

DECLARATION OF HARALD GIGAS

I, Harald Gigas, pursuant to 28 U.S.C. § 1746, hereby declare as follows:

1. I am a Translator at TransPerfect, Inc. My translation qualifications in the German to English language pair include: more than 10 years of fulltime freelance translation experience, including in patent matters.
2. I submit this declaration to certify the accuracy of the English translation of DE 10 2008 056 391.9.
3. My statements are based on personal knowledge and my review of DE 10 2008 056 391.9 and its German to English translation. If called as a witness about the facts contained in these statements, I could testify competently based on such personal knowledge and the investigation I have conducted.
4. I certify that the attached document translated from German to the English language is a true, correct, and complete translation of the corresponding source text from DE 10 2008 056 391.9.
5. All statements made herein of my own knowledge are true, and all statements made on information and belief are believed to be true. Further, I am aware that these statements are made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under 18 U.S.C. § 1001.

I declare under penalty of perjury under the laws of the United States of America that the foregoing is true and correct. Executed on September 5, 2024, at Ansonia, CT.



HARALD GIGAS
9/5/24

FEDERAL REPUBLIC OF GERMANY



**Priority certificate
DE 10 2008 056 391.9
on the submission of a patent application**

Reference number: 10 2008 056 391.9

Application date: November 7, 2008

Applicant/proprietor: OSRAM Opto Semiconductors GmbH, 93055
Regensburg/DE

Title: Organic electronic component and method for its
manufacture

Priority: September 26, 2008 DE 10 2008 049 286.8

IPC: C09 K 11/06, H 01 L 51/54

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Weiss

Description

Organic electronic component and method for its manufacture

- 5 This patent application claims the priority of the German patent application 10 2008 049 286.8, the disclosure content of which is hereby incorporated by reference.

An organic electronic component according to Claim 1 is specified.

- 10 A widespread problem in organic electronic components is to provide a layer that has a very high electron conductivity. The electron conductivity in the component is often the decisive variable for the efficiency and serviceable life of the component. In the case of an organic LED (OLED), the recombination of electrons forms excitons and holes, which can excite substances to emit radiation. In such components, the luminescence also depends directly on
- 15 the exciton density and in turn on the recombination of electrons and holes. In some components, pure crystalline layers are used for electron transport. These purely crystalline layers have the disadvantage that they comprise areas of different conductivity. As a result, the charge carriers always choose the path of the least resistance. This results in a non-uniform electron flow in this layer. At the points where a significantly increased electron
- 20 flow occurs, the layers can overheat and thus incur damage. In the case of electroluminescent components, this irregular electron flow also leads to inhomogeneous emission. In the regions where a higher electron flow occurs and several excitons are formed, the component emits more radiation and is therefore brighter than in the regions where a low electron flow is present.

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One object of embodiments of the invention is to provide an electron-conducting layer in an organic electronic component having a high electron conductivity.

5 The object is achieved by an organic electronic component according to Claim 1. Further embodiments and methods for producing the organic electronic component are the scope of further claims.

10 An embodiment of the organic electronic component comprises a substrate, a first electrode, a second electrode, and an electron-conducting layer arranged such that it is electrically conductively connected to at least one of the electrodes, wherein the electron-conducting layer is obtained by joint vaporization of a metal complex with an organic compound.

15 When the metal complex vaporizes together with an organic compound, these two compounds interact with each other in the gas phase or when they meet on the substrate surface. This interaction causes the compounds to be mutually coordinated. The compounds are deposited in the coordinated state, so that a layer is formed in which short-range order is provided. The term short-range order is understood to mean that not the entire layer per se is crystalline, but that the organic compounds are disposed around the metal complex in its immediate environment according to a specific pattern that depends on the selected metal
20 complex and the organic compound. However, the entire layer itself is amorphous and thus does not have a long-range order. By coordinating the organic compound at the metal complexes and the associated overlap of the orbital, additional electrons can be transferred from the metal to the ligand by a metal-ligand charge-transfer complex. These electrons can be available for electron transportation in the organic electronic component. By increasing
25 the “free” electrons, the electron conductivity in the component is significantly improved. This leads to an increase in the efficiency and serviceable life of the organic electronic component.

In an embodiment of the organic electronic 20 component, the organic compound coordinates to the metal atom.

5 The coordination of the organic compound to the central atom can occur directly via another atom or also via an aromatic system. During or after the coordination of the organic compound, preferably none of the previously present ligands of the metal complex are split off, thus no ligand exchange takes place. The metal complex is thus able to accept further ligands and thus comprises on the central atom free coordination sites, which can be occupied by further ligands.

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In this context, reference is made to a document by F.A. Cotton (F.A. Cotton et al., Organometallics, 1999, 18, 2724-2726). The publication by Cotton shows how an aromatic compound, in this case a six-fold methylated benzene ring, coordinates to a rhodium complex. It is described that the coordination of the aromatic system can lead to a chain formation, wherein two metal complexes are linked by an organic compound. The aromatic compound is in this case positioned perpendicular or almost perpendicular between adjacent, bridged metal complexes.

In a further embodiment of the organic electronic component, the metal complex comprises more than one central atom.

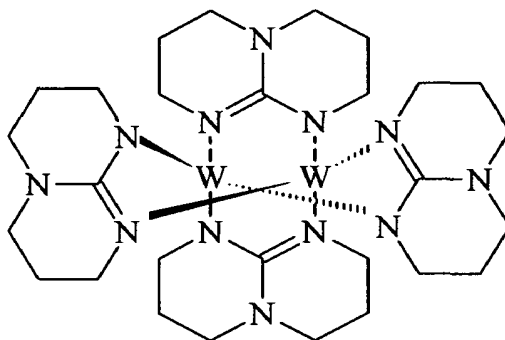
The presence of more than one central atom improves the possibility that several organic compounds will coordinate simultaneously to the metal complex. The metal complex preferably comprises two central metal atoms. In this case, each of the two central atoms has a coordination site without a steric hindrance being generated. The two central atoms of the metal complex in this case may or may not interact with one another. Metal complexes with two central atoms are particularly well suited for the formation of chains. In this context, reference is again made to the publication by Cotton in Organometallics. Herein, the chain formation of a metal complex with two central rhodium atoms is observed. A chain-like sequence of metal complexes and of two aromatic compounds bridging adjacent complexes of is shown. Here, the aromatic compound is positioned perpendicular between the metal complexes and the Rh-Rh axis is positioned perpendicularly on the aromatic compound. For an embodiment according to the invention, the metal complexes having two central atoms, which do not yet have any ligands in the extension of the central atom axis, are preferred, so that the central atom still comprises two free, preferably opposite, coordination sites. This is the case, for example, for the rhodium complex in the publication by Cotton. For such metal complexes, it is particularly easy for steric reasons to attach additional ligands on both opposite sides in extension of the central atom axis.

In an embodiment of the organic electronic component, the central atom or the central atoms are selected from: Cr, Mo or W.

In this case, W is a preferred central metal atom. It is particularly preferred when all central
5 atoms in the metal complex are W. Elements Cr, Mo and W prove to be particularly
advantageous for two reasons. On the one hand, they have the ability of entering into a
coordination with additional ligands, and on the other hand, their metal complexes have a
very low ionization enthalpy when the ligands are suitably selected. This means that these
metal complexes have a high propensity and ability to provide “free” electrons. These
10 electrons can, for example, be transferred to the additionally bonded ligands. By virtue of
this coordination and the associated metal complex ligand electron transfer (charge transfer
complex), the electron-conducting layer can be provided with additional electrons for
charge transport. By virtue of these electrons, the charge transport can be increased in the
organic electronic component, which increases the efficiency of the component. In this

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context, reference is made to a publication by F.A. Cotton (F.A. Cotton et al., Science, Vol. 298, 2002, page 1971-1974). This Cotton publication examines a $W_2(TBD-A)_4$ complex as shown schematically in Figure 5 below:



5

Cotton shows in his publication that this complex belongs to the compounds whose electron configuration comprises closed, i.e., filled, electron shells and still has an extremely low ionization potential. Cotton also shows that the central atoms in this complex can have very high oxidation levels. Thus, many electrons can be donated by the two central W atoms. In a further publication by Cotton (F.A. Cotton et al., Inorganic Chemistry Communications, Vol. 6, 2003, pages 121-126), Cotton shows a synthesis path for the $W_2(TBD-A)_4$ complex.

In a further embodiment of the organic electronic component, the organic compound comprises a heteroaromatic compound.

The organic compound preferably comprises more than one heteroaromatic compound. This allows the organic compound to coordinate to several metal complexes at the same time.

Compared to an aromatic compound, a heteroaromatic compound has the advantage that it can coordinate to a metal complex not only via the aromatic system (π -electrons), as described in the publication by Cotton in Organometallics (as cited above), but that the coordination can also be achieved directly via the heteroatom. The greater the number of heteroaromatic compounds in the organic compound, the greater the number of possible coordination sites for a metal complex. N is a preferred heteroatom in this case. Due to the mostly free electron pair, N has a very good coordination capacity compared to metal complexes.

In a further embodiment of the organic electronic component, the organic compound comprises a heteroaromatic compound that is conjugated with an aromatic compound via a C-C bond.

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C-C bonding is understood to be a carbon-carbon single bond; the heteroaromatic compound and the aromatic compound are therefore not condensed. In contrast to the condensed systems, a system of this type, in which the heteroaromatic compound is linked with further aromatic compounds via single C-C bonds, has the advantage that it is not as sterically demanding and voluminous, and can thus coordinate more easily to a metal complex, or better coordinate to several metal complexes at the same time. The heteroatom in the heteroaromatic compound is preferably N, O or S, wherein N is particularly preferred.

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In a further embodiment of the organic electronic component, the organic compound comprises only heteroaromatic compounds that do not form condensed systems. The heteroaromatics are therefore not condensed with other heteroaromatic or aromatic systems. The steric advantage of non-condensed systems over condensed systems also arises in this case. The heteroatom in the heteroaromatic compound is preferably N, O or S, wherein N is particularly preferred.

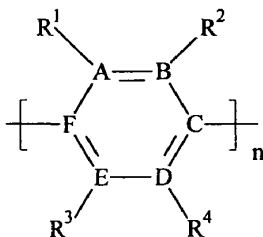
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In a further embodiment of the organic electronic component, the organic compound comprises only heteroaromatic compounds having one or two heteroatoms. The term heteroaromatic compound is understood to be an entire condensed system. The heteroatom or heteroatoms in the heteroaromatic compounds are preferably N, O or S, wherein N is particularly preferred.

In a further embodiment of the organic electronic component, the organic compound comprises only heteroaromatic compounds whose rings are formed from six atoms. In conjugation with other heteroaromatic or aromatic compounds, these heteroaromatic compounds are ideally suited to form a delocalized π electron system, which is readily able to accept additional charges. The heteroatom in the heteroaromatic compound is preferably N, O or S, wherein N is particularly preferred.

In a further embodiment of the organic electronic component, the organic compound has the general formula:



where

– the ring members A through F independently of one another represent C, or one or two
5 ring members can be N,

– n is 2 to 8, wherein the free valences of the ends can independently of one another each
be saturated by H, methyl, phenyl, 2-pyridyl, 3-pyridyl or 4-pyridyl,

– R¹ through R⁴ can each be H, methyl, phenyl, 2-pyridyl, 3-pyridyl or 4-pyridyl

independently of each other and/or R¹ and R² or R³ and R⁴ can be combined with one

10 another by butadiene or azabutadiene units, so that a six-membered ring is formed, and can
also be bonded between the n-th and (n+1)th ring by ethylene or azomethine units, wherein
phenanthrene or azaphenic units are formed.

Compounds with this general formula can coordinate to metal complexes. Furthermore,

15 compounds of this general formula are suitable for adjusting the color impression of the
organic electronic component in the switched-off state.

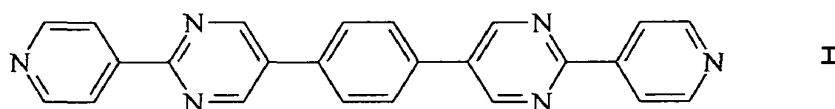
By a suitable selection of the metal complex and the organic compound, a predetermined
color impression for the desired external appearance can be ensured at least in the switched
20 off electronic operating state. This can be possible by forming charge transfer complexes in
the electron-conducting layer. The metal complex and the organic compound form electron-
donor-acceptor complexes whose absorption bands are preferably in the visible wavelength
range. The absorption band of the charge transfer complexes depends on the respective
energetic level of their HOMOs and LUMOs relative to one another. The charge transfer
25 complexes can thus enable a predetermined color impression.

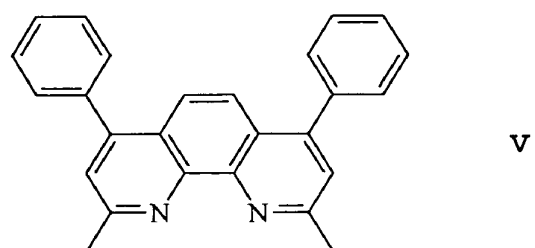
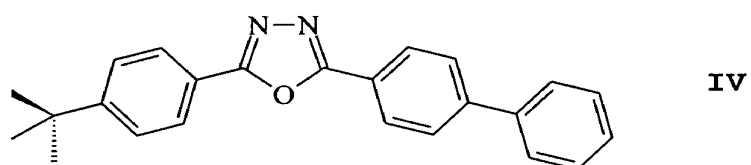
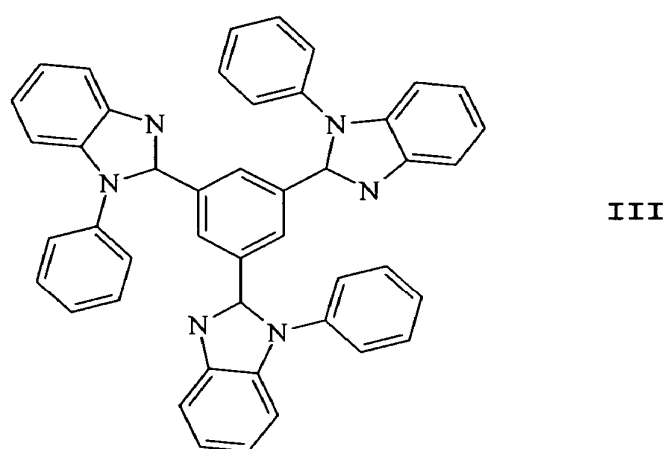
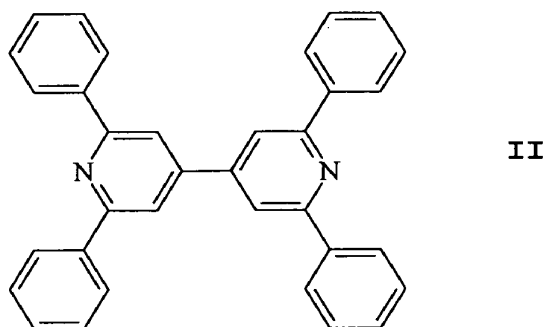
These compounds additionally have good charge transporting properties, which can be controlled by the number of nitrogen atoms in the ring system.

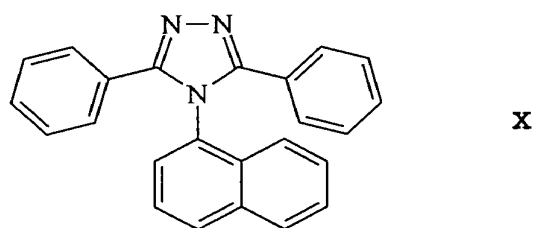
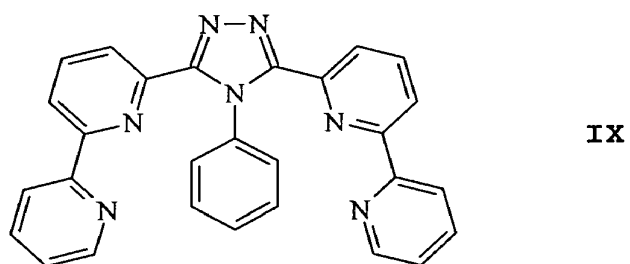
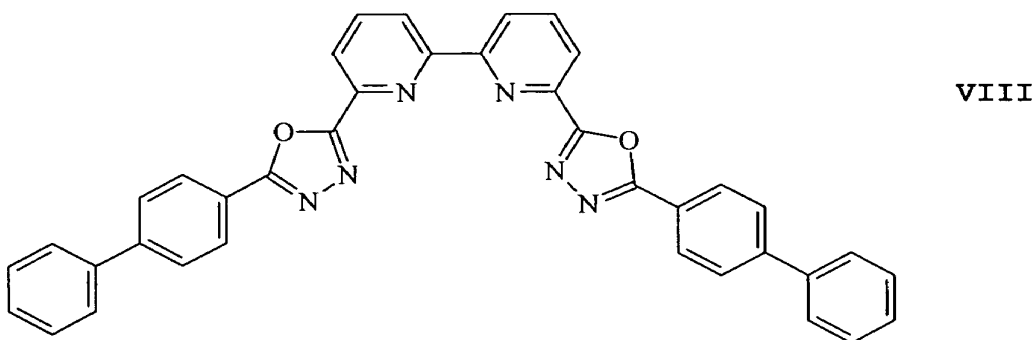
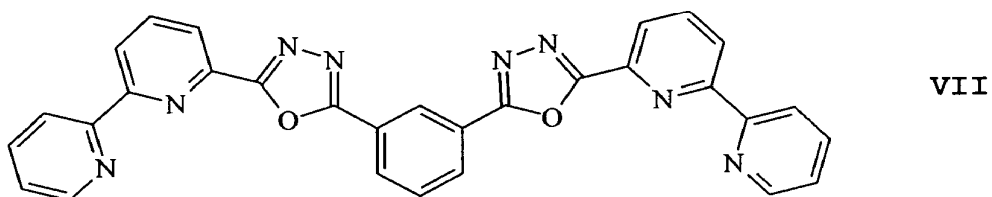
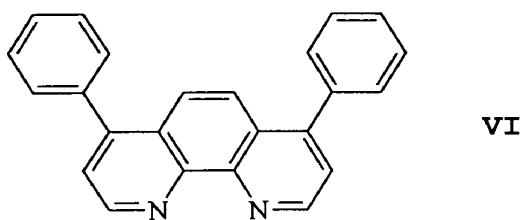
5 The absorption band of the complexes formed by co-condensation specifically influences the resulting color impression of the component in the switched-off state.

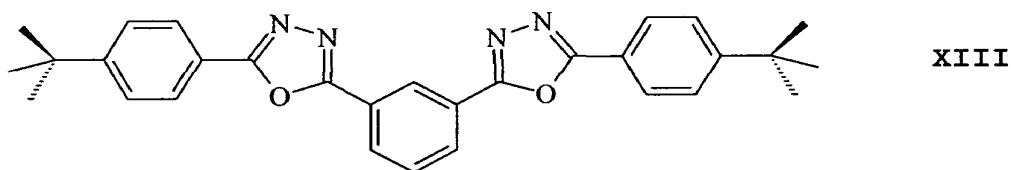
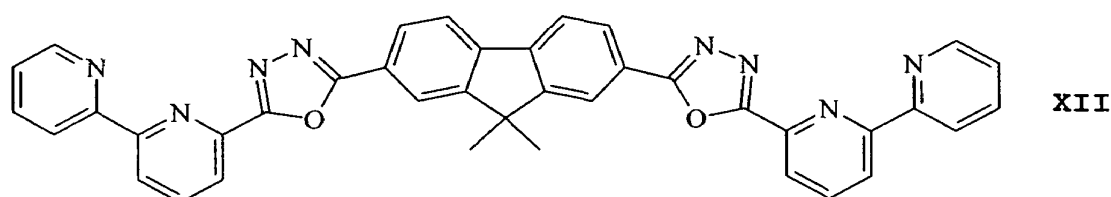
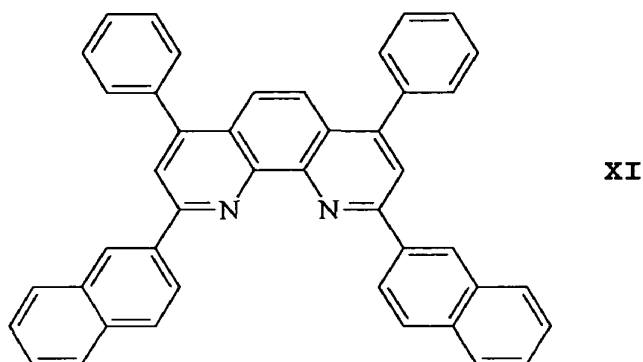
The oligo-pyridyl and/or-pyrimidyl-arenes can be freely permuted in their arrangement and can in turn carry in their periphery phenyl, pyridyl and pyrimidyl as well as hydrogen and methyl as substituents. Oligo is intended to mean a value range of $n = 2$ to 8.

10 In a further embodiment of the organic electronic component, the organic compound is selected from:









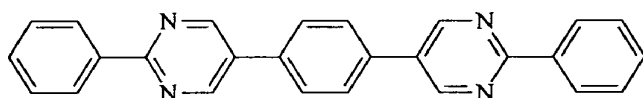
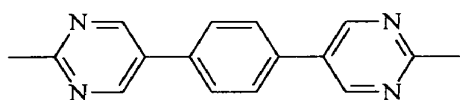
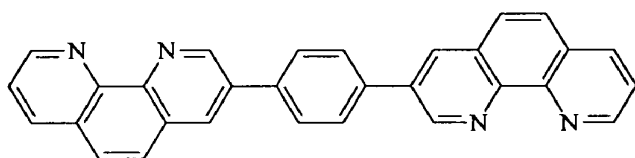
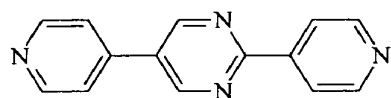
The compounds shown in structures I through XIII are particularly well suited as an organic compound for the electron-conducting layer. Each of these compounds includes an aromatic and also a nitrogen heterocycle.

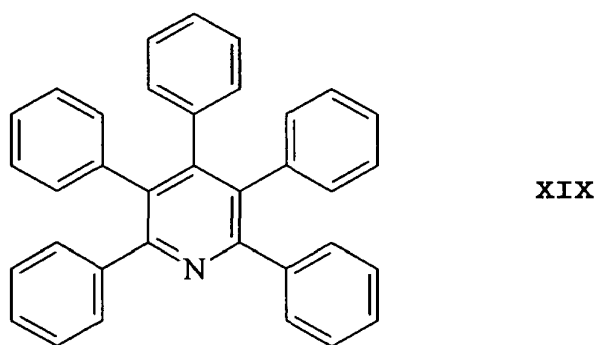
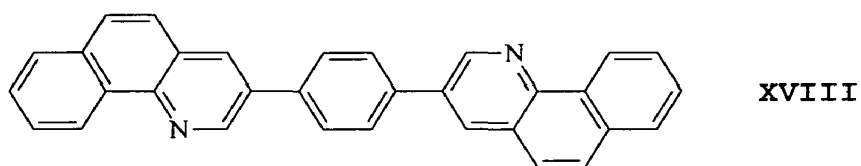
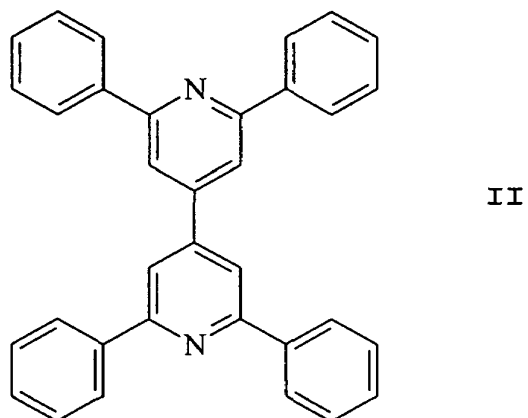
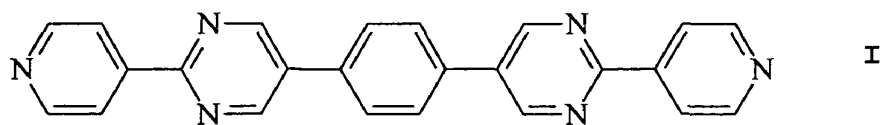
Each of these compounds thus comprises several coordination sites for metal complexes.

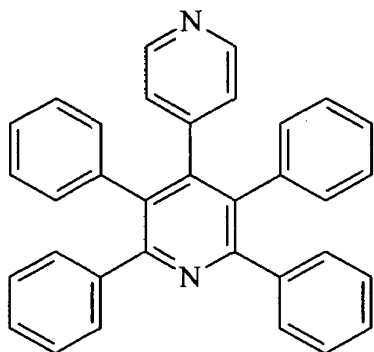
- 5 These compounds I through XIII not only permit the formation of two-dimensional chains, but also the formation of three-dimensional networks by virtue of their plurality of coordination sites. In this case, an organic compound coordinates to more than two metal complexes. Furthermore, these compounds have large, delocalized electron systems, such as condensed aromatic compounds or aromatic compounds that are in electronic conjugation
- 10 with one another. These delocalized electron systems readily allow the compounds to absorb and transport further negative charges because this additional charge can be easily distributed onto several atoms in the molecule. Thus, a coordinated metal complex can readily transfer a negative charge to the organic compound coordinated thereto. In addition, electrons from the organic compounds I through XIII can also be readily transferred

amongst the organic compounds themselves. This is also crucial for good electron conductivity in the electron-conducting layer.

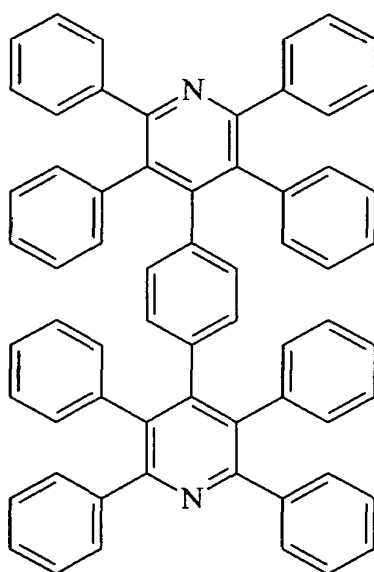
In a further embodiment of the organic electronic component, the organic compound is
5 selected from:

**XIV****XV****XVI****XVII**

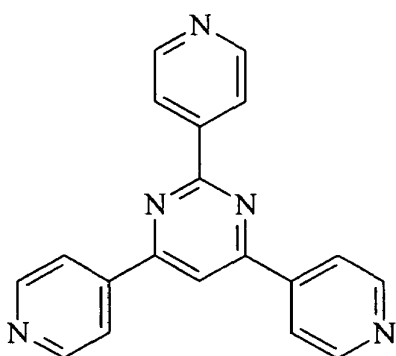




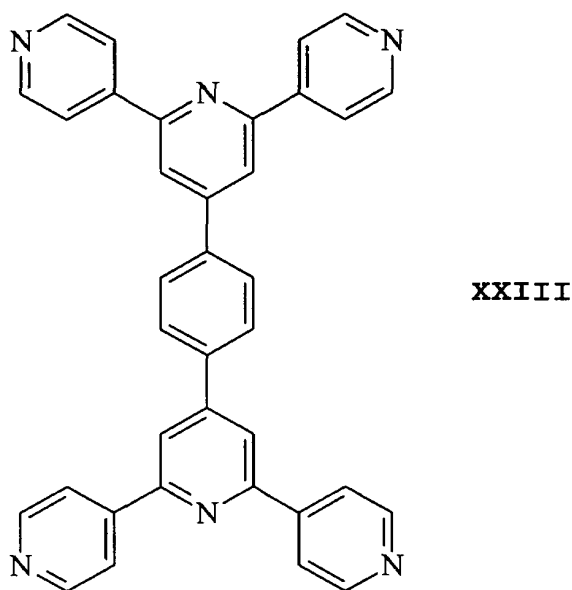
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XXI



XXII



The compounds shown in structures I, II, XIV through XXIII are particularly well suited as organic compounds for the electron-conducting layer. Each of these compounds comprises a nitrogen heterocycle, as well as an additional nitrogen heterocycle or a homoaromatic compound formed from C atoms. Each of these compounds thus comprises several coordination sites for metal complexes. These compounds I, II, XIV through XXIII not only permit the formation of two-dimensional chains, but also the formation of three-dimensional networks by virtue of their plurality of coordination sites. In this case, the organic compound coordinates to more than two metal complexes. Furthermore, these compounds have large, delocalized electron systems, such as condensed aromatic compounds or aromatic compounds that are in electronic conjugation with one another. These delocalized electron systems readily allow the compounds to absorb and transport further negative charges because this additional charge can be easily distributed onto several atoms in the molecule. Thus, a coordinated metal complex can readily transfer a negative charge to the organic compound coordinated thereto. In addition, electrons from the organic compounds I, II, XIV through XXIII can also be readily transferred well amongst the organic compounds themselves 5. This is also crucial for good electron conductivity in the electron-conducting layer.

In an embodiment of the organic electronic component, at least parts of the organic compounds bridge two metal complexes together, so that a chain-like structure is formed and/or at least parts of the organic compounds bridge together more than two metal complexes, so that a network-like structure is formed.

5

By suitable selection of the metal complexes, for example, bi-nuclear metal complexes, and suitable selection of the organic compounds, such as compounds I through XXIII, the joint vaporization of the metal complex with the organic compound in the gas phase or on the deposited surface results in interactions, so that the compounds coordinate together.

10

Coordination is also retained when forming the electron-conducting layer. This coordination can result in the formation of two-dimensional chains or three-dimensional networks. These chains or networks are deposited as such in the vaporization process and are also present as such in the electron-conducting layer in the organic electronic component. The formation of chain-like or network-like structures enables additional

15 electrons to be transferred from the metal complexes to the organic compounds; said electrons are then available for charge transport in the electron-conducting layer. In this context, reference is made to a publication by F.A. Cotton (F.A. Cotton et al., Inorganic Chemistry, Vol. 41, No. 11, 2002, page 2903-2908). On a metal complex with two rhodium

20 centrifugal atoms and an organic silicon compound, this publication shows, among other things, how multiple coordination of several metal complexes to an organic compound can lead to the formation of chain-like structures. Another example in the publication by Cotton uses the example of tripyridine methanol $C(HO-C-(C_5H_4N)_3)$ to show that the pyridine can simultaneously coordinate to two metal complexes via the nitrogen heteroatom and via the aromatic system. The two other pyridine substituents of the molecule can also coordinate to

25 other metal complexes. This example clearly shows that it is possible to coordinate to several metal complexes simultaneously by means of a suitable choice of organic compound. By the corresponding selection of the metal complexes, more than one organic compound can also coordinate to said metal complexes, thus resulting in chain-like and/or network-like structures in the electron-conducting layer.

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In an embodiment of the organic electronic component, the electron-conducting layer is amorphous and comprises a micro- to nanocrystalline short-range structure.

Crystallization of the organic compounds can occur if one deposits organic compounds, such as those used for electron-conducting layers, by vaporization. A purely crystalline electron-conducting layer has proven to be disadvantageous because this layer has regions of variable conductivity. By applying a voltage, different current densities are thus created in the layer. In areas with very high current densities, overheating and damage to the electron-conducting layer may occur. In the case of light-emitting components, the different conductivity additionally led to inhomogeneous emission. The problem is mitigated by a macroscopically to nanoscopically amorphous electron-conducting layer. Such a layer can be obtained by the joint vaporization of the organic compound with a metal complex, wherein the organic compound coordinates to the metal complex and thereby prevents crystallization. However, the metal complex must be used to ensure that the now macroscopically to nanoscopically amorphous structure still has effective electron-conducting properties. This can occur, for example, in that the additional compound provides additional load carriers. An organic compound that coordinates to the metal complex and thus forms microcrystalline structures is able to accept additional charge carriers provided by the central atom. Thus, the mobility of the charge carriers, which is reduced compared to the crystalline layer, is compensated by increasing the number of charge carriers. An organic electronic component, for example an OLED, which comprises such a layer, gives homogeneous light. At the grain boundaries of OLED devices, which comprise macrocrystalline layers, the conductivities change such that inhomogeneous light impressions are obtained, or, for example, an LED is destroyed by overcurrent at certain locations.

In an embodiment of the organic electronic component, the electron-conducting layer comprises no radiation-emitting substances.

Thus, in this embodiment, no radiation can be emitted from the electron-conducting layer.

5 Neither the organic compound nor the metal complex is able to emit radiation in this embodiment.

An embodiment of the organic electronic component comprises a metal complex whose HOMO (highest occupied molecular orbital) is closer to its ionization energy than the
10 LUMO (lowest unoccupied molecular orbital) of the organic compound, which additionally coordinates to the metal complex.

This enables even the metal complexes that have a closed electron structure to transfer electrons from the complex to the ligand via complex-ligand charge transfer. These
15 transferred electrons make a significant contribution to the electron conductivity of the electron-conducting layer. In this context, reference is again made to the publication by Cotton in Science, which has already been discussed in a previous section. In this publication, Cotton describes the extremely low ionization enthalpy of complexes of the general formula $M_2(TBD-A)_4$, wherein the central atom M is selected in the publication
20 from Cr, Mo or W. TBD-A stands for the anion of 1,5,7-triazabicyclo[4.4.0]dec-5-ene. In its publication, Cotton performs a more detailed analysis of the orbitals of the metal complex and the TBD-A ligand. Here, he shows that the low ionization enthalpy is among other things due to the level of the HOMO of the metal complex relative to the LUMO of the TBD-A ligand.

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The organic electronic component is preferably formed as an organic LED (OLED), which comprises an electroluminescent layer. However, the organic electronic component can for example also be an organic field effect transistor, an organic solar cell, or an organic photodetector. An organic field effect transistor (OFET) has three terminals: source, gate
5 and drain. Here, the substrate can be used as a gate electrode. If this is the case, the substrate is then followed by an isolator layer on which the source and drain terminals are arranged. An organic semiconductor layer is arranged between source and drain and also over both terminals. In the organic solar cell, two electrodes are arranged on top of one another on a substrate, between which an organic, photoactive layer is located. The photoactive layer
10 absorbs the light, resulting in charge separation in the layer. The electrons formed in this way migrate to the anode and the holes migrate to the cathode, thus generating a current flow.

The electron-conducting layer is particularly well suited for organic electronic components
15 whose efficiency depends, among other things, on a good electron transport. For example, in an OLED, the luminescence directly depends on the number of excitons formed. This in turn depends on how many electrons and holes recombine. An effective electron and hole transport thus leads to a high recombination rate and thus to a good luminescence and efficiency of the OLED.

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In addition to the organic electronic component itself, methods for manufacturing the organic electronic component are also claimed.

One variant of the method for manufacturing an organic electronic component comprises the method steps: providing a substrate as method step A), applying a first electrode in process step B), depositing an electron-conducting layer on the substrate as method step C), applying a second electrode in the process step D), wherein the electron-conducting layer is deposited by simultaneous vaporization of a metal complex and an organic compound.

Such a method can, for example, be used to produce an organic electronic component, as claimed in claim 1. The electron-conducting layer can be deposited directly on a substrate, or other layers can be deposited on the substrate beforehand, such as an electrode layer, wherein the electron-conducting layer is then deposited on the layers already located on the substrate. The electron-conducting layer is deposited by simultaneous vaporization of a metal complex and an organic compound. Simultaneous vaporization allows the molecules to interact with each other.

In a further method variant, the organic compound coordinates to the metal complex by means of joint vaporization.

20

Due to the simultaneous vaporization of metal complexes and organic compounds, both compounds are simultaneously present next to each other in the gas phase. This enables the organic compound to coordinate to the metal complex in the gas phase. The coordination can be effected, for example, via a heteroaromatic compound in the organic compound.

- 5 Coordination is also retained during the deposition of the electron-conducting layer.

However, there is also the possibility that the metal complexes and the organic compound meet each other first on the surface to be coated or upon contact with the surface and the organic compound coordinates to the metal complex while forming the electron-conducting
10 layer.

In a further method variant, the electron-conducting layer is deposited as a chain-like or network-like structure.

- 15 The coordination of the organic compound to the metal complex in the gas phase allows chain-like or network-like structures to form. These chain-like or network-like structures are then also deposited as such and are also present as such in the electron-conducting layer in the organic electronic component.

When they contact the surface, the molecules are still movable to an extent that the
20 coordination sites meet each other and the corresponding energy contribution is released, which means that coordination can occur.

In one method variant, the degree of cross-linking of the electron-conducting layer is controlled by the ratio between the metal complex and the organic compound during vaporization.

- 5 The degree of cross-linking and thus the formation of network-like or chain-like structures can be controlled by the ratio of metal complex to organic compound. Referring to the molar ratio, the organic compound is vaporized in excess compared to the metal complex.

10 In this case, the proportion of the metal complex in the layer, which comprises the metal complex and the organic compound, can be 1 to 50 mol%, a proportion of 5 to 25 mol% is preferred, and a proportion of 10 to 15 mol% is particularly preferred.

In a further method variant, the organic compound does not coordinate to the metal complex prior to vaporization.

15

The metal complex and the organic compound can, for example, be vaporized from two different, spatially separated batches. However, it is also possible to transfer the two compounds into one batch without a reaction or coordination taking place among the compounds in the solid phase and to then vaporize the compounds from the common batch.

20

In the following, an example of a variant of a manufacturing process is described in more detail.

In a vacuum recipient, 200 mg of $W_2(TBD-A)_4$ is filled into an electrically heated quartz or ceramic crucible. The organic compound of the aforementioned structure I is filled into another quartz or ceramic crucible. A glass plate 60 mm x 60 mm with a textured ITO electrode (indium tin oxide) is mounted on a substrate holder at a distance of approximately 25 cm from the crucibles. The substrate mask is closed and the two sources are regulated to a deposition rate of 4.5 nm/sec. The molar ratio of metal complex to organic compound during vaporization was 1 to 9. An electron-conducting layer with a layer thickness of 150 nm is deposited. The electron-conducting layer comprises a three-dimensional network of the metal complex $W_2(TBD-A)_4$ and the organic compound I. The organic electronic component is completed with a 150 nm thick aluminum electrode.

In a further variant of the previously described method for manufacturing an organic electronic component, which is an OLED, a 10 nm thick layer of the organic compound of the aforementioned structure is vapor-deposited before the electron-conducting layer. Due to the small layer thickness, crystallization of the organic compound does not occur here. The previously vapor-deposited layer of organic compound I reduces the emission extinction by the $W_2(TBD-A)_4$ complex. This means that the fraction of radiation that is reabsorbed in the component is reduced.

In a further method variant, the organic compound of the aforementioned structure II is used instead of the organic compound of the aforementioned structure I.

5 In the following, variants of the invention will be explained in more detail using figures and exemplary embodiments.

The figures show the following:

- 10 Figure 1 a schematic side view of an embodiment, which is formed as an OLED and comprises a separate emitting layer,
- Figure 2 a schematic side view of an embodiment, which is formed as an OLED, and comprises nine layers,
- 15 Figure 3 the structure formulae of three chemical compounds used in an OLED,
- Figure 4 the energy levels in an embodiment of an optoelectronic component,
- 20 Figure 5 three measurement curves of an embodiment of an OLED in which the current density is plotted versus the voltage,
- Figure 6 three measurement curves of an embodiment of an OLED in which the luminescence is plotted versus the voltage,

25

Figure 7 three measurement curves of an embodiment of an OLED in which the radiation efficiency is plotted versus the luminescence,

5 Figure 8 three measurement curves of an embodiment of an OLED in which the luminescence is plotted versus the time,

Figure 9 a schematic side view of an embodiment, which is formed as an organic field effect transistor.

10 Figure 1 shows a layer sequence comprising a substrate 1, a first electrode 2 and a second electrode 4 arranged thereon. The electron-conducting layer 3 and the emitting layer 5 are located between the two electrodes. By applying a voltage to the electrodes, electrons are injected by one of the two electrodes, the cathode, into the layers 3 and 5 and holes are injected by the other electrode. Excitons can be formed by recombination of the electrons
15 and holes. In the embodiment shown in Figure 1, the radiation is emitted from the emitting layer 5. The latter contains the substances that can be excited to emission by excitons. These may be, for example, phosphorescent or fluorescent substances.

Figure 2 shows an embodiment of the component formed as an OLED. The figure shows a
20 schematic side view of a layer stack of nine layers. A first electrode 2, which is for example transparent and made of ITO (indium-tin oxide), is arranged on a substrate 1, which is for example made of glass. A hole injection layer 13, on which in turn a hole transport layer 14 is arranged, is arranged on this electrode 2. An organic active layer - the organic emitting layer 5 - is located on the hole transport layer 14. A hole-blocking layer 16 is arranged on
25 said organic emitting layer 5, followed by an electron transport layer 17, and on which an electron injection layer 18 is arranged. A second electrode 4, for example a metal electrode, is located on the electron injection layer 18.

When a voltage is applied between the first and second electrode layer 2, 4, current flows through the component and radiation is emitted in the emitting layer 5. Said radiation can be decoupled from the component, for example in the form of visible light, for example, via the first electrode layer 2 and the substrate 1. Alternatively, the second electrode layer 4 can
5 either additionally or alone also be transparent, and light can leave the component through both electrode layers or only through the second electrode layer 4.

The electron-conducting layer according to the present invention can be any layer in which electrons are transported. The electron-conducting layer in accordance with the invention is
10 preferably the electron transporting layer 17 or the electron injecting layer 18. By virtue of the improved electron transport, more electrons and holes can recombine, resulting in more excitons being formed. Due to the increased number of excitons, the emission and thus the luminous efficiency is increased.

15

The electron-conducting layer 3 in accordance with the present invention can here also be a charge carrier generation layer (not shown in the figure). This charge carrier generation layer can adjoin a hole transporting layer with or without an intermediate layer. A charge carrier generating layer makes it possible, for example, to stack different OLEDs together.

5 For this purpose, the charge carrier generating layer can be provided with a further voltage supply as an intermediate layer between two OLED stacks. This can mean in particular that the intermediate layer can be adjusted such that the two OLED stacks can be controlled with different voltage potentials.

10 Figure 3 shows the structure of three organic compounds as they can for example be used in an OLED. The first structural formula shows NPB (N,N'-Di(naphthyl-1-yl)-N'-diphenylbenzidine), which is suitable for emitting substances, for example, as a hole transporting layer and matrix. The second structural formula shows Ir(ac) (iridium(III) bis (2-methyldibenzo [f,h]quinoxaline) (acetylacetonate)). The Ir complex can for example be used
15 as a red phosphorescent dye in an OLED. The third structural formula shows TPBI (1,3,5-tris(1-phenyl-1H-benzimidazol-2-yl)benzene), the organic compound III. This compound can be used, among other things, for the hole-blocking layer and for the electron-conducting layer 3.

20 Figure 4 schematically shows the energy levels of the individual layers of an embodiment of a device in accordance with the invention, which is formed as an OLED. The LUMOs and HOMOs of the individual layers are specified, as well as the layer thicknesses of the individual layers. The transparent anode, which is made from ITO, is followed by a layer of NPB with a thickness of 30 nm. This first layer of NPB, which performs the hole transport
25 function, is followed by another layer in the NPB as a matrix material. This second layer of NPB is 7 nm thick and additionally has a proportion of 10 mol-% iridium(III)bis(2-methyldibenzo-[f,h] quinoxaline)(acetyl acetate) (Ir(ac)), whose structural formula is shown in Figure 3. Both the LUMO and the HOMO of the phosphorescent substance Ir(ac) are just below the corresponding energy level of the matrix material NPD. A 10 nm thick
30 layer of TPBI, the organic compound III, follows the emitting layer. This layer has a hole blocking function. The energy levels of TPBI are respectively below the corresponding energy levels of the phosphorescent substance. The hole-blocking layer is followed by the electron-conducting layer (ETL). The latter has a layer thickness of 30 nm in this

embodiment. In the embodiments in accordance with the invention, the electron-conducting layer comprises a metal complex and an organic compound. This electron-conducting layer can be obtained by joint vaporization of the metal complex with the organic compound. In this embodiment, the electron-conducting layer assumes the function of the electron-
5 injecting layer and also of the electron-transporting layer. The energy levels of the electron-conducting layer are above the corresponding energy levels of the hole-blocking layer. The electron-conducting layer is followed by a cathode made of Al. If voltage is now applied to the anode and the cathode, holes are induced by the anode into the hole-transporting and electrons are induced by the cathode into electron-transporting layer. From there, the
10 positive charge carriers, the “holes” and the electrons migrate into the NPB layer, which is doped with the phosphorescent substance. When the holes and the electrons recombine on the red emitter, excitons are generated that can excite the phosphorescing substance to emission.

15

The following Figures 5 through 8 show measurement curves of embodiments in accordance with the invention with a metal complex in the ETL, and also of non-inventive variants without a metal complex in the ETL. The ETL is varied in each case.

- 5 Figure 5 shows three measurement curves (21, 22, 23) in which the current density J is plotted versus the voltage U . For this measurement curve, three OLED components were manufactured from a 120 nm thick indium tin oxide electrode followed by a 150 nm thick electron-conducting layer on which a 150 nm thick Al electrode is arranged. In this measurement, the same organic compound, namely the organic compound of structure V,
- 10 was used for all three measurements for the electron-conducting layers 3 of the three components. In measurement curve 21, a proportion of 10 mol% of $W_2(TBD-A)_4$ is present as a metal complex in the organic compound V. In measurement curve 22, the proportion of $W_2(TBD-A)_4$ as a metal complex is only 1 mol%. The measurement curve 23 was generated with the purely organic compound V, i.e. without metal complex. The diagram in Figure 5
- 15 shows that very good current densities can already be achieved with a proportion of 1 mol% (measurement curve 22) in the metal complex at higher voltages. Even at low voltage, the current densities already achieved with 1 mol% of the metal complex (measurement curve 22) are already significantly better than the current densities achieved with the purely organic compound (measurement curve 23). The current densities achieved in the
- 20 measurement curve 21 with the 10 mol% proportion of $W_2(TBD-A)_4$ are significantly above the corresponding values over the entire measurement range at the same voltage of the other two measurement curves 22 and 23. Figure 5 thus clearly shows the influence of the metal complex on the current density. The “free” electrons additionally provided by the metal complex can thus make a decisive contribution to the electron transport in the OLED
- 25 component.

Figure 6 shows three measurement curves (31, 32, 33) in which the luminescence L is plotted versus the voltage U . Three components were produced for the three measurement curves, the design of which corresponds to the design as described in the explanations on Figure 4. For the three different measurement curves, the material for the electron-

5 conducting layer was varied in each case. For the measurement curve 31, an electron-conducting layer from the organic compound II with a proportion of 10 mol-% of $W_2(TBD-A)_4$ was used. For the measurement curve 32, an electron-conducting layer of the organic compound I with a proportion of 10 mol% of $W_2(TBD-A)_4$ was used. For the measurement curve 33, a device with an electron-conducting layer made of the organic compound I and

10 with an additional layer between the electron-conducting layer and the Al electrode with a thickness of 0.7 nm made of LiF was used. In the measurement curve 33, there is therefore no metal complex in the electron-conducting layer. Figure 6 clearly shows that better luminescences are achieved in the measurement curves 31 and 32 - that is the measurement curves in which the metal complex is respectively present at 10 mol% in the electron-

15 conducting layer - than with the electron-conducting layer comprised only of the purely organic compound. In this experimental arrangement, even better values were achieved with the organic compound II than with the organic compound I. Figure 6 clearly shows that the metal complex has a positive effect on luminescence, which can be seen from the direct comparison of the measurement curves 32 and 33.

20

Figure 7 shows three measurement curves (41, 42, 43) in which the radiation efficiency E is plotted versus the luminescence L . The structure of the components used for these measurement curves corresponds to the structure as described in the explanations regarding Figure 4. The materials of the electron-conducting layer were varied from measurement curve to measurement curve. In the measurement curve 41, a component with a 20 electron-conducting layer from the organic compound I with a proportion of 10 mol% of $W_2(TBD-A)_4$ was used. For the measurement curve 42, a component with an electron-conducting layer from the organic compound II with a proportion of 10 mol% of $W_2(TBD-A)_4$ was used. The measurement curve 43 shows the results of the measurement of a component using the organic compound I, but without a metal complex. The component of the measurement curve 43 additionally comprises a layer of LiF of a thickness of 0.7 nm between the electron-conducting layer and the Al electrode. As can be clearly seen from Figure 7, the measurement curves 41 and 42, in which the electron-conducting layer in addition to the organic compound also have a proportion of 10 mol% in the metal complex, have a significantly improved efficiency compared to the measurement curve 43 with the electron-conducting layer that does not comprise a metal complex. From the measurands in Figure 7, it can therefore be clearly seen that the efficiency of the component can be significantly increased by the metal complex vaporized together with the organic compound.

Figure 8 shows three measurement curves (51, 52, 53) in which the luminescence L is plotted versus the time t . The “service life” is defined as 50% value of the originally adjusted brightness, in this case 1000 cd/m^2 . If a component falls below the threshold value of 500 cd/m^2 , it is deemed no longer usable; its “service life” is considered to be expired.

- 5 For the measurement curves, components were used whose design corresponds to the design as described in the figure description for Figure 4. The electron-conducting layer was varied for each of the three measurement curves. A component for which the electron-conducting layer consists only of the organic compound I was used in the measurement curve 51. The component additionally comprises a further layer of a thickness of 0.7 nm
- 10 LiF between the electron-conducting layer and the Al electrode. In the measurement curve 52, an electron-conducting layer from the organic compound I with a proportion of $10 \text{ mol\%}$ of $\text{W}_2(\text{TBD-A})_4$ was used. For the measurement curve 52, a component with an electron-conducting layer from the organic compound II with a proportion of $10 \text{ mol\%}$ of $\text{W}_2(\text{TBD-A})_4$ was used. Figure 8 clearly shows that significantly better service lives were
- 15 achieved in the two measurement curves 52 and 53 for which the electron-conducting layer has a metal complex than in the measurement curve 51 for which the electron-conducting layer has no metal complex.

In this measurement, the service life (> 2500 h) could yet again be significantly improved in the measurement curve 53 with the organic compound II over the measurement curve 52 with the organic compound I (235 h).

- 5 The measurement curves shown in Figures 5 through 8 each clearly show that the presence of the metal complex, which was vaporized together with the organic compound to form an electron-conducting layer, has a positive influence on the respectively measured electrical and optoelectronic parameters. It was possible to achieve a higher current density, higher luminescence, better efficiency and a longer service life in the corresponding organic
- 10 electronic components by the joint vaporization of the metal complex with the organic compound.

Figure 9 shows a schematic side view of an embodiment of a device in accordance with the invention, which is formed as an organic field effect transistor (OFET). The first electrode

15 2, which is formed as a gate electrode layer, is arranged on the substrate 1. The first electrode 2 is followed by an insulator layer 60, which can for example comprise a dielectric. The second electrode 4 is formed as source-drain contact layers and comprises an electron-conducting layer. A semiconductor 80, which consists of a hole-conducting material, is arranged between the source and drain contact layer. The organic field effect

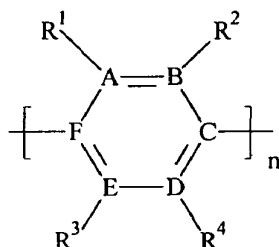
20 transistor further comprises a cover layer 70, which can for example be used as encapsulation.

The invention is not restricted by the description based on exemplary embodiments. Rather, the invention encompasses every new feature and also any combination of features, which in particular comprises any combination of features in the claims, even if the feature or this combination itself is not explicitly specified in the claims or exemplary embodiments.

Claims

1. Organic electronic component, comprising
 - a substrate (1),
 - a first electrode (2),
 - a second electrode (4),
 - an electron-conducting layer (3) arranged such that it is electrically conductively connected to at least one of the electrodes, wherein the electron-conducting layer (3) is obtained by joint vaporization of a metal complex with an organic compound, wherein the metal complex comprises a central metal atom.
2. Organic electronic component according to Claim 1, wherein the organic compound coordinates to the metal complex due to the joint vaporization.
3. Organic electronic component according to any of the above claims, wherein the metal complex comprises more than one central metal atom.
4. Organic electronic component according to any of the above claims, wherein the central metal atom is, or the central metal atoms are, selected from Cr, Mo, or W.
5. Organic electronic component according to any of the above claims, wherein the organic compound comprises a heteroaromatic compound conjugated to an aromatic compound with a C-C bond.

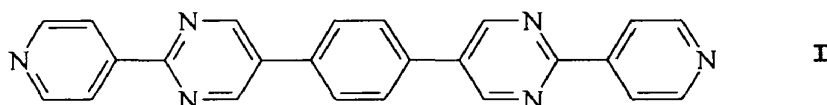
6. Organic electronic component according to any of the above claims, wherein the organic compound has the general formula:

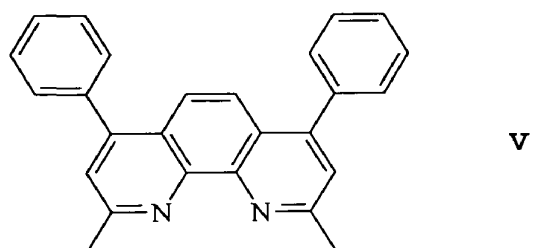
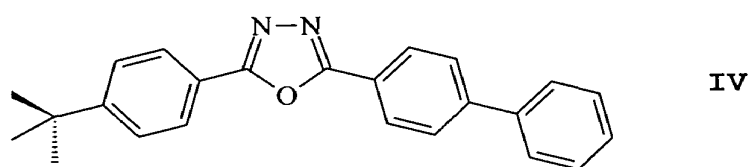
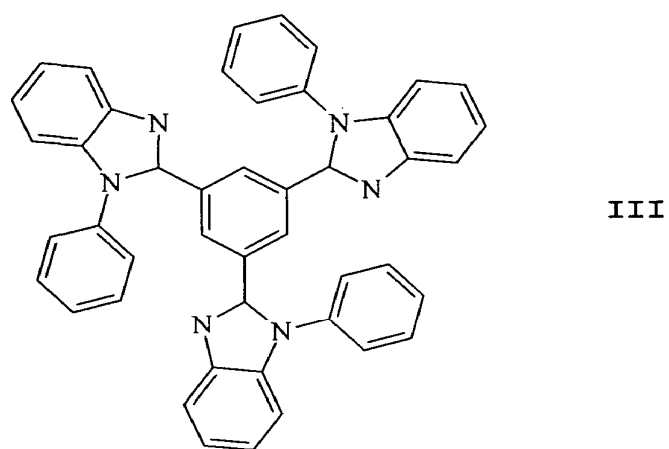
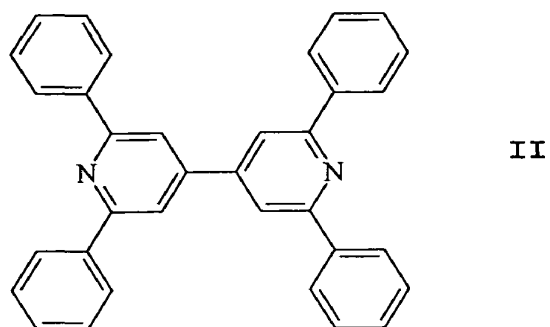


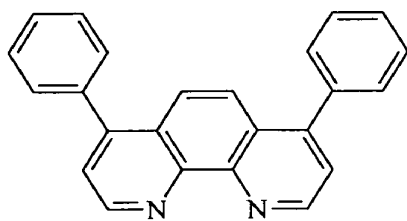
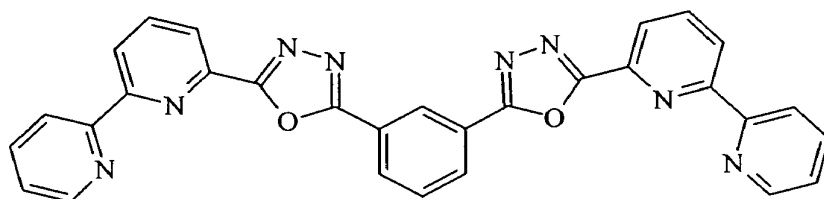
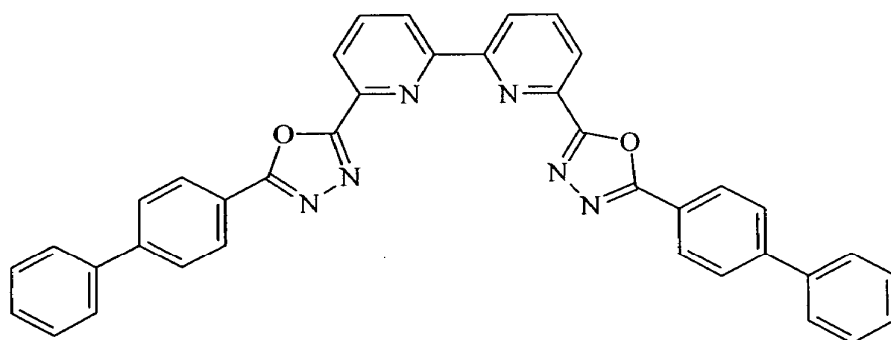
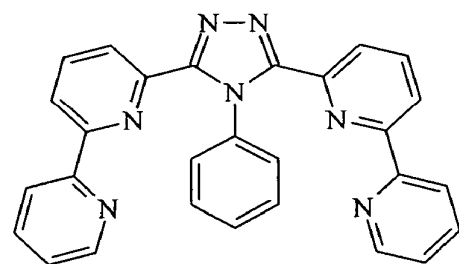
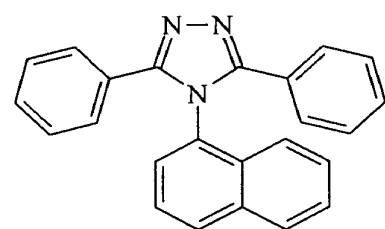
where

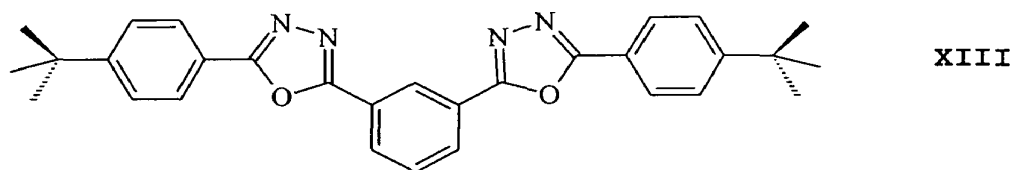
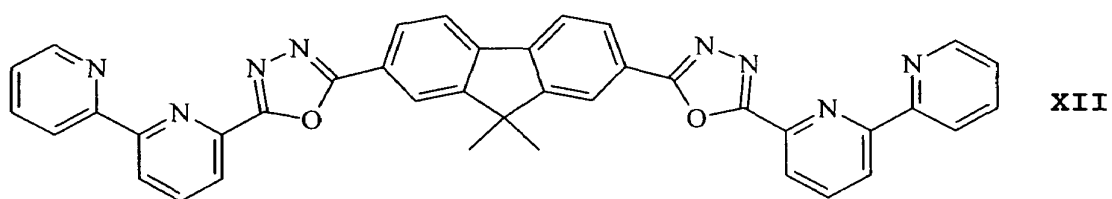
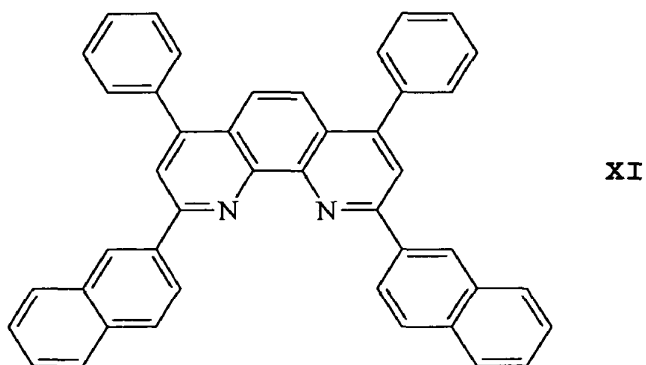
- the ring members A through F independently of one another represent C, or one or two ring members can be N,
- n is 2 to 8, wherein the free valences of the ends can independently of one another each be saturated by H, methyl, phenyl, 2-pyridyl, 3-pyridyl or 4-pyridyl,
- R¹ through R⁴ can each be H, methyl, phenyl, 2-pyridyl, 3-pyridyl or 4-pyridyl independently of each other and/or R¹ and R² or R³ and R⁴ can be combined with one another by butadiene or azabutadiene units, and can also be bonded between the n-th and (n+1)th ring by ethylene or azomethine units, wherein phenanthrene or azaphenic units are formed.

7. Organic electronic component according to any of the above claims, wherein the organic compound is selected from:

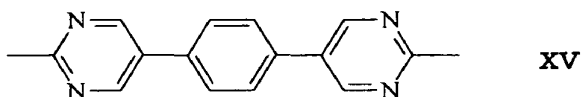
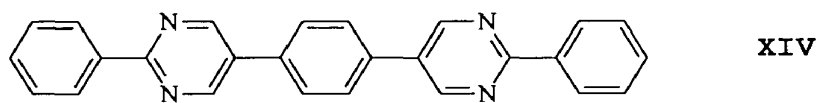


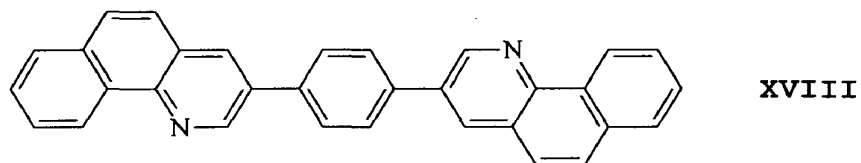
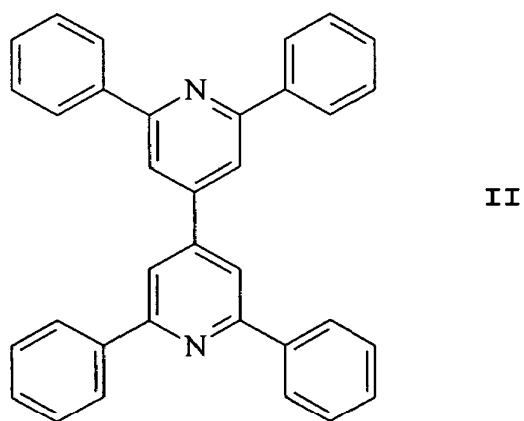
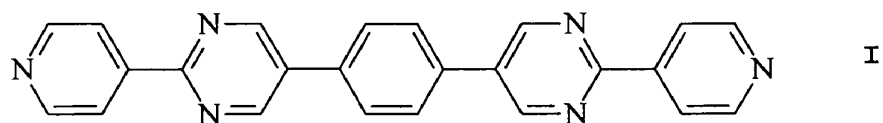
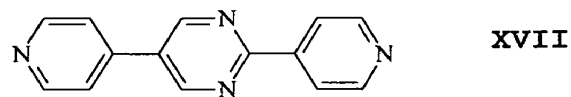
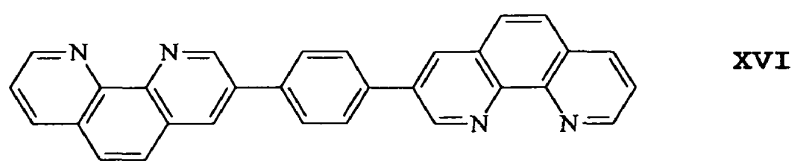


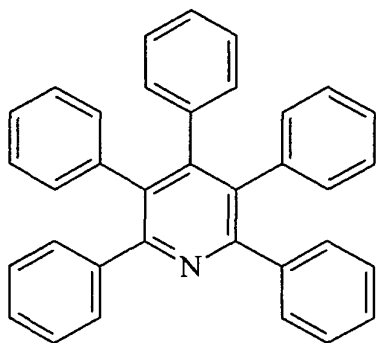
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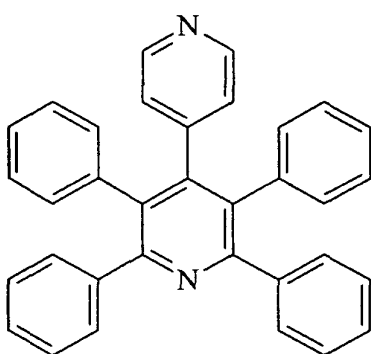
8. Organic electronic component according to any of the above claims, wherein the organic compound is selected from:



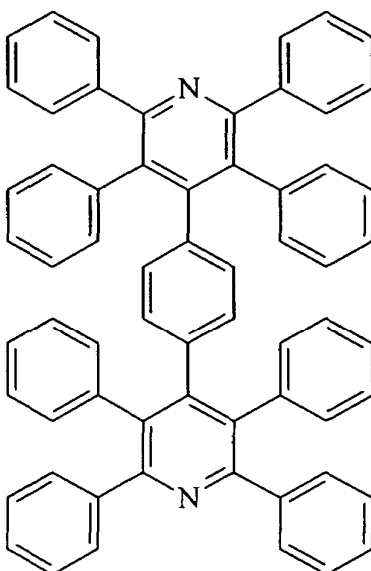




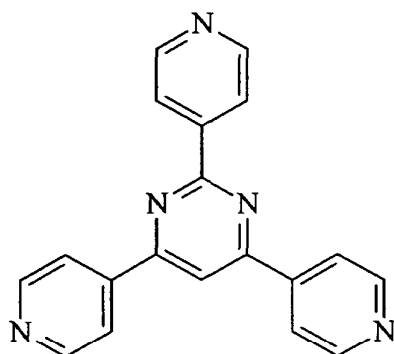
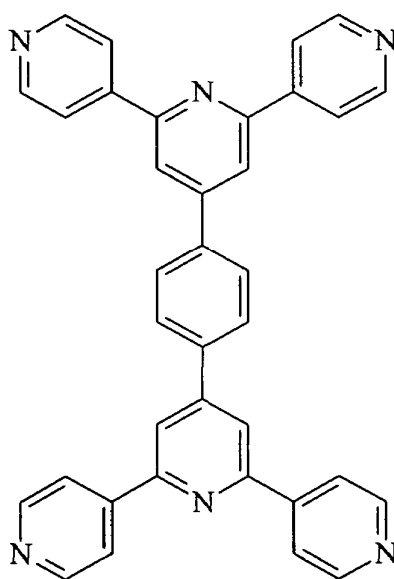
XIX



XX



XXI

**XXII****XXIII**

9. Organic electronic component according to any of the above claims, wherein at least parts of the organic compounds bridge two metal complexes with one another such that a chain-like structure of the metal complexes is formed and/or at least parts of the organic compounds bridge more than two metal complexes together such that a network-like structure of the metal complexes is formed.

10. Organic electronic component according to any of the above claims, formed as an organic LED (OLED) that additionally comprises an organic emitting layer (5).

11. Method for manufacturing an organic electronic component, comprising the method steps of:

- A) providing a substrate (1),
- B) applying a first electrode (2),
- C) depositing an electron-conducting layer (3) on the substrate (1),
- D) applying a second electrode (4), wherein the electron-conducting layer (3) is deposited by simultaneous vaporization of a metal complex and an organic compound.

12. Method according to Claim 11, wherein, during the simultaneous vaporization, the organic compound coordinates in the gas phase to the metal complex.

13. Method according to any of Claims 11 or 12, wherein the electron-conducting layer (3) is deposited as a chain-like or network-like structure.

14. Method according to Claim 13, wherein the degree of cross-linking of the electron-conducting layer (3) is controlled by the ratio between the metal complex and the organic compound during vaporization.

15. Method according to any of Claims 11 through 14, wherein the organic compound does not coordinate to the metal complex prior to vaporization.

Abstract

Organic electronic component and method for its manufacture

Organic electronic component, comprising a substrate, a first electrode, a second electrode,
5 an electron-conducting layer arranged such that it is electrically conductively connected to
at least one of the electrodes, wherein the electron-conducting layer is obtained by joint
vaporization of a metal complex with an organic compound.

10 Significant figure: Fig. 1

Fig 1

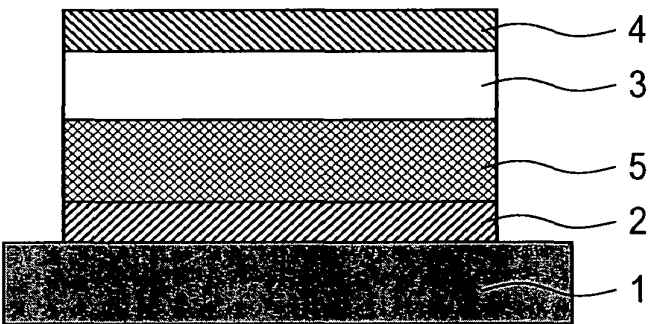


Fig 2

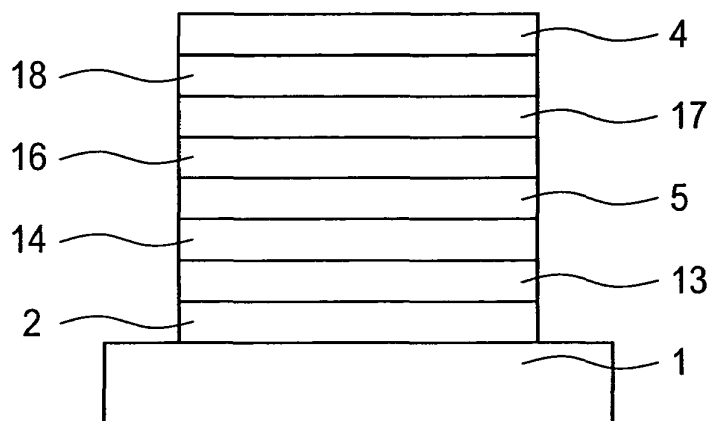


Fig 3

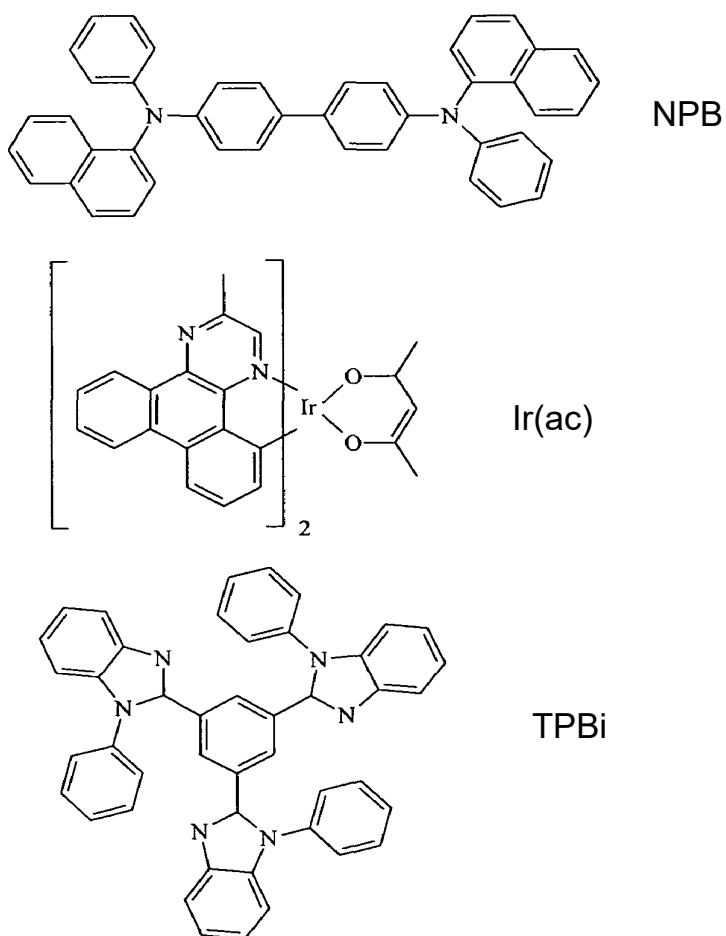


Fig 4

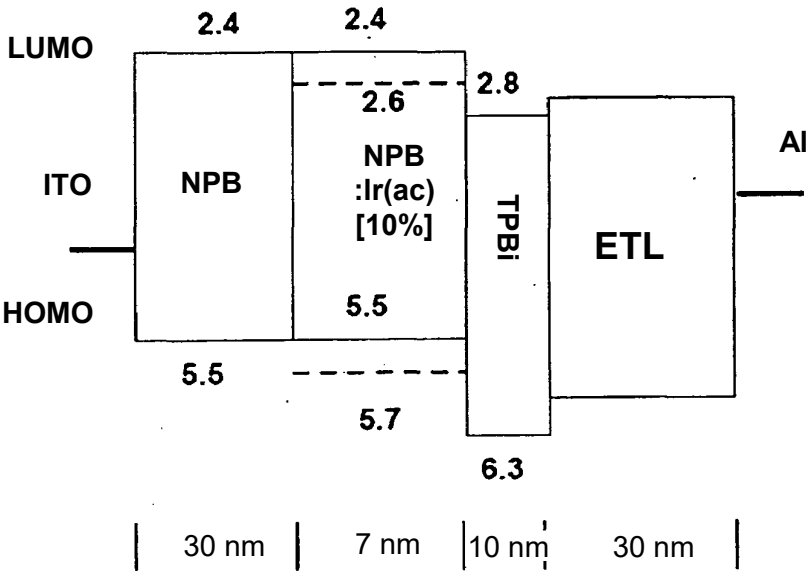


Fig. 5

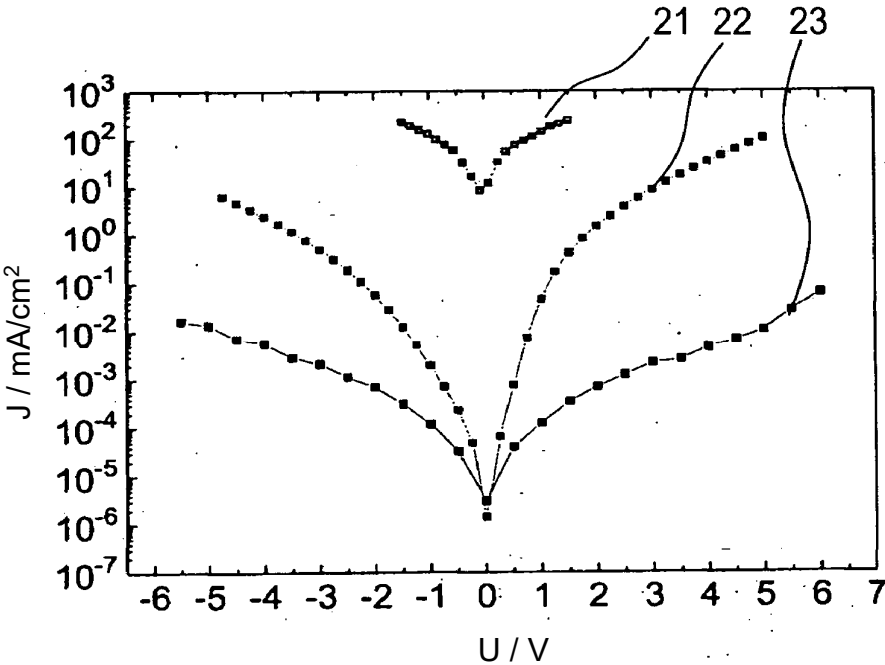


Fig 6

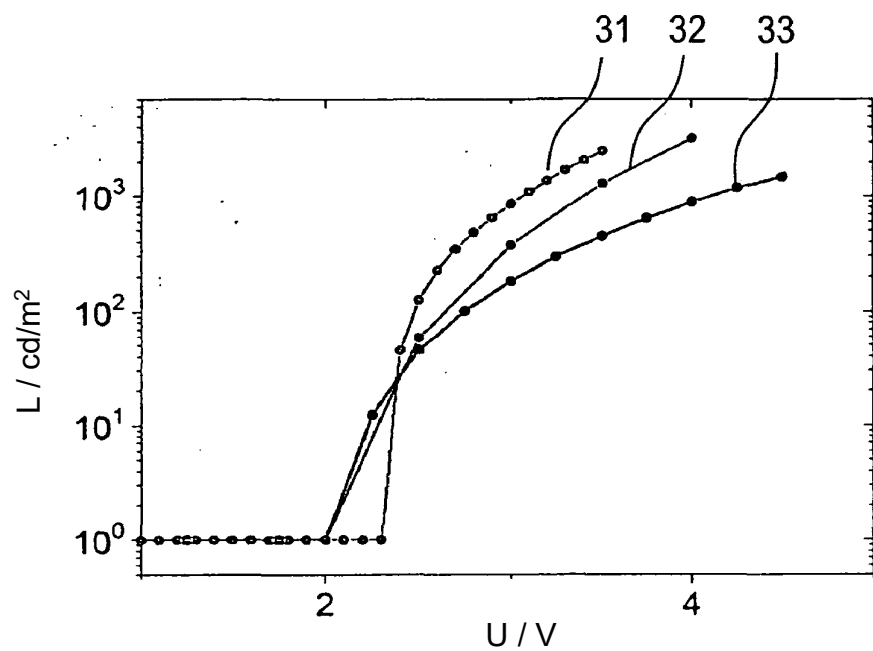


Fig 7

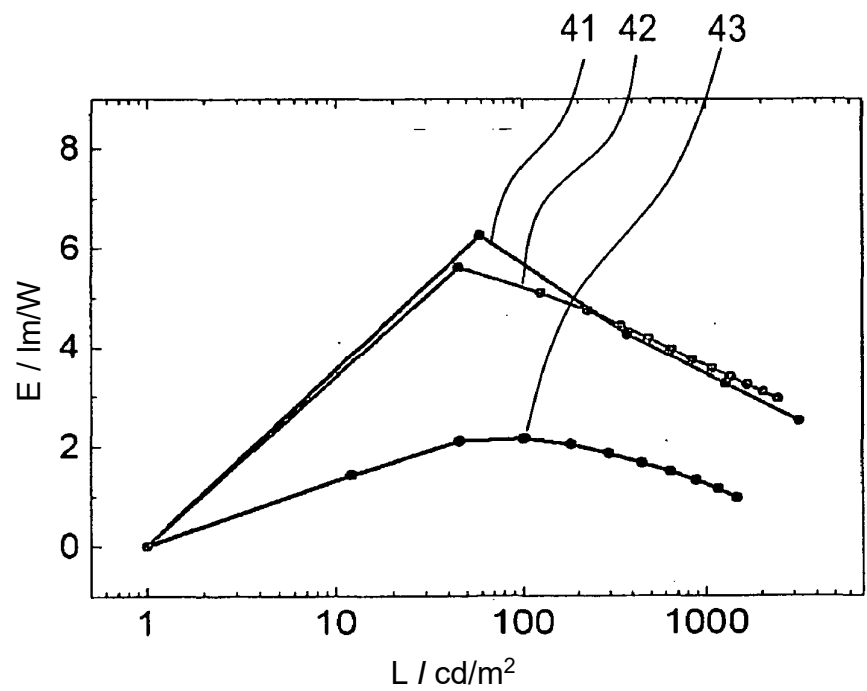


Fig 8

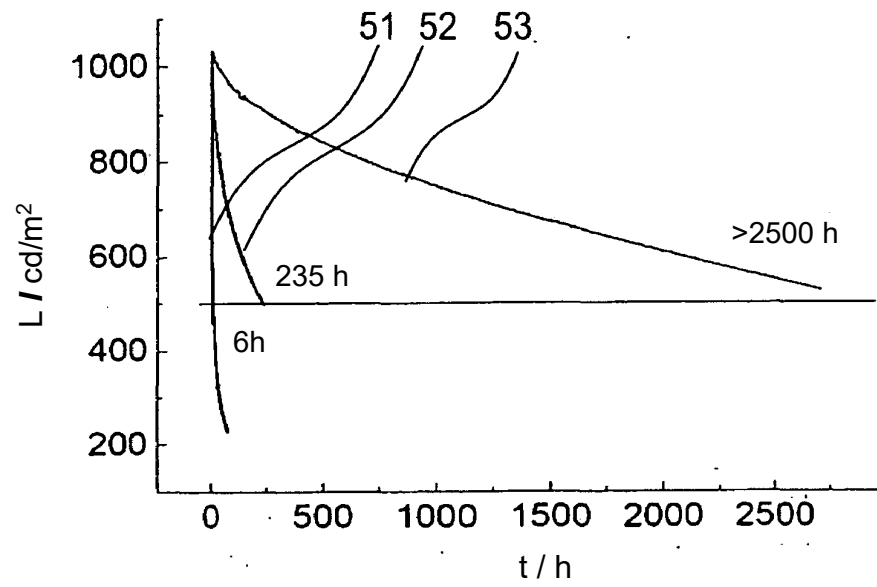
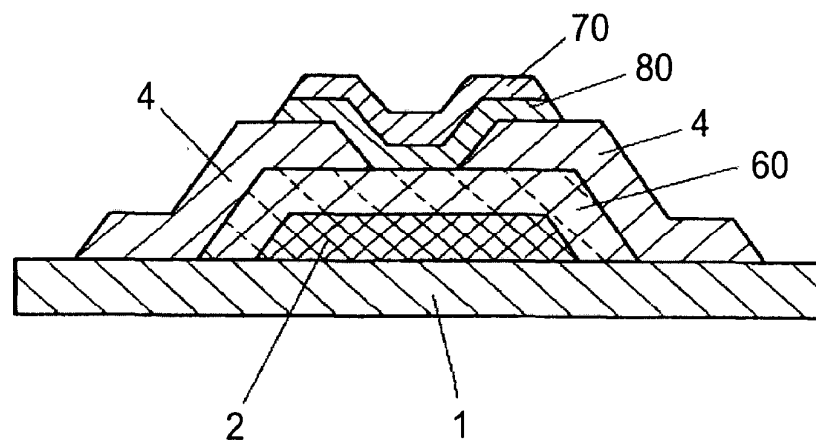


Fig 9



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