed. After reacted for 48 hours at 200° C., the reaction mixture was cooled down to room temperature, and then the ample was then opened. The mixture was then dropped into 1 L of methanol slowly, to deposit the produced polymer. The polymer was filtered, dissolved in chloroform and then reprecipitated in methanol. The reprecipitated polymer was filtered, washed thoroughly with methanol and then dried in a vacuum oven at 40° C., thereby to obtain 3.03 g of white-colored polymer (yield: 75%).

[0229] ¹H NMR (CDCl₃), δ 0.73-1.06 (m, CH₂, CH₃), 2.01 (br, s, CCH₂), 7.34-7.80 (m, aromatic).

Example 65

[0230] Polymerization of 2,7-bis(4-carboxylphenyl)-9,9'-di-n-hexylfluorene (M-11) and 1,4-bis(3-aminophenyl)-3,6-di-hexyloxy benzene (P-29)

[0231] Under a nitrogen atmosphere, 2,7-bis(4-carboxylphenyl)-9,9'-di-n-hexylfluorene 0.718 g (1.25 mmol), 1,4-bis(3-aminophenyl)-3,6-di-hexyloxy benzene 0.575 g (1.25 mmol) and calcium chloride 0.4 g were introduced into a 50 ml flask equipped with a stirrer, and NMP 3 ml, pyridine 1 ml and triphenylphosphite 0.9 ml were added, and then the resulting mixture was reacted for 4 hours at 120° C. The reaction mixture was then cooled down to room temperature and then dropped slowly into 1 L of methanol to deposit the produced polymer. The polymer was filtered, dissolved in chloroform and then reprecipitated in methanol. The reprecipitated polymer was filtered, washed thoroughly with methanol and then dried in a vacuum oven at 40° C., thereby to obtain 1.2 g of white-colored polymer (yield: 97%).

[0232] ¹H NMR (CDCl₃), δ 0.75-1.66 (CH₂, CH₃), 2.03 (br, s, CCH₂), 4.10 (br, —OCH₂), 7.03-7.99 (m, aromatic, and NH).

Example 66

[0233] Polymerization of 2,7-bis[4-(3,4-dicarboxyphenoxy)phenylenevinyl]-9,9'-di-n-hexylfluorene dianhydride (M-37) and 4,4-oxydianiline (P-30)

[0234] After 4,4-oxydianiline (ODA) 0.23 g (1.15 mmol) was introduced into a round bottom flask and dissolved in 4 ml of N-methylpyrrolidone at room temperature under an argon atmosphere, 2,7-bis[4-(3,4-dicarboxy-phenoxy)phenylenevinyl]-9,9'-di-n-hexylfluorene dianhydride 0.99 g (1.15 mmol) and N-methylpyrrolidone 7 ml were added, and then the resulting mixture was reacted for 24 hours. Pyridine 0.55 g (6.95 mmol) and acetic acid anhydride 0.71 g (6.95 mmol) were then added to the mixture, and then the mixture was further reacted for 6 hours at 40° C. to form imide. The mixture was then cooled down to room temperature and precipitated in a mixture of water and methanol (1/1). The precipitates were filtered, washed with methanol several times and then dried at 60° C. under a reduced pressure, thereby to obtain 1.02 g of pale yellow-colored polyimide (yield 86.1%).

[0235] ¹H NMR (CDCl₃), δ 0.72-1.42 (m, CH₂, CH₃), 1.62-2.38 (m, CCH₂), 6.75-8.10 (m, aromatic and vinyl).

Example 67

[0236] Structure analysis, and UV, PL and EL properties

[0237] FIGS. 1 and 3 show NMR spectrum of the monomer in Example 34 and of the polymer P-18 in Example 54. FIG. 2 shows ultraviolet-visible (UV-Vis) and PL spectrum of the monomer M-34 in Example 34. Thin film of polymer P-18 was formed by dissolving the polymer 0.1 g in chloroform 5 ml, filtering the obtained solution using a microfilter of 0.2 micron in size, and then performing spin coating while controlling the spinning speed (generally in the range of 900-1200 rpm) so that the thickness of the film was to be 100 nm. The coated sample was dried at room temperature. UV spectrum was determined, and then PL spectrum was determined in the wavelength of maximum UV peak value. The results were shown in FIG. 4. EL device comprising

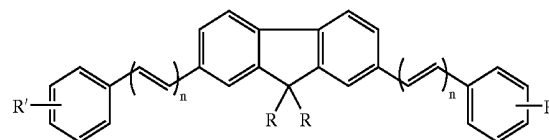
ITO/light emitting layer/electrode was made, and its EL properties were examined. As a light emitting layer, the copolymer itself prepared in Examples as described above was used, or the blend of it in chloroform with a generally used polymer, such as polyvinylcarbazole, polymethylmethacrylate, polystyrene or epoxy resin, was used. As the electrode, aluminum was selected. The EL device was fabricated by performing vacuum deposition of aluminum onto the light emitting layer which was spin coated in a thickness of 100 nm on the ITO glass substrate, as the same manner in preparing the sample for UV-Vis or PL spectrum measurement. EL spectrum results of polymer P-18 itself and of blending it with polyvinylcarbazole are shown in FIGS. 5 and 6.

[0238] The fluorene compounds and the polymers of the present invention can be applied to LED (Light Emitting Diode), that is, an EL element. Also, the compounds and polymers of the present invention have photo and electrical activities, and therefore, show PL properties, nonlinear optical properties, and photo and electrical conductivity, whereby these can be applied to an optical switch, a sensor, a module, a wave guide, a transistor, laser, an optical absorbent, a polymer separating film, etc.

[0239] As the present invention may be embodied in several forms without departing from the spirit or essential properties thereof, it should also be understood that the above-described embodiments are not limited by any of the details of the foregoing description, unless otherwise specified, but rather should be construed broadly within its spirit and scope as defined in the appended claims, and therefore all changes and modifications that fall within the metes and bounds of the claims, or equivalence of such metes and bounds are therefore intended to be embraced by the appended claims.

What is claimed is:

1. A fluorene compound represented by the following general formula:



wherein,

R represents hydrogen, C₁-C₂₂ aliphatic alkyl or alkoxy, C₁-C₂₂ alicyclic alkyl or alkoxy, C₆-C₁₈ aryl or aryloxy, or alkyl or aryl derivatives of silicon, tin or germanium;

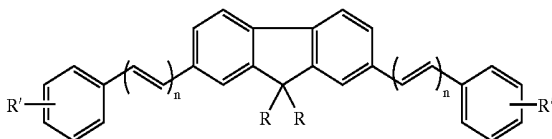
R' means a functional group which presents in meta- or para-position of the phenyl group and is selected from the group consisting of ether, ester, amine, amide, imide, aldehyde, ketone, sulfone, sulfide, nitro, nitrile, acetylene, halogen, carboxylic acid, boronic acid, vinyl, hydrazide, isocyanate, urethane, carbonate, chloromethyl, hydroxy, anhydride, cyanate, azometine, quinoline, oxadiazole and azo; and

n represents 0 or 1.

2. The compound according to claim 1, which has maximum PL wavelength of 300 nm-600 nm.

3. The compound according to claim 1 or 2, which is used as a luminescent material for light emitting layer of an EL element.

4. A fluorene-based polymer, comprising product formed by polymerization of the same or different fluorene compounds represented by the following general formula, or product formed by polymerization of the following fluorene compound and other organic compound:



wherein,

R represents hydrogen, C₁-C₂₂ aliphatic alkyl or alkoxy, C₁C₂₂ alicyclic alkyl or alkoxy, C₆-C₁₈ aryl or aryloxy, or alkyl or aryl derivatives of silicon, tin or germanium;

R' means a functional group which presents in meta- or para-position of the phenyl and is selected from the group consisting of ether, ester, amine, amide, imide, aldehyde, ketone, sulfone, sulfide, nitro, nitrile,

acetylene, halogen, carboxylic acid, boronic acid, vinyl, hydrazide, isocyanate, urethane, carbonate, chloromethyl, hydroxy, anhydride, cyanate, azometine, quinoline, oxadiazole and azo; and

n represents 0 or 1.

5. The fluorene-based polymer according to claim 4, which is in the form of an acid-added salt.

6. The fluorene-based polymer according to claim 5, which is the salt of polyazometine, polyquinoline or polyimide.

7. The fluorene-based polymer according to claim 5, wherein the acid is hydrochloric acid or p-toluenesulfonic acid.

8. The polymer according to claim 4 or 5, which is used as a luminescent material for a light emitting layer of an EL element.

9. An EL element, using the polymer according to any one of claims 1 to 8 as a luminescent material for a light emitting layer of an EL element which consists of anode/light emitting layer/cathode or anode/hole transport layer/light emitting layer/cathode.

10. The EL element according to claim 9, wherein the luminescent material comprises a blend of the polymer according to any one of claims 1 to 8 with polyvinylcarbazole, poly(1,4-hexyloxy-2,5-phenylenevinylene) or poly(3-hexylthiophene).

* * * * *

专利名称(译)	含有各种官能团的苈化合物，其聚合物和使用其的el元素		
公开(公告)号	US20030091859A1	公开(公告)日	2003-05-15
申请号	US10/135728	申请日	2002-05-01
[标]申请(专利权)人(译)	赵贤NAM JUNG成贤 SON桑WON		
申请(专利权)人(译)	CHO HYUN-NAM JUNG成贤 SON桑WON		
当前申请(专利权)人(译)	CHO HYUN-NAM JUNG成贤 SON桑WON		
[标]发明人	CHO HYUN NAM JUNG SUNG HYUN SON SANG WON		
发明人	CHO, HYUN-NAM JUNG, SUNG HYUN SON, SANG WON		
IPC分类号	H01L51/50 C07C13/547 C07C22/04 C07C25/22 C07C25/24 C07C33/36 C07C39/17 C07C43/21 C07C47/546 C07C47/575 C07C49/784 C07C53/44 C07C63/49 C07C65/26 C07C69/00 C07C69/76 C07C205/06 C07C205/22 C07C205/35 C07C205/38 C07C211/50 C07C217/80 C07C217/90 C07C243 /38 C07C255/33 C07C255/34 C07C255/51 C07C255/54 C07C261/02 C07D307/89 C07F5/02 C08G65 /34 C08G73/00 C08G73/06 C08G73/10 C08G73/22 C09B11/02 C09B23/14 C09B69/10 C09K11/06 C09B27/00 C09B31/00 C09B33/00 C09B35/00 C09B37/00 C09B39/00 C09B41/00 C07C245/00 C07C321/00 C07C323/00 C07C381/00 B32B9/00 B32B19/00		
CPC分类号	C07C22/04 C09B69/10 C07C25/24 C07C33/36 C07C43/21 C07C47/546 C07C47/575 C07C63/49 C07C65/26 C07C69/76 C07C205/06 C07C205/22 C07C205/35 C07C205/38 C07C211/50 C07C255/34 C07C255/51 C07C261/02 C07C2103/18 C07F5/025 C09B11/02 C09B23/141 C07C25/22 C07C2603 /18		
优先权	1020010028020 2001-05-22 KR		
其他公开文献	US7318964		
外部链接	Espacenet USPTO		

摘要(译)

本发明涉及苈化合物及其聚合物，其具有各种结构和官能团，并且能够用作有机和聚合物基电致发光 (EL) 元件和其它光学元件的发光材料，并涉及EL元件。使用相同的发光材料。

