



(51) International Patent Classification:

C08G 61/08 (2006.01) *H01L 51/05* (2006.01)
C08G 61/12 (2006.01) *C08F 232/00* (2006.01)
H01B 3/30 (2006.01)

(21) International Application Number:

PCT/EP2014/063113

(22) International Filing Date:

23 June 2014 (23.06.2014)

(25) Filing Language:

English

(26) Publication Language:

English

(30) Priority Data:

13174013.6 27 June 2013 (27.06.2013) EP

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(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:

— with international search report (Art. 21(3))

(54) Title: METATHESIS POLYMERS AS DIELECTRICS

(57) Abstract: Oxacycloolefinic polymers as typically obtained by metathesis polymerization using Ru-catalysts, show good solubility and are well suitable as dielectric material in electronic devices such as capacitors and organic field effect transistors.



Metathesis Polymers as Dielectrics

Description

- 5 The present invention relates to a process for the preparation of an organic electronic device, such as a capacitor or transistor on a substrate, to the device obtainable by that process, to certain oxacycloolefinic polymers and their use as dielectrics, especially as dielectric layer in printed electronic devices such as capacitors and organic field-effect transistors (OFETs).
- 10 Transistors, and in particular OFETs, are used e.g. as components for printed electronic devices such as organic light emitting display, e-paper, liquid crystal display and radiofrequency identification tags.
- 15 An organic field effect transistor (OFET) comprises a semiconducting layer comprising an organic semiconducting material, a dielectric layer comprising a dielectric material, a gate electrode and source/drain electrodes.
- Especially desirable are OFETs wherein the dielectric material can be applied by solution processing techniques. Solution processing techniques are convenient from the point of processability, and can also be applied to plastic substrates. Thus, organic dielectric materials, which are compatible with solution processing techniques, allow the production of low cost organic field effect transistors on flexible substrates.
- 20 Oxanorbornene dicarboximides have been polymerized by ring opening metathesis polymerization (ROMP) to obtain amorphous polymers (Cetinkaya et al., Heteroatom Chemistry (2010), 21, 36-43), or copolymers with tunable magnetic properties (Zha et al., J. Am. Chem. Soc. (2012), 134, 14534).
- 25 WO 12/028278 and US 2008/194740 disclose certain layers comprising a cycloolefinic polymer prepared by Ni-catalysis. WO 12/028279 discloses the same type of polymer for use as a gate dielectric layer in contact with a semiconductor layer.
- It is the object of the present invention to provide a dielectric material which allows easy solution processing while resulting in good dielectric properties and adherence.
- 35 It has now been found that oxacycloolefinic polymers, as typically obtained by Ru-carbene catalyzed ring-opening metathesis polymerization of a bicyclic oxaolefin, show such advantageous properties as a dielectric material.
- 40 The present invention thus primarily pertains to an electronic device containing at least one dielectric material which comprises an oxacycloolefinic polymer.

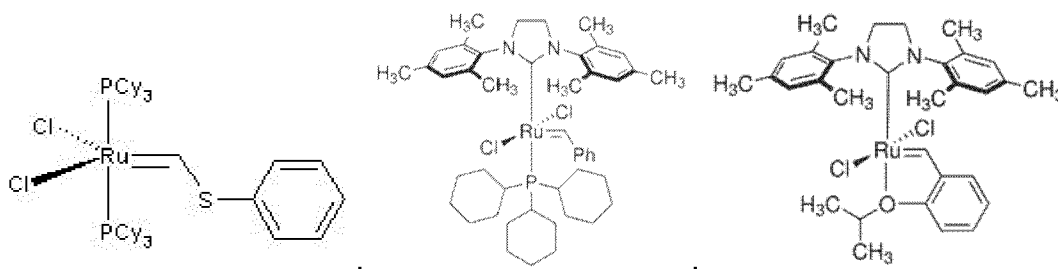
A further advantage of the present dielectric comprising an oxacycloolefinic polymer is its solubility in rather polar solvents, which property allows for solvent processing upon previous layer(s) of material (e.g. organic semiconductors), which show low tendency to dissolve in such media.

5

Ru-carbenes and their use as catalysts in the metathesis polymerization reaction have been widely described in literature, see e.g. US-6407190, US-6465554 and publications cited therein (e.g. column 1, lines 9-37 of US-6465554); US-7037993 (e.g. column 11, line 34, to col. 13 line 10); and references cited further above; examples are

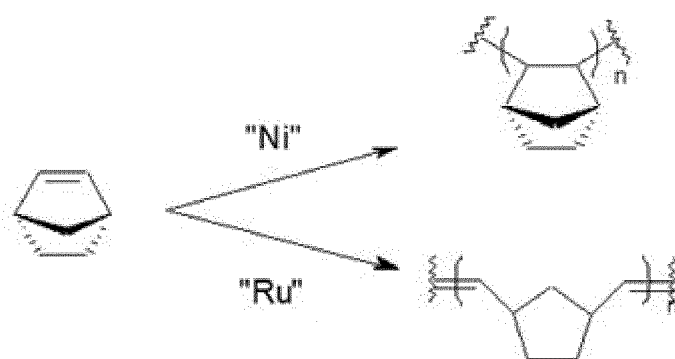
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bis(tricyclohexylphosphine)benzylidene ruthenium(IV) dichloride,



The educt for metathesis polymerization is generally described as a strained cycloolefin, typically a bicyclic olefin such as norbornene (bicyclo[2.2.1]hept-2-ene), which may be unsubstituted or substituted. The type of catalyst thereby determines the type of polymer chain obtained; Ni-catalysts generally lead to polymer chains wherein the original bicyclic structure of the monomer is maintained and the polymer bonds are formed by the former olefinic double bonds. The present Ruthenium carbene catalysts lead to the opening of one ring with formation of a polymer chain containing olefinic double bonds in their non-cyclic parts, as apparent from the below scheme:

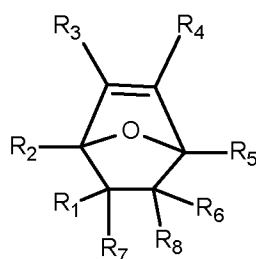
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wherein n denotes the number of repeating units within the polymer chain and "Ru" stands for the Ru-carbene catalyst to be used in accordance with the present invention.

25

The oxacycloolefinic polymer is, consequently, obtained by Ru-carbene catalyzed polymerization of a bicyclic oxaolefin. "Oxa" therein denotes an oxygen atom replacing a CH₂-moiety within the bicyclic ring system of a bicycloolefin. Typical example is a norbornene, wherein one CH₂ has been replaced by oxygen, thus conforming to the structure bicyclo[2.2.1]-5-oxa-hept-2-ene, bicyclo[2.2.1]-6-oxa-hept-2-ene or bicyclo[2.2.1]-7-oxa-hept-2-ene, each of which may be unsubstituted or substituted. A preferred example for such an educt is an oxanorbornene of the formula I

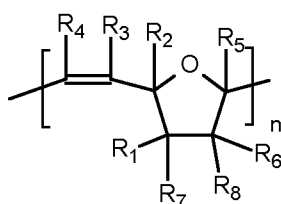


(I)

wherein

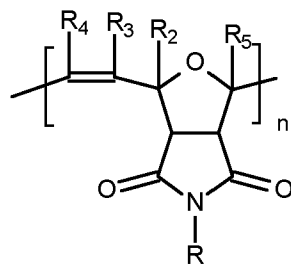
- each of R₁ to R₆ are selected from hydrogen and C₁-C₄alkyl; and R₇ and R₈ are hydrogen or a substituent; or R₇ and R₈ form, together with the carbon atoms they are attached to, a saturated or unsaturated carbocyclic ring of 5 to 12 carbon atoms, which is unsubstituted or substituted, or a saturated or unsaturated ring comprising 4 to 11 carbon atoms and 1 or 2 oxygen atoms or groups NR₉, with R₉ being hydrogen or a substituent, as ring members, which ring is unsubstituted or substituted.

The electronic device according to the present invention thus typically comprises an oxacycloolefinic polymer of the formula II



(II)

- wherein n ranges from 3 to 100 000, and each of R₁ to R₈ are as defined for formula I above. More preferably, the oxacycloolefinic polymer comprises a polymer chain of the formula III



(III)

wherein each of n and R_2 to R_5 are as defined above, and

R is hydrogen, C1-C25alkyl, C1-C25haloalkyl, phenyl, phenyl-C1-C4alkyl, cyclopentyl, cyclohexyl, wherein phenyl moiety or cyclopentyl or cyclohexyl moiety itself is unsubstituted or substituted by C1-C4alkyl, C1-C4alkoxy, OH, halogen.

The electronic device according to the present invention usually is selected from capacitors, transistors such as organic field effect transistors, and devices comprising said capacitor and/or transistor; it contains the oxacycloolefinic polymer preferably as a capacitor layer or gate insulating layer, typically as part of an organic thin film transistor such as an OFET, thus making use of its superior dielectric properties.

Any substituent, wherever mentioned, is typically selected from halogen, C1-C25alkyl, C2-C25alkenyl, C1-C25alkylthio, C1-C25alkoxy, C2-C25alkenyloxy, C4-C10aryl, C1-C9heteroaryl, C3-C12cycloalkyl, C2-C11heterocycloalkyl, each of which is unsubstituted or substituted by R' ; or is C2-C25alkyl, C3-C25alkenyl, C2-C25alkylthio, C2-C25alkoxy, C3-C25alkenyloxy, which is interrupted in its alkyl part by O, CO, COO, CONR, CONR₂, S, SO, SO₂, NR, and is unsubstituted or substituted by R' ; or is selected from the residues OR, COR, CH=NR, CH=N-OH, CH=N-OR, COOR, CONHR, CONRR', CONH-NHR, CONH-NRR', SO₂R, SO₃R, SO₂NHR, SO₂NRR', SO₂NH-NHR, SO₂NH-NRR', S(O)R, S(O)OR, S(O)NHR, S(O)NRR', S(O)NH-NHR, S(O)NH-NRR', SiRR'R'', PORR', PO(OR)R', PO(OR)₂, PO(NHR)₂, PO(NRR')₂, CN, NO₂, NHR, NRR', NH-NHR, NH-NRR', CONROH; and if bonding to saturated carbon may also be oxo;

and wherein R , R' and R'' independently are selected from C1-C25alkyl, C1-C25haloalkyl, C5-C10aryl, C6-C12arylalkyl, C3-C12cycloalkyl, preferably from C1-C6alkyl, phenyl, benzyl, cyclopentyl, cyclohexyl; and R may also be hydrogen;

where each aryl or heteroaryl or cycloalkyl itself is unsubstituted or substituted by C1-C4alkyl, C2-C4alkenyl, C1-C4alkoxy, OH, CHO, C1-C4alkyl-carbonyl, C1-C4alkyl-carbonyloxy, C1-C4alkoxy-carbonyl, allyloxy, halogen.

The invention thus pertains to an electronic device, generally an organic electronic device, as it may be prepared in a printing process on a substrate. The substrate may be

glass, but is typically a plastic film or sheet. Typical devices are capacitors, transistors such as an electronic field effect transistor (OFET), or devices comprising said capacitor and/or transistor. The device of the invention contains at least one dielectric material, usually in the form of a dielectric layer, which comprises the present oxacycloolefinic polymer. The device of the invention generally contains at least one further layer of a functional material, mainly selected from conductors and semiconductors, which usually stands in direct contact with the present oxacycloolefinic polymer dielectric material or layer; examples are OFETs containing the layer of dielectric material according to the invention in direct contact with the electrode and/or the semiconductor.

Present invention further provides a process for the preparation of an electronic device, such as a capacitor or transistor on a substrate, which process comprises the steps of

- i) providing a solution or dispersion of an oxacycloolefinic polymer, as described above, in a suitable solvent, and
- ii) forming a layer on a substrate, an electrode material and/or a semiconductor, and drying said layer.

Preferably, the process does not comprise a step of heat treatment at a temperature of $\geq 150^\circ\text{C}$. More preferably, the process does not comprise a step of heat treatment at a temperature of $\geq 140^\circ\text{C}$. Most preferably, the process does not comprise a step of heat treatment at a temperature of $\geq 120^\circ\text{C}$. Accordingly, the heat treatment in step (ii), if present, usually requires heating the layer to a temperature from the range 30 to 150°C , preferably 40 to 140°C , especially 50 to 120°C .

Suitable as the solvent (hereinbelow also recalled as organic solvent A) is any solvent (or solvent mixture), which is able to dissolve at least 2% by weight, preferably at least 5% by weight, more preferably, at least 8% by weight of the oxacycloolefinic polymer.

As the organic solvent A, generally any solvent may be chosen which has a boiling point (at ambient pressure) from the range of about 80 to 250°C . Solvent A may be a mixture of such solvents. In a preferred process, any component of solvent A has a boiling point from the range $100\text{--}220^\circ\text{C}$, especially $100\text{--}200^\circ\text{C}$. Also of importance are blends using a main solvent (e.g. 70% b.w. or more, such as 95%) having a boiling point around 150°C (e.g. 120 to 180°C) and a minor component (30% b.w. or less, such as 5%) having a high boiling point of more than 200°C , e.g. from the range $200\text{--}250^\circ\text{C}$.

Preferably, the organic solvent A is selected from the group consisting of *N*-methylpyrrolidone, C_{4-8} -cycloalkanone, C_{1-4} -alkyl-C(O)- C_{1-4} -alkyl, C_{1-4} -alkanoic acid C_{1-4} -alkyl ester, wherein the C_{1-4} -alkyl or the C_{1-4} -alkanoic acid can be substituted by hydroxyl or O- C_{1-4} -alkyl, and C_{1-4} -alkyl-O- C_{1-4} -alkylene-O- C_{1-4} -alkylene-O- C_{1-4} -alkyl, and mixtures thereof.

Examples of C₁₋₄-alkyl-C(O)-C₁₋₄-alkyl are ethyl isopropyl ketone, methyl ethyl ketone and methyl isobutyl ketone.

5 Examples of C₁₋₄-alkanoic acid C₁₋₄-alkyl ester, wherein the C₁₋₄-alkyl or the C₁₋₄-alkanoic acid can be substituted by hydroxyl or O-C₁₋₄-alkyl, are ethyl acetate, butyl acetate, isobutyl acetate, (2-methoxy)ethyl acetate, (2-methoxy)propyl acetate and ethyl lactate.

10 An example of C₁₋₄-alkyl-O-C₁₋₄-alkylene-O-C₁₋₄-alkylene-O-C₁₋₄-alkyl is diethyleneglycoldimethylether.

More preferably, the organic solvent A is selected from the group consisting of C₄₋₈-cycloalkanone, C₁₋₄-alkyl-C(O)-C₁₋₄-alkyl, C₁₋₄-alkanoic acid C₁₋₄-alkyl ester, wherein the C₁₋₄-alkyl or the C₁₋₄-alkanoic acid can be substituted by hydroxyl or O-C₁₋₄-alkyl, and C₁₋₄-alkyl-O-C₁₋₄-alkylene-O-C₁₋₄-alkylene-O-C₁₋₄-alkyl, and mixtures thereof. Examples are methyl ethyl ketone (b.p. 80°C), 1,4-dioxane, methyl-isobutyl ketone, butylacetate, 2-hexanone, 3-hexanone, 2-methoxy-1,3-dioxolane, Propylene glycol methyl ether acetate (PGMEA), ethyl lactate, DiGlyme, 5-methyl-3H-furan-2-one (b.p. 169°C [“alpha-angelica lactone”]), dipropylene glycol dimethyl ether (b.p. 175°C [ProGlyde DMM]), N-methylpyrrolidone (NMP), gamma-butyrolactone, acetophenone, isophorone, gamma-aprolactone, 1,2-propylene carbonate (b.p. 241°C); blends of Propylene glycol methyl ether acetate (PGMEA, b.p. 145°C, e.g. 95%) and propylene carbonate (e.g.5%).

25 Most preferably, the organic solvent A is selected from the group consisting of C₅₋₆-cycloalkanone, C₁₋₄-alkanoic acid C₁₋₄-alkyl ester, and mixtures thereof. Even most preferably the organic solvent A is cyclopentanone or PGMEA or mixtures thereof. In particular preferred organic solvents A are PGMEA or mixtures of PGMEA and pentanone, wherein the weight ratio of PGMEA/cyclopentanone is at least from 99/1 to 20/80, more preferably from 99/1 to 30/70.

If the oxacycloolefinic polymer is applied as a solution in an organic solvent A on the layer of the transistor or on the substrate, the oxacycloolefinic polymer can be applied by any possible solution process, such as spin-coating, drop-casting or printing.

35 After applying oxacycloolefinic polymer as a solution in an organic solvent A on the layer of the transistor or on the substrate, a heat treatment at a temperature of below 140 °C, for example at a temperature in the range of 60 to 120 °C, preferably at a temperature of below 120 °C, for example in the range of 60 to 110 °C can be performed.

40

The layer comprising oxacycloolefinic polymer can have a thickness in the range of 100 to 1000 nm, preferably, in the range of 300 to 1000 nm, more preferably 300 to 700 nm.

- 5 The layer comprising oxacycloolefinic polymer can comprise from 50 to 100% by weight, preferably from 80 to 100%, preferably 90 to 100% by weight of oxacycloolefinic polymer based on the weight of the layer comprising oxacycloolefinic polymer. Preferably, the layer comprising oxacycloolefinic polymer essentially consists of oxacycloolefinic polymer.

10

Examples of aromatic rings are phenyl and naphthyl. Phenyl is preferred.

Examples of halogen are fluoro, chloro and bromo.

- 15 Examples of C₁₋₁₀-alkyl are methyl, ethyl, propyl, isopropyl, butyl, *sec*-butyl, isobutyl, *tert*-butyl, pentyl, 2-ethylbutyl, hexyl, heptyl, octyl, nonyl and decyl. Examples of propyl and butyl are n-propyl, isopropyl, n-butyl, *sec*-butyl, isobutyl and *tert*-butyl.

20

Examples of C₄₋₈-cycloalkyl are cyclobutyl, cyclopentyl, cyclohexyl, cycloheptyl and cyclooctyl.

Examples of C₁₋₁₀-haloalkyl are trifluoromethyl and pentafluoroethyl.

25

Examples of C₂₋₁₀-alkenyl are vinyl, CH₂-CH=CH₂, CH₂-CH₂-CH=CH₂.

Examples of C₄₋₁₀-cycloalkenyl are cyclopentyl, cyclohexyl and norbornenyl.

30

Examples of C₁₋₁₀-alkylene are methylene, ethylene, propylene, butylene, pentylene, hexylene and heptylene. Examples of C₁₋₄-alkylene are methylene, ethylene, propylene and butylene

Examples of C₄₋₈-cycloalkylene are cyclobutylene, cyclopentylene, cyclohexylene and cycloheptylene.

- 35 Examples of C₁₋₄-alkanoic acid are acetic acid, propionic acid and butyric acid.

The glass transition temperature of the present oxacycloolefinic polymer, as determined by differential scanning calorimetry, is preferably above 90 °C, more preferably above 130 °C, and more preferably between 150 °C and 300 °C.

40

The molecular weight of the oxacycloolefinic polymer can be in the range of 5000 to 2000000 g/mol, preferably 10000 to 1000000 g/mol (as determined by gel permeation chromatography).

- 5 The transistor on a substrate is preferably a field-effect transistor (FET) on a substrate and more preferably an organic field-effect transistor (OFET) on a substrate.

Usually, an organic field effect transistor comprises a dielectric layer and a semiconducting layer. In addition, an organic field effect transistor usually comprises a gate electrode and source/drain electrodes.

10

Typical designs of organic field effect transistors are the Bottom-Gate design and the Top-Gate design:

- 15 In case of the Bottom-Gate Bottom-Contact (BGBC) design, the gate is on top of the substrate and at the bottom of the dielectric layer, the semiconducting layer is at the top of the dielectric layer and the source/drain electrodes are on top of the semiconducting layer.
- 20 Another design of a field-effect transistor on a substrate is the Top-Gate Bottom-Contact (TGBC) design: The source/drain electrodes are on top of the substrate and at the bottom of the semiconducting layer, the dielectric layer is on top of the semiconducting layer and the gate electrode is on top of the dielectric layer. When prepared by solution processing, here the solvents used for dielectrics must be fully orthogonal with
- 25 respect to the semiconductor (i.e. show good solubility of the dielectric and absolute insolubility of the semiconductor), and additionally compatible with photoresist processing.

The semiconducting layer comprises a semiconducting material. Examples of semiconducting materials are semiconducting materials having p-type conductivity (carrier: holes) and semiconducting materials having n-type conductivity (carrier: electrons).

30

Examples of semiconductors having n-type conductivity are perylenediimides, naphthalenediimides and fullerenes.

- 35 Semiconducting materials having p-type conductivity are preferred. Examples of semiconducting materials having p-type conductivity are molecules such as rubrene, tetracene, pentacene, 6,13-bis(triisopropylethynyl) pentacene, diindenoperylene, perylenediimide and tetracyanoquinodimethane, and polymers such as polythiophenes, in particular poly 3-hexylthiophene (P3HT), polyfluorene, polydiacetylene, poly
- 40 2,5-thienylene vinylene, poly p-phenylene vinylene (PPV) and polymers comprising repeating units having a diketopyrrolopyrrole group (DPP polymers).

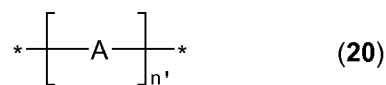
Preferably the semiconducting material is a polymer comprising units having a diketo-pyrrolopyrrole group (DPP polymer).

Examples of DPP polymers and their synthesis are, for example, described in

- 5 US 6,451,459 B1, WO 2005/049695, WO 2008/000664, WO 2010/049321, WO 2010/049323, WO 2010/108873, WO 2010/115767, WO 2010/136353 and WO 2010/136352.

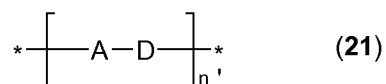
- 10 Preferably, the DPP polymer comprises, preferably essentially consists, of a unit selected from the group consisting of

a polymer unit of formula

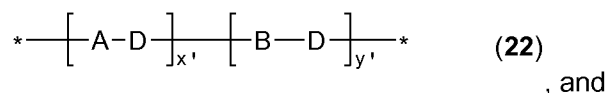


15

a copolymer unit of formula

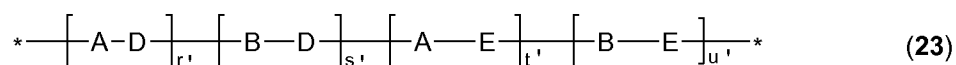


- 20 a copolymer unit of formula



a copolymer unit of formula

25



wherein

- 30 n' is 4 to 1000, preferably 4 to 200, more preferably 5 to 100,

x' is 0.995 to 0.005, preferably x' is 0.2 to 0.8,

y' is 0.005 to 0.995, preferably y' is 0.8 to 0.2, and

$x' + y' = 1$;

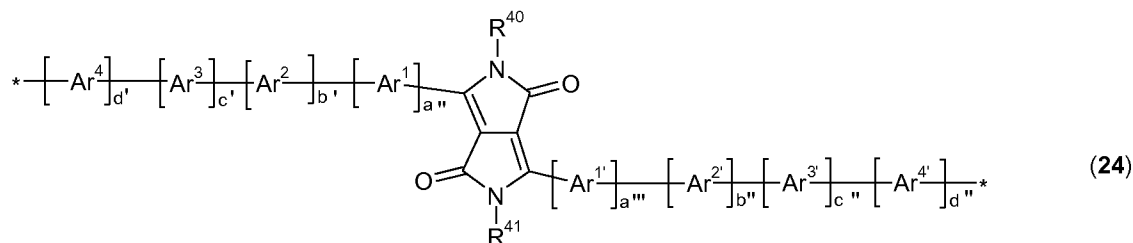
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r' is 0.985 to 0.005,

s' is 0.005 to 0.985,

t' is 0.005 to 0.985,
 u' is 0.005 to 0.985, and
 $r' + s' + t' + u' = 1$;

5 A is a group of formula



wherein

10

a'' is 1, 2, or 3,

a''' is 0, 1, 2, or 3,

b' is 0, 1, 2, or 3,

b'' is 0, 1, 2, or 3,

15

c' is 0, 1, 2, or 3,

c'' is 0, 1, 2, or 3,

d' is 0, 1, 2, or 3,

d'' is 0, 1, 2, or 3,

with the proviso that b'' is not 0, if a''' is 0;

20

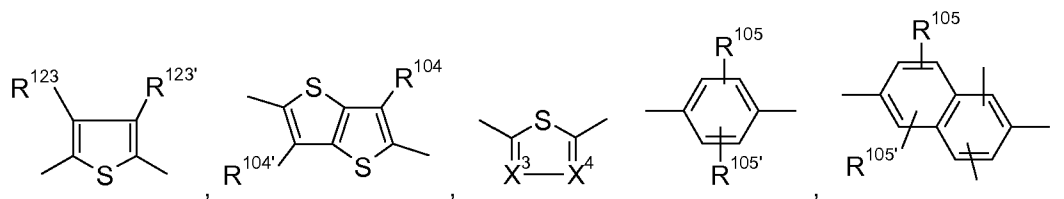
R⁴⁰ and R⁴¹ are the same or different and are selected from the group consisting of hydrogen, C₁-C₁₀₀alkyl, -COOR^{106''}, C₁-C₁₀₀alkyl which is substituted with one or more halogen, hydroxyl, nitro, -CN, or C₆-C₁₈aryl and/or interrupted by -O-, -COO-, -OCO-, or -S-; C₇-C₁₀₀arylalkyl, carbamoyl, C₅-C₁₂cycloalkyl, which can be substituted one to three times with C₁-C₈alkyl and/or C₁-C₈alkoxy, C₆-C₂₄aryl, in particular phenyl or 1- or 2-naphthyl which can be substituted one to three times with C₁-C₈alkyl, C₁-C₂₅thioalkoxy, and/or C₁-C₂₅alkoxy, or pentafluorophenyl, wherein

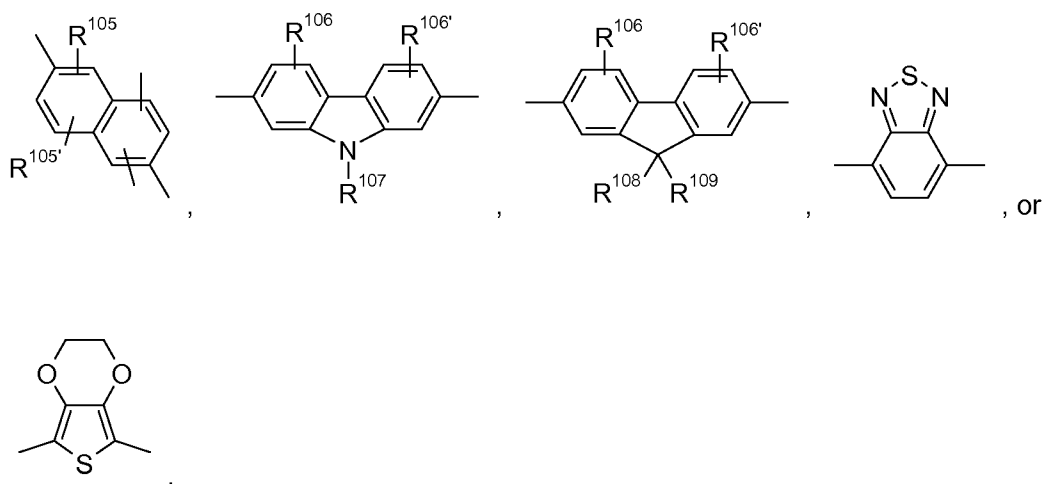
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R^{106''} is C₁-C₅₀alkyl, preferably C₄-C₂₅alkyl,

30

Ar¹, Ar^{1'}, Ar², Ar^{2'}, Ar³, Ar^{3'}, Ar⁴ and Ar^{4'} are independently of each other heteroaromatic, or aromatic rings, which optionally can be condensed and/or substituted, preferably





5

wherein

one of X^3 and X^4 is N and the other is CR^{99} ,

10 wherein R^{99} is hydrogen, halogen, preferably F, or C_1 - C_{25} alkyl, preferably a C_4 - C_{25} alkyl, which may optionally be interrupted by one or more oxygen or sulphur atoms, C_7 - C_{25} arylalkyl, or C_1 - C_{25} alkoxy,

15 R^{104} , $R^{104'}$, R^{123} and $R^{123'}$ are independently of each other hydrogen, halogen, preferably F, or C_1 - C_{25} alkyl, preferably a C_4 - C_{25} alkyl, which may optionally be interrupted by one or more oxygen or sulphur atoms, C_7 - C_{25} arylalkyl, or C_1 - C_{25} alkoxy,

20 R^{105} , $R^{105'}$, R^{106} and $R^{106'}$ are independently of each other hydrogen, halogen, C_1 - C_{25} alkyl, which may optionally be interrupted by one or more oxygen or sulphur atoms; C_7 - C_{25} arylalkyl, or C_1 - C_{18} alkoxy,

R^{107} is C_7 - C_{25} arylalkyl, C_6 - C_{18} aryl; C_6 - C_{18} aryl which is substituted by C_1 - C_{18} alkyl, C_1 - C_{18} perfluoroalkyl, or C_1 - C_{18} alkoxy; C_1 - C_{18} alkyl; C_1 - C_{18} alkyl which is interrupted by -O-, or -S-, or -COOR¹²⁴;

25

R^{124} is C_1 - C_{25} alkyl, preferably C_4 - C_{25} alkyl, which may optionally be interrupted by one or more oxygen or sulphur atoms, C_7 - C_{25} arylalkyl,

30 R^{108} and R^{109} are independently of each other H, C_1 - C_{25} alkyl, C_1 - C_{25} alkyl which is substituted by E' and/or interrupted by D' , C_7 - C_{25} arylalkyl, C_6 - C_{24} aryl, C_6 - C_{24} aryl which is substituted by G, C_2 - C_{20} heteroaryl, C_2 - C_{20} heteroaryl which is substituted by G, C_2 - C_{18} alkenyl, C_2 - C_{18} alkynyl, C_1 - C_{18} alkoxy, C_1 - C_{18} alkoxy which is substituted by E' and/or interrupted by D' , or C_7 - C_{25} arylalkyl,

or

R¹⁰⁸ and R¹⁰⁹ together form a group of formula =CR¹¹⁰R¹¹¹, wherein

- 5 R¹¹⁰ and R¹¹¹ are independently of each other H, C₁-C₁₈alkyl, C₁-C₁₈alkyl which is substituted by E' and/or interrupted by D', C₆-C₂₄aryl, C₆-C₂₄aryl which is substituted by G, or C₂-C₂₀heteroaryl, or C₂-C₂₀heteroaryl which is substituted by G,

or

10

R¹⁰⁸ and R¹⁰⁹ together form a five or six membered ring, which optionally can be substituted by C₁-C₁₈alkyl, C₁-C₁₈alkyl which is substituted by E' and/or interrupted by D', C₆-C₂₄aryl, C₆-C₂₄aryl which is substituted by G, C₂-C₂₀heteroaryl, C₂-C₂₀heteroaryl which is substituted by G, C₂-C₁₈alkenyl, C₂-C₁₈alkynyl, C₁-C₁₈alkoxy, C₁-C₁₈alkoxy which is substituted by E' and/or interrupted by D', or C₇-C₂₅aralkyl, wherein

15

D' is -CO-, -COO-, -S-, -O-, or -NR¹¹²-,

E' is C₁-C₈thioalkoxy, C₁-C₈alkoxy, CN, -NR¹¹²R¹¹³, -CONR¹¹²R¹¹³, or halogen,

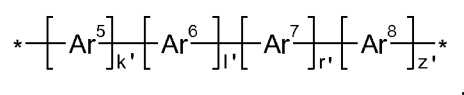
20

G is E', or C₁-C₁₈alkyl, and

R¹¹² and R¹¹³ are independently of each other H; C₆-C₁₈aryl; C₆-C₁₈aryl which is substituted by C₁-C₁₈alkyl, or C₁-C₁₈alkoxy; C₁-C₁₈alkyl; or C₁-C₁₈alkyl which is interrupted by -O- and

25

B, D and E are independently of each other a group of formula



30

or a group of formula (24),

with the proviso that in case B, D and E are a group of formula (24), they are different from A, wherein

35

k' is 1,

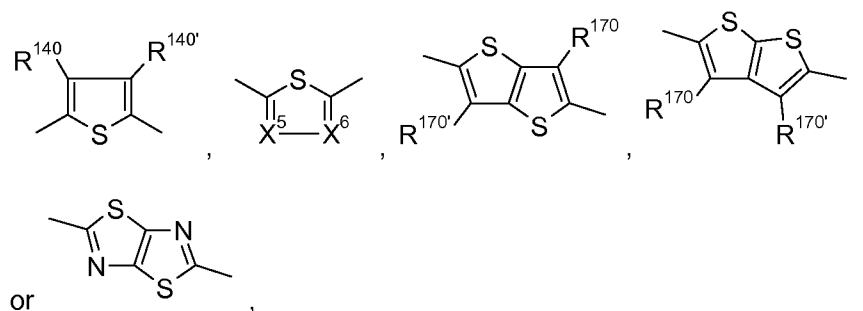
l' is 0, or 1,

r' is 0, or 1,

z' is 0, or 1, and

40

Ar⁵, Ar⁶, Ar⁷ and Ar⁸ are independently of each other a group of formula



5

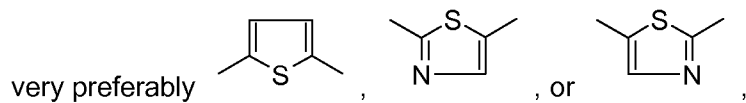
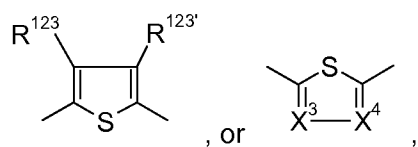
wherein one of X⁵ and X⁶ is N and the other is CR¹⁴⁰,

R¹⁴⁰, R^{140'}, R¹⁷⁰ and R^{170'} are independently of each other H, or a C₁-C₂₅alkyl, preferably C₆-C₂₅alkyl, which may optionally be interrupted by one or more oxygen atoms.

10

Preferred polymers are described in WO2010/049321.

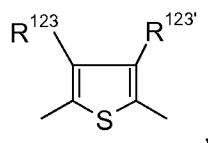
15 Ar¹ and Ar^{1'} are preferably



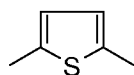
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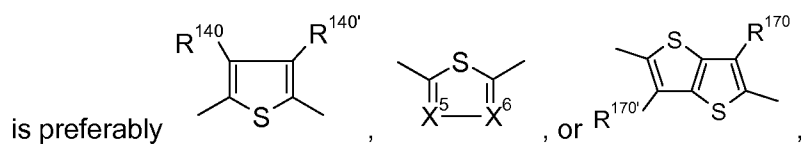
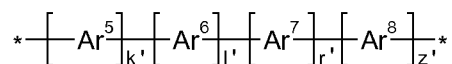
Ar², Ar^{2'}, Ar³, Ar^{3'}, Ar⁴ and Ar^{4'} are preferably



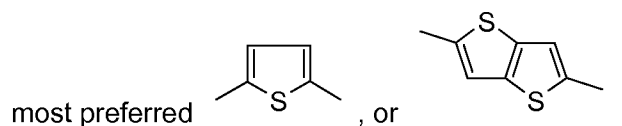
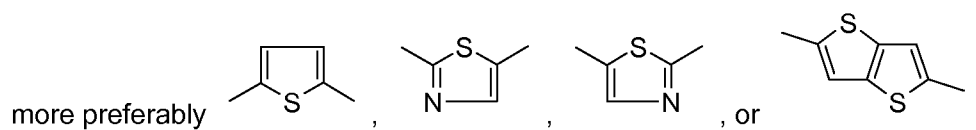
5 more preferably



10 The group of formula



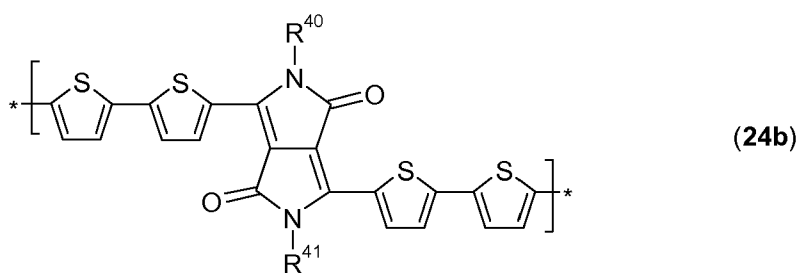
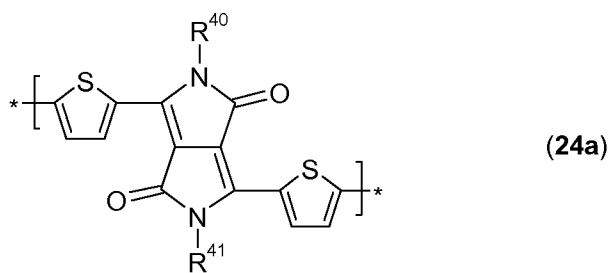
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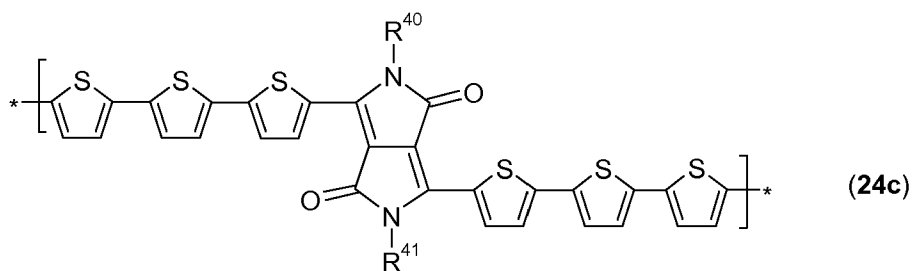
20

R⁴⁰ and R⁴¹ are the same or different and are preferably selected from hydrogen, C₁-C₁₀₀alkyl, more preferably a C₈-C₃₆alkyl.

A is preferably selected from the group consisting of

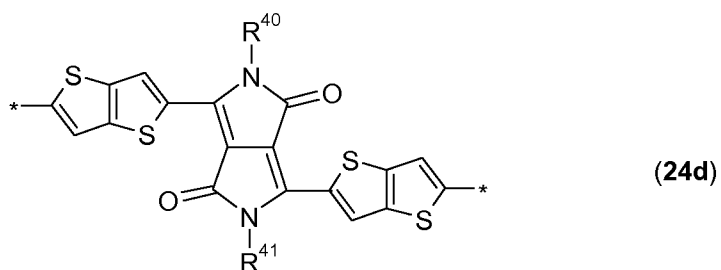


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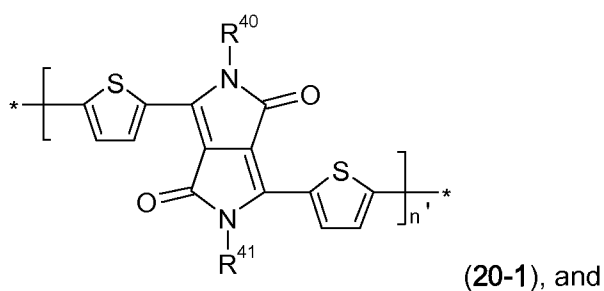


and

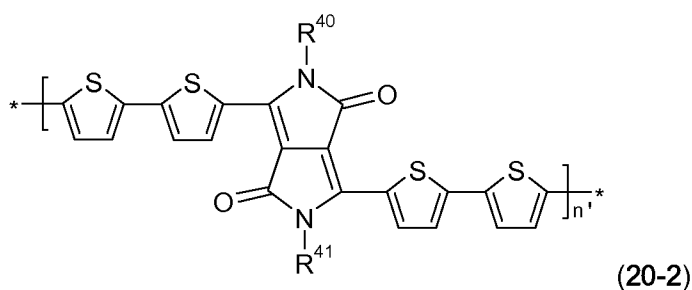
10



Examples of preferred DPP polymers comprising, preferably consisting essentially of, a polymer unit of formula (20) are shown below:



5



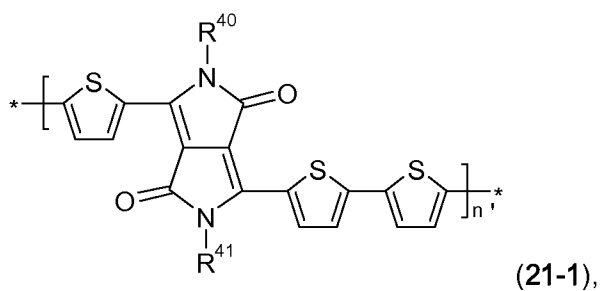
wherein

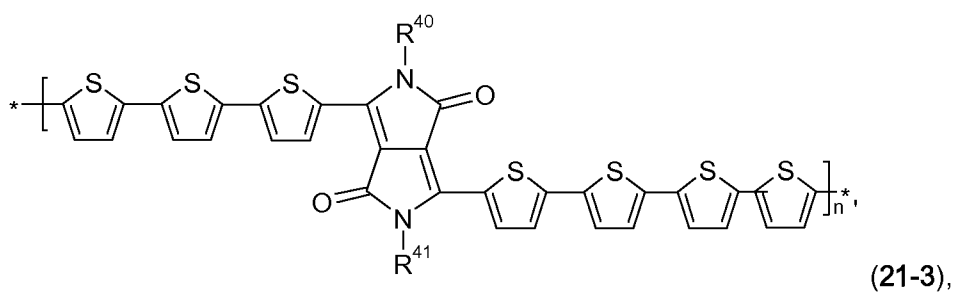
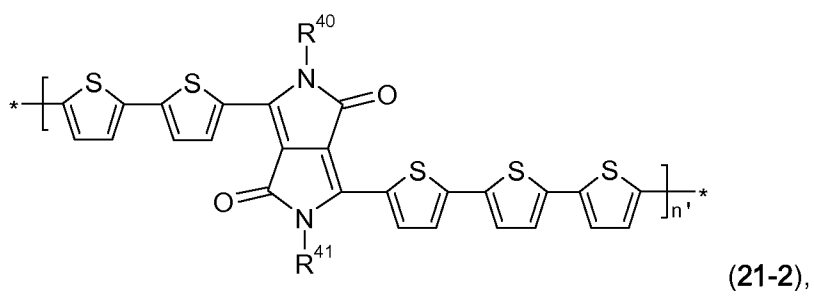
R^{40} and R^{41} are C_1 - C_{36} alkyl, preferably C_8 - C_{36} alkyl, and

10 n' is 4 to 1000, preferably 4 to 200, more preferably 5 to 100.

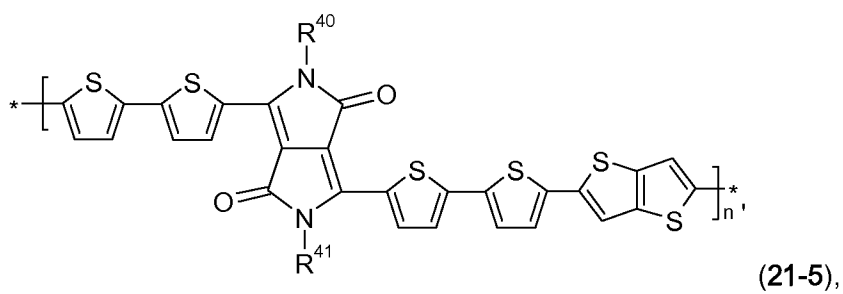
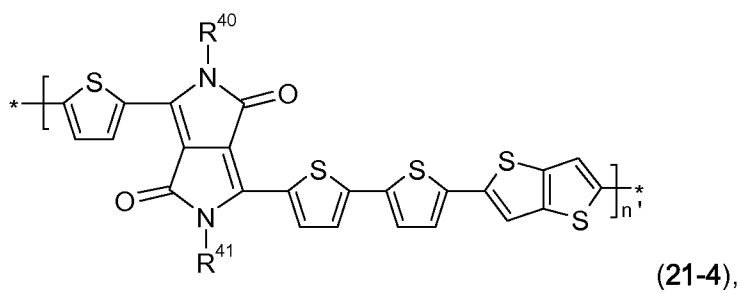
Examples of preferred DPP polymers comprising, preferably consisting essentially of, a copolymer unit of formula (21) are shown below:

15

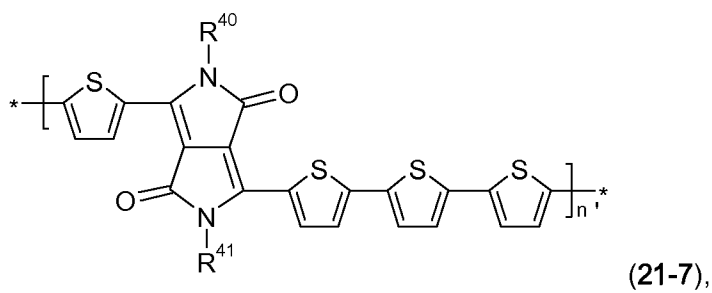
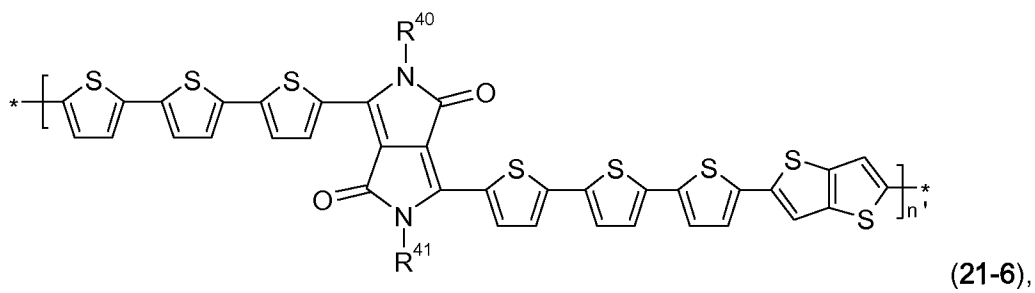




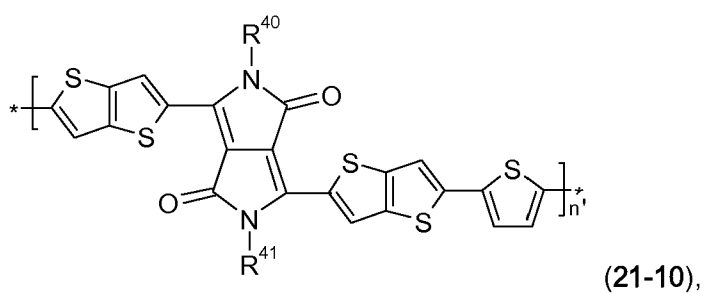
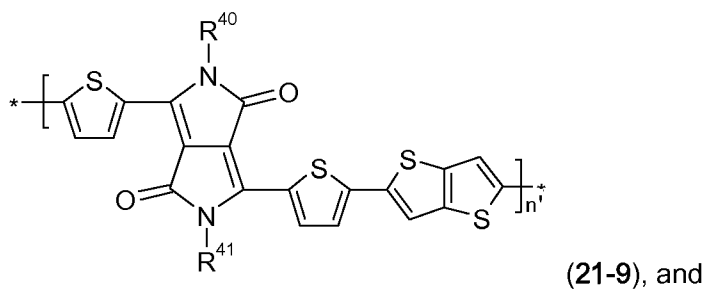
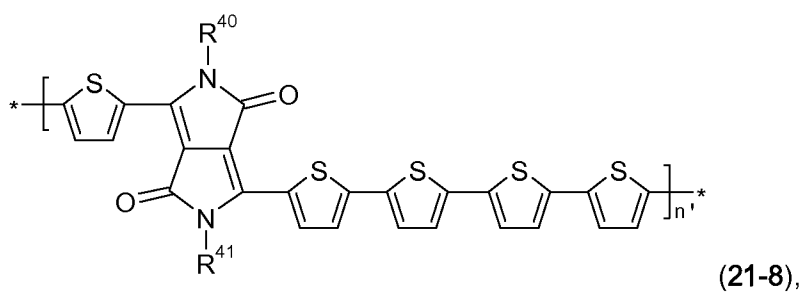
5



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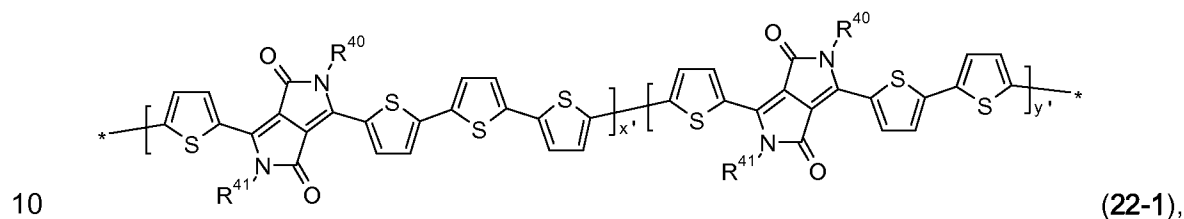


wherein

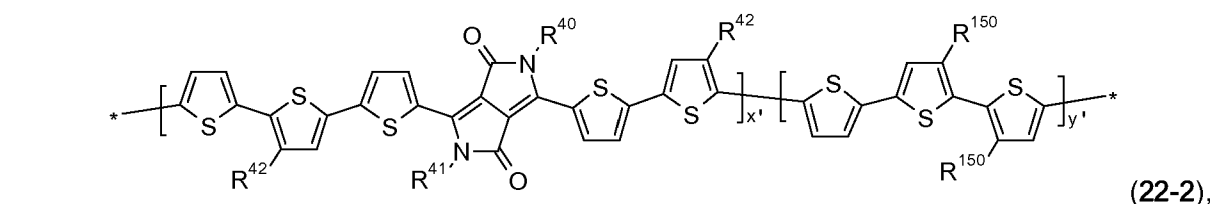
R^{40} and R^{41} are C_1 - C_{36} alkyl, preferably C_8 - C_{36} alkyl, and
 n' is 4 to 1000, preferably 4 to 200, more preferably 5 to 100.

5

Examples of preferred DPP polymers comprising, preferably essentially consisting of, a copolymer unit of formula (22) are shown below:



and



wherein

R^{40} and R^{41} are C_1 - C_{36} alkyl, preferably C_8 - C_{36} alkyl,

R^{42} is C_1 - C_{18} alkyl,

R^{150} is a C_4 - C_{18} alkyl group,

20 $x' = 0.995$ to 0.005 , preferably $x' = 0.4$ to 0.9 ,

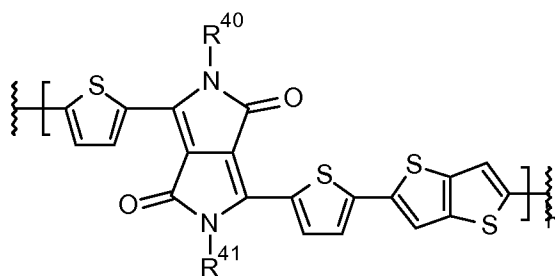
$y' = 0.005$ to 0.995 , preferably $y' = 0.6$ to 0.1 , and

$x + y = 1$.

25 DPP Polymers comprising, preferably consisting essentially of, a copolymer unit of formula (22-1) are more preferred than DPP polymers comprising, preferably consisting essentially of, a copolymer unit of formula (22-2).

30 The DPP polymers preferably have a weight average molecular weight of 4,000 Daltons or greater, especially 4,000 to 2,000,000 Daltons, more preferably 10,000 to 1,000,000 and most preferably 10,000 to 100,000 Daltons.

DPP Polymers comprising, preferably consisting essentially of, a copolymer unit of formula

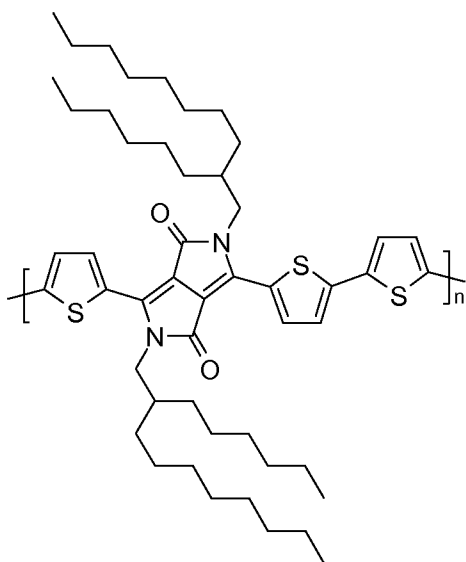


(21-9)

(with R40, R41 being alkyl, such as 2-hexyldecyl)

5

or a copolymer unit of formula (21-1) are particularly preferred. Reference is, for example made to example 1 of WO2010/049321:



(Mw = 39'500)

10

The dielectric layer comprises a dielectric material. The dielectric material can be silicon/silicium dioxide, or, preferably, an organic polymer such as poly(methylmethacrylate) (PMMA), poly(4-vinylphenol) (PVP), poly(vinyl alcohol) (PVA), anzo-

15

cyclobutene (BCB), polyimide (PI).

Preferably, the dielectric layer comprises the present oxacycloolefinic polymer.

The substrate can be any suitable substrate such as glass, or a plastic substrate. Preferably the substrate is a plastic substrate such as polyethersulfone, polycarbonate, polysulfone, polyethylene terephthalate (PET) and polyethylene naphthalate (PEN). More preferably, the plastic substrate is a plastic foil.

20

Also part of the invention is a transistor obtainable by above process.

An advantage of the process of the present invention is that the present oxacycloolefinic polymer is resistant to shrinkage.

5

Another advantage of the process of the present invention is that the present oxacycloolefinic polymer shows a high chemical and thermal stability. As a consequence, the process of the present invention can be used to prepare, for example, an organic field effect transistor, wherein the layer comprising present oxacycloolefinic polymer is the dielectric layer, wherein the electrodes on top of the dielectric layer can be applied by evaporation through a shadow mask.

10

Another advantage of the process of the present invention is that present oxacycloolefinic polymer is soluble in an organic solvent (solvent A). Preferably, it is possible to prepare a 2% by weight, more preferably a 5% by weight and most preferably a 8% by weight solution of present oxacycloolefinic polymer in the organic solvent. Thus, it is possible to apply present oxacycloolefinic polymer by solution processing techniques.

15

Another advantage of the process of the present invention is that the organic solvent used to dissolve present oxacycloolefinic polymer

20

- (i) preferably has a boiling point (at ambient pressure) of below 160 °C, preferably below 150 °C, more preferably below 120 °C, and thus can be removed by heat treatment at a temperature of below 120 °C, preferably at a temperature in the range of 60 to 110 °C, and
- (ii) preferably does not dissolve suitable semiconducting materials such as diketopyrrolopyrrol (DPP) thiophenes, and thus allows the formation of a smooth border when applying the present oxacycloolefinic polymer on a semiconducting layer comprising diketopyrrolopyrrol (DPP) thiophenes.

25

Another advantage of the process of the present invention is that all steps of the process can be performed at ambient atmosphere, which means that no special precautions such as nitrogen atmosphere are necessary.

30

The advantage of the transistor of the present invention, preferably, wherein the transistor is an organic field effect transistor and wherein the layer comprising present oxacycloolefinic polymer is the dielectric layer and the semiconducting layer comprises a semiconducting material, for example a diketopyrrolopyrrole (DPP) thiophene polymer, is that the transistor shows a high mobility, a high Ion/Ioff ratio and a low gate leakage.

35

40

The following examples illustrate the invention. Wherever noted, room temperature (r.t.) depicts a temperature from the range 22-25°C; over night means a period of 12 to

15 hours; percentages are given by weight, if not indicated otherwise. Molecular weight is as determined by gel permeation chromatography, if not indicated otherwise.

The glass transition temperature is determined by differential scanning calorimetry (DSC), using a Mettler-Toledo DSC 822E® with Mettler-Toledo Stare® Software 9.10,

- 5 closed standard aluminium crucible (40 microliter), sample weighing range 4000 - 10000 mg, nitrogen 50ml/min, temperature gradient:

first heating 20 - 300 °C with 20 °C/min, followed by
cooling from 300 - 20°C with 20°C/min, and
second heating from 20 - 300 °C with 20 °C/min.

- 10 Further abbreviations:

Mw molecular weight as obtained by high temperature gel permeation chromatography

NMP N-Methylpyrrolidone

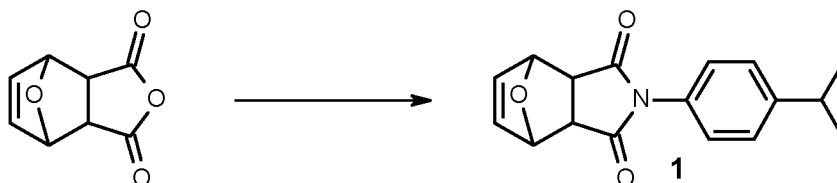
PDI polydispersity (by high temperature gel permeation chromatography)

- 15 Tg glass transition temperature

b.p. boiling point (at 1 atmosphere pressure)

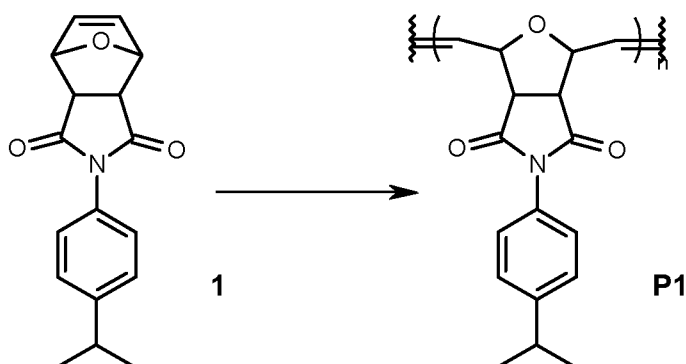
Example 1

- 20 a) Preparation of monomer 1



- 100 g of p-isopropylaniline (1 eq, 0.74 mol) is added to a solution of 122.9 g of exo-3,6-Epoxy-1,2,3,6-tetrahydrophthalic anhydride (1 eq, 0.74 mol) in acetone and stirred for 2 h. The resulting precipitate is filtrated, washed with acetone, dried and mixed with 27 g of sodium acetate in 550 mL of acetic anhydride. The mixture is then stirred for 2 h at reflux and cooled down at 0°C. The resulting precipitate is filtrated, washed with water, recrystallized in methanol and dried to yield the corresponding 1 as a pure white solid. Yield = 71 %; ¹H-NMR (CDCl₃): δ (ppm) 1.18 (d, 6H), 1.56 (s, 2H), 2.79 (s, 2H), 2.94 m, 1H), 3.03 (s, 2H), 5.42 (s, 2H), 6.59 (s, 2H), 7.20 (d, 2H), 7.33 (d, 2H).

b) Polymer P1



63 mg of (1,3-Bis-(2,4,6-trimethylphenyl)-2-imidazolidinylidene)dichloro(o-
 5 isopropoxyphenylmethylene)ruthenium (0.5% mol, 100 μ mol) is added to 2 g of 1 (1 eq, 18 mmol) in 15 mL of anhydrous dichloromethane under Nitrogen. After being stirred for 4 h at reflux, 10 mL of anhydrous dichloromethane and 1 mL of ethylvinylether are added. The mixture is poured in cold ethanol. The precipitate is filtrated, dissolved in a minimum amount of dichloromethane and poured in cold heptane. The precipitate is
 10 filtrated, dried to yield the corresponding pure polymer P1 as a white solid. Yield = 61 %
 Mw = 161 kDa / PDI = 2.1 / Tg = 228 °C

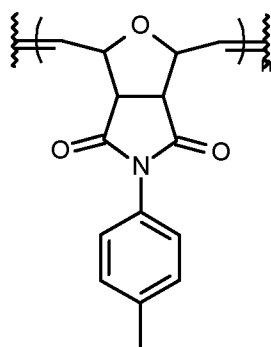
Sodium content 14 mg/kg

Phosphore content 24 mg/kg

Ruthenium content 117 mg/kg

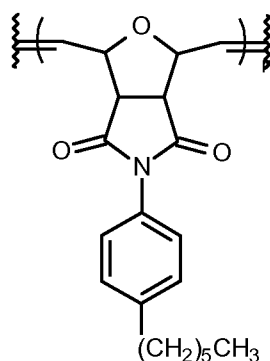
15

Example 2: In analogy to example 1, the following polymers are prepared:



20 a) Polymer P2:
 Mw = 46.5 kDa
 PDI = 1.46
 Tg = 238 °C

24



b) Polymer P3:

Mw = 69 kDa

PDI = 1.60

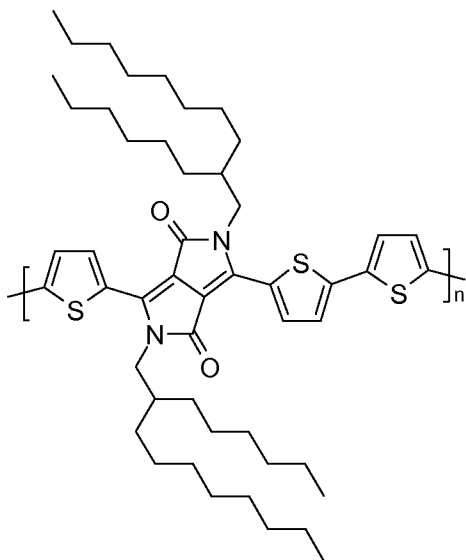
Tg = 144 °C

5

Example 3: Preparation of a top-gate, bottom contact (TGBC) field effect transistor comprising a gate dielectric layer of **P1**

- 10 Gold is sputtered onto poly(ethylene terephthalate) (PET) foil to form an approximately 40 nm thick film and then source/drain electrodes (channel length: 10 μ m; channel width: 10 mm) are structured by photolithography process. A 0.75% (weight/weight) solution of a diketopyrrolopyrrole (DPP)-thiophene-polymer (polymer 21-1 according to example 1 of WO2010/049321:

15



; Mw = 39'500)

- in toluene is filtered through a 0.45 μ m polytetrafluoroethylene (PTFE) filter and then applied by spin coating (15 seconds at 1300 rpm, acceleration 10.000 rpm/s. The wet organic semi-conducting polymer layer is dried at 100°C on a hot plate for 30 seconds.
- 20 A 8% (weight/weight) solution of **P1** in Methoxypropyl Acetate is filtered through a 0.45

µm filter and then applied by spin coating (1100rpm, 60 seconds). The wet layer film is pre-baked at 100°C for 20 minutes on a hot plate to obtain a 365 nm thick layer. Gate electrodes of gold (thickness approximately 120 nm) are evaporated through a shadow mask on the P1 layer. The whole process is performed without a protective atmosphere.

Measurement of the characteristics of the top gate, bottom contact (TGBC) field effect transistors are measured with a Keithley® 2612A semiconductor parameter analyser.

10 The drain current I_{ds} in relation to the gate voltage V_{gs} (transfer curve) for the top-gate, bottom-contact (TGBC) field effect transistor comprising a P1 gate dielectric at a source voltage V_{sd} of -20V (upper curves) is shown in Fig. 1.

15 The top-gate, bottom-contact (TGBC) field effect transistor comprising a P1 as gate dielectric shows a mobility of 0.36 cm²/Vs (calculated for the saturation regime) and an Ion/Ioff ratio of 5 E+5.

20 The drain current I_{ds} in relation to the drain voltage V_{ds} (output curve) for the top-gate, bottom-contact (TGBC) field effect transistor comprising P1 at a gate voltage V_{gs} of 0V (squares), -5V (stars), -10V (lozenges), -15V (triangles), and -20V (circles) is shown in Fig. 2.

Example 4: Preparation of a capacitor

25 A 8 % (weight/weight) solution of polymer P1 as obtained in example 1b in Methoxy-propyl Acetate is filtered through a 0.45 µm filter and applied on a clean glass substrate with indium tin oxide (ITO) electrodes by spin coating (1100 rpm, 30 seconds). The wet film is pre-baked at 100°C for 20 minutes on a hot plate to obtain a 490 nm thick layer. Gold electrodes (area = 3 mm²) are then vacuum-deposited through a shadow mask on the P1 layer at < 1x10⁻⁶ Torr.

The capacitor thus obtained is characterized in the following way:

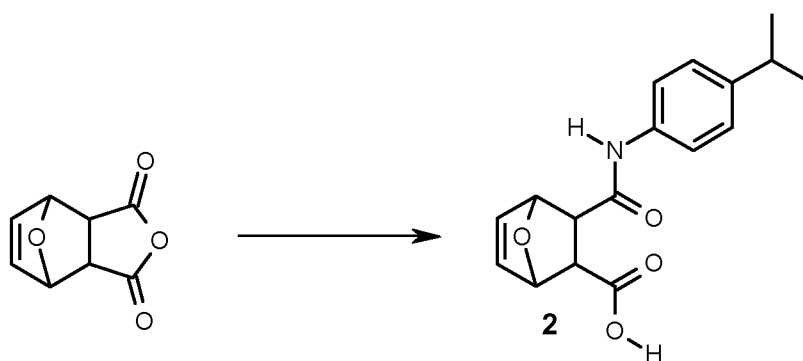
35 The relative permittivity ϵ_r and the loss factor $\tan(\delta) = \epsilon_r''$ are deduced from the complex capacity measured with a LCR meter Agilent 4284A (signal amplitude 1 V). Current /Voltage (I/V) curves are obtained with a semiconductor parameter analyser Agilent 4155C. The breakdown voltage is the voltage E_d where the current reaches a value of 1 µA. The volume resistivity ρ is calculated from the resistance, sample thickness and electrode surface.

40 In the same way, capacitors are prepared and investigated using polymers 2 and 3. results are compiled in the below table.

Polymer	ρ [Ωcm]	ϵ_r 20Hz	ϵ_r 100kHz	ϵ_r'' 20Hz	ϵ_r'' 100kHz	Ed [V/ μm]
<u>1</u>	2.5 E+15	3.15	3.01	0.037	0.040	>190
<u>2</u>	1.9 E+15	3.05	2.92	0.037	0.022	>143
<u>3</u>	3.8 E+15	2.87	2.76	0.029	0.025	171

Example 5: Alternative Preparation of Polymer

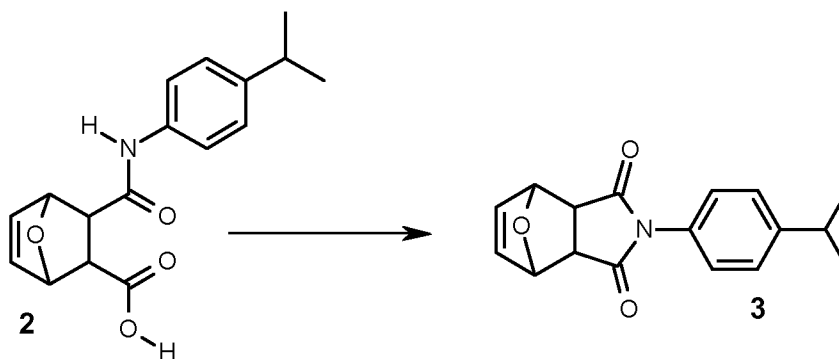
5 a) Preparation of monomer 2



100 g of p-isopropylaniline (1 eq, 0.74 mol) is added to a solution of 122.9 g of exo-3,6-Epoxy-1,2,3,6-tetrahydrophthalic anhydride (1 eq, 0.74 mol) in acetone. The mixture is then stirred for 2 h. The resulting precipitate is filtrated, washed with acetone and dried to yield the corresponding pure 2 as a white solid. Yield = 87%

$^1\text{H-NMR}$ (DMSO): δ (ppm) 1.19 (d, 6H), 2.67 (d, 1H), 2.79 (d, 1H), 2.83 (m, 1H), 5.03 (s, 1H), 5.14 (s, 1H), 6.50 (m, 2H), 7.15 (d, 2H), 7.44 (d, 2H), 9.60 (s, 1H).

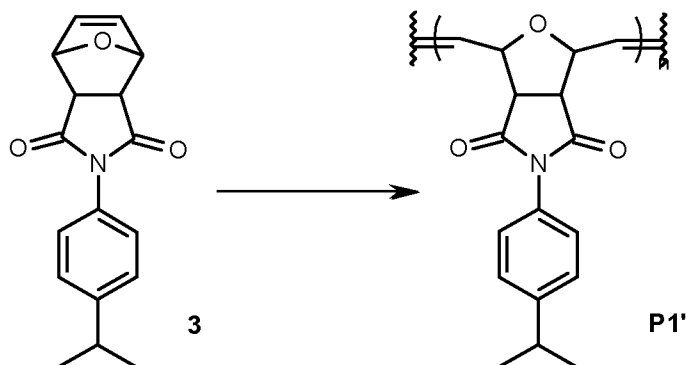
b) Preparation of monomer 3



182.4 g of 2 (1 eq, 0.63 mol) is added to 550 mL of acetic anhydride and 27 g of sodium acetate (0.5 eq, 0.33 mol). The mixture is then stirred for 2 h at reflux and cooled down at 0°C. The resulting precipitate is filtrated, washed with water, recrystallized for methanol and dried to yield the corresponding pure 3 as a white solid. Yield = 79 %

¹H-NMR (CDCl₃): δ (ppm) 1.18 (d, 6H), 1.56 (s, 2H), 2.79 (s, 2H), 2.94 (m, 1H), 3.03 (s, 2H), 5.42 (s, 2H), 6.59 (s, 2H), 7.20 (d, 2H), 7.33 (d, 2H).

5 c) Polymer P1'



80 mg of Bis(tricyclohexylphosphine)benzylidene ruthenium(IV) dichloride (0.5% mol, 100 μmol) is added to 5 g of 3 (1 eq, 18 mmol) in 15 mL of anhydrous dichloromethane under Nitrogen. After being stirred for 5 h at room temperature, 10 mL of anhydrous dichloromethane and 1 mL of ethylvinylether are added. The mixture is poured in cold ethanol. The precipitate is filtrated, dissolved in a minimum amount of dichloromethane and poured in cold heptane. The precipitate is filtrated, dried to yield the corresponding pure polymer 1' as a white solid. Yield = 61 %

15 Mw = 128 kDa

PDI = 3.4

Tg = 228 °C

Na content 14 mg/kg

P content 24 mg/kg

20 Ru content 117 mg/kg

Brief description of Figures:

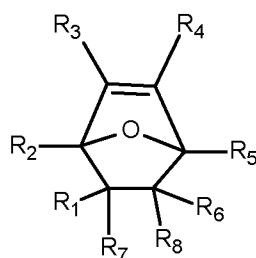
25 Fig. 1 shows drain current I_{ds} in relation to the gate voltage V_{gs} (transfer curve) for the TGBC field effect transistor comprising a polymer 1 gate dielectric at a source voltage V_{sd} of -20V (upper curves).

Fig 2 shows the output curves for the TGBC field effect transistor comprising polymer 1 at a gate voltage V_{gs} of 0V (squares), -5V (stars), -10V (lozenges), -15V (triangles), and -20V (circles).

30

Claims

1. Electronic device containing at least one dielectric material which comprises an oxacycloolefinic polymer.
- 5 2. Electronic device according to claim 1, wherein the oxacycloolefinic polymer has been prepared by Ru-carbene catalyzed ring-opening metathesis polymerization of a bicyclic oxaolefin.
3. Gate insulator layer comprising a polymer prepared by Ru-carbene catalyzed ring-opening metathesis polymerization and/or an oxacycloolefinic polymer.
- 10 4. Electronic device or gate insulating layer according to any of claims 1-3, wherein the oxacycloolefinic polymer is present as a layer essentially consisting of the oxacycloolefinic polymer.
5. Electronic device or gate insulating layer according to any of claims 1-3, wherein the polymer has been obtained by Ru-carbene catalyzed ring-opening metathesis polymerization of an oxanorbornene, which is especially an oxanorbornene of the formula I
- 15



(I)

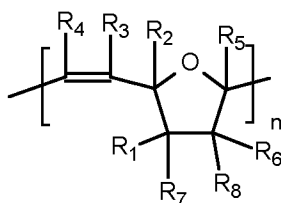
wherein

each of R₁ to R₆ are selected from hydrogen and C₁-C₄alkyl; and

- 20 R₇ and R₈ are hydrogen or a substituent; or R₇ and R₈ form, together with the carbon atoms they are attached to, a saturated or unsaturated carbocyclic ring of 5 to 12 carbon atoms, which is unsubstituted or substituted, or a saturated or unsaturated ring comprising 4 to 11 carbon atoms and 1 or 2 oxygen atoms or groups NR₉, with R₉ being hydrogen or a substituent, as ring members, which
- 25 ring is unsubstituted or substituted.

6. Electronic device or gate insulating layer according to any of claims 1-4, wherein the oxacycloolefinic polymer comprises a polymer chain of the formula II

29



(II)

wherein n ranges from 3 to 100 000, and each of R₁ to R₈ are as defined in claim 5.

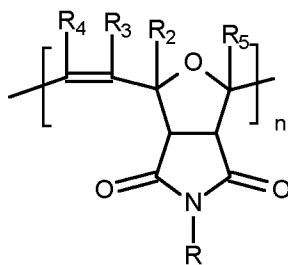
7. Electronic device or gate insulating layer according to any of claims 5 or 6,

- 5 wherein any substituent is selected from hydrogen, halogen, C₁-C₂₅alkyl, C₂-C₂₅alkenyl, C₁-C₂₅alkylthio, C₁-C₂₅alkoxy, C₂-C₂₅alkenyloxy, C₄-C₁₀aryl, C₁-C₉heteroaryl, C₃-C₁₂cycloalkyl, C₂-C₁₁heterocycloalkyl, each of which is unsubstituted or substituted by R'; or is C₂-C₂₅alkyl, C₃-C₂₅alkenyl, C₂-C₂₅alkylthio, C₂-C₂₅alkoxy, C₃-C₂₅alkenyloxy, which is interrupted in its alkyl part by O, CO, COO, CONR, CONRCO, S, SO, SO₂, NR, and is unsubstituted or substituted by R'; or is selected from the residues OR, COR, CH=NR, CH=N-OH, CH=N-OR, COOR, CONHR, CONRR', CONH-NHR, CONH-NRR', SO₂R, SO₃R, SO₂NHR, SO₂NRR', SO₂NH-NHR, SO₂NH-NRR', S(O)R, S(O)OR, S(O)NHR, S(O)NRR', S(O)NH-NHR, S(O)NH-NRR', SiRR'R'', PORR', PO(OR)R', PO(OR)₂, PO(NHR)₂, PO(NRR')₂, CN, NO₂, NHR, NRR', NH-NHR, NH-NRR', CONROH; and if bonding to saturated carbon may also be oxo;
- 10
- 15

and wherein R, R' and R'' independently are selected from C₁-C₂₅alkyl, C₁-C₂₅haloalkyl, C₅-C₁₀aryl, C₆-C₁₂arylalkyl, C₃-C₁₂cycloalkyl, preferably from C₁-C₆alkyl, phenyl, benzyl, cyclopentyl, cyclohexyl; and R may also be hydrogen;

- 20 where each aryl or heteroaryl or cycloalkyl itself is unsubstituted or substituted by C₁-C₄alkyl, C₂-C₄alkenyl, C₁-C₄alkoxy, OH, CHO, C₁-C₄alkyl-carbonyl, C₁-C₄alkyl-carbonyloxy, C₁-C₄alkoxy-carbonyl, allyloxy, halogen.

8. Electronic device or gate insulating layer according to any of claims 1-7, wherein the oxacycloolefinic polymer comprises a polymer chain of the formula III



(III)

wherein each of n and R₂ to R₅ are as defined in claim 5, and

R is hydrogen, C₁-C₂₅alkyl, C₁-C₂₅haloalkyl, phenyl, phenyl-C₁-C₄alkyl, cyclopentyl, cyclohexyl, wherein phenyl moiety or cyclopentyl or cyclohexyl moiety itself is unsubstituted or substituted by C₁-C₄alkyl, C₁-C₄alkoxy, OH, halogen.

- 5 9. Electronic device according to any of claims 1 to 8, wherein the oxacycloolefinic polymer has a glass transition temperature, as determined by differential scanning calorimetry, above 90°C and/or a molecular weight, as determined by gel permeation chromatography, from the range 5000 to 2000000 g/mol, preferably 10000 to 1000000 g/mol.
- 10 10. Electronic device according to any of claims 1-9, selected from capacitors, transistors such as organic field effect transistors, and devices comprising said capacitor and/or transistor.
11. Electronic device according to any of claims 1 to 10, further comprising a substrate and comprising at least one further layer of a functional material in direct contact with the oxacycloolefinic polymer dielectric.
- 15 12. Electronic device according to claim 11, wherein a layer of the oxacycloolefinic polymer as a dielectric material is in direct contact with an electrode layer and/or a semiconductor layer, especially a layer of an organic semiconductor such as a (co)polymer of the diketopyrrolopyrrole class.
- 20 13. Process of the for the preparation of an electronic device, such as a capacitor or transistor on a substrate, which process comprises the steps of
- i) providing a solution or dispersion of an oxacycloolefinic polymer in a suitable solvent, and
- 25 ii) forming a layer on a substrate, an electrode material and/or a semiconductor, and drying said layer.
14. Use of an oxacycloolefinic polymer as defined in any of claims 1-9 as a dielectric, especially as dielectric layer in a printed electronic device such as a capacitor or an organic field-effect transistor.

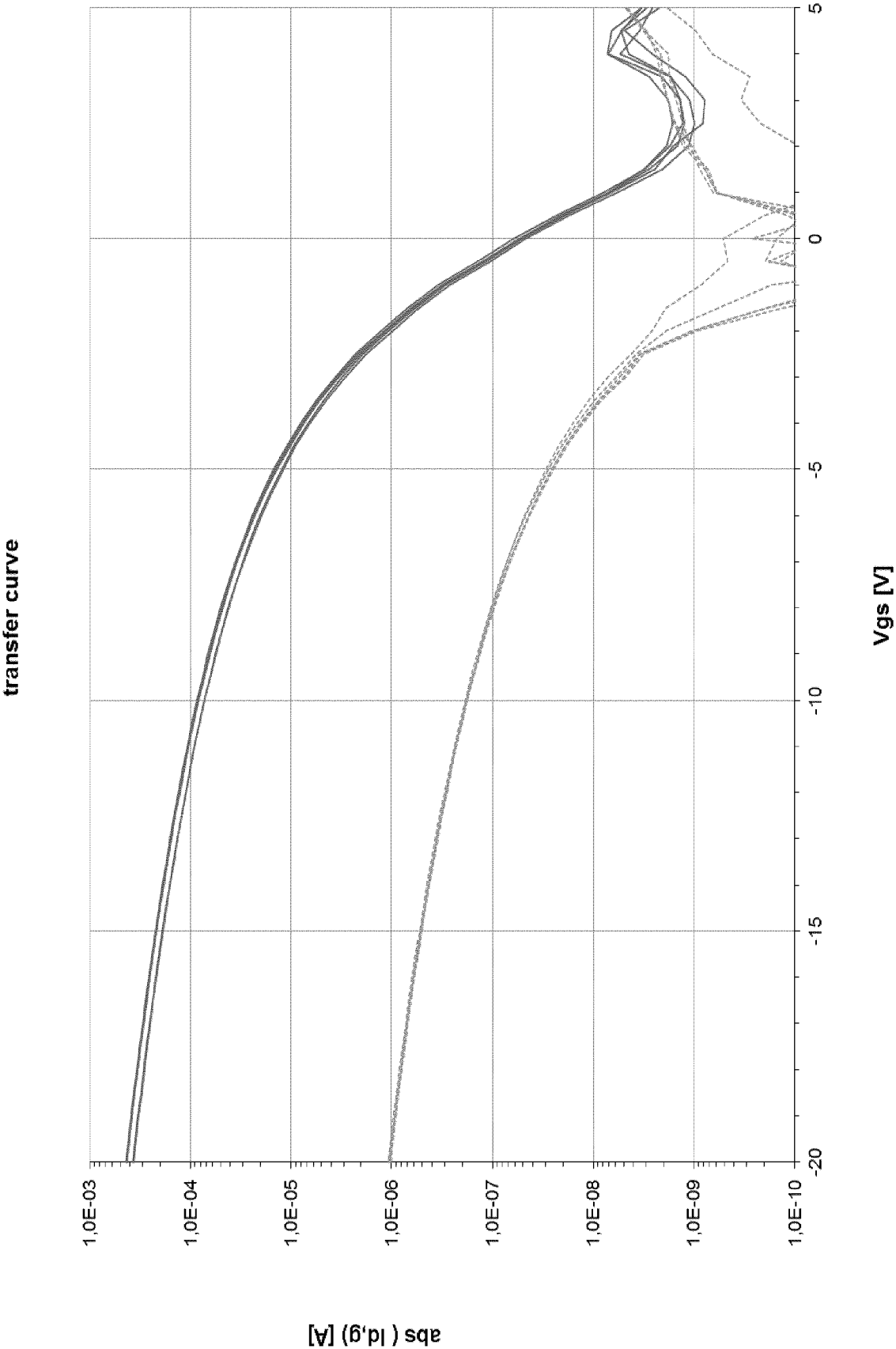
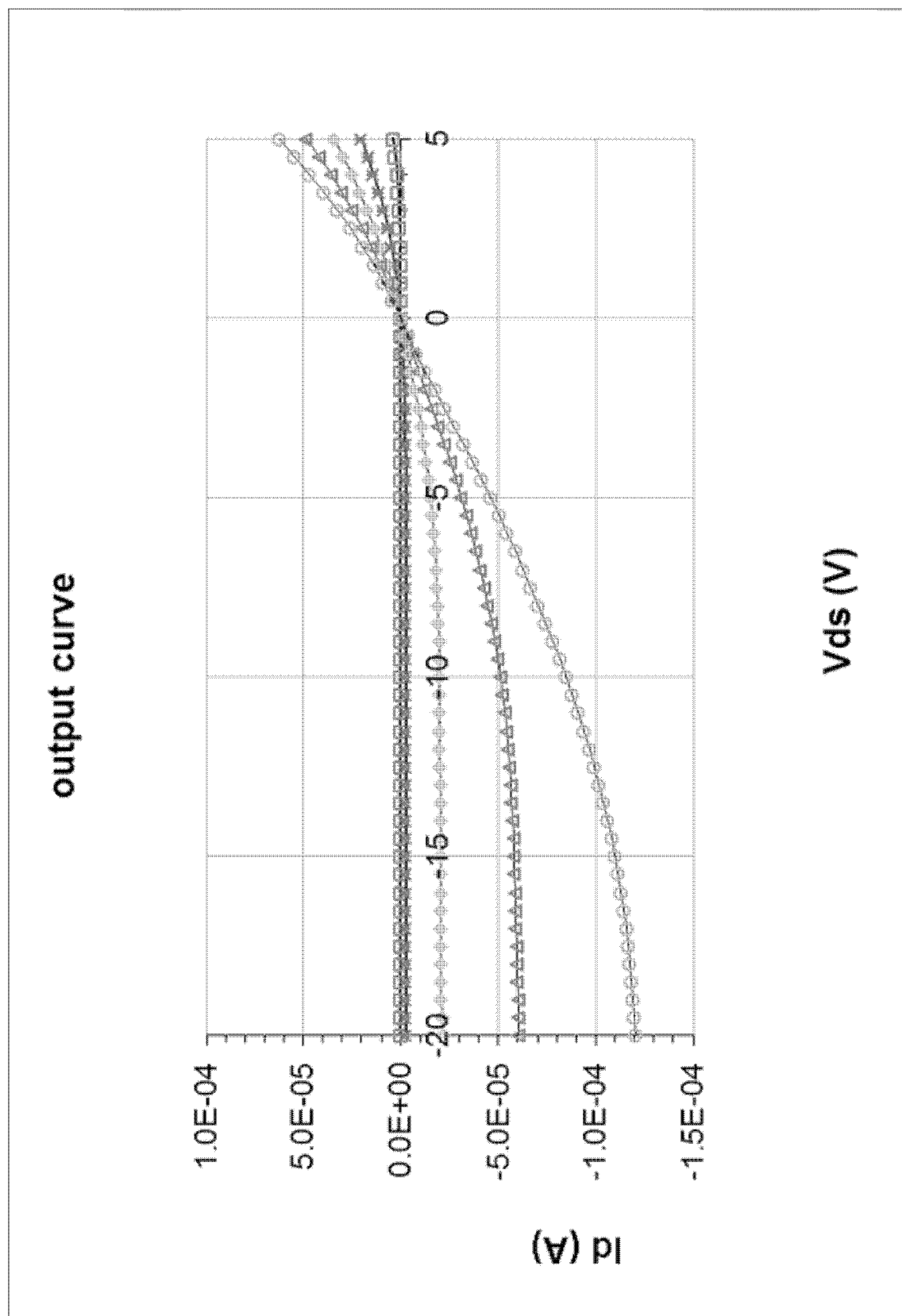


Fig 1

Fig 2



INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2014/063113

A. CLASSIFICATION OF SUBJECT MATTER INV. C08G61/08 C08G61/12 H01B3/30 H01L51/05 C08F232/00 ADD.		
According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED Minimum documentation searched (classification system followed by classification symbols) C08G H01B H01L C09D C09J C08F		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched		
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) EPO-Internal, CHEM ABS Data, WPI Data		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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☒ Further documents are listed in the continuation of Box C. ☒ See patent family annex.		
* Special categories of cited documents : "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier application or patent but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family		
Date of the actual completion of the international search 25 July 2014		Date of mailing of the international search report 01/08/2014
Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016		Authorized officer Meiners, Christian

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2014/063113

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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X	WO 03/041185 A2 (3M INNOVATIVE PROPERTIES CO [US]) 15 May 2003 (2003-05-15) page 10, line 4 - page 12, line 29	1-14
X	EP 2 239 561 A1 (UNIV GRAZ TECH [AT]; NANOTECCT WEIZ FORSCHUNGSGMBH [AT]) 13 October 2010 (2010-10-13) paragraphs [0046] - [0048], [0073]; claims 1-4	1-14
X	ANDREAS KLUG ET AL: "Organic field-effect transistor based sensors with sensitive gate dielectrics used for low-concentration ammonia detection", ORGANIC ELECTRONICS, vol. 14, no. 2, 1 February 2013 (2013-02-01), pages 500-504, XP055089446, ISSN: 1566-1199, DOI: 10.1016/j.orgel.2012.11.030 abstract; figures 1-3	3,6-10
X	US 2012/056249 A1 (MUELLER DAVID CHRISTOPH [DE] ET AL) 8 March 2012 (2012-03-08) paragraph [0030] - paragraph [0032]; claims 1,8-10,13,24-39	1,3,6-10

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