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(54) **Title:** FORMULATION OF AN ORGANIC FUNCTIONAL MATERIAL COMPRISING AN EPOXY GROUP CONTAINING SOLVENT

(57) **Abstract:** The present invention relates to formulations containing at least one organic functional material and at least a first organic solvent, wherein said first organic solvent contains at least one epoxy-group as well as to electronic devices prepared by using these formulations.

FORMULATION OF AN ORGANIC FUNCTIONAL MATERIAL COMPRISING
AN EPOXY GROUP CONTAINING SOLVENT

Technical Field

5 The present invention relates to formulations containing at least one organic functional material and at least a first organic solvent, wherein said first organic solvent contains at least one epoxy-group, as well as to electroluminescent devices prepared by using these formulations.

Background Art

10 Organic Light Emitting Devices (OLEDs) have been fabricated for a long time by vacuum deposition processes. Other techniques such as inkjet printing have been recently thoroughly investigated because of their advantages such as cost savings and scale-up possibilities. One of the main challenges in multi-layer printing is to identify the relevant parameters to obtain a homogeneous deposition of inks on the substrate. To trigger
15 these parameters, such as surface tension, viscosity or boiling point, some additives can be added to the formulation.

Technical Problem and Object of the Invention

20 Many solvents have been proposed in organic electronic devices for inkjet printing. However, the number of important parameters playing a role during deposition and the drying process makes the choice of the solvent very challenging. Thus, the formulations containing organic semiconductors used for deposition by inkjet printing still need to be improved. One object
25 of the present invention is to provide a formulation of an organic semiconductor which allows a controlled deposition to form organic semiconductor layers having good layer properties and efficiency performance. A further object of the present invention is to provide a formulation of an organic semiconductor which allows an uniform application of ink droplets on a
30 substrate when used e.g. in an inkjet printing method thereby giving good layer properties and efficiency performance.

Solution to Problem

The above objects of the present invention are solved by providing a formulation comprising at least one organic functional material and at least a first organic solvent, wherein said first organic solvent contains at least one epoxy-group, preferably one epoxy-group.

Advantageous Effects of Invention

The inventors have surprisingly found that the use of an organic solvent, which contains at least one epoxy-group as a first solvent allows a complete control of the surface tension and induces an effective ink deposition to form uniform and well-defined organic layers of functional materials which have good layer properties and performance.

Brief Description of Drawings

Figure 1 shows a typical layer structure of a device containing a substrate, an ITO anode, a hole-injection layer (HIL), a hole-transport layer (HTL), a green-emissive layer (G-EML), a hole blocking layer (HBL), an electron-transport layer (ETL) and an Al cathode.

Description of Embodiments

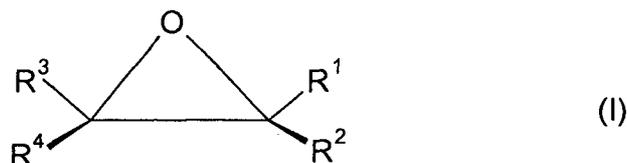
The present invention relates to a formulation containing at least one organic functional material and at least a first organic solvent, wherein said first organic solvent contains at least one epoxy-group, preferably one epoxy-group.

Preferred Embodiments

In a first preferred embodiment, the first organic solvent, which contains one epoxy group, is an epoxy group containing solvent according to general formula (I)

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- 3 -



5

wherein

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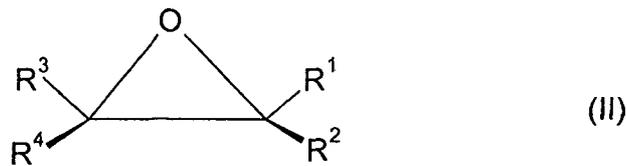
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R^1 , R^2 , R^3 and R^4 are identical or different at each occurrence, and are H, D, F, Cl, Br, I, NO₂, CN, a straight-chain alkyl or alkoxy group having from 1 to 20 carbon atoms or a branched or cyclic alkyl or alkoxy group having from 3 to 20 carbon atoms, in which one or more nonadjacent CH₂ groups may be replaced by -O-, -S-, -NR⁵-, -CONR⁵-, -CO-O-, -C=O-, -CH=CH- or -C≡C-, and in which one or more hydrogen atoms may be replaced by F, or an aryl or heteroaryl group which has from 4 to 14 carbon atoms and may be substituted by one or more nonaromatic R⁵ radicals, and a plurality of substituents R⁵, either on the same ring or on the two different rings, may together in turn form a mono- or polycyclic, aliphatic or aromatic ring system, which may be substituted by a plurality of substituents R⁵;

R^5 are identical or different at each instance, and are a straight-chain alkyl or alkoxy group having from 1 to 20 carbon atoms or a branched or cyclic alkyl or alkoxy group having from 3 to 20 carbon atoms, in which one or more nonadjacent CH₂ groups may be replaced by -O-, -S-, -CO-O-, -C=O-, -CH=CH- or -C≡C-, and in which one or more hydrogen atoms may be replaced by F, or an aryl or heteroaryl group which has from 4 to 14 carbon atoms and may be substituted by one or more nonaromatic R⁵ radicals.

In a first more preferred embodiment, the first organic solvent, which contains one epoxy group, is an epoxy group containing solvent according to general formula (II)

- 4 -



5

wherein

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R^1 and R^3 is H, D, F, Cl, Br, I, NO₂, CN, a straight-chain alkyl or alkoxy group having from 1 to 20 carbon atoms or a branched or cyclic alkyl or alkoxy group having from 3 to 20 carbon atoms, in which one or more nonadjacent CH₂ groups may be replaced by -O-, -S-, -NR⁵-, -CONR⁵-, -CO-O-, -C=O-, -CH=CH- or -C≡C-, and in which one or more hydrogen atoms may be replaced by F, or an aryl or heteroaryl group which has from 4 to 14 carbon atoms and may be substituted by one or more nonaromatic R⁵ radicals, and a plurality of substituents R⁵, either on the same ring or on the two different rings, may together in turn form a mono- or polycyclic, aliphatic or aromatic ring system, which may be substituted by a plurality of substituents R⁵;

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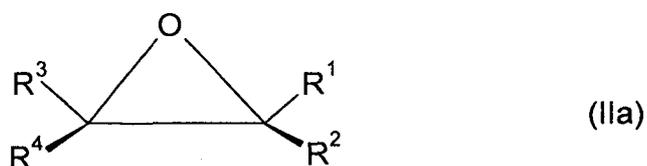
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R^2 and R^4 form together a mono- or polycyclic, aliphatic or aromatic ring system, which may be substituted by a plurality of substituents R⁵;

R^5 are identical or different at each instance, and are a straight-chain alkyl or alkoxy group having from 1 to 20 carbon atoms or a branched or cyclic alkyl or alkoxy group having from 3 to 20 carbon atoms, in which one or more nonadjacent CH₂ groups may be replaced by -O-, -S-, -CO-O-, -C=O-, -CH=CH- or -C≡C-, and in which one or more hydrogen atoms may be replaced by F, or an aryl or heteroaryl group which has from 4 to 14 carbon atoms and may be substituted by one or more nonaromatic R⁵ radicals.

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In a first most preferred embodiment, the first organic solvent, which contains one epoxy group, is an epoxy group containing solvent according to general formula (IIa)



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wherein

R¹ is H

R³ is H, D, F, Cl, Br, I, NO₂, CN, a straight-chain alkyl or alkoxy group having from 1 to 20 carbon atoms or a branched or cyclic alkyl or alkoxy group having from 3 to 20 carbon atoms, in which one or more nonadjacent CH₂ groups may be replaced by -O-, -S-, -NR⁵-, -CONR⁵-, -CO-O-, -C=O-, -CH=CH- or -C≡C-, and in which one or more hydrogen atoms may be replaced by F, or an aryl or heteroaryl group which has from 4 to 14 carbon atoms and may be substituted by one or more nonaromatic R⁵ radicals, and a plurality of substituents R⁵, either on the same ring or on the two different rings, may together in turn form a mono- or polycyclic, aliphatic or aromatic ring system, which may be substituted by a plurality of substituents R⁵;

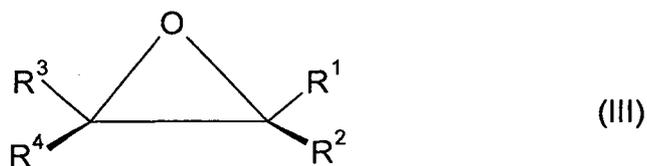
R² and R⁴ form together a mono- or polycyclic, aliphatic or aromatic ring system, which may be substituted by a plurality of substituents R⁵;

R⁵ are identical or different at each instance, and are a straight-chain alkyl or alkoxy group having from 1 to 20 carbon atoms or a branched or cyclic alkyl or alkoxy group having from 3 to 20 carbon atoms, in which one or more nonadjacent CH₂ groups may be replaced by -O-, -S-, -CO-O-, -C=O-, -CH=CH- or -C≡C-, and in which one or more hydrogen atoms may be replaced by F, or an aryl or heteroaryl group which has from 4 to 14 carbon atoms and may be substituted by one or more nonaromatic R⁵ radicals.

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In a second more preferred embodiment, the first organic solvent, which contains one epoxy group, is an epoxy group containing solvent according to general formula (III)

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wherein

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R^1 , R^2 , R^3 and R^4 are identical or different at each occurrence, and are H, D, F, Cl, Br, I, NO₂, CN, a straight-chain alkyl or alkoxy group having from 1 to 20 carbon atoms or a branched or cyclic alkyl or alkoxy group having from 3 to 20 carbon atoms, in which one or more nonadjacent CH₂ groups may be replaced by -O-, -S-, -NR⁵-, -CONR⁵-, -CO-O-, -C=O-, -CH=CH- or -C≡C-, and in which one or more hydrogen atoms may be replaced by F, or an aryl or heteroaryl group which has from 4 to 14 carbon atoms and may be substituted by one or more nonaromatic R⁵ radicals, and a plurality of substituents R⁵, either on the same ring or on the two different rings, may together in turn form a mono- or polycyclic, aliphatic or aromatic ring system, which may be substituted by a plurality of substituents R⁵; and

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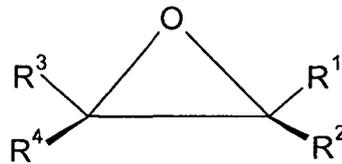
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R⁵ are identical or different at each instance, and are a straight-chain alkyl or alkoxy group having from 1 to 20 carbon atoms or a branched or cyclic alkyl or alkoxy group having from 3 to 20 carbon atoms, in which one or more nonadjacent CH₂ groups may be replaced by -O-, -S-, -CO-O-, -C=O-, -CH=CH- or -C≡C-, and in which one or more hydrogen atoms may be replaced by F, or an aryl or heteroaryl group which has from 4 to 14 carbon atoms and may be substituted by one or more nonaromatic R⁵ radicals.

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In a second most preferred embodiment, the first organic solvent, which contains one epoxy group, is an epoxy group containing solvent according to general formula (IIia)

5



(IIia)

10

wherein

R^1 , R^2 and R^3 are H;

R^4 is a straight-chain alkyl or alkoxy group having from 1 to 20 carbon atoms or a branched or cyclic alkyl or alkoxy group having from 3 to 20 carbon atoms, in which one or more nonadjacent CH_2 groups may be replaced by $-\text{O}-$, $-\text{S}-$, $-\text{NR}^5-$, $-\text{CONR}^5-$, $-\text{CO}-\text{O}-$, $-\text{C}=\text{O}-$, $-\text{CH}=\text{CH}-$ or $-\text{C}\equiv\text{C}-$, and in which one or more hydrogen atoms may be replaced by F, or an aryl or heteroaryl group which has from 4 to 14 carbon atoms and may be substituted by one or more nonaromatic R^5 radicals, and a plurality of substituents R^5 , either on the same ring or on the two different rings, may together in turn form a mono- or polycyclic, aliphatic or aromatic ring system, which may be substituted by a plurality of substituents R^5 ; and

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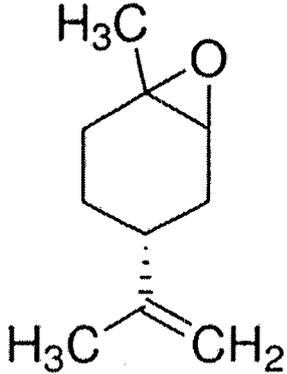
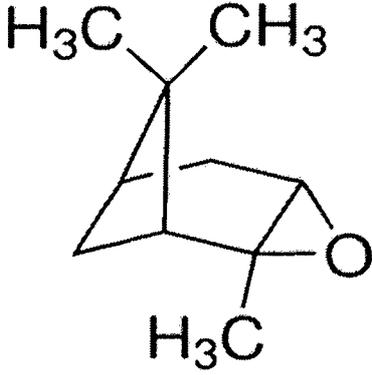
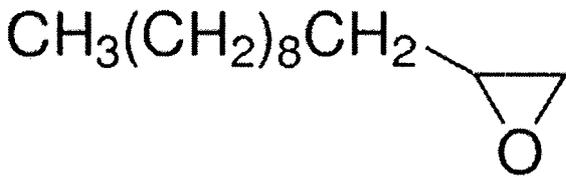
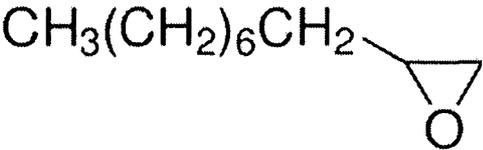
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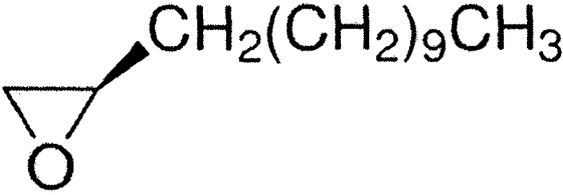
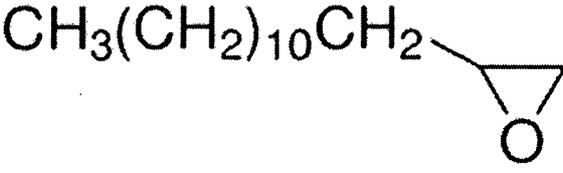
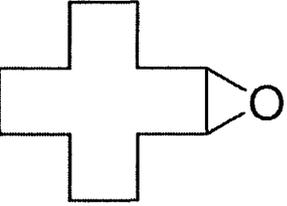
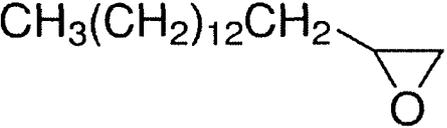
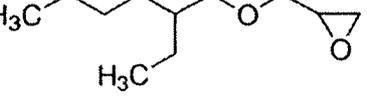
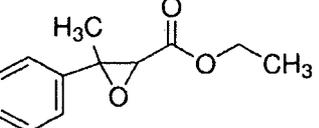
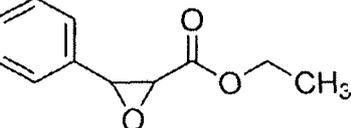
R^5 are identical or different at each instance, and are a straight-chain alkyl or alkoxy group having from 1 to 20 carbon atoms or a branched or cyclic alkyl or alkoxy group having from 3 to 20 carbon atoms, in which one or more nonadjacent CH_2 groups may be replaced by $-\text{O}-$, $-\text{S}-$, $-\text{CO}-\text{O}-$, $-\text{C}=\text{O}-$, $-\text{CH}=\text{CH}-$ or $-\text{C}=\text{C}-$, and in which one or more hydrogen atoms may be replaced by F, or an aryl or heteroaryl group which has from 4 to 14 carbon atoms and may be substituted by one or more nonaromatic R^5 radicals.

25

30

Examples of preferred epoxy-group containing solvents and their boiling points (BP) are shown in the following Table 1.

5	Substance	BP (°C) at 1atm
10	 <p>Limonene oxide, CAS: 203719-54-4</p>	270
15	 <p>α-pinene oxide, CAS: 1686-14-2</p>	295
25	 <p>1,2-epoxy dodecane, CAS: 2855-19-8</p>	251
30	 <p>1,2-epoxydecane, CAS: 2404-44-6</p>	214

5	 <p>1,2-epoxytridecane, CAS: 59829-81-1</p>	269
10	 <p>1,2-epoxytetradecane, CAS: 3234-28-4</p>	297
15	 <p>1,2-epoxycyclododecane, CAS: 286-99-7</p>	274
20	 <p>1,2-epoxyhexadecane, CAS: 7320-37-8</p>	322 (calc)
25	 <p>2-ethylhexyl glycidyl, CAS: 2461-15-6</p>	255
25	 <p>Ethyl-3-methyl-3-phenylglycidate, CAS: 77-83-8</p>	272-275
30	 <p>Ethyl-3-phenylglycidate,</p>	303

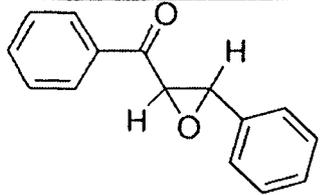
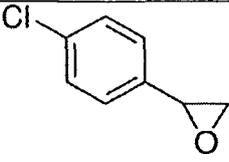
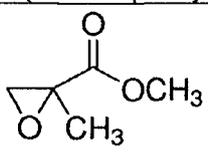
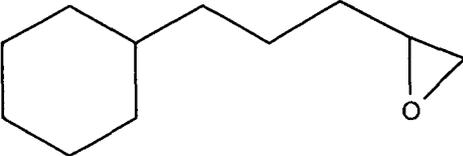
5	 <p>Trans-1,3-diphenyl-2,3-epoxypropan-1-one; CAS: 7570-86-7</p>	solid
10	 <p>2-(4-chlorophenyl)oxirane; CAS: 2788-86-5</p>	
15	 <p>Methyl 2-methylglycidate; CAS: 58653-97-7</p>	255
15		247 (calc)

Table 1: Preferred epoxy-group containing solvents and their boiling points (BP).

Preferably, the first solvent has a surface tension of ≥ 20 mN/m. More preferably, the surface tension of the first solvent is in the range from 25 to 40 mN/m and most preferably in the range from 28 to 37.5 mN/m.

The content of the first solvent is preferably in the range from 50 to 100 vol.-%, more preferably in the range from 75 to 99 vol.-% and most preferably in the range from 90 to 99 vol.-%, based on the total amount of solvents in the formulation.

Consequently, the content of the second solvent is preferably in the range from 0 to 50 vol.-%, more preferably in the range from 1 to 25 vol.-% and

most preferably in the range from **1** to **10** vol.-%, based on the total amount of solvents in the formulation.

5 Preferably, the first solvent has a boiling point in the range from **100** to **400°C**, more preferably in the range from **150** to **350°C**.

The formulations according to the present invention comprise in one preferred embodiment at least a second solvent which is different from the first solvent. The second solvent is employed together with the first solvent.

10

In one embodiment, the second solvent could be an epoxy-group containing solvent, which is different from the first solvent. Nevertheless, preferably, the second solvent does not contain an epoxy group.

15 Suitable second solvents are preferably organic solvents which include inter alia, alcohols, aldehydes, ketones, ethers, esters, amides such as **di-Ci-2-**alkylformamides, sulfur compounds, nitro compounds, hydrocarbons, halogenated hydrocarbons (e.g. chlorinated hydrocarbons), aromatic or heteroaromatic hydrocarbons and halogenated aromatic or heteroaromatic

20

Preferably, the second solvent can be chosen from one of the following groups: substituted and non-substituted aromatic or linear esters such as ethyl benzoate, butyl benzoate; substituted and non-substituted aromatic or

25 linear ethers such as 3-phenoxytoluene or anisole; substituted or non-substituted arene derivatives such as xylene; indane derivatives such as hexamethylindane; substituted and non-substituted aromatic or linear ketones; substituted and non-substituted heterocycles such as pyrrolidinones, pyridines, pyrazines; other fluorinated or chlorinated

30 aromatic hydrocarbons.

Particularly preferred second organic solvents are, for example, 1,2,3,4-tetramethylbenzene, 1,2,3,5-tetramethylbenzene, 1,2,3-trimethylbenzene, 1,2,4,5-tetramethylbenzene, 1,2,4-trichlorobenzene, 1,2,4-trimethylbenzene, 1,2-dihydronaphthalene, 1,2-dimethylnaphthalene, 1,3-benzodioxolane, 1,3-diisopropylbenzene, 1,3-dimethylnaphthalene, 1,4-benzodioxane, 1,4-diisopropylbenzene, 1,4-dimethylnaphthalene, 1,5-dimethyltetralin, 1-benzothiophene, thianaphthalene, 1-bromonaphthalene, 1-chloromethylnaphthalene, 1-ethylnaphthalene, 1-methoxynaphthalene, 1-methylnaphthalene, 1-methylindole, 2,3-benzofuran, 2,3-dihydrobenzofuran, 2,3-dimethylanisole, 2,4-dimethylanisole, 2,5-dimethylanisole, 2,6-dimethylanisole, 2,6-dimethylnaphthalene, 2-bromo-3-bromomethylnaphthalene, 2-bromomethylnaphthalene, 2-bromonaphthalene, 2-ethoxynaphthalene, 2-ethylnaphthalene, 2-isopropylanisole, 2-methylanisole, 2-methylindole, 3,4-dimethylanisole, 3,5-dimethylanisole, 3-bromoquinoline, 3-methylanisole, 4-methylanisole, 5-decanolide, 5-methoxyindane, 5-methoxyindole, 5-tert-butyl-m-xylene, 6-methylquinoline, 8-methylquinoline, acetophenone, anisole, benzonitrile, benzothiazole, benzyl acetate, bromobenzene, butyl benzoate, butyl phenyl ether, cyclohexylbenzene, decahydronaphthol, dimethoxytoluene, 3-phenoxytoluene, diphenyl ether, propiophenone, ethylbenzene, ethyl benzoate, hexylbenzene, indane, hexamethylindane, indene, isochroman, cumene, m-cymene, mesitylene, methyl benzoate, o-, m-, p-xylene, propyl benzoate, propylbenzene, o-dichlorobenzene, pentylbenzene, phenetol, ethoxybenzene, phenyl acetate, p-cymene, propiophenone, sec-butylbenzene, t-butylbenzene, thiophene, toluene, veratrol, monochlorobenzene, o-dichlorobenzene, pyridine, pyrazine, pyrimidine, pyrrolidinone, morpholine, dimethylacetamide, dimethyl sulfoxide, decalin and/or mixtures of these compounds.

These solvents can be employed individually or as a mixture of two, three or more solvents forming the second solvent.

Preferably, the second solvent has a boiling point in the range from 100 to 400°C, more preferably in the range from 150 to 350°C.

5 The at least one organic functional material has a solubility in the first as well as in the second solvent which is preferably in the range from 1 to 250 g/l and more preferably in the range from 1 to 50 g/l.

10 The content of the at least one organic functional material in the formulation is in the range from 0.001 to 20 weight-%, preferably in the range from 0.01 to 10 weight-%, more preferably in the range from 0.1 to 5 weight-% and most preferably in the range from 0.3 to 5 weight-%, based on the total weight of the formulation.

15 The formulation according to the present invention has a surface tension preferably in the range from 10 to 50 mN/m and more preferably in the range from 25 to 40 mN/m.

20 Furthermore, the formulation according to the present invention has a viscosity preferably in the range from 1 to 50 mPa·s, more preferably in the range from 2 to 40 mPa·s, and most preferably in the range from 2 to 20 mPa·s.

25 Preferably, the organic solvent blend comprises a surface tension in the range from 15 to 80 mN/m, more preferably in the range from 20 to 60 mN/m and most preferably in the range from 25 to 40 mN/m. The surface tension can be measured using a FTA (First Ten Angstrom) 1000 contact angle goniometer at 20°C. Details of the method are available from First Ten Angstrom as published by Roger P. Woodward, Ph.D. "Surface Tension Measurements Using the Drop Shape Method". Preferably, the
30 pendant drop method can be used to determine the surface tension. This measurement technique dispenses a drop from a needle in a bulk liquid or gaseous phase. The shape of the drop results from the relationship

between the surface-tension, gravity and density differences. Using the pendant drop method, the surface tension is calculated from the shadow image of a pendant drop using <http://www.kruss.de/services/education-theory/glossary/drop-shape-analysis>. A commonly used and commercially available high precision drop shape analysis tool, namely FTA1000 from First Ten Angstrom, was used to perform all surface tension measurements. The surface tension is determined by the software FTA1000. All measurements were performed at room temperature which is in the range between 20°C and 22°C. The standard operating procedure includes the determination of the surface tension of each formulation using a fresh disposable drop dispensing system (syringe and needle). Each drop is measured over the duration of one minute with sixty measurements which are later on averaged. For each formulation three drops are measured. The final value is averaged over said measurements. The tool is regularly cross-checked against various liquids having well known surface tensions.

The viscosity of the formulations and solvents according to the present invention is measured with a 1° cone-plate rotational rheometer of the type Discovery AR3 (Thermo Scientific). The equipment allows a precise control of the temperature and sheer rate. The measurement of the viscosity is carried out at a temperature of 25.0°C (+/- 0.2°C) and a sheer rate of 500 s⁻¹. Each sample is measured three times and the obtained measured values are averaged.

The formulation according to the present invention comprises at least one organic functional material which can be employed for the production of functional layers of electronic devices. Functional materials are generally the organic materials which are introduced between the anode and the cathode of an electronic device.

The term organic functional material denotes, inter alia, organic conductors, organic semiconductors, organic fluorescent compounds, organic phosphorescent compounds, organic light-absorbent compounds, organic light-sensitive compounds, organic photosensitisation agents and other organic photoactive compounds. The term organic functional material furthermore encompasses organometallic complexes of transition metals, rare earths, lanthanides and actinides.

The organic functional material is selected from the group consisting of fluorescent emitters, phosphorescent emitters, host materials, matrix materials, exciton-blocking materials, electron-transport materials, electron-injection materials, hole-conductor materials, hole-injection materials, n-dopants, p-dopants, wide-band-gap materials, electron-blocking materials and hole-blocking materials.

Preferred embodiments of organic functional materials are disclosed in detail in WO 2011/076314 A1, where this document is incorporated into the present application by way of reference.

In a preferred embodiment, the organic functional material is an organic semiconductor selected from the group consisting of hole-injecting, hole-transporting, emitting, electron-transporting and electron-injecting materials.

More preferably, the organic functional material is an organic semiconductor selected from the group consisting of hole-injecting and hole-transporting materials.

The organic functional material can be a compound having a low molecular weight, a polymer, an oligomer or a dendrimer, where the organic functional material may also be in the form of a mixture. Thus, the formulations according to the present invention may comprise two different compounds

having a low molecular weight, one compound having a low molecular weight and one polymer or two polymers (blend).

5 Organic functional materials are frequently described via the properties of the frontier orbitals, which are described in greater detail below. Molecular orbitals, in particular also the highest occupied molecular orbital (HOMO) and the lowest unoccupied molecular orbital (LUMO), their energy levels and the energy of the lowest triplet state T_i or of the lowest excited singlet state S_i of the materials are determined via quantum-chemical calculations.

10 In order to calculate organic substances without metals, firstly a geometry optimisation is carried out using the "Ground State/Semi-empirical/Default Spin/AM1/Charge 0/Spin Singlet" method. An energy calculation is subsequently carried out on the basis of the optimised geometry. The "TD-SCF/DFT/Default Spin/B3PW91" method with the "6-31 G(d)" base set (charge 0,

15 spin singlet) is used here. For metal-containing compounds, the geometry is optimised via the "Ground State/Hartree-Fock/Default Spin/LanL2MB/Charge 0/Spin Singlet" method. The energy calculation is carried out analogously to the above-described method for the organic substances, with the difference that the "LanL2DZ" base set is used for the metal atom

20 and the "6-31 G(d)" base set is used for the ligands. The energy calculation gives the HOMO energy level HE_h or LUMO energy level LE_h in hartree units. The HOMO and LUMO energy levels in electron volts calibrated with reference to cyclic voltammetry measurements are determined therefrom as follows:

25

$$\text{HOMO(eV)} = ((HE_h * 27.212) - 0.9899) / 1.1206$$

$$\text{LUMO(eV)} = ((LE_h * 27.212) - 2.0041) / 1.385$$

For the purposes of the present application, these values are to be regarded as HOMO and LUMO energy levels respectively of the materials.

30

The lowest triplet state T_1 is defined as the energy of the triplet state having the lowest energy which arises from the quantum-chemical calculation described.

- 5 The lowest excited singlet state S_1 is defined as the energy of the excited singlet state having the lowest energy which arises from the quantum-chemical calculation described.

10 The method described herein is independent of the software package used and always gives the same results. Examples of frequently used programs for this purpose are "Gaussian09W" (Gaussian Inc.) and Q-Chem 4.1 (Q-Chem, Inc.).

15 Compounds having hole-injection properties, also called hole-injection materials herein, simplify or facilitate the transfer of holes, i.e. positive charges, from the anode into an organic layer. In general, a hole-injection material has an HOMO level which is in the region of or above the level of the anode, i.e. in general is at least -5.3 eV.

20 Compounds having hole-transport properties, also called hole-transport materials herein, are capable of transporting holes, i.e. positive charges, which are generally injected from the anode or an adjacent layer, for example a hole-injection layer. A hole-transport material generally has a high HOMO level of preferably at least -5.4 eV. Depending on the structure of an
25 electronic device, it may also be possible to employ a hole-transport material as hole-injection material.

The preferred compounds which have hole-injection and/or hole-transport
30 properties include, for example, triarylamine, benzidine, tetraaryl-para-phenylenediamine, triarylphosphine, phenothiazine, phenoxazine, dihydrophenazine, thianthrene, dibenzo-para-dioxin, phenoxathiylene, carbazole, azulene, thiophene, pyrrole and furan derivatives and further O-, S- or N-

containing heterocycles having a high HOMO (HOMO = highest occupied molecular orbital).

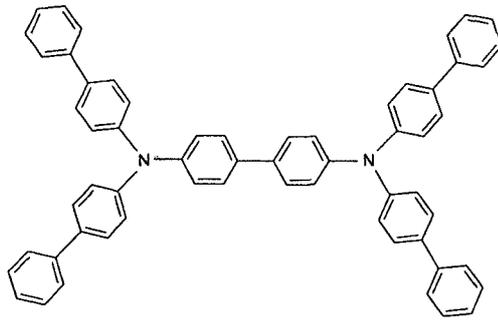
As compounds which have hole-injection and/or hole-transport properties,
5 particular mention may be made of phenylenediamine derivatives
(US 3615404), arylamine derivatives (US 3567450), amino-substituted
chalcone derivatives (US 3526501), styrylanthracene derivatives (JP-A-56-
46234), polycyclic aromatic compounds (EP 1009041), polyaryalkane
derivatives (US 361 5402), fluorenone derivatives (JP-A-54-1 10837), hydra-
10 zone derivatives (US 3717462), acylhydrazones, stilbene derivatives (JP-A-
61-210363), silazane derivatives (US 4950950), polysilanes (JP-A-2-
204996), aniline copolymers (JP-A-2-282263), thiophene oligomers
(JP Heisei 1 (1989) 211399), polythiophenes, poly(N-vinylcarbazole) (PVK),
polypyrroles, polyanilines and other electrically conducting macromole-
15 cules, porphyrin compounds (JP-A-63-2956965, US 4720432), aromatic
dimethylidene-type compounds, carbazole compounds, such as, for exam-
ple, CDBP, CBP, mCP, aromatic tertiary amine and styrylamine compounds
(US 4127412), such as, for example, triphenylamines of the benzidine type,
triphenylamines of the styrylamine type and triphenylamines of the diamine
20 type. It is also possible to use arylamine dendrimers (JP Heisei 8 (1996)
193191), monomeric triarylamine (US 3180730), triarylamine containing
one or more vinyl radicals and/or at least one functional group containing
active hydrogen (US 3567450 and US 3658520), or tetraaryldiamines (the
two tertiary amine units are connected via an aryl group). More triarylmino
25 groups may also be present in the molecule. Phthalocyanine derivatives,
naphthalocyanine derivatives, butadiene derivatives and quinoline deriva-
tives, such as, for example, dipyrzino[2,3-f:2',3'-h]quinoxalinehexacarbo-
nitrile, are also suitable.

30 Preference is given to aromatic tertiary amines containing at least two terti-
ary amine units (US 2008/01 0231 1 A 1, US 4720432 and US 5061569),

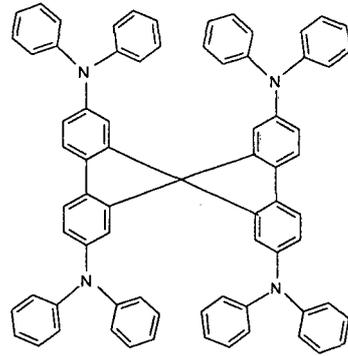
such as, for example, NPD (a-NPD = 4,4'-bis[N-(1-naphthyl)-N-phenylamino]biphenyl) (US 5061569), TPD 232 (= N,N'-bis-(N,N'-diphenyl-4-aminophenyl)-N,N'-diphenyl-4,4'-diamino-1,1'-biphenyl) or MTDATA (MTDATA or m-MTDATA = 4,4',4''-tris[3-methylphenyl]phenylamino]triphenylamine) (JP-A-4-308688), TBDB (= N,N,N',N'-tetra(4-biphenyl)-diaminobiphenylene), TAPC (= 1,1-bis(4-di-p-tolylaminophenyl)cyclohexane), TAPPP (= 1,1-bis(4-di-p-toylaminophenyl)-3-phenylpropane), BDTAPVB (= 1,4-bis[2-[4-[N,N-di(p-tolyl)amino]phenyl]vinyl]benzene), TTB (= N,N,N',N'-tetra-p-tolyl-4,4'-diaminobiphenyl), TPD (= 4,4'-bis[N-3-methylphenyl]-N-phenylamino)biphenyl), N,N,N',N'-tetraphenyl-4,4''-diamino-1,1',4',1''-V-quaterphenyl, likewise tertiary amines containing carbazole units, such as, for example, TCTA (= 4-(9H-carbazol-9-yl)-N,N-bis[4-(9H-carbazol-9-yl)phenyl]benzenamine). Preference is likewise given to hexazatriphenylene compounds in accordance with US 2007/0092755 A 1 and phthalocyanine derivatives (for example H₂Pc, CuPc (= copper phthalocyanine), CoPc, NiPc, ZnPc, PdPc, FePc, MnPc, CIAIPc, CIGaPc, CIIInPc, CISnPc, Cl₂SiPc, (HO)AlPc, (HO)GaPc, VOPc, TiOPc, MoOPc, GaPc-O-GaPc).

Particular preference is given to the following triarylamine compounds of the formulae (TA-1) to (TA-12), which are disclosed in EP 1162193 B 1, EP 650 955 B 1, *Synth.Metals* **1997**, 91(1-3), 209, DE 196461 19 A 1, WO 2006/122630 A 1, EP 1 860 097 A 1, EP 1834945 A 1, JP 08053397 A, US 6251531 B 1, US 2005/0221 124, JP 08292586 A, US 7399537 B2, US 2006/0061265 A 1, EP 1 661 888 and WO 2009/041635. The said compounds of the formulae (TA-1) to (TA-12) may also be substituted:

5

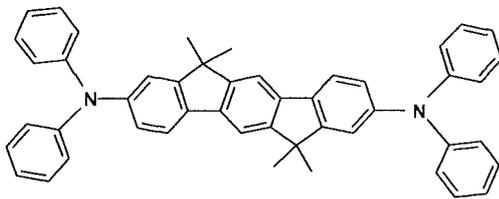


formula TA-1

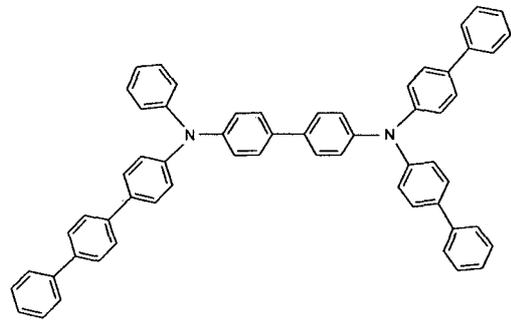


formula TA-2

10

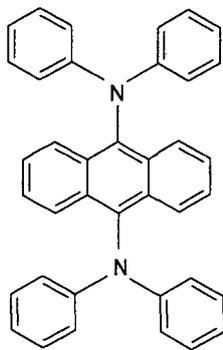


formula TA-3

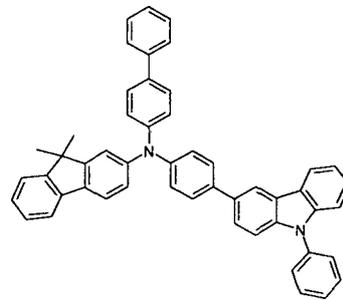


formula TA-4

15

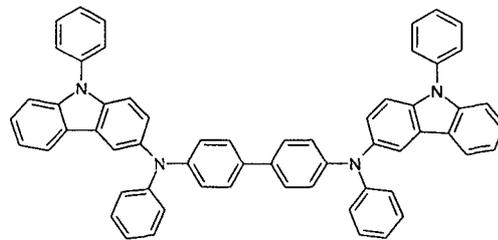


formula TA-5

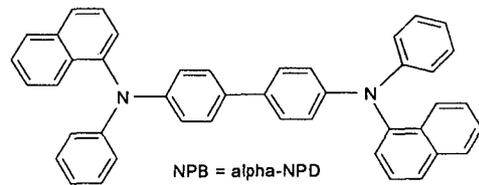


formula TA-6

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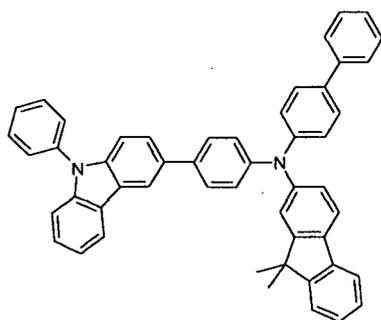
formula TA-7



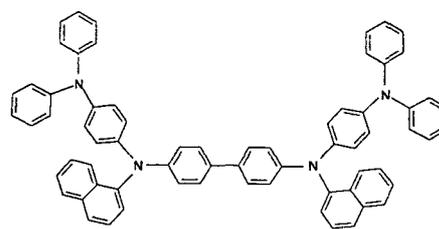
formula TA-8

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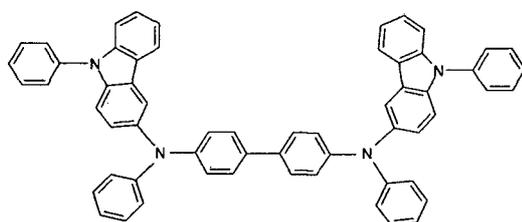


formula TA-9

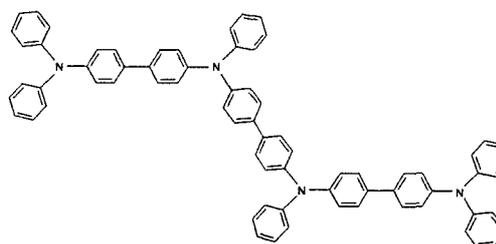


formula TA-10

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formula TA-11



formula TA-12

15

Further compounds which can be employed as hole-injection materials are described in EP 0891 121 A 1 and EP 1029909 A 1, injection layers in general in US 2004/01741 16 A 1.

20

These arylamines and heterocycles which are generally employed as hole-injection and/or hole-transport materials preferably result in an HOMO in the polymer of greater than -5.8 eV (vs. vacuum level), particularly preferably greater than -5.5 eV.

25

Compounds which have electron-injection and/or electron-transport properties are, for example, pyridine, pyrimidine, pyridazine, pyrazine, oxadiazole, quinoline, quinoxaline, anthracene, benzanthracene, pyrene, perylene, benzimidazole, triazine, ketone, phosphine oxide and phenazine derivatives, but also triarylboranes and further O-, S- or N-containing heterocycles having a low LUMO (LUMO = lowest unoccupied molecular orbital).

30

Particularly suitable compounds for electron-transporting and electron-injecting layers are metal chelates of 8-hydroxyquinoline (for example LiQ, AIQ₃, GaQ₃, MgQ₂, ZnQ₂, InQ₃, ZrQ₄), BAIQ, Ga oxinoid complexes, 4-azaphenanthren-5-ol-Be complexes (US 5529853 A, cf. formula ET-1),

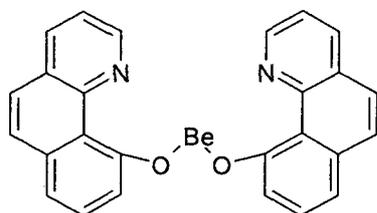
5 butadiene derivatives (US 4356429), heterocyclic optical brighteners (US 4539507), benzimidazole derivatives (US 2007/0273272 A1), such as, for example, TPBI (US 5766779, cf. formula ET-2), 1,3,5-triazines, for example spirobifluorenyl triazine derivatives (for example in accordance with DE 102008064200), pyrenes, anthracenes, tetracenes, fluorenes, spiro-

10 fluorenes, dendrimers, tetracenes (for example rubrene derivatives), 1,10-phenanthroline derivatives (JP 2003-1 15387, JP 2004-31 1184, JP 2001-267080, WO 02/043449), silacyclopentadiene derivatives (EP 1480280, EP 1478032, EP 1469533), borane derivatives, such as, for example, tri-arylborane derivatives containing Si (US 2007/0087219 A1, cf. formula ET-

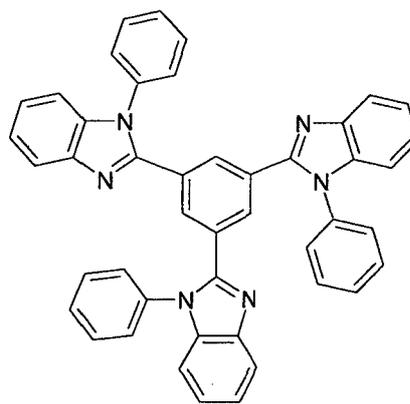
15 3), pyridine derivatives (JP 2004-200162), phenanthrolines, especially 1,10-phenanthroline derivatives, such as, for example, BCP and Bphen, also several phenanthrolines connected via biphenyl or other aromatic groups (US 2007-0252517 A1) or phenanthrolines connected to anthracene (US 2007-0122656 A1, cf. formulae ET-4 and ET-5).

20

25



formula ET-1



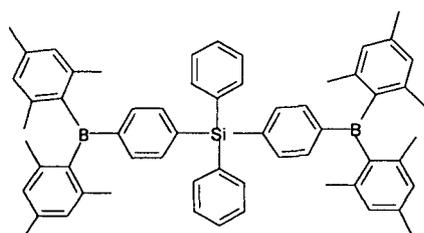
TPBI

2,2',2''-(1,3,5-benzenetriyl)tris(1-phenyl-1H-benzimidazole)

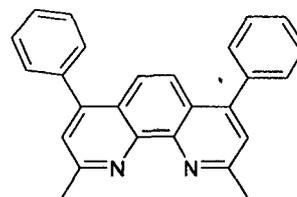
formula ET-2

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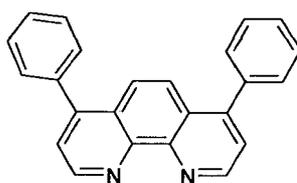


formula ET-3



formula ET-4

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formula ET-5

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Likewise suitable are heterocyclic organic compounds, such as, for example, thiopyran dioxides, oxazoles, triazoles, imidazoles or oxadiazoles.

Examples of the use of five-membered rings containing N, such as, for

example, oxazoles, preferably 1,3,4-oxadiazoles, for example compounds of the formulae ET-6, ET-7, ET-8 and ET-9, which are disclosed, inter alia,

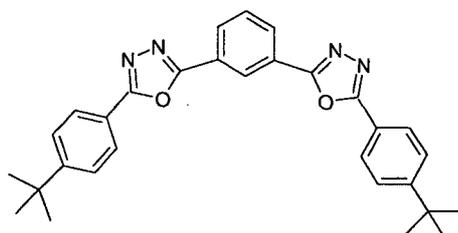
in US 2007/0273272 A1; thiazoles, oxadiazoles, thiadiazoles, triazoles, inter alia, see US 2008/010231 1 A1 and Y.A. Levin, M.S. Skorobogatova,

Khimiya Geterotsiklicheskikh Soedinenii 1967 (2), 339-341, preferably

20

compounds of the formula ET-10, silacyclopentadiene derivatives. Preferred compounds are the following of the formulae (ET-6) to (ET-10):

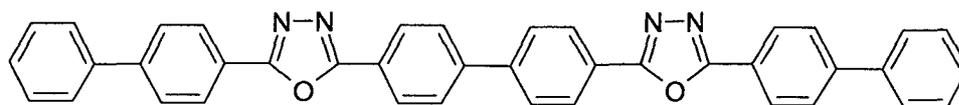
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formula ET-6

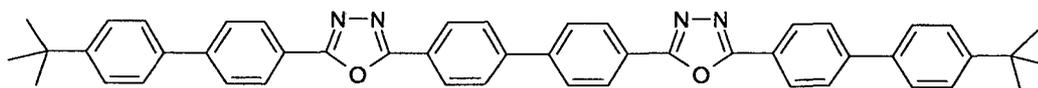
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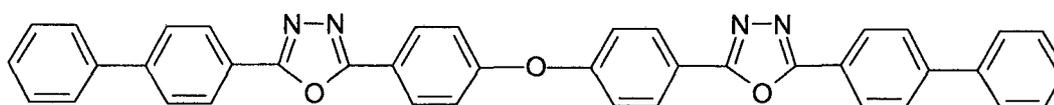
formula ET-7

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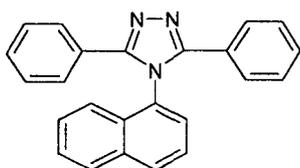
formula ET-8

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formula ET-9

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formula ET-10

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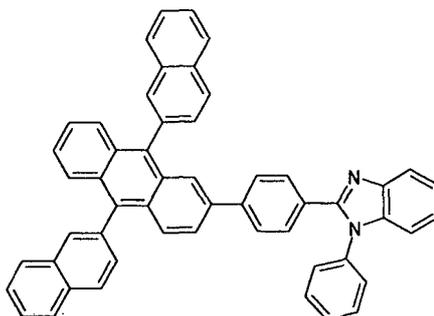
It is also possible to employ organic compounds, such as derivatives of fluorenone, fluorenylidene methane, perylene tetracarboxylic acid, anthraquinone dimethane, diphenyl quinone, anthrone and anthraquinone diethylenediamine.

25

Preference is given to 2,9,10-substituted anthracenes (with 1- or 2-naphthyl and 4- or 3-biphenyl) or molecules which contain two anthracene units (US 2008/0193796 A 1, cf. formula ET-11). Also very advantageous is the connection of 9,10-substituted anthracene units to benzimidazole derivatives (US 2006/147747 A and EP 1551206 A 1, cf. formulae ET-12 and ET-13).

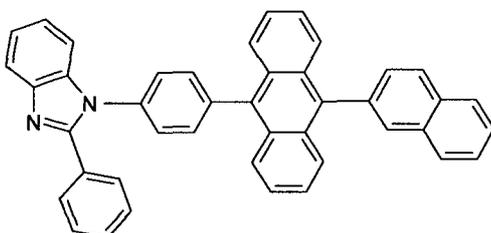
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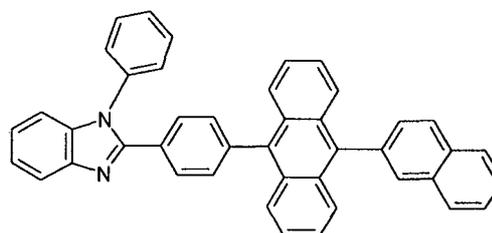


formula ET-11

10



formula ET-12



formula ET-13

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The compounds which are able to generate electron-injection and/or electron-transport properties preferably result in an LUMO of less than -2.5 eV (vs. vacuum level), particularly preferably less than -2.7 eV.

20

The present formulations may comprise emitters. The term emitter denotes a material which, after excitation, which can take place by transfer of any type of energy, allows a radiative transition into a ground state with emission of light. In general, two classes of emitter are known, namely fluorescent and phosphorescent emitters. The term fluorescent emitter denotes materials or compounds in which a radiative transition from an excited singlet state into the ground state takes place. The term phosphorescent emitter preferably denotes luminescent materials or compounds which contain transition metals.

25

30

Emitters are frequently also called dopants if the dopants cause the properties described above in a system. A dopant in a system comprising a

matrix material and a dopant is taken to mean the component whose proportion in the mixture is the smaller. Correspondingly, a matrix material in a system comprising a matrix material and a dopant is taken to mean the component whose proportion in the mixture is the greater. Accordingly, the term phosphorescent emitter can also be taken to mean, for example, phosphorescent dopant.

Compounds which are able to emit light include, inter alia, fluorescent emitters and phosphorescent emitters. These include, inter alia, compounds containing stilbene, stilbenamine, styrylamine, coumarine, rubrene, rhodamine, thiazole, thiadiazole, cyanine, thiophene, paraphenylene, perylene, phtalocyanine, porphyrin, ketone, quinoline, imine, anthracene and/or pyrene structures. Particular preference is given to compounds which are able to emit light from the triplet state with high efficiency, even at room temperature, i.e. exhibit electrophosphorescence instead of electrofluorescence, which frequently causes an increase in the energy efficiency. Suitable for this purpose are firstly compounds which contain heavy atoms having an atomic number of greater than 36. Preference is given to compounds which contain d- or f-transition metals which satisfy the above-mentioned condition. Particular preference is given here to corresponding compounds which contain elements from group 8 to 10 (Ru, Os, Rh, Ir, Pd, Pt). Suitable functional compounds here are, for example, various complexes, as described, for example, in WO 02/068435 A 1, WO 02/081488 A 1, EP 1239526 A2 and WO 2004/026886 A2.

Preferred compounds which can serve as fluorescent emitters are described by way of example below. Preferred fluorescent emitters are selected from the class of the monostyrylamines, the distyrylamines, the tristyrylamines, the tetrastyrylamines, the styrylphosphines, the styryl ethers and the arylamines.

A monostyrylamine is taken to mean a compound which contains one substituted or unsubstituted styryl group and at least one, preferably aromatic, amine. A distyrylamine is taken to mean a compound which contains two substituted or unsubstituted styryl groups and at least one, preferably aromatic, amine. A tristyrylamine is taken to mean a compound which contains three substituted or unsubstituted styryl groups and at least one, preferably aromatic, amine. A tetrastyrylamine is taken to mean a compound which contains four substituted or unsubstituted styryl groups and at least one, preferably aromatic, amine. The styryl groups are particularly preferably stilbenes, which may also be further substituted. Corresponding phosphines and ethers are defined analogously to the amines. An arylamine or an aromatic amine in the sense of the present invention is taken to mean a compound which contains three substituted or unsubstituted aromatic or heteroaromatic ring systems bonded directly to the nitrogen. At least one of these aromatic or heteroaromatic ring systems is preferably a condensed ring system, preferably having at least 14 aromatic ring atoms. Preferred examples thereof are aromatic anthracenamines, aromatic anthracenediamines, aromatic pyrenenamines, aromatic pyrenediamines, aromatic chrysenamines or aromatic chrysenediamines. An aromatic anthracenamine is taken to mean a compound in which one diarylamino group is bonded directly to an anthracene group, preferably in the 9-position. An aromatic anthracenediamine is taken to mean a compound in which two diarylamino groups are bonded directly to an anthracene group, preferably in the 2,6- or 9,10-position. Aromatic pyrenenamines, pyrenediamines, chrysenamines and chrysenediamines are defined analogously thereto, where the diarylamino groups are preferably bonded to the pyrene in the 1-position or in the 1,6-position.

Further preferred fluorescent emitters are selected from indenofluorenamines or indenofluorenediamines, which are described, inter alia, in WO 2006/122630; benzoindenofluorenamines or benzoindenofluorenedi-

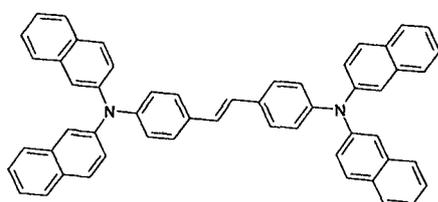
amines, which are described, inter alia, in WO 2008/006449; and dibenzoindenofluorenamines or dibenzoindenofluorenediamines, which are described, inter alia, in WO 2007/140847.

- 5 Examples of compounds from the class of the styrylamines which can be employed as fluorescent emitters are substituted or unsubstituted tristilbenamines or the dopants described in WO 2006/000388, WO 2006/058737, WO 2006/000389, WO 2007/065549 and WO 2007/1 15610. Distyrylbenzene and distyrylbiphenyl derivatives are described in US 5121029.
- 10 Further styrylamines can be found in US 2007/0122656 A 1.

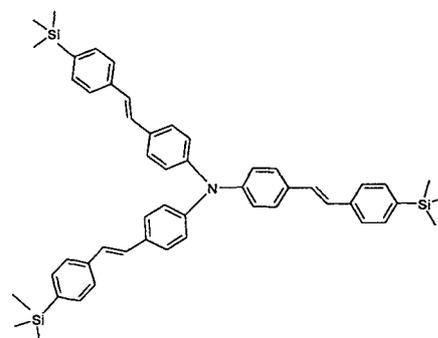
Particularly preferred styrylamine compounds are the compounds of the formula EM-1 described in US 7250532 B2 and the compounds of the formula EM-2 described in DE 10 2005 058557 A 1:

15

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formula EM-1

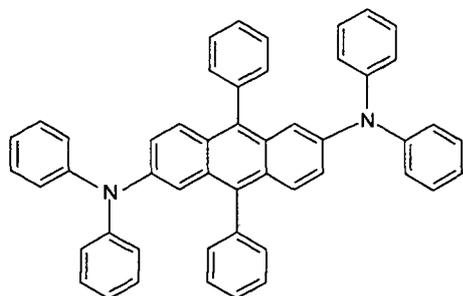


formula EM-2

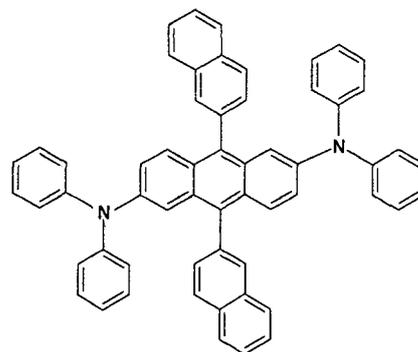
- 25 Particularly preferred triarylamine compounds are compounds of the formulae EM-3 to EM-15 disclosed in CN 1583691 A, JP 08/053397 A and US 6251 531 B1, EP 1957606 A 1, US 2008/01 13101 A 1, US 2006/210830 A , WO 2008/006449 and DE 102008035413 and derivatives thereof:

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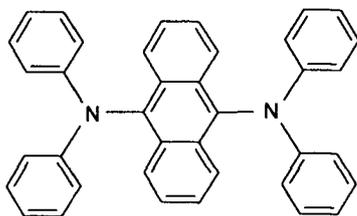


formula EM-3

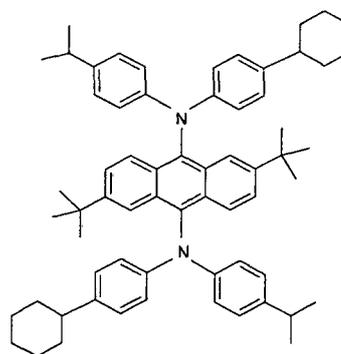


formula EM-4

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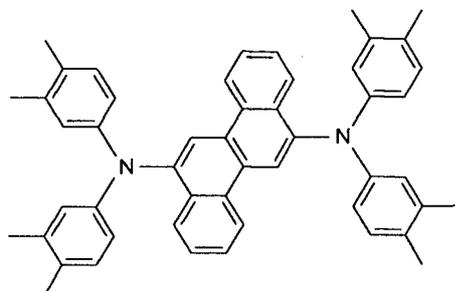


formula EM-5

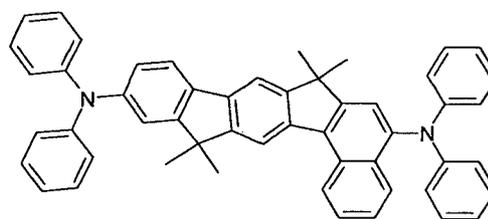


formula EM-6

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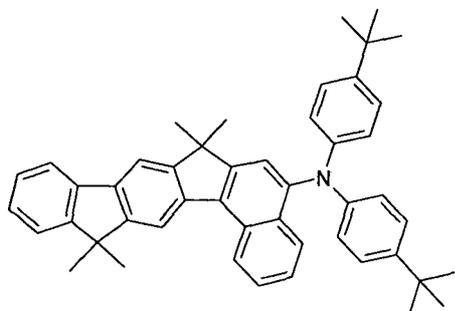


formula EM-7

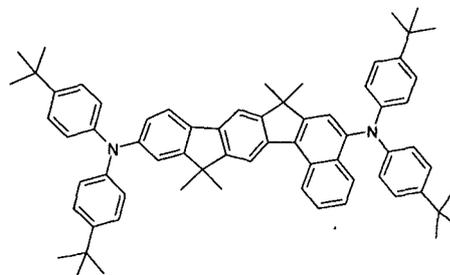


formula EM-8

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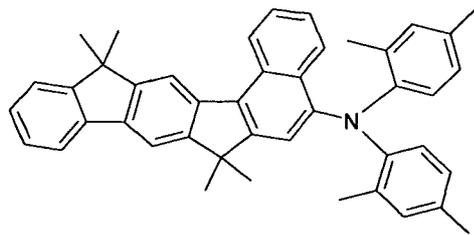
formula EM-9



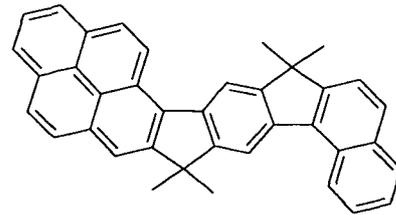
formula EM-10

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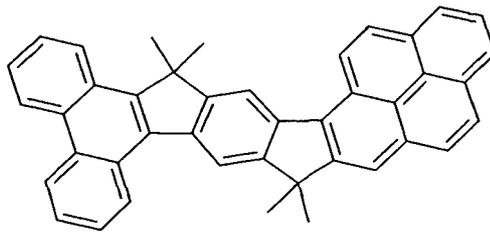


formula EM-11

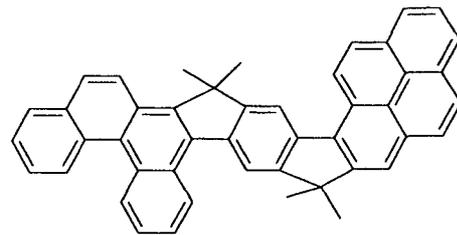


formula EM-12

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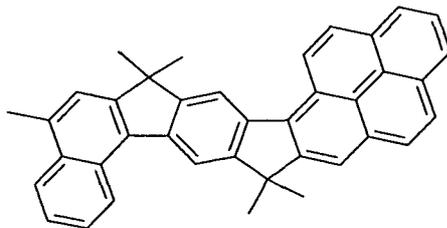


formula EM-13



formula EM-14

15



formula EM-15

20

Further preferred compounds which can be employed as fluorescent emitters are selected from derivatives of naphthalene, anthracene, tetracene, benzanthracene, benzophenanthrene (DE 10 2009 005746), fluorene, fluoranthene, perflanthene, indenoperylene, phenanthrene, perylene (US 2007/0252517 A1), pyrene, chrysene, decacyclene, coronene, tetraphenylcyclopentadiene, pentaphenylcyclopentadiene, fluorene, spirofluorene, rubrene, coumarine (US 4769292, US 6020078, US 2007/0252517 A1), pyran, oxazole, benzoxazole, benzothiazole, benzimidazole, pyrazine, cinnamic acid esters, diketopyrrolopyrrole, acridone and quinacridone (US 2007/0252517 A1).

30

Of the anthracene compounds, particular preference is given to 9,10-substituted anthracenes, such as, for example, 9,10-diphenylanthracene

and 9,10-bis(phenylethynyl)anthracene. 1,4-Bis(9'-ethynylantraceny)-benzene is also a preferred dopant.

5 Preference is likewise given to derivatives of rubrene, coumarine, rhodamine, quinacridone, such as, for example, DMQA (= N,N'-dimethylquinacridone), dicyanomethylenepyrans, such as, for example, DCM (= 4-(dicyanoethylene)-6-(4-dimethylaminostyryl-2-methyl)-4H-pyran), thiopyran, polymethine, pyrylium and thiapyrylium salts, periflanthene and indenoperylene.

10 Blue fluorescent emitters are preferably polyaromatic compounds, such as, for example, 9,10-di(2-naphthylanthracene) and other anthracene derivatives, derivatives of tetracene, xanthene, perylene, such as, for example, 2,5,8,11-tetra-*t*-butylperylene, phenylene, for example 4,4'-bis(9-ethyl-3-carbazovinylene)-1,1'-biphenyl, fluorene, fluoranthene, arylpyrenes
15 (US 2006/0222886 A1), arylenevinylenes (US 5121029, US 5130603), bis-(azinyl)imine-boron compounds (US 2007/0092753 A1), bis(azinyl)methene compounds and carbostyryl compounds.

20 Further preferred blue fluorescent emitters are described in C.H. Chen et al.: "Recent developments in organic electroluminescent materials" *Macromol. Symp.* 125, (1997) 1-48 and "Recent progress of molecular organic electroluminescent materials and devices" *Mat. Sci. and Eng. R*, 39 (2002), 143-222.

25 Further preferred blue-fluorescent emitters are the hydrocarbons disclosed in DE 102008035413.

Preferred compounds which can serve as phosphorescent emitters are described below by way of example.

30

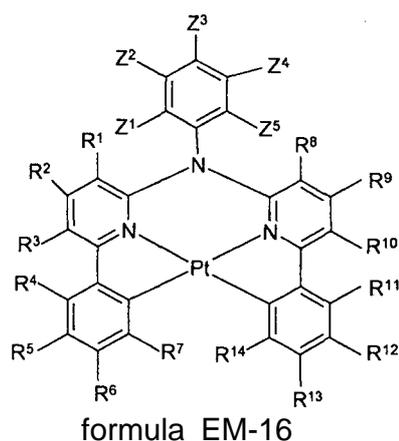
Examples of phosphorescent emitters are revealed by WO 00/70655, WO 01/41512, WO 02/02714, WO 02/15645, EP 1191613, EP 1191612,

EP 1191614 and WO 2005/033244. In general, all phosphorescent complexes as are used in accordance with the prior art for phosphorescent OLEDs and as are known to the person skilled in the art in the area of organic electroluminescence are suitable, and the person skilled in the art will be able to use further phosphorescent complexes without inventive step.

Phosphorescent metal complexes preferably contain Ir, Ru, Pd, Pt, Os or Re, more preferably Ir.

Preferred ligands are 2-phenylpyridine derivatives, 7,8-benzoquinoline derivatives, 2-(2-thienyl)pyridine derivatives, 2-(1-naphthyl)pyridine derivatives, 1-phenylisoquinoline derivatives, 3-phenylisoquinoline derivatives or 2-phenylquinoline derivatives. All these compounds may be substituted, for example by fluoro, cyano and/or trifluoromethyl substituents for blue. Auxiliary ligands are preferably acetylacetonate or picolinic acid.

In particular, complexes of Pt or Pd with tetradentate ligands of the formula EM-16 are suitable



The compounds of the formula EM-16 are described in greater detail in US 2007/0087219 A 1, where, for an explanation of the substituents and

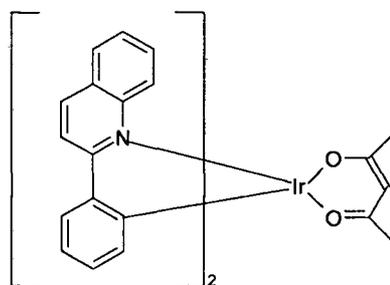
indices in the above formula, reference is made to this specification for disclosure purposes. Furthermore, Pt-porphyrin complexes having an enlarged ring system (US 2009/0061681 A1) and Ir complexes, for example 2,3,7,8,12,13,17,18-octaethyl-21 H, 23H-porphyrin-Pt(II), tetraphenyl-Pt(II) 5 tetrabenzoporphyrin (US 2009/0061681 A1), c/s-bis(2-phenylpyridinato-N,C^{2'})Pt(II), c/s-bis(2-(2'-thienyl)pyridinato-N,C^{3'})Pt(II), c/s-bis(2-(2'-thienyl)-quinolinato-N,C^{5'})Pt(II), (2-(4,6-difluorophenyl)pyridinato-N,C^{2'})Pt(II) (acetyl- acetate), or tris(2-phenylpyridinato-N,C^{2'})Ir(III) (= Ir(ppy)₃, green), bis(2- phenylpyridinato-N,C^{2'})Ir(III) (acetylacetonate) (= Ir(ppy)₂ acetylacetonate, 10 green, US 2001/0053462 A1, Baldo, Thompson et al. *Nature* 403, (2000), 750-753), bis(1-phenylisoquinolinato-N,C^{2'})(2-phenylpyridinato-N,C^{2'})- iridium(III), bis(2-phenylpyridinato-N,C^{2'})(1-phenylisoquinolinato-N,C^{2'})- iridium(III), bis(2-(2'-benzothienyl)pyridinato-N,C^{3'})iridium(III) (acetyl- acetate), bis(2-(4',6'-difluorophenyl)pyridinato-N,C^{2'})iridium(III) (picco- 15 linate) (Flrpic, blue), bis(2-(4',6'-difluorophenyl)pyridinato-N,C^{2'})Ir(III) (tetrakis(l-pyrazolyl)borate), tris(2-(biphenyl-3-yl)-4-tert-butylpyridine)- iridium(III), (ppz)₂Ir(5phdpym) (US 2009/0061681 A1), (45ooppz)₂- Ir(5phdpym) (US 2009/0061681 A1), derivatives of 2-phenylpyridine-Ir com- 20 plexes, such as, for example, PQIr (= iridium(III) bis(2-phenylquinolyl- N,C^{2'})acetylacetonate), tris(2-phenylisoquinolinato-N,C)Ir(III) (red), bis(2- (2'-benzo[4, 5-a]thienyl)pyridinato-N,C^{3'})Ir (acetylacetonate) ([Btp2Ir(acac)], red, Adachi et al. *Appl. Phys. Lett.* 78 (2001), 1622-1624).

Likewise suitable are complexes of trivalent lanthanides, such as, for 25 example, Tb³⁺ and Eu³⁺ (J. Kido et al. *Appl. Phys. Lett.* 65 (1994), 2124, Kido et al. *Chem. Lett.* 657, 1990, US 2007/0252517 A1), or phosphores- cent complexes of Pt(II), Ir(I), Rh(I) with maleonitrile dithiolate (Johnson et al., *JACS* 105, 1983, 1795), Re(I) tricarbonyl-diimine complexes (Wrighton, *JACS* 96, 1974, 998, inter alia), Os(II) complexes with cyano ligands and 30 bipyridyl or phenanthroline ligands (Ma et al., *Synth. Metals* 94, 1998, 245).

Further phosphorescent emitters having tridentate ligands are described in US 6824895 and US 10/729238. Red-emitting phosphorescent complexes are found in US 6835469 and US 6830828.

- 5 Particularly preferred compounds which are used as phosphorescent dopants are, inter alia, the compounds of the formula EM-17 described, inter alia, in US 2001/0053462 A1, and *Inorg. Chem.* 2001, 40(7), 1704-1711, *JACS* 2001, 123(18), 4304-4312, and derivatives thereof.

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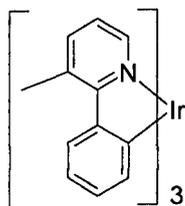
formula EM-17

Derivatives are described in US 7378162 B2, US 6835469 B2 and JP 2003/253145 A.

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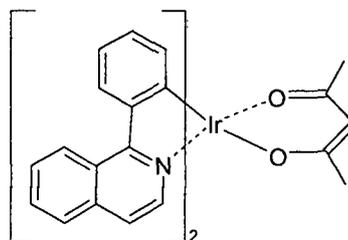
Furthermore, the compounds of the formulae EM-18 to EM-21 described in US 7238437 B2, US 2009/008607 A1 and EP 1348711, and derivatives thereof, can be employed as emitters.

25



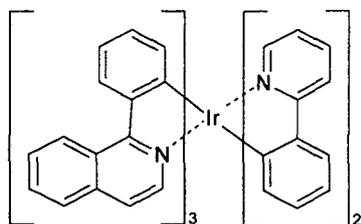
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formula EM-18

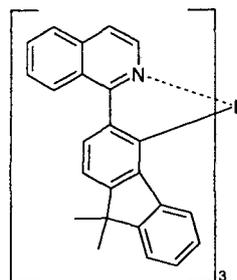


formula EM-19

5



formula EM-20



formula EM-21

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Quantum dots can likewise be employed as emitters, these materials being disclosed in detail in WO 2011/076314 A1.

15

Compounds which are employed as host materials, in particular together with emitting compounds, include materials from various classes of substances.

20

Host materials generally have larger band gaps between HOMO and LUMO than the emitter materials employed. In addition, preferred host materials exhibit properties of either a hole- or electron-transport material. Furthermore, host materials can have both electron- and hole-transport properties.

25

Host materials are in some cases also called matrix material, in particular if the host material is employed in combination with a phosphorescent emitter in an OLED.

30

Preferred host materials or co-host materials, which are employed, in particular, together with fluorescent dopants, are selected from the classes of the oligoarylenes (for example 2,2',7,7'-tetraphenylspirobifluorene in accordance with EP 676461 or dinaphthylanthracene), in particular the oligoarylenes containing condensed aromatic groups, such as, for example, anthracene, benzanthracene, benzophenanthrene (DE 10 2009 005746, WO 2009/069566), phenanthrene, tetracene, coronene, chrysene, fluorene, spirofluorene, perylene, phthaloperylene, naphthaloperylene, decacyclene,

rubrene, the oligoarylenevinylenes (for example DPVBi = 4,4'-bis(2,2-diphenylethenyl)-1,1'-biphenyl or spiro-DPVBi in accordance with EP 676461), the poly podal metal complexes (for example in accordance with WO 04/081017), in particular metal complexes of 8-hydroxyquinoline, for example **AIQ3** (= aluminium(III) tris(8-hydroxyquinoline)) or bis(2-methyl-8-quinolinolato)-4-(phenylphenolinolato)aluminium, also with imidazole chelate (US 2007/0092753 A1) and the quinoline-metal complexes, aminoquinoline-metal complexes, benzoquinoline-metal complexes, the hole-conducting compounds (for example in accordance with WO 2004/05891 1), the electron-conducting compounds, in particular ketones, phosphine oxides, sulfoxides, etc. (for example in accordance with WO 2005/084081 and WO 2005/084082), the atropisomers (for example in accordance with WO 2006/048268), the boronic acid derivatives (for example in accordance with WO 2006/1 17052) or the benzanthracenes (for example in accordance with WO 2008/145239).

Particularly preferred compounds which can serve as host materials or co-host materials are selected from the classes of the oligoarylenes, comprising anthracene, benzanthracene and/or pyrene, or atropisomers of these compounds. An oligoarylene in the sense of the present invention is intended to be taken to mean a compound in which at least three aryl or arylene groups are bonded to one another.

Preferred host materials are selected, in particular, from compounds of the formula (H-1),



where Ar⁴, Ar⁵, Ar⁶ are on each occurrence, identically or differently, an aryl or heteroaryl group having 5 to 30 aromatic ring atoms, which may optionally be substituted, and p represents an integer in the range from 1 to 5; the

sum of the π electrons in Ar⁴, Ar⁵ and Ar⁶ is at least 30 if $p = 1$ and at least 36 if $p = 2$ and at least 42 if $p = 3$.

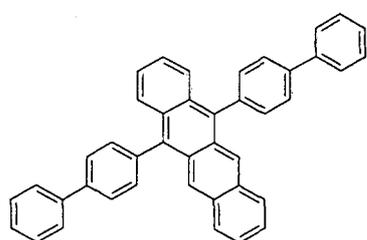
5 In the compounds of the formula (H-1), the group Ar⁵ particularly preferably stands for anthracene, and the groups Ar⁴ and Ar⁶ are bonded in the 9- and 10-position, where these groups may optionally be substituted. Very particularly preferably, at least one of the groups Ar⁴ and/or Ar⁶ is a condensed aryl group selected from 1- or 2-naphthyl, 2-, 3- or 9-phenanthrenyl or 2-, 3-, 4-, 5-, 6- or 7-benzanthracenyl. Anthracene-based compounds are
10 described in US 2007/0092753 A 1 and US 2007/025251 7 A 1, for example 2-(4-methylphenyl)-9, 10-di-(2-naphthyl)anthracene, 9-(2-naphthyl)-10-(1,1'-biphenyl)anthracene and 9,10-bis[4-(2,2-diphenylethenyl)phenyl]anthracene, 9,10-diphenylanthracene, 9,10-bis(phenylethynyl)anthracene and 1,4-bis(9'-ethynylanthracenyl)benzene. Preference is also given to com-
15 pounds containing two anthracene units (US 2008/0193796 A1), for example 10,10'-bis[1,1',A',1"]terphenyl-2-yl-9,9'-bisanthracenyl.

Further preferred compounds are derivatives of arylamine, styrylamine, fluorescein, diphenylbutadiene, tetraphenylbutadiene, cyclopentadiene,
20 tetraphenylcyclopentadiene, pentaphenylcyclopentadiene, coumarine, oxadiazole, bisbenzoxazoline, oxazole, pyridine, pyrazine, imine, benzothiazole, benzoxazole, benzimidazole (US 2007/0092753 A1), for example 2,2',2''-(1,3,5-phenylene)tris[1-phenyl-1H-benzimidazole], aldazine, stilbene, styrylarylene derivatives, for example 9,10-bis[4-(2,2-diphenyl-
25 ethenyl)phenyl]anthracene, and distyrylarylene derivatives (US 5121029), diphenylethylene, vinylanthracene, diaminocarbazole, pyran, thiopyran, diketopyrrolopyrrole, polymethine, cinnamic acid esters and fluorescent dyes.

30 Particular preference is given to derivatives of arylamine and styrylamine, for example TNB (= 4,4'-bis[N-(1-naphthyl)-N-(2-naphthyl)amino]biphenyl). Metal-oxinoid complexes, such as LiQ or AlQ₃, can be used as co-hosts.

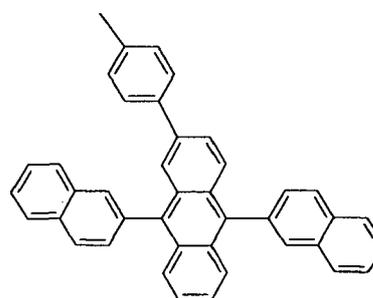
Preferred compounds with oligoarylene as matrix are disclosed in US 2003/0027016 A1, US 7326371 B2, US 2006/043858 A, WO 2007/114358, WO 2008/145239, JP 3148176 B2, EP 1009044, US 2004/018383, 5 WO 2005/061656 A1, EP 0681019B1, WO 2004/013073A1, US 5077142, WO 2007/065678 and DE 102009005746, where particularly preferred compounds are described by the formulae H-2 to H-8.

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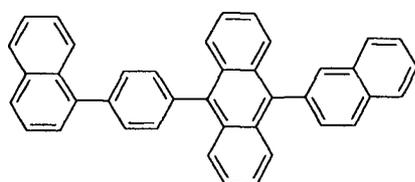
formula H-2

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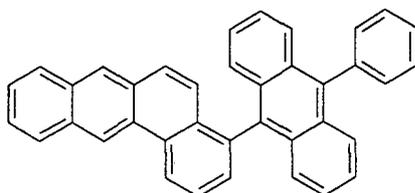
formula H-3

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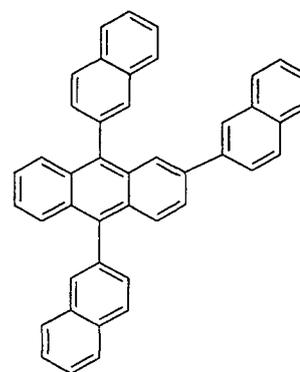
formula H-4

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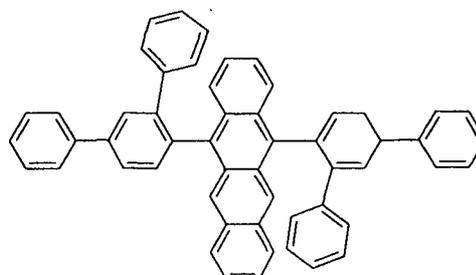


formula H-6

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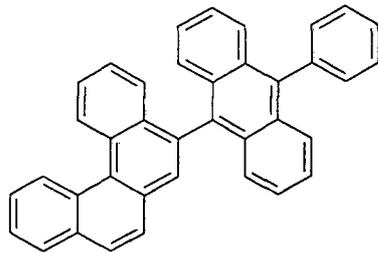


formula H-5



formula H-7

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formula H-8

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Furthermore, compounds which can be employed as host or matrix include materials which are employed together with phosphorescent emitters.

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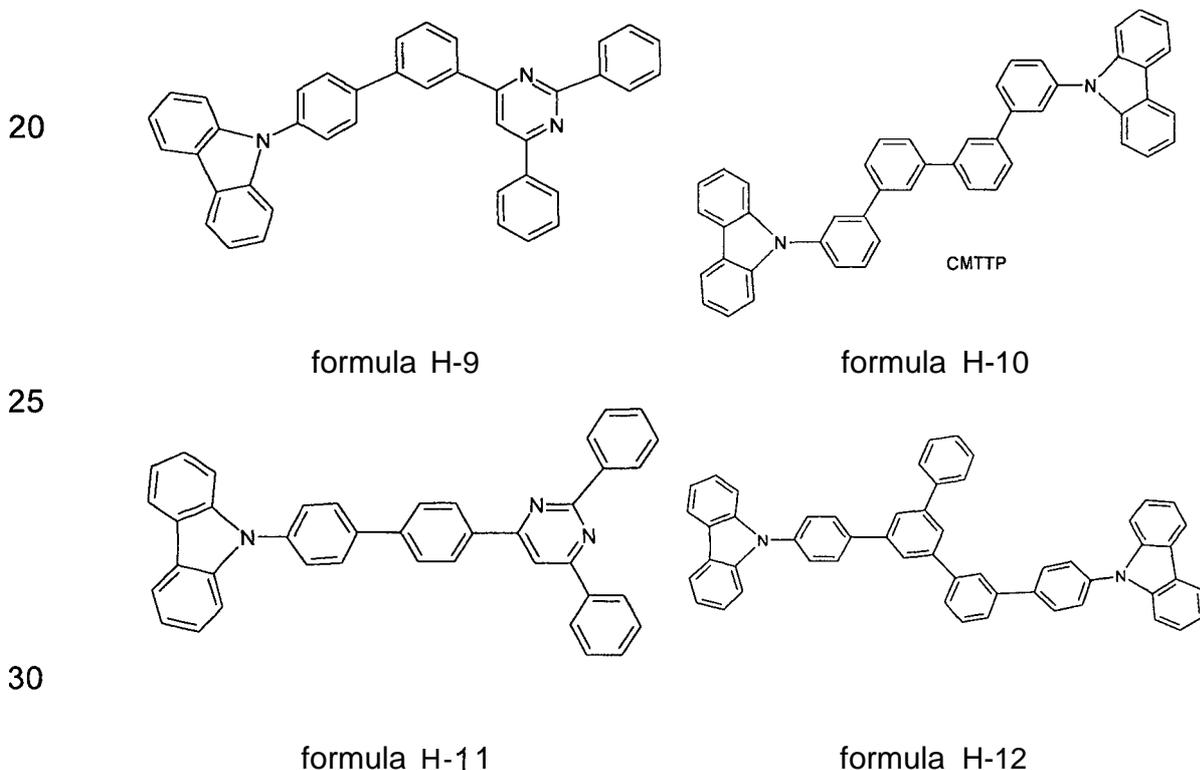
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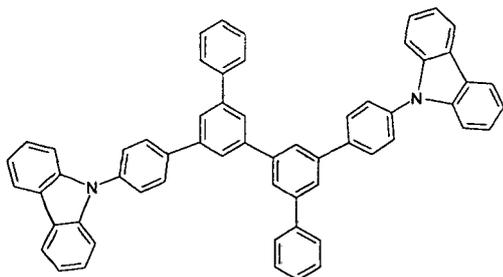
These compounds, which can also be employed as structural elements in polymers, include CBP (N,N-biscarbazolylbiphenyl), carbazole derivatives (for example in accordance with WO 2005/039246, US 2005/0069729, JP 2004/288381, EP 1205527 or WO 2008/086851), azacarbazoles (for example in accordance with EP 1617710, EP 161771 1, EP 1731584 or JP 2005/347160), ketones (for example in accordance with WO 2004/093207 or in accordance with DE 102008033943), phosphine oxides, sulfoxides and sulfones (for example in accordance with WO 2005/003253), oligophenylenes, aromatic amines (for example in accordance with US 2005/0069729), bipolar matrix materials (for example in accordance with WO 2007/137725), silanes (for example in accordance with WO 2005/111172), 9,9-diarylfuorene derivatives (for example in accordance with DE 102008017591), azaboroles or boronic esters (for example in accordance with WO 2006/1 17052), triazine derivatives (for example in accordance with DE 102008036982), indolocarbazole derivatives (for example in accordance with WO 2007/063754 or WO 2008/056746), indenocarbazole derivatives (for example in accordance with DE 102009023155 and DE 102009031 021), diazaphosphole derivatives (for example in accordance with DE 102009022858), triazole derivatives, oxazoles and oxazole derivatives, imidazole derivatives, polyaryllkane derivatives, pyrazoline derivatives, pyrazolone derivatives, distyrylpyrazine derivatives, thiopyran

dioxide derivatives, phenylenediamine derivatives, tertiary aromatic amines, styrylamines, amino-substituted chalcone derivatives, indoles, hydrazone derivatives, stilbene derivatives, silazane derivatives, aromatic dimethyldene compounds, carbodiimide derivatives, metal complexes of 8-hydroxy-quinoline derivatives, such as, for example, **AIQ3**, which may also contain triarylaminophenol ligands (US 2007/0134514 A1), metal complex/poly-silane compounds, and thiophene, benzothiophene and dibenzothiophene derivatives.

Examples of preferred carbazole derivatives are mCP (= 1,3-N,N-dicarbazolylbenzene (= 9,9'-(1,3-phenylene)bis-9H-carbazole)) (formula H-9), CDBP (= 9,9'-(2,2'-dimethyl[1,1'-biphenyl]-4,4'-diyl)bis-9H-carbazole), 1,3-bis(N,N'-dicarbazolyl)benzene (= 1,3-bis(carbazol-9-yl)benzene), PVK (polyvinylcarbazole), 3,5-di(9H-carbazol-9-yl)biphenyl and CMTTP (formula H-10). Particularly referred compounds are disclosed in US 2007/0128467 A1 and US 2005/0249976 A1 (formulae H-11 and H-13).



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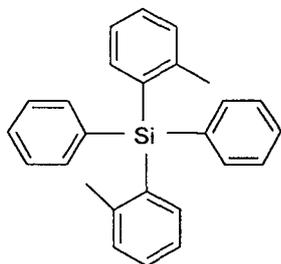
formula H-13

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Preferred tetraaryl-Si compounds are disclosed, for example, in US 2004/02091 15, US 2004/02091 16, US 2007/0087219 A 1 and in H. Gilman, E.A. Zuech, Chemistry & Industry (London, United Kingdom), 1960, 120.

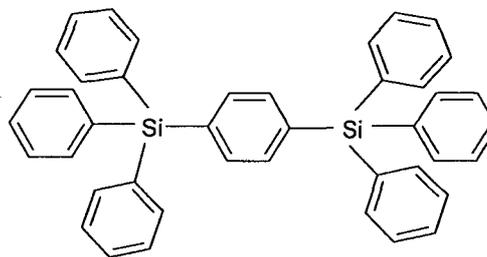
Particularly preferred tetraaryl-Si compounds are described by the formulae H-14 to H-21 .

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UGH1

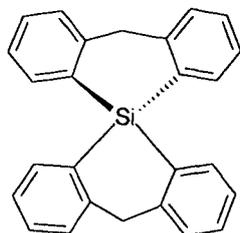
formula H-14



UGH2

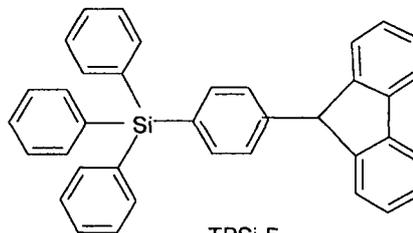
formula H-15

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UGH4

formula H-16

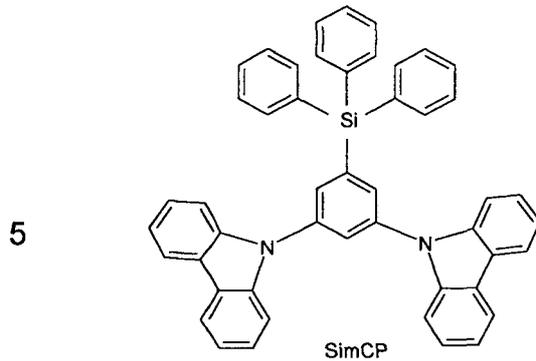


TPSi-F

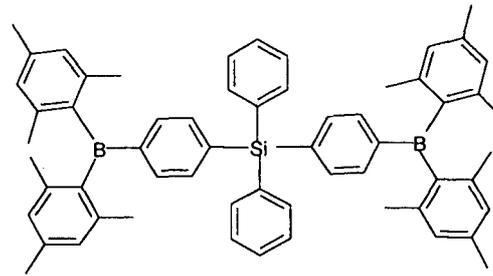
Triphenyl-[4-(9-phenyl-9H-fluoren-9-yl)phenyl]silane

formula H-17

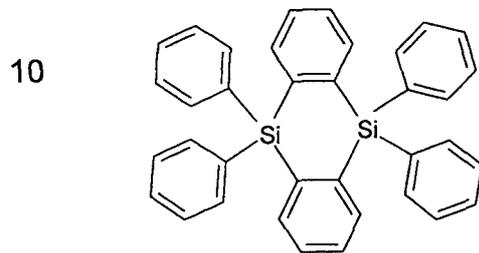
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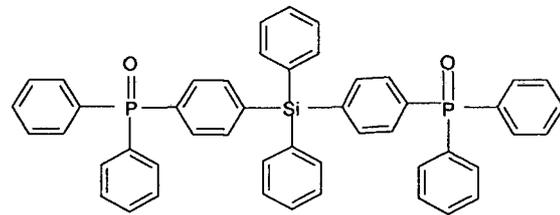
formula H-18



formula H-19



formula H-20

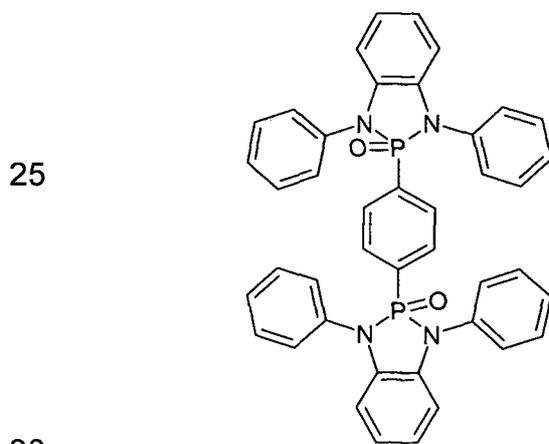


formula H-21

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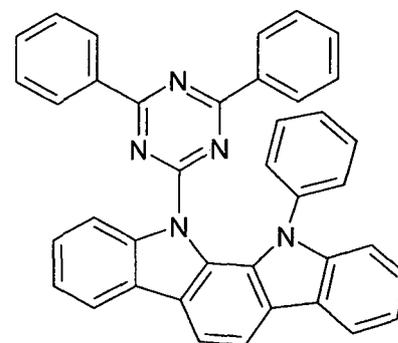
Particularly preferred compounds from group 4 for the preparation of the matrix for phosphorescent dopants are disclosed, inter alia, in DE 102009022858, DE 102009023155, EP 652273 B 1, WO 2007/063754 and WO 2008/056746, where particularly preferred compounds are described by the formulae H-22 to H-25.

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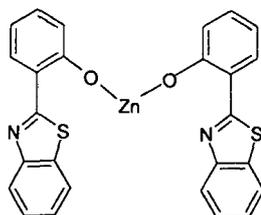
formula H-22

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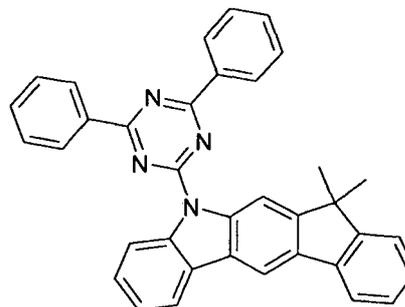


formula H-23

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formula H-24



formula H-25

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With respect to the functional compounds which can be employed in accordance with the invention and which can serve as host material, especial preference is given to substances which contain at least one nitrogen atom. These preferably include aromatic amines, triazine derivatives and carbazole derivatives. Thus, carbazole derivatives in particular exhibit surprisingly high efficiency. Triazine derivatives result in unexpectedly long lifetimes of the electronic devices.

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It may also be preferred to employ a plurality of different matrix materials as a mixture, in particular at least one electron-conducting matrix material and at least one hole-conducting matrix material. Preference is likewise given to the use of a mixture of a charge-transporting matrix material and an electrically inert matrix material which is not involved in the charge transport to a significant extent, if at all, as described, for example, in WO 2010/108579.

25

It is furthermore possible to employ compounds which improve the transition from the singlet state to the triplet state and which, employed in support of the functional compounds having emitter properties, improve the phosphorescence properties of these compounds. Suitable for this purpose are, in particular, carbazole and bridged carbazole dimer units, as described, for example, in WO 2004/070772 A2 and WO 2004/1 13468 A1. Also suitable for this purpose are ketones, phosphine oxides, sulfoxides,

30

sulfones, silane derivatives and similar compounds, as described, for example, in WO 2005/040302 A 1.

n-Dopants herein are taken to mean reducing agents, i.e. electron donors.

5 Preferred examples of n-dopants are $W(hpp)_4$ and other electron-rich metal complexes in accordance with WO 2005/086251 A2, P=N compounds (for example WO 2012/175535 A1, WO 2012/175219 A1), naphthylencarbo-
diimides (for example WO 2012/168358 A1), fluorenes (for example
WO 2012/031735 A1), free radicals and diradicals (for example
10 EP 1837926 A1, WO 2007/1 07306 A 1), pyridines (for example EP 2452946
A 1, EP 2463927 A1), N-heterocyclic compounds (for example WO
2009/000237 A1) and acridines as well as phenazines (for example US
2007/145355 A1).

15 Furthermore, the formulations may comprise a wide-band-gap material as functional material. Wide-band-gap material is taken to mean a material in the sense of the disclosure content of US 7,294,849. These systems exhibit particularly advantageous performance data in electroluminescent devices.

20 The compound employed as wide-band-gap material can preferably have a band gap of 2.5 eV or more, preferably 3.0 eV or more, particularly preferably 3.5 eV or more. The band gap can be calculated, inter alia, by means of the energy levels of the highest occupied molecular orbital (HOMO) and the lowest unoccupied molecular orbital (LUMO).

25 Furthermore, the formulations may comprise a hole-blocking material (HBM) as functional material. A hole-blocking material denotes a material which prevents or minimises the transmission of holes (positive charges) in a multilayer system, in particular if this material is arranged in the form of a
30 layer adjacent to an emission layer or a hole-conducting layer. In general, a hole-blocking material has a lower HOMO level than the hole-transport

material in the adjacent layer. Hole-blocking layers are frequently arranged between the light-emitting layer and the electron-transport layer in OLEDs.

5 It is basically possible to employ any known hole-blocking material. In addition to other hole-blocking materials described elsewhere in the present application, advantageous hole-blocking materials are metal complexes (US 2003/0068528), such as, for example, bis(2-methyl-8-quinolinolato)(4-phenylphenolato)aluminium(III) (BAIQ). Fac-tris(1-phenylpyrazolato-N,C2)-iridium(III) ($\text{Ir}(\text{ppz})_3$) is likewise employed for this purpose (US 2003/10 0175553 A1). Phenanthroline derivatives, such as, for example, BCP, or phthalimides, such as, for example, TMPP, can likewise be employed.

Furthermore, advantageous hole-blocking materials are described in WO 00/70655 A2, WO 01/41512 and WO 01/93642 A 1.

15 Furthermore, the formulations may comprise an electron-blocking material (EBM) as functional material. An electron-blocking material denotes a material which prevents or minimises the transmission of electrons in a multilayer system, in particular if this material is arranged in the form of a layer adjacent to an emission layer or an electron-conducting layer. In general, an electron-blocking material has a higher LUMO level than the electron-transport material in the adjacent layer.

25 It is basically possible to employ any known electron-blocking material. In addition to other electron-blocking materials described elsewhere in the present application, advantageous electron-blocking materials are transition-metal complexes, such as, for example, $\text{Ir}(\text{ppz})_3$ (US 2003/0175553).

30 The electron-blocking material can preferably be selected from amines, tri-arylamines and derivatives thereof.

Furthermore, the functional compounds which can be employed as organic functional materials in the formulations preferably have, if they are low-molecular-weight compounds, a molecular weight of $\leq 3,000$ g/mol, more preferably $\leq 2,000$ g/mol and most preferably $\leq 1,000$ g/mol.

5

Of particular interest are furthermore functional compounds which are distinguished by a high glass-transition temperature. In this connection, particularly preferred functional compounds which can be employed as organic functional material in the formulations are those which have a glass-transition temperature of $\geq 70^\circ\text{C}$, preferably $\geq 100^\circ\text{C}$, more preferably $\geq 125^\circ\text{C}$ and most preferably $\geq 150^\circ\text{C}$, determined in accordance with DIN 51005.

10

The formulations may also comprise polymers as organic functional materials. The compounds described above as organic functional materials, which frequently have a relatively low molecular weight, can also be mixed with a polymer. It is likewise possible to incorporate these compounds covalently into a polymer. This is possible, in particular, with compounds which are substituted by reactive leaving groups, such as bromine, iodine, chlorine, boronic acid or boronic acid ester, or by reactive, polymerisable groups, such as olefins or oxetanes. These can be used as monomers for the production of corresponding oligomers, dendrimers or polymers. The oligomerisation or polymerisation here preferably takes place via the halogen functionality or the boronic acid functionality or via the polymerisable group. It is furthermore possible to crosslink the polymers via groups of this type. The compounds and polymers according to the invention can be employed as crosslinked or uncrosslinked layer.

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Polymers which can be employed as organic functional materials frequently contain units or structural elements which have been described in the context of the compounds described above, inter alia those as disclosed and extensively listed in WO 02/077060 A 1, in WO 2005/014689 A2 and in

WO 201 1/076314 A 1. These are incorporated into the present application by way of reference. The functional materials can originate, for example, from the following classes:

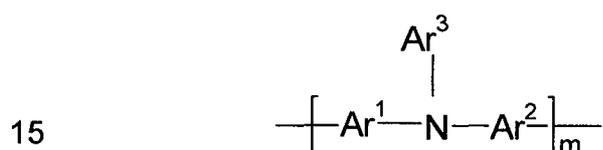
- 5 Group 1: structural elements which are able to generate hole-injection and/or hole-transport properties;
- Group 2: structural elements which are able to generate electron-injection and/or electron-transport properties;
- 10 Group 3: structural elements which combine the properties described in relation to groups 1 and 2;
- Group 4: structural elements which have light-emitting properties, in particular phosphorescent groups;
- 15 Group 5: structural elements which improve the transition from the so-called singlet state to the triplet state;
- Group 6: structural elements which influence the morphology or also the emission colour of the resultant polymers;
- Group 7: structural elements which are typically used as backbone.

25 The structural elements here may also have various functions, so that a clear assignment need not be advantageous. For example, a structural element of group 1 may likewise serve as backbone.

30 The polymer having hole-transport or hole-injection properties employed as organic functional material, containing structural elements from group 1, may preferably contain units which correspond to the hole-transport or hole-injection materials described above.

Further preferred structural elements of group 1 are, for example, triaryl-amine, benzidine, tetraaryl-para-phenylenediamine, carbazole, azulene, thiophene, pyrrole and furan derivatives and further O-, S- or N-containing heterocycles having a high HOMO. These arylamines and heterocycles preferably have an HOMO of above -5.8 eV (against vacuum level), particularly preferably above -5.5 eV.

Preference is given, inter alia, to polymers having hole-transport or hole-injection properties, containing at least one of the following recurring units of the formula HTP-1 :



HTP-1

in which the symbols have the following meaning:

Ar^1 is, in each case identically or differently for different recurring units, a single bond or a monocyclic or polycyclic aryl group, which may optionally be substituted;

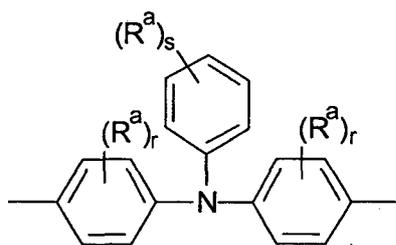
Ar^2 is, in each case identically or differently for different recurring units, a monocyclic or polycyclic aryl group, which may optionally be substituted;

Ar^3 is, in each case identically or differently for different recurring units, a monocyclic or polycyclic aryl group, which may optionally be substituted;

m is 1, 2 or 3.

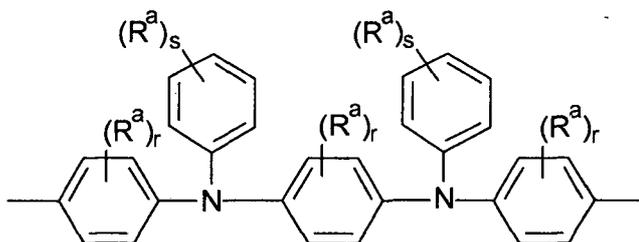
Particular preference is given to recurring units of the formula HTP-1 which are selected from the group consisting of units of the formulae HTP-1 A to HTP-1 C:

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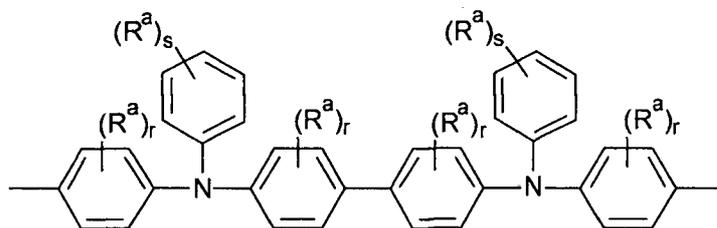
HTP-1A



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HTP-1 B



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HTP-1 C

in which the symbols have the following meaning:

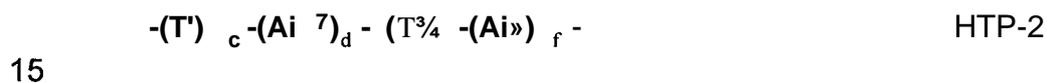
30

5 R^a is on each occurrence, identically or differently, H, a substituted or unsubstituted aromatic or heteroaromatic group, an alkyl, cycloalkyl, alkoxy, aralkyl, aryloxy, arylthio, alkoxycarbonyl, silyl or carboxyl group, a halogen atom, a cyano group, a nitro group or a hydroxyl group;

r is 0, 1, 2, 3 or 4, and

s is 0, 1, 2, 3, 4 or 5.

10 Preference is given, inter alia, to polymers having hole-transport or hole-injection properties, containing at least one of the following recurring units of the formula HTP-2:



in which the symbols have the following meaning:

20 T^1 and T^2 are selected independently from thiophene, selenophene, thieno[2,3-b]thiophene, thieno[3,2-b]thiophene, dithienothiophene, pyrrole and aniline, where these groups may be substituted by one or more radicals R^b ;

25 R^b is selected independently on each occurrence from halogen, -CN, -NC, -NCO, -NCS, -OCN, -SCN, -C(=O)NR^oR^{oo}, -C(=O)X, -C(=O)R^o, -NH₂, -NR^oR^{oo}, -SH, -SR^o, -SO₃H, -SO₂R^o, -OH, -NO₂, -CF₃, -SF₅, an optionally substituted silyl, carbyl or hydrocarbyl group having 1 to 40 carbon atoms, which may optionally be substituted and may optionally contain one or more heteroatoms;

30 R^o and R^{oo} are each independently H or an optionally substituted carbyl or hydrocarbyl group having 1 to 40 carbon atoms, which may optionally be substituted and may optionally contain one or more heteroatoms;

5 Ar⁷ and Ar⁸ represent, independently of one another, a monocyclic or polycyclic aryl or heteroaryl group, which may optionally be substituted and may optionally be bonded to the 2,3-position of one or both adjacent thiophene or selenophene groups;

c and e are, independently of one another, 0, 1, 2, 3 or 4, where
 $1 < c + e \leq 6$;

10 d and f are, independently of one another, 0, 1, 2, 3 or 4.

Preferred examples of polymers having hole-transport or hole-injection properties are described, inter alia, in WO 2007/131582 A1 and WO 2008/009343 A1.

15 The polymer having electron-injection and/or electron-transport properties employed as organic functional material, containing structural elements from group 2, may preferably contain units which correspond to the electron-injection and/or electron-transport materials described above.

20 Further preferred structural elements of group 2 which have electron-injection and/or electron-transport properties are derived, for example, from pyridine, pyrimidine, pyridazine, pyrazine, oxadiazole, quinoline, quinoxaline and phenazine groups, but also triarylborane groups or further O-, S- or
25 N-containing heterocycles having a low LUMO level. These structural elements of group 2 preferably have an LUMO of below -2.7 eV (against vacuum level), particularly preferably below -2.8 eV.

30 The organic functional material can preferably be a polymer which contains structural elements from group 3, where structural elements which improve the hole and electron mobility (i.e. structural elements from groups 1 and 2) are connected directly to one another. Some of these structural elements

can serve as emitters here, where the emission colours may be shifted, for example, into the green, red or yellow. Their use is therefore advantageous, for example, for the generation of other emission colours or a broad-band emission by polymers which originally emit in blue.

5

The polymer having light-emitting properties employed as organic functional material, containing structural elements from group 4, may preferably contain units which correspond to the emitter materials described above. Preference is given here to polymers containing phosphorescent groups, in particular the emitting metal complexes described above which contain corresponding units containing elements from groups 8 to 10 (Ru, Os, Rh, Ir, Pd, Pt).

10

The polymer employed as organic functional material containing units of group 5 which improve the transition from the so-called singlet state to the triplet state can preferably be employed in support of phosphorescent compounds, preferably the polymers containing structural elements of group 4 described above. A polymeric triplet matrix can be used here.

15

Suitable for this purpose are, in particular, carbazole and connected carbazole dimer units, as described, for example, in DE 10304819 A 1 and DE 10328627 A 1. Also suitable for this purpose are ketone, phosphine oxide, sulfoxide, sulfone and silane derivatives and similar compounds, as described, for example, in DE 10349033 A 1. Furthermore, preferred structural units can be derived from compounds which have been described above in connection with the matrix materials employed together with phosphorescent compounds.

20

25

The further organic functional material is preferably a polymer containing units of group 6 which influence the morphology and/or the emission colour of the polymers. Besides the polymers mentioned above, these are those which have at least one further aromatic or another conjugated structure

30

which do not count amongst the above-mentioned groups. These groups accordingly have only little or no effect on the charge-carrier mobilities, the non-organometallic complexes or the singlet-triplet transition.

5 Structural units of this type are able to influence the morphology and/or the emission colour of the resultant polymers. Depending on the structural unit, these polymers can therefore also be used as emitters.

10 In the case of fluorescent OLEDs, preference is therefore given to aromatic structural elements having 6 to 40 C atoms or also tolan, stilbene or bis-styrylarylene derivative units, each of which may be substituted by one or more radicals. Particular preference is given here to the use of groups derived from 1,4-phenylene, 1,4-naphthylene, 1,4- or 9,10-anthrylene, 1,6-, 2,7- or 4,9-pyrenylene, 3,9- or 3,10-perylenylene, 4,4'-biphenylene, 4,4"-
15 terphenylylene, 4,4'-bi-1,1'-naphthylylene, 4,4'-tolanylene, 4,4'-stilbenylene or 4,4"-bisstyrylarylene derivatives.

The polymer employed as organic functional material preferably contains units of group 7, which preferably contain aromatic structures having 6 to
20 40 C atoms which are frequently used as backbone.

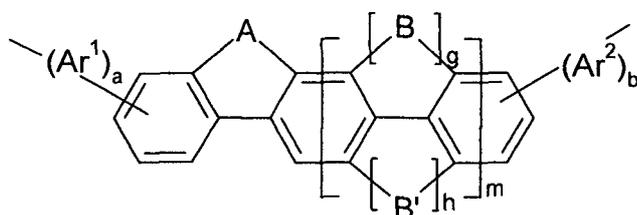
These include, inter alia, 4,5-dihydropyrene derivatives, 4,5,9,10-tetrahydropyrene derivatives, fluorene derivatives, which are disclosed, for example, in US 5962631, WO 2006/052457 A2 and WO 2006/1 18345 A 1,
25 9,9-spirobifluorene derivatives, which are disclosed, for example, in WO 2003/020790 A 1, 9,10-phenanthrene derivatives, which are disclosed, for example, in WO 2005/104264 A 1, 9,10-dihydrophenanthrene derivatives, which are disclosed, for example, in WO 2005/014689 A2, 5,7-dihydrodibenzoxepine derivatives and cis- and trans-indenofluorene
30 derivatives, which are disclosed, for example, in WO 2004/041901 A 1 and WO 2004/113412 A2, and binaphthylene derivatives, which are disclosed, for example, in WO 2006/063852 A 1, and further units which are disclosed,

for example, in WO 2005/056633 A1, EP 1344788 A1, WO 2007/043495 A1, WO 2005/033174 A1, WO 2003/099901 A1 and DE 102006003710.

Particular preference is given to structural units of group 7 which are selected from fluorene derivatives, which are disclosed, for example, in
 5 US 5,962,631, WO 2006/052457 A2 and WO 2006/1 18345 A1, spiro-bifluorene derivatives, which are disclosed, for example, in WO 2003/020790 A1, benzofluorene, dibenzofluorene, benzothiophene and dibenzofluorene groups and derivatives thereof, which are disclosed, for example,
 10 in WO 2005/056633 A1, EP 1344788 A1 and WO 2007/043495 A1.

Especially preferred structural elements of group 7 are represented by the general formula PB-1 :

15



20

formula PB-1

in which the symbols and indices have the following meanings:

A, B and B' are each, also for different recurring units, identically or differently, a divalent group, which is preferably selected from -CR^cR^d-, -NR^c-,
 25 -PRS -O-, -S-, -SO-, -SO₂-, -CO-, -CS-, -CSe-, -P(=O)R^c-, -P(=S)R^c- and -SiR^cR^d-;

R^c and R^d are selected on each occurrence, independently, from H, halo-
 30 gen, -CN, -NC, -NCO, -NCS, -OCN, -SCN, -C(=O)NR^oR^o-, -C(=O)X, -C(=O)R^o-, -NH₂, -NR^oR^{oo}-, -SH, -SR^o-, -SO₃H, -SO₂R^o-, -OH, -NO₂, -CF₃,

-SF₅, an optionally substituted silyl, carbonyl or hydrocarbyl group having 1 to 40 carbon atoms, which may optionally be substituted and may optionally contain one or more heteroatoms, where the groups R^c and R^d may optionally form a spiro group with a fluorene radical to which they are bonded;

5

X is halogen;

R^e and R⁰⁰ are each, independently, H or an optionally substituted carbonyl or hydrocarbyl group having 1 to 40 carbon atoms, which may optionally be substituted and may optionally contain one or more heteroatoms;

10

g is in each case, independently, 0 or 1 and h is in each case, independently, 0 or 1, where the sum of g and h in a sub-unit is preferably 1;

15

m is an integer ≥ 1 ;

Ar¹ and Ar² represent, independently of one another, a monocyclic or polycyclic aryl or heteroaryl group, which may optionally be substituted and may optionally be bonded to the 7,8-position or the 8,9-position of an indenofluorene group; and

20

a and b are, independently of one another, 0 or 1.

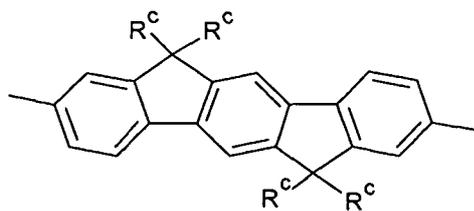
If the groups R^c and R^d form a spiro group with the fluorene group to which these groups are bonded, this group preferably represents a spirobifluorene.

25

Particular preference is given to recurring units of the formula PB-1 which are selected from the group consisting of units of the formulae PB-1A to PB-1E:

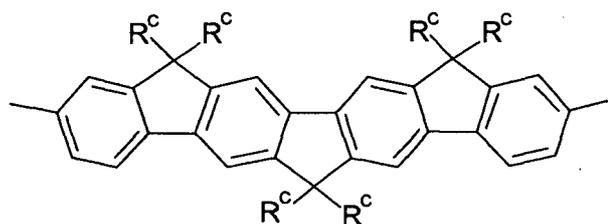
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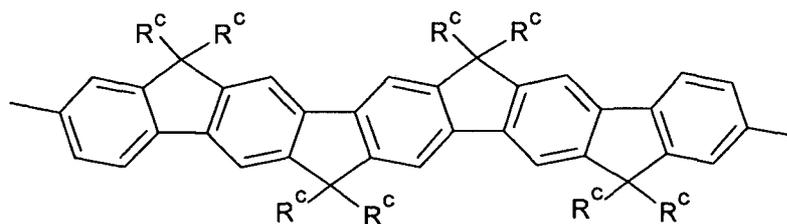
formula PB-1A

10



formula PB-1B

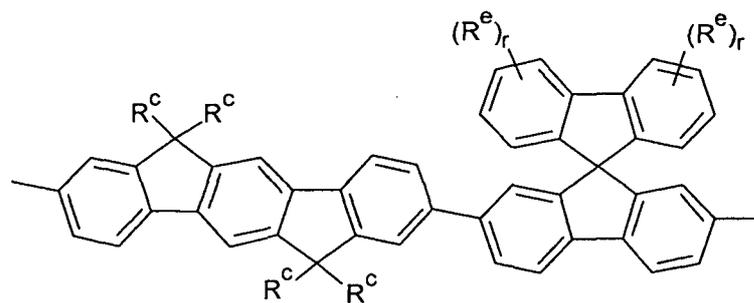
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formula PB-1C

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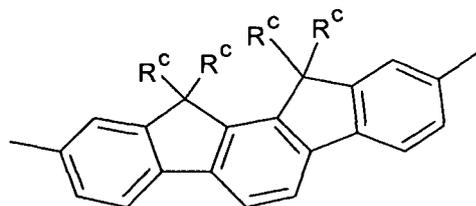
25



formula PB-1D

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formula PB-1E

where R^c has the meaning described above for formula PB-1, r is 0, 1, 2, 3 or 4, and R^e has the same meaning as the radical R^c.

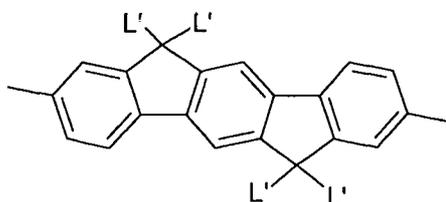
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R^e is preferably -F, -Cl, -Br, -I, -CN, -NO₂, -NCO, -NCS, -OCN, -SCN, -C(=O)NR⁰⁰, -C(=O)X, -C(=O)R⁰, -NR⁰⁰, an optionally substituted silyl, aryl or heteroaryl group having 4 to 40, preferably 6 to 20, C atoms, or a straight-chain, branched or cyclic alkyl, alkoxy, alkylcarbonyl, alkoxy-carbonyl, alkylcarbonyloxy or alkoxy-carbonyloxy group having 1 to 20, preferably 1 to 12, C atoms, where one or more hydrogen atoms may optionally be substituted by F or Cl, and the groups R⁰, R⁰⁰ and X have the meaning described above for formula PB-1.

15

Particular preference is given to recurring units of the formula PB-1 which are selected from the group consisting of units of the formulae PB-1 F to PB-1 I:

20



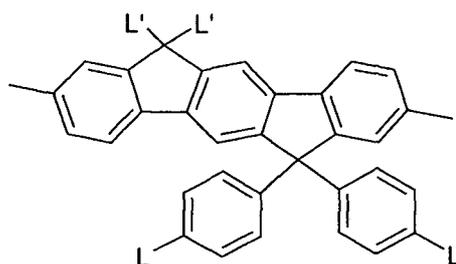
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formula PB-1F

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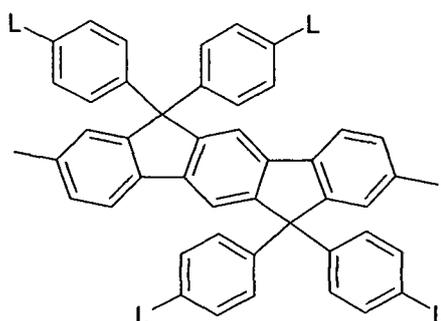
- 58 -

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formula PB-1G

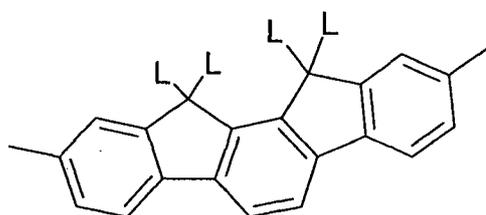
10



formula PB-1H

15

20



formula PB-1 1

in which the symbols have the following meaning:

25 L is H, halogen or an optionally fluorinated, linear or branched alkyl or alkoxy group having 1 to 12 C atoms and preferably stands for H, F, methyl, i-propyl, t-butyl, n-pentoxy or trifluoromethyl; and

L' is an optionally fluorinated, linear or branched alkyl or alkoxy group
30 having 1 to 12 C atoms and preferably stands for n-octyl or n-octyloxy.

For carrying out the present invention, preference is given to polymers which contain more than one of the structural elements of groups 1 to 7 described above. It may furthermore be provided that the polymers preferably contain more than one of the structural elements from one group described above, i.e. comprise mixtures of structural elements selected from one group.

Particular preference is given, in particular, to polymers which, besides at least one structural element which has light-emitting properties (group 4), preferably at least one phosphorescent group, additionally contain at least one further structural element of groups 1 to 3, 5 or 6 described above, where these are preferably selected from groups 1 to 3.

The proportion of the various classes of groups, if present in the polymer, can be in broad ranges, where these are known to the person skilled in the art. Surprising advantages can be achieved if the proportion of one class present in a polymer, which is in each case selected from the structural elements of groups 1 to 7 described above, is preferably in each case ≥ 5 mol%, particularly preferably in each case ≥ 10 mol%.

The preparation of white-emitting copolymers is described in detail, inter alia, in DE 10343606 A 1.

In order to improve the solubility, the polymers may contain corresponding groups. It may preferably be provided that the polymers contain substituents, so that on average at least 2 non-aromatic carbon atoms, particularly preferably at least 4 and especially preferably at least 8 non-aromatic carbon atoms are present per recurring unit, where the average relates to the number average. Individual carbon atoms here may be replaced, for example, by O or S. However, it is possible for a certain proportion, optionally all recurring units, to contain no substituents which contain non-aromatic carbon atoms. Short-chain substituents are preferred here, since long-chain

substituents can have adverse effects on layers which can be obtained using organic functional materials. The substituents preferably contain at most 12 carbon atoms, preferably at most 8 carbon atoms and particularly preferably at most 6 carbon atoms in a linear chain.

5

The polymer employed in accordance with the invention as organic functional material can be a random, alternating or regioregular copolymer, a block copolymer or a combination of these copolymer forms.

10 in a further embodiment, the polymer employed as organic functional material can be a non-conjugated polymer having side chains, where this embodiment is particularly important for phosphorescent OLEDs based on polymers. In general, phosphorescent polymers can be obtained by free-radical copolymerisation of vinyl compounds, where these vinyl compounds
15 contain at least one unit having a phosphorescent emitter and/or at least one charge-transport unit, as is disclosed, inter alia, in US 7250226 B2. Further phosphorescent polymers are described, inter alia, in JP 2007/211243 A2, JP 2007/197574 A2, US 7250226 B2 and JP 2007/059939 A.

20 In a further preferred embodiment, the non-conjugated polymers contain backbone units, which are connected to one another by spacer units. Examples of such triplet emitters which are based on non-conjugated polymers based on backbone units are disclosed, for example, in DE 102009023154.

25

In a further preferred embodiment, the non-conjugated polymer can be designed as fluorescent emitter. Preferred fluorescent emitters which are based on non-conjugated polymers having side chains contain anthracene or benzanthracene groups or derivatives of these groups in the side chain,
30 where these polymers are disclosed, for example, in JP 2005/108556, JP 2005/285661 and JP 2003/338375.

These polymers can frequently be employed as electron- or hole-transport materials, where these polymers are preferably designed as non-conjugated polymers.

5 Furthermore, the functional compounds employed as organic functional materials in the formulations preferably have, in the case of polymeric compounds, a molecular weight M_w of $\geq 10,000$ g/mol, particularly preferably $\geq 20,000$ g/mol and especially preferably $\geq 50,000$ g/mol.

10 The molecular weight M_w of the polymers here is preferably in the range from 10,000 to 2,000,000 g/mol, particularly preferably in the range from 20,000 to 1,000,000 g/mol and very particularly preferably in the range from 50,000 to 300,000 g/mol. The molecular weight M_w is determined by means of GPC (= gel permeation chromatography) against an internal polystyrene
15 standard.

The publications cited above for description of the functional compounds are incorporated into the present application by way of reference for disclosure purposes.

20

The formulations according to the invention may comprise all organic functional materials which are necessary for the production of the respective functional layer of the electronic device. If, for example, a hole-transport, hole-injection, electron-transport or electron-injection layer is built
25 up precisely from one functional compound, the formulation comprises precisely this compound as organic functional material. If an emission layer comprises, for example, an emitter in combination with a matrix or host material, the formulation comprises, as organic functional material, precisely the mixture of emitter and matrix or host material, as described in
30 greater detail elsewhere in the present application.

Besides the said components, the formulation according to the invention may comprise further additives and processing assistants. These include, inter alia, surface-active substances (surfactants), lubricants and greases, additives which modify the viscosity, additives which increase the conductivity, dispersants, hydrophobicising agents, adhesion promoters, flow improvers, antifoams, deaerating agents, diluents, which may be reactive or unreactive, fillers, assistants, processing assistants, dyes, pigments, stabilisers, sensitisers, nanoparticles and inhibitors.

The present invention furthermore relates to a process for the preparation of a formulation according to the invention, wherein the at least first organic solvent, which contains at least one epoxy-group, and the at least one organic functional material, which can be employed for the production of functional layers of electronic devices, are mixed.

A formulation in accordance with the present invention can be employed for the production of a layer or multilayered structure in which the organic functional materials are present in layers, as are required for the production of preferred electronic or opto-electronic components, such as OLEDs.

The formulation of the present invention can preferably be employed for the formation of functional layers on a substrate or one of the layers applied to the substrate. The substrates can either have bank structures or not.

The present invention likewise relates to a process for the production of an electronic device in which a formulation according to the present invention is applied to a substrate and dried.

The functional layers can be produced, for example, by flood coating, dip coating, spray coating, spin coating, screen printing, relief printing, gravure printing, rotary printing, roller coating, flexographic printing, offset printing or

nozzle printing, preferably ink-jet printing on a substrate or one of the layers applied to the substrate.

5 After the application of a formulation according to the invention to a substrate or a functional layer already applied, a drying step can be carried out in order to remove the solvent from the continuous phase described above. The drying can preferably be carried out at relatively low temperature and over a relatively long period in order to avoid bubble formation and to obtain a uniform coating. The drying can preferably be carried out at a
10 temperature in the range from 80 to 300°C, more preferably 150 to 250°C and most preferably 160 to 200°C. The drying here can preferably be carried out at a pressure in the range from 10^{-6} mbar to 2 bar, more preferably in the range from 10^{-2} mbar to 1 bar and most preferably in the range from 10^{-1} mbar to 100 mbar. During the drying process, the
15 temperature of the substrates can be vary from -15°C to 250°C. The duration of the drying depends on the degree of drying to be achieved, where small amounts of water can optionally be removed at relatively high temperature and in combination with sintering, which is preferably to be carried out.

20 It may furthermore be provided that the process is repeated a number of times, with formation of different or identical functional layers. Crosslinking of the functional layer formed can take place here in order to prevent dissolution thereof, as is disclosed, for example, in EP 0 637 899 A 1.

25 The present invention also relates to an electronic device obtainable by a process for the production of an electronic device.

30 The present invention furthermore relates to an electronic device having at least one functional layer comprising at least one organic functional material which is obtainable by the above-mentioned process for the production of an electronic device.

An electronic device is taken to mean a device which comprises anode, cathode and at least one functional layer in between, where this functional layer comprises at least one organic or organometallic compound.

5

The organic electronic device is preferably an organic electroluminescent device (OLED), a polymeric electroluminescent device (PLED), an organic integrated circuit (O-IC), an organic field-effect transistor (O-FET), an organic thin-film transistor (O-TFT), an organic, light-emitting transistor (O-LET), an organic solar cell (O-SC), an organic photovoltaic (OPV) cell, an organic, optical detector, an organic photoreceptor, an organic field-quench device (O-FQD), an organic electrical sensor, a light-emitting electrochemical cell (LEC) or an organic laser diode (O-laser), more preferably an organic electroluminescent device (OLED) or a polymeric electroluminescent device (PLED).

10
15

Active components are generally the organic or inorganic materials which are introduced between the anode and the cathode, where these active components effect, maintain and/or improve the properties of the electronic device, for example its performance and/or its lifetime, for example charge-injection, charge-transport or charge-blocking materials, but in particular emission materials and matrix materials. The organic functional material which can be employed for the production of functional layers of electronic devices accordingly preferably comprises an active component of the electronic device.

20

25

Organic electroluminescent devices are a preferred embodiment of the present invention. The organic electroluminescent device comprises a cathode, an anode and at least one emitting layer.

30

It is furthermore preferred to employ a mixture of two or more triplet emitters together with a matrix. The triplet emitter having the shorter-wave

emission spectrum serves as co-matrix here for the triplet emitter having the longer-wave emission spectrum.

5 The proportion of the matrix material in the emitting layer in this case is preferably between 50 and 99.9% by vol., more preferably between 80 and 99.5% by vol. and most preferably between 92 and 99.5% by vol. for fluorescent emitting layers and between 85 and 97% by vol. for phosphorescent emitting layers.

10 Correspondingly, the proportion of the dopant is preferably between 0.1 and 50% by vol., more preferably between 0.5 and 20% by vol. and most preferably between 0.5 and 8% by vol. for fluorescent emitting layers and between 3 and 15% by vol. for phosphorescent emitting layers.

15 An emitting layer of an organic electroluminescent device may also encompass systems which comprise a plurality of matrix materials (mixed-matrix systems) and/or a plurality of dopants. In this case too, the dopants are generally the materials whose proportion in the system is the smaller and the matrix materials are the materials whose proportion in the system is the
20 greater. In individual cases, however, the proportion of an individual matrix material in the system may be smaller than the proportion of an individual dopant.

The mixed-matrix systems preferably comprise two or three different matrix
25 materials, more preferably two different matrix materials. One of the two materials here is preferably a material having hole-transporting properties and the other material is a material having electron-transporting properties. However, the desired electron-transporting and hole-transporting properties of the mixed-matrix components may also be combined principally or
30 completely in a single mixed-matrix component, where the further mixed-matrix component(s) fulfil(s) other functions. The two different matrix materials may be present here in a ratio of 1:50 to 1:1, preferably 1:20 to

1:1, more preferably 1:10 to 1:1 and most preferably 1:4 to 1:1. Mixed-matrix systems are preferably employed in phosphorescent organic electroluminescent devices. Further details on mixed-matrix systems can be found, for example, in WO 2010/108579.

5

Apart from these layers, an organic electroluminescent device may also comprise further layers, for example in each case one or more hole-injection layers, hole-transport layers, hole-blocking layers, electron-transport layers, electron-injection layers, exciton-blocking layers, electron-blocking layers, charge-generation layers (IDMC 2003, Taiwan; Session 21
10 OLED (5), T. Matsumoto, T. Nakada, J. Endo, K. Mori, N. Kawamura, A. Yokoi, J. Kido, *Multiphoton Organic EL Device Having Charge Generation Layer*) and/or organic or inorganic p/n junctions. It is possible here for one or more hole-transport layers to be p-doped, for example with metal oxides,
15 such as **M0O3** or **WO3**, or with (per)fluorinated electron-deficient aromatic compounds, and/or for one or more electron-transport layers to be n-doped. It is likewise possible for interlayers, which have, for example, an exciton-blocking function and/or control the charge balance in the electro-
luminescent device, to be introduced between two emitting layers. How-
20 ever, it should be pointed out that each of these layers does not necessarily have to be present. These layers may likewise be present on use of the formulations according to the invention, as defined above.

25

In a further embodiment of the present invention, the device comprises a plurality of layers. The formulation according to the present invention can preferably be employed here for the production of a hole-transport, hole-injection, electron-transport, electron-injection and/or emission layer.

30

The present invention accordingly also relates to an electronic device which comprises at least three layers, but in a preferred embodiment all said layers, from hole-injection, hole-transport, emission, electron-transport, electron-injection, charge-blocking and/or charge-generation layer and in

which at least one layer has been obtained by means of a formulation to be employed in accordance with the present invention. The thickness of the layers, for example the hole-transport and/or hole-injection layer, can preferably be in the range from 1 to 500 nm, more preferably in the range
5 from 2 to 200 nm.

The device may furthermore comprise layers built up from further low-molecular-weight compounds or polymers which have not been applied by the use of formulations according to the present invention. These can also
10 be produced by evaporation of low-molecular-weight compounds in a high vacuum.

It may additionally be preferred to use the compounds to be employed not as the pure substance, but instead as a mixture (blend) together with further polymeric, oligomeric, dendritic or low-molecular-weight substances of
15 any desired type. These may, for example, improve the electronic properties or themselves emit.

In a preferred embodiment of the present invention, the formulations
20 according to the invention comprise organic functional materials which are employed as host materials or matrix materials in an emitting layer. The formulation here may comprise the emitters described above in addition to the host materials or matrix materials. The organic electroluminescent device here may comprise one or more emitting layers. If a plurality of
25 emission layers are present, these preferably have a plurality of emission maxima between 380 nm and 750 nm, resulting overall in white emission, i.e. various emitting compounds which are able to fluoresce or phosphoresce are used in the emitting layers. Very particular preference is given to three-layer systems, where the three layers exhibit blue, green and orange
30 or red emission (for the basic structure see, for example, WO 2005/011013). White-emitting devices are suitable, for example, as backlighting of LCD displays or for general lighting applications.

It is also possible for a plurality of OLEDs to be arranged one above the other, enabling a further increase in efficiency with respect to the light yield to be achieved.

5

In order to improve the coupling-out of light, the final organic layer on the light-exit side in OLEDs can, for example, also be in the form of a nano-foam, resulting in a reduction in the proportion of total reflection.

10

Preference is furthermore given to an organic electroluminescent device in which one or more layers are applied by means of a sublimation process, in which the materials are applied by vapour deposition in vacuum sublimation units at a pressure below 10^{-5} mbar, preferably below 10^{-6} mbar, more preferably below 10^{-7} mbar.

15

It may furthermore be provided that one or more layers of an electronic device according to the present invention are applied by means of the OVPD (organic vapour phase deposition) process or with the aid of carrier-gas sublimation, in which the materials are applied at a pressure between

20

10^{-5} mbar and 1 bar.

It may furthermore be provided that one or more layers of an electronic device according to the present invention are produced from solution, such as, for example, by spin coating, or by means of any desired printing process, such as, for example, screen printing, flexographic printing or

25

offset printing, but particularly preferably LITI (light induced thermal imaging, thermal transfer printing) or ink-jet printing.

30

These layers may also be applied by a process in which no compound of the formula (I), (II), (IIa), (III) or (IIia) is employed. An orthogonal solvent can preferably be used here, which, although dissolving the functional

material of a layer to be applied, does not dissolve the layer to which the functional material is applied.

5 The device usually comprises a cathode and an anode (electrodes). The electrodes (cathode, anode) are selected for the purposes of the present invention in such a way that their band energies correspond as closely as possible to those of the adjacent, organic layers in order to ensure highly efficient electron or hole injection.

10 The cathode preferably comprises metal complexes, metals having a low work function, metal alloys or multilayered structures comprising various metals, such as, for example, alkaline-earth metals, alkali metals, main-group metals or lanthanoids (for example Ca, Ba, Mg, Al, In, Mg, Yb, Sm, etc.). In the case of multilayered structures, further metals which have a
15 relatively high work function, such as, for example, Ag and Ag nanowire (Ag NW) can also be used in addition to the said metals, in which case combinations of the metals, such as, for example, Ca/Ag or Ba/Ag, are generally used. It may also be preferred to introduce a thin interlayer of a material having a high dielectric constant between a metallic cathode and
20 the organic semiconductor. Suitable for this purpose are, for example, alkali-metal or alkaline-earth metal fluorides, but also the corresponding oxides (for example LiF, U₂O, BaF₂, MgO, NaF, etc.). The layer thickness of this layer is preferably between 0.1 and 10 nm, more preferably between 0.2 and 8 nm, and most preferably between 0.5 and 5 nm.

25 The anode preferably comprises materials having a high work function. The anode preferably has a potential greater than 4.5 eV vs. vacuum. Suitable for this purpose are on the one hand metals having a high redox potential, such as, for example, Ag, Pt or Au. On the other hand, metal/metal oxide
30 electrodes (for example Al/Ni/NiO_x, Al/PtO_x) may also be preferred. For some applications, at least one of the electrodes must be transparent in order to facilitate either irradiation of the organic material (O-SCs) or the

coupling-out of light (OLEDs/PLEDs, O-lasers). A preferred structure uses a transparent anode. Preferred anode materials here are conductive, mixed metal oxides. Particular preference is given to indium tin oxide (ITO) or indium zinc oxide (IZO). Preference is furthermore given to conductive, doped organic materials, in particular conductive, doped polymers, such as, for example, poly(ethylenedioxythiophene) (PEDOT) and polyaniline (PANI) or derivatives of these polymers. It is furthermore preferred for a p-doped hole-transport material to be applied as hole-injection layer to the anode, where suitable p-dopants are metal oxides, for example MOO_3 or WO_3 , or (per)fluorinated electron-deficient aromatic compounds. Further suitable p-dopants are HAT-CN (hexacyanohexaazatriphenylene) or the compound NPD9 from Novaled. A layer of this type simplifies hole injection in materials having a low HOMO, i.e. an HOMO with a large value.

in general, all materials as are used for the layers in accordance with the prior art can be used in the further layers, and the person skilled in the art will be able to combine each of these materials with the materials according to the invention in an electronic device without inventive step.

The device is correspondingly structured in a manner known per se, depending on the application, provided with contacts and finally hermetically sealed, since the lifetime of such devices is drastically shortened in the presence of water and/or air.

The formulations according to the invention and the electronic devices, in particular organic electroluminescent devices, obtainable therefrom are distinguished over the prior art by one or more of the following surprising advantages:

1. The electronic devices obtainable using the formulations according to the invention exhibit very high stability and a very long lifetime compared with electronic devices obtained using conventional methods.

2. The formulations according to the invention can be processed using conventional methods, so that cost advantages can also be achieved thereby.

5

3. The organic functional materials employed in the formulations according to the invention are not subject to any particular restrictions, enabling the process of the present invention to be employed comprehensively.

10

4. The coatings obtainable using the formulations of the present invention exhibit excellent quality, in particular with respect to the uniformity of the coating.

15

These above-mentioned advantages are not accompanied by an impairment of the other electronic properties.

It should be pointed out that variations of the embodiments described in the present invention fall within the scope of this invention. Each feature disclosed in the present invention can, unless this is explicitly excluded, be replaced by alternative features which serve the same, an equivalent or a similar purpose. Thus, each feature disclosed in the present invention is, unless stated otherwise, to be regarded as an example of a generic series or as an equivalent or similar feature.

20

25

All features of the present invention can be combined with one another in any way, unless certain features and/or steps are mutually exclusive. This applies, in particular, to preferred features of the present invention. Equally, features of non-essential combinations can be used separately (and not in combination).

30

5 It should furthermore be pointed out that many of the features, and in particular those of the preferred embodiments of the present invention, are themselves inventive and are not to be regarded merely as part of the embodiments of the present invention. For these features, independent protection can be sought in addition or as an alternative to each invention presently claimed.

10 The teaching on technical action disclosed with the present invention can be abstracted and combined with other examples.

The invention is explained in greater detail below with reference to working examples, but without being restricted thereby.

15 The person skilled in the art will be able to use the descriptions to produce further electronic devices according to the invention without the need to employ inventive skill and thus can carry out the invention throughout the range claimed.

20

25

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Working Examples

The working examples presented below were made using the device structure shown in Figure 1. The hole-injection layer (HIL) and hole transport layer (HTL) of all examples were prepared by an inkjet printing process to achieve the desired thickness. For the emissive layer, the individual solvents used in Examples 1 to 12 are listed in Table 2 below:

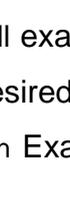
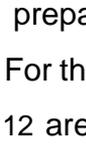
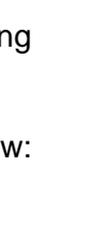
	Solvent(s) used	Viscosity (cPoise)	Surface Tension (dyne/cm)	Boiling point (°C)
10	1,2-epoxydodecane $\text{CH}_3(\text{CH}_2)_{10}\text{CH}_2$ 	2.36	28.70	251
	3-phenoxytoluene 	4.40	37.40	271
15	Limonene oxide 	1.78	29.05	270
20	Alpha-pinene oxide 	3.67	29.14	295
	1,2-epoxy decane $\text{CH}_3(\text{CH}_2)_8\text{CH}_2$ 	1.70	26.34	214
25	1,2-epoxy hexadecane $\text{CH}_3(\text{CH}_2)_{14}\text{CH}_2$ 	(solid)	(solid)	322
	1,2-epoxy tetradecane $\text{CH}_3(\text{CH}_2)_{12}\text{CH}_2$ 	3.80	30.69	297
30	1,2-epoxy cyclododecane 	15.0	36.0	274

Table 2: List of solvents used in Examples 1 to 12

The viscosity of the formulations and solvents was measured using a TA instruments ARG2 rheometer over a shear rate range of 10 to 1000 s⁻¹ using 40 mm parallel plate geometry. Measurement was taken as an average between 200 to 800 s⁻¹ where the temperature and shear rate are exactly controlled. The viscosities given in Table 3 are the viscosities of each formulation measured at a temperature of 25°C and a shear rate of 500 s⁻¹. Each solvent is measured three times. The stated viscosity value is averaged over said measurements.

Preferably, the organic solvent blend can comprise a surface tension in the range from 15 to 80 mN/m, more preferably in the range from 20 to 60 mN/m and most preferably in the range from 25 to 40 mN/m. The surface tension can be measured using a FTA (First Ten Angstrom) 1000 contact angle goniometer at 20°C. Details of the method are available from First Ten Angstrom as published by Roger P. Woodward, Ph.D. "Surface Tension Measurements Using the Drop Shape Method". Preferably, the pendant drop method can be used to determine the surface tension. All measurements were performed at room temperature being in the range between 20°C and 22°C. For each formulation three drops are measured. The final value is averaged over said measurements. The tool is regularly cross-checked against various liquids having well known surface tensions.

Examples 1 to 12 are fabricated by using the same architecture where the HIL and HTL are inject printed to achieve same thicknesses. The solvent(s) used in the EML are different and the details are listed in Table 3

Example	Layer	Solvent(s)/(%)	Cone. (g/L)	Solvent(s) viscosity (cPoise)	Solvent(s) surface tension (dyne/cm)
5	1 Green EML	1,2-epoxydodecane (100%)	20	29	2.4
	2 Green EML	1,2-epoxydodecane (80%) : 3-phenoxytoluene (20%)	20		
	3 Green EML	1,2-epoxydodecane (60%) : 3-phenoxytoluene (40%)	20		
10	4 Green EML	1,2-epoxydodecane (50%) : 3-phenoxytoluene (50%)	20		
	5 Green EML	1,2-epoxydodecane (40%) : 3-phenoxytoluene (60%)	20		
	6 Green EML	1,2-epoxydodecane (20%) : 3-phenoxytoluene (80%)	20		
15	7 Green EML	Limonene oxide (50%) : 3-phenoxytoluene (50%)	20		
	8 Green EML	Alpha-pinene oxide (50%) 3-phenoxytoluene (50%)	20		
	9 Green EML	1,2-epoxydecane (100%)	14	27	1.7
20	10 Green EML	1,2-epoxy tetradecane (100%)	14	31	3.8
	11 Green EML	1,2-epoxycyclododecane (30%) 1,2-epoxydodecane (70%)	14	31.5	3.2
25	12 Green EML	1,2-epoxyhexadecane (50%) 1,2-epoxydodecane (50%)	14	30.5	3.3

table 3: Details of formulations used in Examples 1 to 12

Description of the Fabrication Process

30 Glass substrates covered with pre-structured ITO and bank material were cleaned using ultrasonication in isopropanol followed by de-ionized water, then dried using an air-gun and a subsequent annealing on a hot-plate at 230°C for 2 hours.

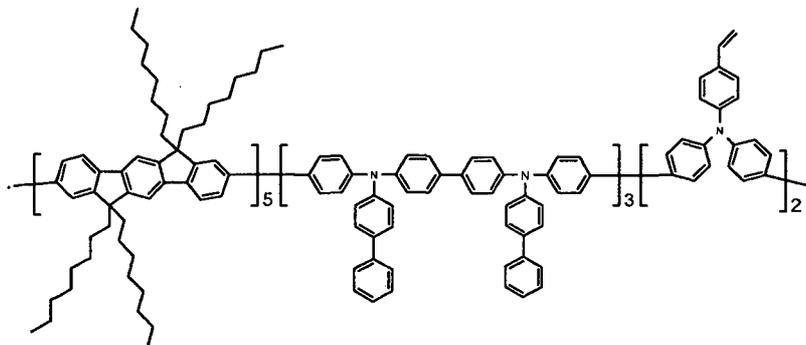
A hole-injection layer (HIL) using PEDOT-PSS (Clevios AI4083, Heraeus) was inkjet-printed onto the substrate and dried in vacuum. The HIL was then annealed at 185°C for 30 minutes in air.

5

On top of the HIL, a hole-transport layer (HTL) was inkjet-printed, dried in vacuum and annealed at 210°C for 30 minutes in nitrogen atmosphere. As material for the hole-transport layer polymer HTM-1 was used. The structure of the polymer HTM-1 is the following:

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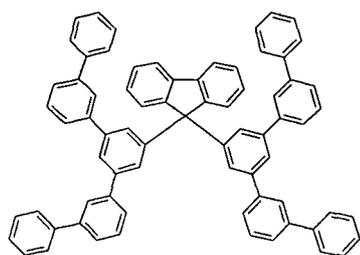


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The green emissive layer (G-EML) was also inkjet-printed, vacuum dried and annealed at 160°C for 10 minutes in nitrogen atmosphere. The ink for the green emissive layer contained in all working examples two host materials (i.e. HM-1 and HM-2) as well as one triplett emitter (EM-1). The materials were used in the following ratio: HM-1 : HM-2 : EM-1 = 40 : 40 : 20. Only the solvent(s) differ from example to example, as can be seen from Table 3. The structures of these materials are the following:

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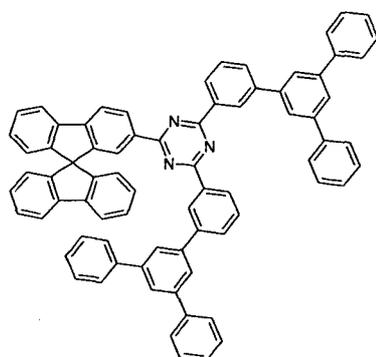
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HM-1

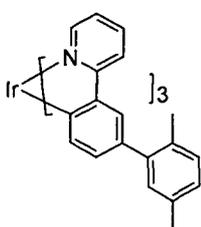
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HM-2

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EM-1

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All the inkjet printing processes were done under yellow light and under ambient conditions.

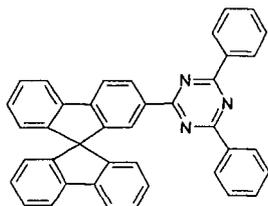
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The devices were then transferred into the vacuum deposition chamber where the deposition of a hole blocking layer (HBL), an electron-transport layer (ETL), and a cathode (Al) was done using thermal evaporation. The devices were then characterized in the glovebox.

25

As a hole-blocking material for the hole blocking layer ETM-1 was used. The material has the following structure:

30



ETM-1

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In the electron transport layer (ETL) a 50:50 mixture of ETM-1 and LiQ was used. LiQ is lithium 8-hydroxyquinolate.

5 To measure the OLED performance in current density-luminance-voltage performance, the device is driven by sweeping voltage from -5V to 25 V provided by a Keithley 2400 source measure unit. The voltage over the OLED device as well as the current through the OLED devices are recorded by the Keithley 2400 SMU. The brightness of the device is detected with a calibrated photodiode. The photo current is measured with
10 a Keithley 6485/E picoammeter. For the spectra, the brightness sensor is replaced by a glass fiber which is connected to an Ocean Optics USB2000+ spectrometer.

Results and Discussion

15

Example 1

An inkjet printed OLED device is prepared with the printed layer using 1,2-epoxydodecane as solvent for the emissive layer. The structure of the pixelated OLED device is glass / ITO / HIL (40 nm) / HTM (20 nm) / EML
20 (60nm) / HBL (10 nm) / ETL (40 nm) / Al whereby the bank was pre-fabricated on the substrate to form pixelated device. In this case, the green emissive materials dissolved in 1,2-epoxydodecane at 20 mg/ml concentration.

25 The luminance efficiency at 5000 cd/m² is 51.96 cd/A. The efficiency of this OLED device is very good but the voltage at 5000 cd/m² is high at 18.1 V.

Examples 2 to 12

Inkjet printed OLED devices are prepared with the printed layers using the
30 solvent(s) for the emissive layer as described in Table 3. The structure of the pixelated OLED devices was in all examples the same as in Example 1.

Example 2

At $L = 5000 \text{ cd/m}^2$, the luminance efficiency is 45.15 cd/A and 19.08 V. The efficiency of this OLED device shows good values. The changes in formulation composition can have various advantages in creating wide range of formulations with different physical properties that can improve processing windows.

Example 3

At $L = 5000 \text{ cd/m}^2$, the luminance efficiency is 46.42 cd/A. The efficiency of this OLED device shows good values. The changes in formulation composition can have various advantages in creating wide range of formulations with different physical properties that can improve processing windows. The efficiency of this OLED device shows very good values and the voltage at 5000 cd/m^2 is lower compared to Example 1 and 2 at 13.51 V.

Example 4

At $L = 5000 \text{ cd/m}^2$, the luminance efficiency is 51-70 cd/A. The efficiency of this OLED device shows good values and the voltage at 5000 cd/m^2 is very low at 8.12 V.

Example 5

At $L = 5000 \text{ cd/m}^2$, the luminance efficiency is 40.41 cd/A. The decrease of epoxy solvent in the formulation in Example 5 has impact on efficiency and voltage (15.76 V).

Example 6

At $L = 5000 \text{ cd/m}^2$, the voltage is 14.43 V and the luminance efficiency is 47.49 cd/A. The efficiency is a good value but the voltage applied at 5000 cd/m^2 is relatively high.

Example 7

At $L = 5000 \text{ cd/m}^2$, the luminance efficiency is 40.19 cd/A. This example demonstrated another epoxy solvent, limonene oxide mixed with 3-phenoxytoluene that achieved reasonable efficiency above 40 cd/A but the
5 voltage applied at 5000 cd/m^2 is relatively high at around 14.46 V.

Example 8

At $L = 5000 \text{ cd/m}^2$, the luminance efficiency is 32.62 cd/A. This example demonstrated another epoxy solvent, alpha pinene oxide mixed with 3-
10 phenoxytoluene that achieved reasonable efficiency around 33 cd/A but the voltage applied at 5000 cd/m^2 is relatively high at around 11 V.

Example 9

At $L = 5000 \text{ cd/m}^2$, the luminance efficiency is 57.56 cd/A. This example
15 using 1,2-epoxydecane demonstrated highest efficiency value among all the epoxy group containing solvents used in Examples 1 to 12, with the voltage applied at 5000 cd/m^2 is pretty low at around 9.47 V.

Example 10

At $L = 5000 \text{ cd/m}^2$, the luminance efficiency is 32.78 cd/A. This example
20 using 1,2-epoxytetradecane demonstrated lowest efficiency value among all the epoxy solvents in Examples 1 to 12, with the voltage applied at 5000 cd/m^2 is relatively low at around 10.1 V. The reason is that 1,2-epoxytetradecane has a relatively high boiling point at 297°C .

25

Example 11

At a voltage of 16.79V and $L = 5000 \text{ cd/m}^2$, the luminance efficiency is
43.95 cd/A. This example showed large processing window for epoxy
based solvents including high viscosity solvent like 1,2-epoxy-
30 cyclododecane at 15 cPoise that can also be used as inkjet printing solvent.

Example 12

At $L = 5000 \text{ cd/m}^2$, the luminance efficiency is very high and achieved 52.96 cd/A at around 11 V of operating voltage. This example showed large processing window for epoxy based solvents including solid epoxy group
5 containing solvent like 1,2-epoxyhexadodecane that can also be used as part of inkjet printing solvent.

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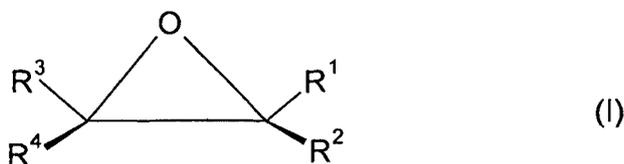
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Patent Claims

1. Formulation containing at least one organic functional material and at least a first organic solvent, wherein said first organic solvent contains at least one epoxy-group, preferably one epoxy-group.
2. Formulation according to claim 1, wherein the first organic solvent, which contains one epoxy group, is an epoxy group containing solvent according to general formula (I)



wherein

R^1 , R^2 , R^3 and R^4 are identical or different at each occurrence, and are H, D, F, Cl, Br, I, NO₂, CN, a straight-chain alkyl or alkoxy group having from 1 to 20 carbon atoms or a branched or cyclic alkyl or alkoxy group having from 3 to 20 carbon atoms, in which one or more nonadjacent CH₂ groups may be replaced by -O-, -S-, -NR⁵-, -CONR⁵-, -CO-O-, -C=O-, -CH=CH- or -C≡C-, and in which one or more hydrogen atoms may be replaced by F, or an aryl or heteroaryl group which has from 4 to 14 carbon atoms and may be substituted by one or more nonaromatic R⁵ radicals, and a plurality of substituents R⁵, either on the same ring or on the two different rings, may together in turn form a mono- or polycyclic, aliphatic or aromatic ring system, which may be substituted by a plurality of substituents R⁵;

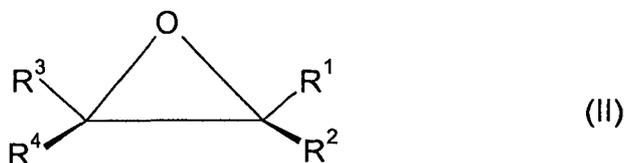
R⁵ are identical or different at each instance, and are a straight-chain alkyl or alkoxy group having from 1 to 20 carbon atoms or a branched or cyclic alkyl or alkoxy group having from 3 to 20 carbon atoms, in which one or more nonadjacent CH₂ groups may be

replaced by -O-, -S-, -CO-O-, -C=O-, -CH=CH- or -C≡C-, and in which one or more hydrogen atoms may be replaced by F, or an aryl or heteroaryl group which has from 4 to 14 carbon atoms and may be substituted by one or more nonaromatic R⁵ radicals.

5

3. Formulation according to claim 1 or 2, wherein the first organic solvent, which contains one epoxy group, is an epoxy group containing solvent according to general formula (II)

10



wherein

15

R¹ and R³ is H, D, F, Cl, Br, I, NO₂, CN, a straight-chain alkyl or alkoxy group having from 1 to 20 carbon atoms or a branched or cyclic alkyl or alkoxy group having from 3 to 20 carbon atoms, in which one or more nonadjacent CH₂ groups may be replaced by -O-, -S-, -NR⁵-, -CONR⁵-, -CO-O-, -C=O-, -CH=CH- or -C≡C-, and in which one or more hydrogen atoms may be replaced by F, or an aryl or heteroaryl group which has from 4 to 14 carbon atoms and may be substituted by one or more nonaromatic R⁵ radicals, and a plurality of substituents R⁵, either on the same ring or on the two different rings, may together in turn form a mono- or polycyclic, aliphatic or aromatic ring system, which may be substituted by a plurality of substituents R⁵;

20

25

R² and R⁴ form together a mono- or polycyclic, aliphatic or aromatic ring system, which may be substituted by a plurality of substituents R⁵; R⁵ are identical or different at each instance, and are a straight-chain alkyl or alkoxy group having from 1 to 20 carbon atoms or a branched or cyclic alkyl or alkoxy group having from 3 to 20 carbon atoms, in which one or more nonadjacent CH₂ groups may be

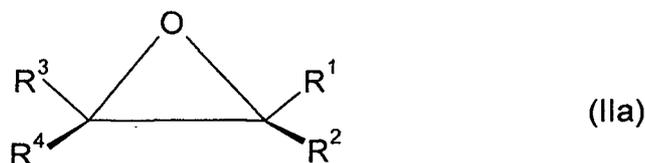
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replaced by -O-, -S-, -CO-O-, -C=O-, -CH=CH- or -C≡C-, and in which one or more hydrogen atoms may be replaced by F, or an aryl or heteroaryl group which has from 4 to 14 carbon atoms and may be substituted by one or more nonaromatic R⁵ radicals.

5

4. Formulation according to one or more of claims 1 to 3, wherein the first organic solvent, which contains one epoxy group, is an epoxy group containing solvent according to general formula (IIa)

10



wherein

15

R¹ is H

R³ is H, D, F, Cl, Br, I, NO₂, CN, a straight-chain alkyl or alkoxy group having from 1 to 20 carbon atoms or a branched or cyclic alkyl or alkoxy group having from 3 to 20 carbon atoms, in which one or more nonadjacent CH₂ groups may be replaced by -O-, -S-, -NR⁵-, -CONR⁵-, -CO-O-, -C=O-, -CH=CH- or -C≡C-, and in which one or more hydrogen atoms may be replaced by F, or an aryl or heteroaryl group which has from 4 to 14 carbon atoms and may be substituted by one or more nonaromatic R⁵ radicals, and a plurality of substituents R⁵, either on the same ring or on the two different rings, may together in turn form a mono- or polycyclic, aliphatic or aromatic ring system, which may be substituted by a plurality of substituents R⁵;

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R² and R⁴ form together a mono- or polycyclic, aliphatic or aromatic ring system, which may be substituted by a plurality of substituents R⁵;

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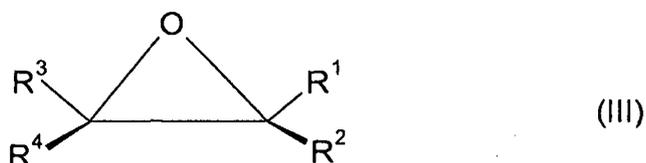
R⁵ are identical or different at each instance, and are a straight-chain alkyl or alkoxy group having from 1 to 20 carbon atoms or a branched or cyclic alkyl or alkoxy group having from 3 to 20 carbon

atoms, in which one or more nonadjacent CH₂ groups may be replaced by -O-, -S-, -CO-O-, -C=O-, -CH=CH- or -C≡C-, and in which one or more hydrogen atoms may be replaced by F, or an aryl or heteroaryl group which has from 4 to 14 carbon atoms and may be substituted by one or more nonaromatic R⁵ radicals.

5

5. Formulation according to claim 1 or 2, wherein the first organic solvent, which contains one epoxy group, is an epoxy group containing solvent according to general formula (III)

10



15

wherein

R¹, R², R³ and R⁴ are identical or different at each occurrence, and are H, D, F, Cl, Br, I, NO₂, CN, a straight-chain alkyl or alkoxy group having from 1 to 20 carbon atoms or a branched or cyclic alkyl or alkoxy group having from 3 to 20 carbon atoms, in which one or more nonadjacent CH₂ groups may be replaced by -O-, -S-, -NR⁵-, -CONR⁵-, -CO-O-, -C=O-, -CH=CH- or -C≡C-, and in which one or more hydrogen atoms may be replaced by F, or an aryl or heteroaryl group which has from 4 to 14 carbon atoms and may be substituted by one or more nonaromatic R⁵ radicals, and a plurality of substituents R⁵, either on the same ring or on the two different rings, may together in turn form a mono- or polycyclic, aliphatic or aromatic ring system, which may be substituted by a plurality of substituents R⁵; and R⁵ are identical or different at each instance, and are a straight-chain alkyl or alkoxy group having from 1 to 20 carbon atoms or a branched or cyclic alkyl or alkoxy group having from 3 to 20 carbon atoms, in which one or more nonadjacent CH₂ groups may be

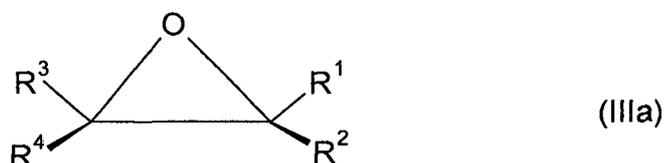
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replaced by -O-, -S-, -CO-O-, -C=O-, -CH=CH- or -C≡C-, and in which one or more hydrogen atoms may be replaced by F, or an aryl or heteroaryl group which has from 4 to 14 carbon atoms and may be substituted by one or more nonaromatic R⁵ radicals.

5

6. Formulation according to claim 1 or 2, wherein the first organic solvent, which contains one epoxy group, is an epoxy group containing solvent according to general formula (IIia)

10



15

wherein

R¹, R² and R³ are H;

R⁴ is a straight-chain alkyl or alkoxy group having from 1 to 20 carbon atoms or a branched or cyclic alkyl or alkoxy group having from 3 to 20 carbon atoms, in which one or more nonadjacent CH₂ groups may be replaced by -O-, -S-, -NR⁵-, -CONR⁵-, -CO-O-, -C=O-, -CH=CH- or -C≡C-, and in which one or more hydrogen atoms may be replaced by F, or an aryl or heteroaryl group which has from 4 to 14 carbon atoms and may be substituted by one or more nonaromatic R⁵ radicals, and a plurality of substituents R⁵, either on the same ring or on the two different rings, may together in turn form a mono- or polycyclic, aliphatic or aromatic ring system, which may be substituted by a plurality of substituents R⁵; and

25

30

R⁵ are identical or different at each instance, and are a straight-chain alkyl or alkoxy group having from 1 to 20 carbon atoms or a branched or cyclic alkyl or alkoxy group having from 3 to 20 carbon atoms, in which one or more nonadjacent CH₂ groups may be replaced by -O-, -S-, -CO-O-, -C=O-, -CH=CH- or -C≡C-, and in which

one or more hydrogen atoms may be replaced by F, or an aryl or heteroaryl group which has from 4 to 14 carbon atoms and may be substituted by one or more nonaromatic R⁵ radicals.

- 5 7. Formulation according to one or more of claims 1 to 6, wherein the first solvent has a surface tension of ≥ 25 mN/m.
8. Formulation according to one or more of claims 1 to 7, wherein the content of the first solvent is in the range from 50 to 100 vol.-%, based on the total amount of solvents in the formulation.
- 10 9. Formulation according to one or more of claims 1 to 8, wherein the first solvent has a boiling point in the range from 100 to 400°C.
- 15 10. Formulation according to one or more of claims 1 to 9, wherein the formulation comprises at least one second solvent which is different from the first solvent.
- 20 11. Formulation according to one or more of claims 1 to 10, wherein the second solvent has a boiling point in the range from 100 to 400°C.
12. Formulation according to one or more of claims 1 to 11, wherein the at least one organic functional material has a solubility in the first as well as in the second solvent in the range from 1 to 250 g/l.
- 25 13. Formulation according to one or more of claims 1 to 12, wherein the formulation has a surface tension in the range from 1 to 70 mN/m.
14. Formulation according to one or more of claims 1 to 13, wherein the formulation has a viscosity in the range from 1 to 50 mPa·s.
- 30 15. Formulation according to one or more of claims 1 to 14, wherein the content of the at least one organic functional material in the

formulation is in the range from 0.001 to 20 weight-%, based on the total weight of the formulation.

- 5 16. Formulation according to one or more of claims 1 to 15, wherein the at least one organic functional material is selected from the group consisting of organic conductors, organic semiconductors, organic fluorescent compounds, organic phosphorescent compounds, organic light-absorbent compounds, organic light-sensitive compounds, organic photosensitisation agents and other organic photoactive
- 10 compounds such as organometallic complexes of transition metals, rare earths, lanthanides and actinides.
17. Formulation according to claim 16, wherein the at least one organic functional material is selected from the group consisting of fluorescent
- 15 emitters, phosphorescent emitters, host materials, matrix materials, exciton-blocking materials, electron-transport materials, electron-injection materials, hole-conductor materials, hole-injection materials, n-dopants, p-dopants, wide-band-gap materials, electron-blocking materials and hole-blocking materials.
- 20 18. Formulation according to claim 16, wherein the at least one organic functional material is an organic semiconductor selected from the group consisting of hole-injecting, hole-transporting, emitting, electron-transporting and electron-injecting materials.
- 25 19. Formulation according to claim 18, wherein the at least one organic semiconductor is selected from the group consisting of hole-injecting and hole-transporting materials.
- 3^Q 20. Formulation according to claim 19, wherein the hole-injecting and hole-transporting material is a polymeric compound or a blend of a polymeric compound and a non-polymeric compound.

21. Process for the preparation of a formulation according to one or more of claims 1 to 20, wherein the at least one organic functional material and the at least first solvent are mixed.
- 5 22. Process for the preparation of an electroluminescent device, wherein at least one layer of the electroluminescent device is prepared in that a formulation according to one of more of claims 1 to 20 is deposited, preferably printed, on a surface and subsequently dried.
- 10 23. Electroluminescent device, wherein at least one layer is prepared in that a formulation according to one or more of claims 1 to 20 is deposited, preferably printed, on a surface and subsequently dried.

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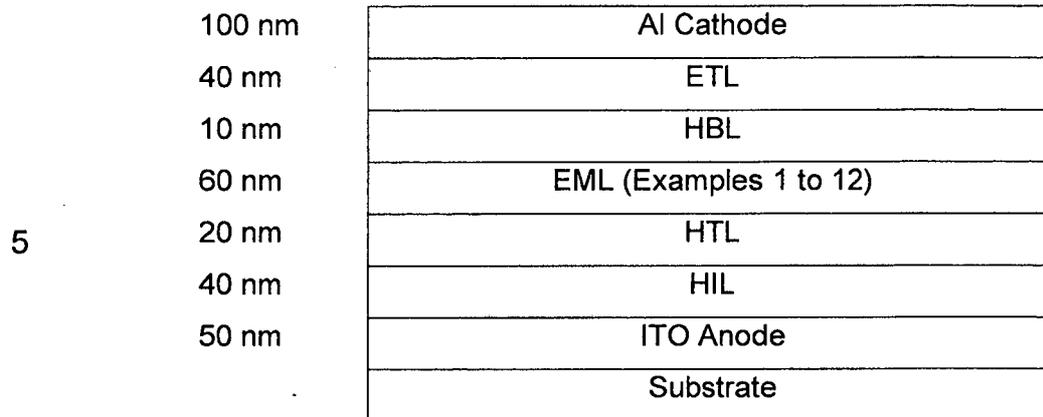


Figure 1

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INTERNATIONAL SEARCH REPORT

International application No PCT/EP2016/001318
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A. CLASSIFICATION OF SUBJECT MATTER
INV. H01L51/00
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)
H01L

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 , WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	wo 2010/147818 AI (UNIVERSAL DISPLAY CORP [US] ; CHEON KWANG-OHK [US] ; XIA CHUANJUN [US] ;) 23 December 2010 (2010-12-23) paragraph [0004] paragraph [0021] - paragraph [0022] paragraph [0024] paragraph [0046] - paragraph [0048] -----	22,23

Further documents are listed in the continuation of Box C. See patent family annex.

* Special categories of cited documents :

<p>"A" document defining the general state of the art which is not considered to be of particular relevance</p> <p>"E" earlier application or patent but published on or after the international filing date</p> <p>"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)</p> <p>"O" document referring to an oral disclosure, use, exhibition or other means</p> <p>"P" document published prior to the international filing date but later than the priority date claimed</p>	<p>"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</p> <p>"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</p> <p>"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</p> <p>"&" document member of the same patent family</p>
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Date of the actual completion of the international search 30 August 2016	Date of mailing of the international search report 06/09/2016
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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 Johnson , Claire
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INTERNATIONAL SEARCH REPORT

International application No.
PCT/EP2016/001318

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. Claims Nos.: $\begin{matrix} 1 & 2^1 \\ \pm & \pm \end{matrix}$
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

see FURTHER INFORMATION sheet PCT/ISA/210

3. Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.

3. As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos. :

4. No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos. :

Remark on Protest

- The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

Continuation of Box 11.2

Claims Nos.: 1-21

Claim 1 is directed to a formulation containing at least one organic functional material and at least one first organic solvent, wherein said first organic solvent contains at least one epoxy-group.

The term "organic functional material" does not have a generally recognized meaning, except in so far as it must comprise an organic moiety. Thus it must be interpreted as simply meaning any material which comprises an organic moiety.

Furthermore, the term "solvent", which might be assumed to mean a compound which is liquid at least at room temperature, apparently does not necessarily have this meaning in the present case, as amongst the preferred "epoxy-group containing solvents" shown in Table 1 on p. 8-10 is a compound which is solid at room temperature (the first compound on p. 10). Thus the term "solvent" does not have any meaning in claim 1 beyond being an entity which has the capability of dissolving an undefined solute.

In view of the above, claim 1 is directed to a composition comprising a material comprising an organic moiety and an organic compound containing at least one epoxy group.

However, considering the extremely limited number of working examples in the application (8 epoxy-containing compounds in a formulation with one type of organic functional material) such a composition not only lacks support and disclosure in the sense of Articles 6 and 5 PCT, it also belongs to the state of the art to such an extent that no meaningful search of such a composition can be performed (for example, any solution or mixture of an organic solvent and an epoxide-containing compound anticipates this claim).

In fact, what the applicant purports to have invented is a way of making organic electronic devices by deposition of a formulation comprising an organic functional material and an epoxide solvent on a substrate and drying said formulation (p. 1, 1. 20 to p. 2, 1. 12). Thus it is not the formulation itself, but rather its use that lies at the core of the invention. This use (or process) feature is considered to be an essential technical feature of the present invention.

The only claim that reflects the invention is process claim 22. As the device of claim 23 is formed by applying the process of claim 23, this claim is also considered to be supported and disclosed as required by Articles 6 and 5 PCT.

The applicant's attention is drawn to the fact that claims relating to inventions in respect of which no international search report has been established need not be the subject of an international preliminary examination (Rule 66.1(e) PCT). The applicant is advised that the EPO policy when acting as an International Preliminary Examining Authority is normally not to carry out a preliminary examination on matter which has not been searched. This is the case irrespective of whether or not the claims are amended following receipt of the search report or during any

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

Chapter II procedure. If the application proceeds into the regional phase before the EPO, the applicant is reminded that a search may be carried out during examination before the EPO (see EPO Guidelines C-IV, 7.2), should the problems which led to the Article 17(2) declaration be overcome.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2016/001318

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
wo 2010147818 AI	23-12-2010	CN 102460759 A	16-05-2012
		EP 2962338 AI	06-01-2016
		JP 5684250 B2	11-03-2015
		JP 2012531012 A	06-12-2012
		KR 20120037409 A	19-04-2012
		TW 201107435 A	01-03-2011
		US 2010323464 AI	23-12-2010
		US 2012270349 AI	25-10-2012
		Wo 2010147818 AI	23-12-2010
