Title: LIGHT EMITTING DEVICE AND ELECTRONIC EQUIPMENT

Abstract: A light emitting device of the present invention includes anodes; a cathode; and positive hole transport layers provided between the anodes and the cathode; light emitting functional layers provided between the positive hole transport layers and the cathode in a state of being in contact with the positive hole transport layers; a positive hole transport layer provided between the positive hole transport layer and the cathode in a state of being in contact with the light emitting functional layers; and a light emitting functional layer provided between the positive hole transport layer and the cathode in a state of being in contact with the positive hole transport layer, in which the thickness of the positive hole transport layer is 2 nm or less.
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Light emitting device and electronic equipment

[Technical Field]
The present invention relates to a light emitting device and electronic equipment.

[Background Art]
An organic electroluminescent element (a so-called organic EL element) is a light emitting element having a structure in which at least one light emitting layer is inserted between an anode and a cathode. In the light emitting element, electrons are injected from the cathode side to the light emitting layer and positive holes are injected from the anode side thereto by applying an electric field between the cathode and the anode, an excitor is generated by recombining the electrons and the positive holes in the light emitting layer, and energy is released as light while the excitor returns to a ground state.

For example, when a display device is configured using the light emitting element, respective red light emitting elements, green light emitting elements, and blue light emitting elements are used in a form of a combination thereof, as for example disclosed in JP 2011/029666 A. The light emitting device disclosed in JP 2011/029666 A includes a light emitting element having a red light emitting layer, a light emitting element having a green light emitting layer, and a light emitting element having a blue light emitting layer, and the blue light emitting layer is formed on the red light emitting layer and the green light emitting layer as a common layer. The light emitting device can be effectively produced by forming the red light emitting layer and the green light emitting layer using a liquid phase process such as an ink jet method and by forming the blue light emitting layer and a common layer as a further layer on the cathode side of the blue light emitting layer using a vapor phase process such as a deposition method.
However, the light emitting device disclosed in JP 2011/029666 A has a problem in that a carrier has poor transportability at the interface between a positive hole transport layer and a blue light emitting layer and light emission efficiency is low because the blue light emitting layer formed by the vapor phase process is directly provided on the positive hole transport layer formed by the liquid phase process in the blue light emitting element.

[Summary of Invention]

[Technical Problem]
An object of the present invention is to provide a light emitting device which includes a plurality of light emitting elements (a first light emitting element and a second light emitting element) having luminescent colors different from each other, improves light emission efficiency of the respective light emitting elements, and can be effectively produced, and electronic equipment which includes such a light emitting device.

[Solution to Problem]
The present invention is made to solve at least a part of the above-described problems and can be realized as the following modes or application examples.

(Application example 1)
A light emitting device of the present invention includes: a first light emitting element which includes a first anode, a common cathode, a first positive hole transport layer that is provided between the first anode and the common cathode, and a first light emitting functional layer that is provided between the first positive hole transport layer and the common cathode in a state of being in contact with the first positive hole transport layer; and a second light emitting element which includes a second anode, the common cathode, a second positive hole transport layer that is provided between the
second anode and the common cathode, a common positive hole transport layer that is provided between the second positive hole transport layer and the common cathode in a state of being in contact with the second positive hole transport layer, and a second light emitting functional layer that is provided between the common positive hole transport layer and the common cathode in a state of being in contact with the common positive hole transport layer, in which the common positive hole transport layer is provided between the common cathode and the first light emitting functional layer in a state of being in contact with the first light emitting functional layer, and the thickness of the common positive hole transport layer is 2 nm or less.

According to the light emitting device, the first positive hole transport layer, the first light emitting functional layer, and the second positive hole transport layer can be respectively formed for each of the respective elements using a liquid phase process, and the common positive hole transport layer and the second light emitting functional layer can be respectively formed on the two elements in common using a vapor phase process. Therefore, the first light emitting element and the second light emitting element can be effectively produced.

When the first light emitting element and the second light emitting element are formed in this manner, the common positive hole transport layer formed using the vapor phase process which is the same as that of the second light emitting functional layer can be provided between the second positive hole transport layer and the second light emitting functional layer in the second light emitting element, and thus an electrical barrier related to movement of a carrier between the second positive hole transport layer and the second light emitting functional layer can be lowered when compared to a case in which the second positive hole transport layer is directly laminated on the second light emitting functional layer which is produced by a production method different from that of the second positive hole transport layer.
Therefore, the carrier (positive hole) is smoothly transported to the second light emitting functional layer so that the light emission efficiency can be improved.

On the other hand, in the first light emitting element, since the common positive hole transport layer provided between the first light emitting functional layer and the second light emitting functional layer is extremely thin, the carrier (electrons) can be delivered from the second light emitting functional layer to the first light emitting functional layer. Therefore, the first light emitting functional layer can be allowed to selectively emit light without allowing the second light emitting functional layer to emit light in the first light emitting element.

Further, since the common positive hole transport layer is extremely thin, it is possible to suppress increases in the driving voltage of the first light emitting element and the second light emitting element caused by the common positive hole transport layer being provided therebetween.

For the reason described above, in the light emitting device which includes a plurality of light emitting elements (the first light emitting element and the second light emitting element) having luminescent colors different from each other, it is possible to improve the light emission efficiency of the respective light emitting elements and to effectively produce the light emitting device.

(Application example 2)
In the light emitting device of the present invention, it is preferable that the first positive hole transport layer, the first light emitting functional layer, and the second positive hole transport layer be respectively formed using a liquid phase process, and the common positive hole transport layer and the second light emitting functional layer be respectively formed using a vapor phase process.
Therefore, it is possible to effectively produce the first light emitting element and the second light emitting element.

(Application example 3)

In the light emitting device of the present invention, it is preferable that the first positive hole transport layer be configured using a high molecular positive hole transport material, and the second positive hole transport layer and the common positive hole transport layer be respectively configured using a low molecular positive hole transport material.

In this manner, the first positive hole transport layer having high dimensional precision can be effectively formed using a liquid phase process. In addition, a carrier (positive hole) can be smoothly transported from the first positive hole transport layer to the first light emitting functional layer by forming the first light emitting functional layer and the first positive hole transport layer using a liquid phase process.

Moreover, the second positive hole transport layer and the common positive hole transport layer having high dimensional precision can be effectively formed using a vapor phase process. Particularly, the extremely thin common positive hole transport layer can be formed to have high precision (excellent controllability) by forming the common positive hole transport layer using the vapor phase process. Further, even when the second positive hole transport layer and the common positive hole transport layer are formed by performing production methods which are different from each other, the carrier (positive hole) can be smoothly transported from the second positive hole transport layer to the common positive hole transport layer because positive hole transport materials constituting the second positive hole transport layer and the common positive hole transport layer are both low molecules.
(Application example 4)  
In the light emitting device of the present invention, it is preferable that the second positive hole transport layer be configured by containing a material having a characteristic which is the same as or approximate to a characteristic of a constituent material of the common positive hole transport layer.

In this manner, the carrier (positive hole) can be smoothly transported from the second positive hole transport layer to the second light emitting functional layer through the common positive hole transport layer.

(Application example 5)  
In the light emitting device of the present invention, it is preferable that the constituent material of the common positive hole transport layer have an electron blocking property.

In this manner, it is possible for the second light emitting functional layer to effectively emit light by using the electron blocking property of the common positive hole transport layer in the second light emitting element. In contrast, in the first light emitting element, when the electron blocking property of the common positive hole transport layer is exceedingly high, the first light emitting functional layer does not emit light or the light emission efficiency is considerably decreased. Therefore, in this case, it is extremely useful to decrease the electron blocking property of the common positive hole transport layer in the first light emitting element by making the thickness of the common positive hole transport layer extremely small.

(Application example 6)  
In the light emitting device of the present invention, it is preferable that a constituent material of the first light emitting functional layer be configured of a low molecular material as a main material.
In this manner, it is possible to compensate for the decrease in the light emission efficiency of the first light emitting element due to the common positive hole transport layer provided improving the light emission efficiency of the first light emitting functional layer. As a result, the light emission between the first light emitting element and the second light emitting element can be excellently balanced.

(Application example 7)
In the light emitting device of the present invention, it is preferable that the thickness of the common positive hole transport layer be 1 nm or less.

In this manner, in the first light emitting element, the carrier (electrons) can be effectively delivered from the second light emitting functional layer to the first light emitting functional layer by decreasing the electron blocking property of the common positive hole transport layer.

(Application example 8)
It is preferable that in the light emitting device of the present invention a third light emitting element include a third anode, the common cathode, a third positive hole transport layer that is provided between the third anode and the common cathode, and a third light emitting functional layer that is provided between the third positive hole transport layer and the common cathode in a state of being in contact with the third positive hole transport layer, the common positive hole transport layer be in contact with the third light emitting functional layer, and the first light emitting element, the second light emitting element, and the third light emitting element have luminescent colors which are different from one another.

In this manner, in the light emitting device which includes the first light emitting element, the second light emitting element, and the third light emitting element having luminescent colors different from one another, it is
possible to improve the light emission efficiency of the respective light emitting elements and to effectively produce the light emitting device.

(Application example 9)

In the light emitting device of the present invention, it is preferable that the luminescent color of the first light emitting element be red, the luminescent color of the second light emitting element be blue, and the luminescent color of the third light emitting element be green.

In this manner, in the light emitting device which includes the red light emitting element, the green light emitting element, and the blue light emitting element, it is possible to improve light emission efficiency of the respective light emitting elements and to effectively produce the light emitting device. Consequently, it is possible to provide the light emitting device which can perform full-color display with high efficiency at low cost.

(Application example 10)

Electronic equipment of the present invention includes the light emitting device of the present invention.

According to such electronic equipment, since the electronic equipment includes the light emitting device with high efficiency and low cost, it is possible to achieve a reduction in cost and power consumption.

[Brief Description of the Drawings]

Fig. 1 is a cross-sectional view illustrating a light emitting device (display device) according to an embodiment of the present invention.

Fig. 2A is a view for describing a method of producing the light emitting device illustrated in Fig. 1.
Fig. 2B is a view for describing a method of producing the light emitting device illustrated in Fig. 1.

Fig. 2C is a view for describing a method of producing the light emitting device illustrated in Fig. 1.

Fig. 2D is a view for describing a method of producing the light emitting device illustrated in Fig. 1.

Fig. 3A is a view for describing a method of producing the light emitting device illustrated in Fig. 1.

Fig. 3B is a view for describing a method of producing the light emitting device illustrated in Fig. 1.

Fig. 3C is a view for describing a method of producing the light emitting device illustrated in Fig. 1.

Fig. 3D is a view for describing a method of producing the light emitting device illustrated in Fig. 1.

Fig. 4A is a view for describing a method of producing the light emitting device illustrated in Fig. 1.

Fig. 4B is a view for describing a method of producing the light emitting device illustrated in Fig. 1.

Fig. 4C is a view for describing a method of producing the light emitting device illustrated in Fig. 1.
Fig. 5 is a perspective view illustrating the configuration of a mobile (or laptop) personal computer which is an example of electronic equipment of the present invention.

Fig. 6 is a perspective view illustrating the configuration of a mobile phone (including a PHS) which is an example of the electronic equipment of the present invention.

Fig. 7 is a perspective view illustrating the configuration of a digital still (?) camera which is an example of the electronic equipment of the present invention.

Fig. 8A is a graph illustrating the lifetime of the light emitting element of G pixels in Examples 1, 9, and 10 and Comparative Examples 1 and 2.

Fig. 8B is a graph illustrating the lifetime of the light emitting element of B pixels in Examples 1 and 10 and Comparative Examples 1 and 2.

[Description of Embodiments]

Hereinafter, a light emitting device and electronic equipment of the present invention will be described with reference to preferred embodiments illustrated in the figures. Further, for convenience of description, the scales of the respective units are appropriately changed in the respective figures, therefore the scales of the configurations illustrated in the figures do not necessarily match the actual scales thereof.

[Light emitting device]

First, a display device which is an example of the light emitting device of the present invention will be described.

Fig. 1 is a cross-sectional view illustrating the light emitting device (display device) according to an embodiment of the present invention. In addition,
hereinafter, for convenience of description, the upper side in Fig. 1 is referred to as the "upside" and the lower side in Fig. 1 is referred to as the "downside."

A light emitting device 100 illustrated in Fig. 1 is provided with a plurality of light emitting elements 1R, 1G, and 1B in correspondence with sub pixels 100R (R pixel), 100G (G pixel), and 100B (B pixel) and constitutes a display panel having a bottom emission structure. In addition, in the present embodiment, an example in which an active matrix system is employed will be described as a driving system of the display device, but a passive matrix system may be employed.

The light emitting device 100 includes a circuit substrate 20, a plurality of light emitting elements 1R, 1G, and 1B which are provided on the circuit substrate 20, and a sealing substrate 40.

The circuit substrate 20 includes a substrate 21, an interlayer insulation film 22 provided on the substrate 21, a plurality of switching elements 23, and a plurality of wirings 24.

The substrate 21 is substantially transparent (colorless and transparent, colored and transparent, or translucent). For this reason, the light from the respective light emitting elements 1R, 1G, and 1B can be extracted from the substrate 21 side. Examples of constituent materials of the substrate 21 include a resin material such as polyethylene terephthalate, polyethylene naphthalate, polypropylene, a cycloolefin polymer, polyamide, polyether sulfone, polymethyl methacrylate, polycarbonate, or polyarylate; and a glass material such as quartz glass or soda glass, and one or more kinds of these can be used in combination.

Further, when a top emission structure in which the light from the light emitting elements 1R, 1G, and 1B is extracted from the opposite side to the
substrate 21 is adopted, the substrate 21 may be an opaque substrate. Examples of the opaque substrate include a substrate configured of a ceramic material such as alumina; a metal substrate such as stainless steel whose surface is formed of an oxide film (insulating film); and a substrate configured of a resin material.

A plurality of switching elements 23 are arranged in the form of matrix on the substrate 21. The respective switching elements 23 are provided in correspondence with the respective light emitting elements 1R, 1G, and 1B and are transistors for driving the respective light emitting elements 1R, 1G, and 1B.

The respective switching elements 23 include a semiconductor layer 231 made of silicon, a gate insulation layer 232 formed on the semiconductor layer 231, a gate electrode 233 formed on the gate insulation layer 232, a source electrode 234, and a drain electrode 235.

The interlayer insulation film 22 configured of an insulation material is formed so as to cover the plurality of switching elements 23. The wire 24 is provided on the interlayer insulation film 22.

The light emitting elements 1R, 1G, and 1B are provided in correspondence with the respective switching elements 23 on the interlayer insulation film 22. In the present embodiment, the light emitting element 1R is configured so that light of a red color (R) is radiated, the light emitting element 1G is configured so that light of a green color (G) is radiated, and the light emitting element 1B is configured so that light of a blue color (B) is radiated.

Specifically, the light emitting element 1R (first light emitting element) is configured by laminating an anode 3R (first electrode), a positive hole injection layer 4R, a positive hole transport layer 5R (first positive hole transport layer), a light emitting functional layer 6R (first light emitting
functional layer), a positive hole transport layer 7 (common positive hole transport layer), a light emitting functional layer 6B (second light emitting functional layer), an electron transport layer 8, an electron injection layer 9, and a cathode 10 (common cathode) on the interlayer insulation film 22 in this order.

In the same manner, the light emitting element 1G (third light emitting element) is configured by laminating an anode 3G (third electrode), a positive hole injection layer 4G, a positive hole transport layer 5G (third positive hole transport layer), a light emitting functional layer 6G (third light emitting functional layer), the positive hole transport layer 7 (common positive hole transport layer), the light emitting functional layer 6B (second light emitting functional layer), the electron transport layer 8, the electron injection layer 9, and the cathode 10 (common cathode) on the interlayer insulation film 22 in this order.

On the other hand, the light emitting element 1B (second light emitting element) is configured by laminating an anode 3B (second electrode), a positive hole injection layer 4B, a positive hole transport layer 5B (second positive hole transport layer), the positive hole transport layer 7 (common positive hole transport layer (intermediate layer)), the light emitting functional layer 6B (second light emitting functional layer), the electron transport layer 8, the electron injection layer 9, and the cathode 10 (common cathode) on the interlayer insulation film 22 in this order.

Here, the anodes 3R, 3G, and 3B constitute pixel electrodes which are individually provided for each of the corresponding light emitting elements 1R, 1G, and 1B and are electrically connected to the drain electrode of the switching element 23 through the wire 24. In addition, the positive hole injection layers 4R, 4G, and 4B, the positive hole transport layers 5R, 5G, and 5B, the light emitting functional layer 6R, and the light emitting functional layer 6G are individually provided for each of the corresponding
light emitting elements 1R, 1G, and 1B. Further, hereinafter, the light emitting elements 1R, 1G, and 1B are collectively referred to as "light emitting elements 1", the anodes 3R, 3G, and 3B are collectively referred to as "anodes 3", the positive hole injection layers 4R, 4G, and 4B are collectively referred to as "positive hole injection layers 4", and the positive hole transport layers 5R, 5G, and 5B are collectively referred to as "positive hole transport layers 5".

On the other hand, the cathode 10 constitutes a common electrode provided in the light emitting elements 1R, 1G, and 1B in common. Further, the positive hole transport layer 7 (common positive hole transport layer), the light emitting functional layer 6B, the electron transport layer 8, and the electron injection layer 9 are provided in the light emitting elements 1R, 1G, and 1B in common.

According to the light emitting device 100, the positive hole transport layers 5R, 5G, and 5B and the light emitting functional layers 6R and 6G can be individually formed for each of the respective elements using a liquid phase process and the positive hole transport layer 7 and the light emitting functional layer 6B can be respectively formed on the three elements in common using a vapor phase process. Therefore, the light emitting elements 1R, 1G, and 1B can be effectively produced.

When the light emitting elements 1R, 1G, and 1B are formed in this manner, the positive hole transport layer 7 formed using the vapor phase process which is the same as that of the light emitting functional layer 6B can be provided between the positive hole transport layer 5B and the light emitting functional layer 6B in the light emitting element 1B, and thus an electrical barrier related to the movement of a carrier between the positive hole transport layer 5B and the light emitting functional layer 6B can be lowered when compared to a case in which the positive hole transport layer 5B is directly laminated on the light emitting functional layer 6B which is
produced by a production method different from that of the positive hole transport layer 5B. Therefore, the carrier (positive hole) is smoothly transported to the light emitting functional layer 6B so that the light emission efficiency can be improved.

A partition 31 (bank) configured of a resin material is provided among the adjacent light emitting elements 1R, 1G, and 1B. In addition, the sealing substrate 40 is bonded to the light emitting elements 1R, 1G, and 1B through a resin layer 32 configured of a thermosetting resin such as an epoxy resin.

Since the respective light emitting elements 1R, 1G, and 1B of the present embodiment are bottom emission types as described above, the sealing substrate 40 may be a transparent substrate or an opaque substrate and a material which is the same as that of the above-described substrate 21 can be used as a constituent material of the sealing substrate 40.

Hereinafter, the light emitting elements 1R, 1G, and 1B will be described.

In the light emitting elements 1R, 1G, and 1B, electrons are supplied (injected) from the cathode 10 with respect to the light emitting functional layers 6R, 6G, and 6B and positive holes are supplied (injected) from the anodes 3R, 3G, and 3B. In addition, in the light emitting functional layers 6R, 6G, and 6B, the positive holes and the electrons are recombined with each other, excitons (excitons) are generated by the energy released during the recombination, and the energy (fluorescence or phosphorescence) is released (emitted) when the state of the excitons returns to a ground state.

Here, the light emitting functional layer 6B is provided in the light emitting elements 1R and 1G, but the light emitting functional layers 6R and 6G are allowed to selectively emit light without allowing the light emitting functional layer 6B to emit light. In this manner, the light emitting elements 1R, 1G,
and 1B respectively emit light of a red color, light of a green color, and light of a blue color.

Hereinafter, the configurations of respective units of the light emitting elements 1R, 1G, and 1B will be simply described.

[Anode]
The anodes 3 (3R, 3G, and 3B) are electrodes that inject positive holes into the positive hole injection layer 4 (4R, 4G, and 4B). It is preferable to respectively use materials having a large work function and excellent conductivity as constituent materials of the anodes 3R, 3G, and 3B. Specific examples of the constituent materials of the anodes 3R, 3G, and 3B include oxides such as Indium Tin Oxide (ITO), Indium Zinc Oxide (IZO), In, SnO2, Sb-containing SnO2, or Al-containing ZnO; Au, Pt, Ag, Cu, or an alloy containing these, and one or more kinds of these can be used in combination. In addition, the constituent materials of the anodes 3R, 3G, and 3B may be the same as or different from one another, but anodes 3R, 3G, and 3B can be collectively formed using the same materials so that the productivity can be improved.

[Positive hole injection layer]
The positive hole injection layers 4 (4R, 4G, and 4B) have functions of improving positive hole injection efficiency from the anodes 3 (3R, 3G, and 3B).

Examples of the constituent materials (positive hole injection materials) of the positive hole injection layers 4R, 4G, and 4B, which are not particularly limited, include a mixture (PEDOT: PSS) in which polystyrene sulfonate (PSS) as a dopant is added to a polythiophene derivative such as polyethylene dioxythiophene (PEDOT); polystyrene; polypyrrole; polyaniline; oligoaniline; polyacetylene; and a high molecular positive hole
injection material of a derivative thereof, and one or more kinds of these can be used in combination. In addition, the constituent materials of the positive hole injection layers 4R, 4G, and 4B may be the same as or different from one another, but highly productive and stabilized positive hole injection layers 4R, 4G, and 4B can be formed at low cost when the constituent materials of the positive hole injection layers 4R, 4G, and 4B are the same as one another.

The thicknesses of the positive hole injection layers 4R, 4G, and 4B, which are not particularly limited, are preferably in the range of 10 nm to 150 nm and more preferably in the range of 20 nm to 100 nm.

[Positive hole transport layer]
The positive hole transport layer 5R (first positive hole transport layer) has a function of transporting positive holes injected from the anode 3R through the positive hole injection layer 4R to the light emitting functional layer 6R. In the same manner, the positive hole transport layer 5G (third positive hole transport layer) has a function of transporting positive holes injected from the anode 3G through the positive hole injection layer 4G to the light emitting functional layer 6G.

In addition, the positive hole transport layer 5R has an electron blocking property and a function of preventing decrease of the function of the positive hole injection layer 4R due to intrusion of electrons into the positive hole injection layer 4R. Similarly, the positive hole transport layer 5G has an electron blocking property and a function of preventing decrease of the function of the positive hole injection layer 4G due to intrusion of the electrons into the positive hole injection layer 4G.

The positive hole transport layer 5B (second positive hole transport layer) and the positive hole transport layer 7 (common positive hole transport layer 7) have a function of transporting positive holes injected from the
anode 3B through the positive hole injection layer 4B to the light emitting functional layer 6B.

Moreover, the positive hole transport layers 5B and 7 have the electron blocking property and a function of preventing decrease of the function of the positive hole injection layer 4B due to intrusion of electrons into the positive hole injection layer 4B. In addition, since the common positive hole transport layer 7 is extremely thin as described below, the electron blocking property of the positive hole transport layer 7 alone is extremely low and the movement of the electrons is not inhibited in the light emitting elements 1R and 1G.

Examples of the constituent materials of the positive hole transport layers 5R, 5G, and 5B include an amine-based compound of a triphenylamine-based polymer or the like such as TFB (poly(9,9-dioctyl-fluorene-co-N-(4-butylphenyl)-diphenylamine)); a positive hole transport material of a polysilane-based high molecule containing a polyfluorene derivative (PF) or a poly(paraphenylenylene)vinylene derivative (PPV), a poly(paraphenylenylene) derivative (PPP), polyvinyl carbazole (PVK), a polythiophene derivative, and polymethyl phenyl silane (PMPS); a low molecular positive hole transport material such as m-MTDATA(4,4',4''-tris(N-3-methylphenylamino)triphenylamine), TCTA(4,4',4''-tri(N-carbazole group)triphenylamine), or alpha-NPD(bis(N-(1-naphthyl)-N-phenyl)benzidine), and one or more kinds of these can be used in combination. Further, the constituent materials of the positive hole transport layers 5R, 5G, and 5B (the first positive hole transport layer, the second positive hole transport layer, and the third positive hole transport layer) may be the same as or different from one another, but the light emission balance between the light emitting elements 1R and 1G and the light emitting element 1B can be easily adjusted when the constituent materials of the positive hole transport layers 5R and 5G (the first positive hole transport layer and the third positive hole transport layer) are the same as each other and the constituent material of the
positive hole transport layer 5B (the second positive hole transport layer) is different from those of the positive hole transport layers 5R and 5G.

Further, it is preferable that the positive hole transport layers 5R and 5G be respectively configured using a high molecular weight positive hole transport material and the positive hole transport layers 5B and 7 be respectively configured using a low molecular weight positive hole transport material. In this manner, the positive hole transport layers 5R and 5G with high dimension precision can be effectively formed using the liquid phase process. In addition, the carrier (positive hole) can be smoothly transported from the positive hole transport layers 5R and 5G to the light emitting functional layers 6R and 6G by forming the light emitting functional layers 6R and 6G and the positive hole transport layers 5R and 5G using the liquid phase process.

Furthermore, the positive hole transport layers 5B and 7 with high dimension precision can be effectively formed using the vapor phase process. Particularly, the extremely thin positive hole transport layer 7 can be formed with high precision (excellent controllability) by forming the positive hole transport layer 7 using the vapor phase process. Further, even when the positive hole transport layer 5B and the positive hole transport layer 7 are formed by performing production methods which are different from each other, the carrier (positive hole) can be smoothly transported from the positive hole transport layer 5B to the positive hole transport layer 7 because positive hole transport materials constituting the positive hole transport layer 5B and the positive hole transport layer 7 are both low molecular weight molecules.

Here, in a case in which the positive hole transport layer 5B is configured using the low molecular weight positive hole transport material, the positive hole transport layer 5B may contain the high molecular weight positive hole transport material in addition to the low molecular weight positive hole transport material.
transport material, and the content of the low molecular weight positive hole transport material with respect to the positive hole transport layer 5B is preferably in the range of 50 wt% to 100 wt%, more preferably in the range of 70 wt% to 100 wt%, and most preferably in the range of 90 wt% to 100 wt%.

Further, examples of the constituent material of the common positive hole transport layer 7 include a low molecular weight positive hole transport material such as m-MTDATA(4,4',4''-tris(N-3-methylphenylamino)-triphenylamine), TCTA(4,4',4''-tri(N-carbazole group)triphenylamine), or alpha-NPD(bis(N-(1-naphthyl)-N-phenyl)benzidine), and one or more kinds of these can be used in combination. Further, the constituent material of the positive hole transport layer 7 (common positive hole transport layer) may be the same as or different from the positive hole transport layers 5R, 5G, and 5B, but the carrier (positive hole) can be smoothly transported from the positive hole transport layer 5B to the light emitting functional layer 6B through the positive hole transport layer 7 when the constituent material of the positive hole transport layer 7 contains a material which is the same as or approximate to the constituent material of the positive hole transport layer 5B (second positive hole transport layer).

In a preferred embodiment, the positive hole transport layer 5B (second positive hole transport layer) and the common positive hole transport layer 7 comprise as a low molecular weight positive hole transport material a triarylamine compound having three aromatic or heteroaromatic ring system $A_r^1, A_r^2, A_r^3$. The triarylamine compounds of both layers may be identical or different, preferably identical.

Preferably, the triarylamine compound has the following formula (I):
where

Ar\(^1\) to Ar\(^3\) is on each occurrence, in each case identically or differently, a mono- or polycyclic, aromatic or heteroaromatic ring system having 5 to 60 aromatic ring atoms, which may be substituted by one or more radicals R;

R is on each occurrence, identically or differently, H, D, F, Cl, Br, I, N(R\(^1\))\(^2\), CN, NO\(_2\), Si(R\(^1\))\(^3\), B(OR\(^1\))\(^2\), C(=0)R\(^1\), P(=0)(R\(^1\))\(^2\), S(=0)R\(^1\), S(=0)2R\(^1\), OSO\(_2\)R\(^1\), a straight-chain alkyl, alkoxy or thioalkoxy group having 1 to 40 C atoms or a branched or cyclic alkyl, alkoxy or thioalkoxy group having 3 to 40 C atoms, each of which may be substituted by one or more radicals R\(^1\), where one or more non-adjacent CH\(_2\) groups may be replaced by R\(^1\)C=CR\(^1\), C≡C, Si(R\(^1\))\(^2\), C=0, C=S, C=NR\(^1\), P(=O)(R\(^1\)), SO, SO\(_2\), NR\(^1\), O, S or CONR\(^1\) and where one or more H atoms may be replaced by D, F, Cl, Br, I or CN, or a mono- or polycyclic, aromatic or heteroaromatic ring system having 5 to 60 aromatic ring atoms, which may in each case be substituted by one or more radicals R\(^1\), or an aryloxy or heteroaryloxy group having 5 to 60 aromatic ring atoms, which may be substituted by one or more radicals R\(^1\), or an aralkyl or heteroaralkyl group having 5 to 60 aromatic ring atoms, which may be substituted by one or more radicals R\(^1\), or a diarylamino group, diheteroarylamino group or arylheteroarylamino group having 10 to 40 aromatic ring atoms, which may be substituted by one or more radicals R\(^1\), or a crosslinkable group Q, where two or more radicals R may also form a mono- or polycyclic, aliphatic, aromatic and/or benzo-fused ring system with one another;

R\(^1\) is on each occurrence, identically or differently, H, D, F or an aliphatic hydrocarbon radical having 1 to 20 C atoms, an aromatic and/or a heteroaromatic hydrocarbon radical having 5 to 20 C atoms, in which,
In addition, one or more H atoms may be replaced by F; where two or more substituents R¹ may also form a mono- or polycyclic, aliphatic or aromatic ring system with one another.

In a preferred embodiment, the triarylamine compound of formula (I) is characterised in that at least one of Ar¹, Ar² and/or Ar³ is substituted by Ar⁴ in at least one, preferably in one of the two ortho positions, where Ar⁴ is a mono- or polycyclic, aromatic or heteroaromatic ring system having 5 to 60 aromatic ring atoms, which may be substituted by one or more radicals R.

Ar⁴ here may either be linked directly, i.e. via a single bond, to Ar¹, Ar² and/or Ar³ or alternatively via a linking group X.

In a preferred embodiment, one of Ar¹, Ar² and Ar³, e.g. Ar³ is substituted by Ar⁴ in one of the two ortho positions. The compound of formula (I) thus preferably has the following formula (la):

![Diagram](image)

where Ar¹, Ar², Ar³, Ar⁴ and R can adopt the meanings indicated above, q = 0, 1, 2, 3, 4, 5 or 6, preferably 0, 1, 2, 3 or 4, X = CR₂, NR, S⁻₁R₂, O, S, C=O or P=O, preferably CR₂, NR, O or S, and r = 0 or 1, preferably 0.

In another preferred embodiment of the present invention, the compound of formula (I) is characterised in that Ar³ is substituted by Ar⁴ in one of the two ortho positions, and Ar³ is additionally linked to Ar⁴ in the meta position that is adjacent to the substituted ortho position.

The compound of formula (I) thus preferably has the following formula (lb):
where $A_{r1}, A_{r2}, A_{r3}, A_{r4}$ and $R$ can adopt the meanings indicated above,

$m = 0, 1, 2, 3$ or $4$,

$n = 0, 1, 2$ or $3$,

$X = CR_2, NR, SiR_2, O, S, C=0$ or $P=0$, preferably $CR_2, NR, O$ or $S$, and

$s$ and $t$ are each $0$ or $1$, where the sum $(s + t) = 1$ or $2$, preferably $1$.

In a first more preferred embodiment, the compound of formula (I) is selected from the following formulae (II), (III) and (IV):

where $A_{r1}, A_{r2}, A_{r4}$ and $R$ can adopt the meanings indicated above,
m = 0, 1, 2, 3 or 4,
n = 0, 1, 2 or 3, and
X = CR₂, NR, SiR₂, O, S, C=0 or P=0, preferably CR₂, NR, O or S.

In a particularly preferred embodiment, the compound of formula (II) is selected from the following formula (V):

![Chemical Structure](image)

where Ar¹, Ar², R and m can adopt the meanings indicated above, and
p = 0, 1, 2, 3, 4 or 5.

Examples of preferred compounds of formula (V) are depicted in the following table:

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
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<tbody>
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<td></td>
</tr>
</tbody>
</table>

(Va) | (Vb) | (Vc) |
(Vd) | (Ve) | (Vf) |
where $A_{r1}$, $A_{r2}$, $R$, $m$, $n$ and $p$ can adopt the meanings indicated above, and $k = 0$, 1 or 2.

In a further particularly preferred embodiment, the compound of formula (III) is selected from the following formula (VI):

$$
\begin{align*}
&\text{where } A_{r1}, A_{r2}, R, m \text{ and } n \text{ can adopt the meanings indicated above.}
\end{align*}
$$

Examples of preferred compounds of formula (VI) are depicted in the following table:
where $A_{r1}, A_{r2}, R, m, n$ and $p$ can adopt the meanings indicated above.

In still a further particularly preferred embodiment, the compound of formula (IV) is selected from the following formula (VII):

where $A_{r1}, A_{r2}, R, m$ and $n$ can adopt the meanings indicated above.

Examples of preferred compounds of formula (VII) are depicted in the following table:
where \( \text{Ar}^1, \text{Ar}^2, R, m, n \) and \( p \) can adopt the meanings indicated above.

In a very particularly preferred embodiment, the compound of formula (V) is selected from the following formula (VIII):

\[
\text{(VIII)}
\]

where \( R, m \) and \( p \) can adopt the meanings indicated above.

Examples of preferred compounds of formula (VIII) are depicted in the following table:

<table>
<thead>
<tr>
<th></th>
<th>(VIIIa)</th>
<th>(VIIIb)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><img src="image1.png" alt="Image" /></td>
<td><img src="image2.png" alt="Image" /></td>
</tr>
<tr>
<td>(VIIIc)</td>
<td><img src="image3.png" alt="Image" /></td>
<td><img src="image4.png" alt="Image" /></td>
</tr>
<tr>
<td>(VIIId)</td>
<td><img src="image5.png" alt="Image" /></td>
<td><img src="image6.png" alt="Image" /></td>
</tr>
</tbody>
</table>
where \( R, k, m, n \) and \( p \) can adopt the meanings indicated above.

In a further very particularly preferred embodiment, the compound of formula (VI) is selected from the following formula (IX):

\[
\text{(IX)}
\]

where \( R, X, m \) and \( n \) can adopt the meanings indicated above.

Examples of preferred compounds of formula (IX) are depicted in the following table:
where $R$, $m$, $n$ and $p$ can adopt the meanings indicated above, and $v = 1$ to 20, preferably 1 to 10.

In still a further very particularly preferred embodiment, the compound of formula (VII) is selected from compounds of the following formula (X):

<table>
<thead>
<tr>
<th>(IXa)</th>
<th>(IXb)</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="Structure" /></td>
<td><img src="image2" alt="Structure" /></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>(IXc)</th>
<th>(IXd)</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image3" alt="Structure" /></td>
<td><img src="image4" alt="Structure" /></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>(IXe)</th>
<th>(IXf)</th>
<th>(IXg)</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image5" alt="Structure" /></td>
<td><img src="image6" alt="Structure" /></td>
<td><img src="image7" alt="Structure" /></td>
</tr>
</tbody>
</table>
where $R$, $X$, $m$ and $n$ can adopt the meanings indicated above.

Examples of preferred compounds of formula (X) are depicted in the following table:

<table>
<thead>
<tr>
<th>(Xa)</th>
<th>(Xb)</th>
<th>(Xc)</th>
</tr>
</thead>
</table>

where $R$, $m$ and $n$ can adopt the meanings indicated above.

The term "mono- or polycyclic, aromatic ring system" in the present application is taken to mean an aromatic ring system having 6 to 60, preferably 6 to 30 and particularly preferably 6 to 24 aromatic ring atoms, which does not necessarily contain only aromatic groups, but instead in which a plurality of aromatic units may also be interrupted by a short non-aromatic unit (< 10% of the atoms other than H, preferably < 5% of the atoms other than H), such as, for example, an sp$^3$-hybridised C atom or O or N atom, a CO group, etc. Thus, for example, systems such as, for example, 9,9'-spiro-bifluorene, 9,9-diarylfluorene and 9,9-dialkylfluorene are also intended to be taken to be aromatic ring systems.

The aromatic ring systems may be mono- or polycyclic, i.e. they may contain one ring (for example phenyl) or a plurality of rings, which may also be
condensed (for example naphthyl) or covalently linked (for example biphenyl), or contain a combination of condensed and linked rings.

Preferred aromatic ring systems are, for example, phenyl, biphenyl, terphenyl, [1,1':3',1"]terphenyl-2'-yl, quaterphenyl, naphthyl, anthracene, binaphthyl, phenanthrene, dihydrophenanthrene, pyrene, dihydropyrene, chrysene, perylene, tetracene, pentacene, benzopyrene, fluorene, indene, indenofluorene and spirobifluorene.

The term "mono- or polycyclic, heteroaromatic ring system" in the present application is taken to mean an aromatic ring system having 5 to 60, preferably 5 to 30 and particularly preferably 5 to 24 aromatic ring atoms, where one or more of these atoms is (are) a heteroatom. The "mono- or polycyclic, heteroaromatic ring system" does not necessarily contain only aromatic groups, but instead may also be interrupted by a short non-aromatic unit (< 10% of the atoms other than H, preferably < 5% of the atoms other than H), such as, for example, an sp³-hybridised C atom or O or N atom, a CO group, etc.

The heteroaromatic ring systems may be mono- or polycyclic, i.e. they may contain one ring or a plurality of rings, which may also be condensed or covalently linked (for example pyridylphenyl), or contain a combination of condensed and linked rings. Preference is given to fully conjugated heteroaryl groups.

Preferred heteroaromatic ring systems are, for example, 5-membered rings, such as pyrrole, pyrazole, imidazole, 1,2,3-triazole, 1,2,4-triazole, tetrazole, furan, thiophene, selenophene, oxazole, isoxazole, 1,2-thiazole, 1,3-thiazole, 1,2,3-oxadiazole, 1,2,4-oxadiazole, 1,2,5-oxadiazole, 1,3,4-oxadiazole, 1,2,3-thiadiazole, 1,2,4-thiadiazole, 1,2,5-thiadiazole, 1,3,4-thiadiazole, 6-membered rings, such as pyridine, pyridazine, pyrimidine, pyrazine, 1,3,5-triazine, 1,2,4-triazine, 1,2,3-triazine, 1,2,4,5-tetrazine, 1,2,3,4-tetrazine, 1,2,3,5-tetrazine, or groups having a plurality of rings, such as carbazole, indenocarbazole, indole, isoindole, indolizine, indazole, benzimidazole, benzotriazoles, pyridines, pyridazine, pyrimidine, pyrazine, 1,3,5-triazine, 1,2,4-triazine, 1,2,3-triazine, 1,2,4,5-tetrazine, 1,2,3,4-tetrazine, 1,2,3,5-tetrazine, or groups having a plurality of rings, such as carbazole, indenocarbazole, indole, isoindole, indolizine, indazole, benzimidazole, benzotriazoles, pyridines, pyridazine, pyrimidine, pyrazine, 1,3,5-triazine, 1,2,4-triazine, 1,2,3-triazine, 1,2,4,5-tetrazine, 1,2,3,4-tetrazine, 1,2,3,5-tetrazine, or groups having a plurality of rings, such as carbazole, indenocarbazole, indole, isoindole, indolizine, indazole, benzimidazole, benzotriazoles, pyridines, pyridazine, pyrimidine, pyrazine, 1,3,5-triazine, 1,2,4-triazine, 1,2,3-triazine, 1,2,4,5-tetrazine, 1,2,3,4-tetrazine, 1,2,3,5-tetrazine, or groups having a plurality of rings, such as carbazole, indenocarbazole, indole, isoindole, indolizine, indazole, benzimidazole, benzotriazoles, pyridines, pyridazine, pyrimidine, pyrazine, 1,3,5-triazine, 1,2,4-triazine, 1,2,3-triazine, 1,2,4,5-tetrazine, 1,2,3,4-tetrazine, 1,2,3,5-tetrazine, or groups having a plurality of rings, such as carbazole, indenocarbazole, indole, isoindole, indolizine, indazole, benzimidazole, benzotriazoles, pyridines, pyridazine, pyrimidine, pyrazine, 1,3,5-triazine, 1,2,4-triazine, 1,2,3-triazine, 1,2,4,5-tetrazine, 1,2,3,4-tetrazine, 1,2,3,5-tetrazine, or groups having a plurality of rings, such as carbazole, indenocarbazole, indole, isoindole, indolizine, indazole, benzimidazole, benzotriazoles, pyridines, pyridazine, pyrimidine, pyrazine, 1,3,5-triazine, 1,2,4-triazine, 1,2,3-triazine, 1,2,4,5-tetrazine, 1,2,3,4-tetra-
zole, anthroxazole, phenanthroxazole, isoxazole, benzothiazole, benzo-furan, isobenzofuran, dibenzofuran, quinoline, isoquinoline, pteridine, benzo-5,6-quinoline, benzo-6,7-quinoline, benzo-7,8-quinoline, benzoiso-quinoline, acridine, phenothiazine, phenoxazine, benzopyridazine, benzo-pyrimidine, quinoxaline, phenazine, naphthyridine, azacarbazole, benzo-carboline, phenanthridine, phenanthroline, thieno[2,3b]thiophene, thieno-[3,2b]thiophene, dithienothiophene, isobenzothiophene, dibenzothiophene, benzothiadiazothiophene or combinations of these groups.

The mono- or polycyclic, aromatic or heteroaromatic ring system may be unsubstituted or substituted. Substituted in the present application means that the mono- or polycyclic, aromatic or heteroaromatic ring system contains one or more substituents R.

R is on each occurrence preferably, identically or differently, H, D, F, Cl, Br, l, N(R\(^1\))\(_2\), CN, NO\(_2\), Si(R\(^1\))\(_3\), B(OR\(^1\))\(_2\), C(=O)R\(^1\), P(=O)(R\(^1\))\(_2\), S(=O)R\(^1\), a straight-chain alkyl, alkoxy or thioalkoxy group having 1 to 40 C atoms or an alkenyl or alkynyl group having 2 to 40 C atoms or a branched or cyclic alkyl, alkoxy or thioalkoxy group having 3 to 40 C atoms, each of which may be substituted by one or more radicals R\(^1\), where one or more non-adjacent CH\(_2\) groups may be replaced by R\(^1\)C=CR\(^1\), C≡C, Si(R\(^1\))\(_2\), C=O, C=S, C=NR\(^1\); P(=O)(R\(^1\))\(_2\), SO, SO\(_2\), NR\(^1\), O, S or CONR\(^1\); and where one or more H atoms may be replaced by D, F, Cl, Br, I or CN, or an aromatic or heteroaromatic ring system having 5 to 60 aromatic ring atoms, which may in each case be substituted by one or more radicals R\(^1\), or an aryloxy or heteroaryloxy group having 5 to 60 aromatic ring atoms, which may be substituted by one or more radicals R\(^1\), or an aralkyl or hetero-aralkyl group having 5 to 60 aromatic ring atoms, which may be substituted by one or more radicals R\(^1\), or a diarylamino group, diheteroarylamino group or arylheteroarylamino group having 10 to 40 aromatic ring atoms, which may be substituted by one or more radicals R\(^1\); two or more radicals R here may also form a mono- or polycyclic, aliphatic, aromatic and/or benzo-fused ring system with one another.

R is on each occurrence particularly preferably, identically or differently, H, D, F, Cl, Br, l, N(R\(^1\))\(_2\), Si(R\(^1\))\(_3\), B(OR\(^1\))\(_2\), C(=O)R\(^1\), P(=O)(R\(^1\))\(_2\), a straight-
chain alkyl or alkoxy group having 1 to 20 C atoms or an alkenyl or alkynyl group having 2 to 20 C atoms or a branched or cyclic alkyl or alkoxy group having 3 to 20 C atoms, each of which may be substituted by one or more radicals R¹, where one or more non-adjacent CH₂ groups may be replaced by R¹C=CR\_\_C≡C, Si(R¹)₂, C≡C, C≡NR¹, C=NR¹, P(=O)(R¹)₁, NR¹, O or CONR¹ and where one or more H atoms may be replaced by F, Cl, Br or I, or an aromatic or heteroaromatic ring system having 5 to 30 aromatic ring atoms, which may in each case be substituted by one or more radicals R¹, or an aryloxy or heteroaryloxy group having 5 to 30 aromatic ring atoms, which may be substituted by one or more radicals R¹, or an aralkyl or heteroaralkyl group having 5 to 30 aromatic ring atoms, which may be substituted by one or more radicals R¹, or a diarylamino group, diheteroarylamino group or arylheteroarylamino group having 10 to 20 aromatic ring atoms, which may be substituted by one or more radicals R¹; two or more radicals R here may also form a mono- or polycyclic, aliphatic, aromatic and/or benzo-fused ring system with one another.

R is on each occurrence very particularly preferably, identically or differentially, H, a straight-chain alkyl or alkoxy group having 1 to 10 C atoms or an alkenyl or alkynyl group having 2 to 10 C atoms or a branched or cyclic alkyl or alkoxy group having 3 to 10 C atoms, each of which may be substituted by one or more radicals R¹, where one or more non-adjacent CH₂ groups may be replaced by R¹C=CR\_\_C≡C, C≡C, C≡O, C≡NR¹, C=NR¹, O or CONR¹, or an aromatic or heteroaromatic ring system having 5 to 20 aromatic ring atoms, which may in each case be substituted by one or more radicals R¹, or an aryloxy or heteroaryloxy group having 5 to 20 aromatic ring atoms, which may be substituted by one or more radicals R¹, or an aralkyl or heteroaralkyl group having 5 to 20 aromatic ring atoms, which may be substituted by one or more radicals R¹, or a diarylamino group, diheteroarylamino group or arylheteroarylamino group having 10 to 20 aromatic ring atoms, which may be substituted by one or more radicals R¹; two or more radicals R here may also form a mono- or polycyclic, aliphatic, aromatic and/or benzo-fused ring system with one another.
The compounds of formulae (I) to (X) have preferably a molecular weight of 
≤ 3000 g/mol, more preferably a molecular weight of ≤ 2000 g/mol and most 
preferably a molecular weight of ≤ 1500 g/mol.

The compounds of formulae (I) to (X) have preferably a molecular weight of 
≥ 500 g/mol, more preferably a molecular weight of ≥ 700 g/mol and most 
preferably a molecular weight of ≥ 900 g/mol.

In a further preferred embodiment, the positive hole transport layer 5B 
(second positive hole transport layer) comprises beside the low molecular 
weight triarylamine compound selected from formulae (I) to (X) a polymer 
which contains at least one structural unit of the following formula (XI):

\[ \text{Ar}^3 \text{N} \text{Ar}^2 \text{Ar}^1 \]

where

\( \text{Ar}^1 \text{to Ar}^3 \) is on each occurrence, in each case identically or differently, a 
mono- or polycyclic, aromatic or heteroaromatic ring system having 5 to 
60 aromatic ring atoms, which may be substituted by one or more radicals \( R \);

\( R \) is on each occurrence, identically or differently, H, D, F, Cl, Br, I,
N(R\(^1\))\(_2\), CN, NO\(_2\), Si(R\(^1\))\(_3\), B(OR\(^1\))\(_2\), C(=0)R\(^1\), P(=0)(R\(^1\))\(_2\), S(=O)R\(_1\)
S(=O)2R\(^1\), OSO2R\(^1\), a straight-chain alkyl, alkoxy or thioalkoxy group 
having 1 to 40 C atoms or a branched or cyclic alkyl, alkoxy or thio-
alkoxy group having 3 to 40 C atoms, each of which may be substitu-
ted by one or more radicals \( R^1 \), where one or more non-adjacent CH2 
groups may be replaced by \( R^1 C=CR^1 \), C≡C, Si(R\(^1\))\(_2\), C=0, C=S,
C=NR\(_1\), P(=0)(R\(^1\)), SO, SO\(_2\), NR\(^1\), O, S or CONR\(^1\) and where one or 
more H atoms may be replaced by D, F, Cl, Br, I or CN, or a mono- 
or polycyclic, aromatic or heteroaromatic ring system having 5 to 60
aromatic ring atoms, which may in each case be substituted by one or more radicals $R^1$, or an aryloxy or heteroaryloxy group having 5 to 60 aromatic ring atoms, which may be substituted by one or more radicals $R^1$, or an aralkyl or heteroaralkyl group having 5 to 60 aromatic ring atoms, which may be substituted by one or more radicals $R^1$, or a diarylamino group, diheteroarylamino group or arylheteroarylamino group having 10 to 40 aromatic ring atoms, which may be substituted by one or more radicals $R^1$, where two or more radicals $R$ may also form a mono- or polycyclic, aliphatic, aromatic and/or benzo-fused ring system with one another; 

$R^1$ is on each occurrence, identically or differently, $H$, $D$, $F$ or an aliphatic hydrocarbon radical having 1 to 20 C atoms, an aromatic and/or a heteroaromatic hydrocarbon radical having 5 to 20 C atoms, in which, in addition, one or more H atoms may be replaced by F; where two or more substituents $R^1$ may also form a mono- or polycyclic, aliphatic or aromatic ring system with one another; and

the dashed lines represent bonds to adjacent structural units in the polymer.

In a preferred embodiment the structural unit of formula (XI) is characterised in that $\text{Ar}^3$ is substituted by $\text{Ar}^4$ in at least one, preferably in one of the two ortho positions, where $\text{Ar}^4$ is a mono- or polycyclic, aromatic or heteroaromatic ring system having 5 to 60 aromatic ring atoms, which may be substituted by one or more radicals $R$.

$\text{Ar}^4$ here may either be linked directly, i.e. via a single bond, to $\text{Ar}^3$ or alternatively via a linking group $X$.

The structural unit of the formula (XI) thus preferably has the structure of the following formula (Xla):
where \( A_r^1, A_r^2, A_r^3, A_r^4 \) and \( R \) can adopt the meanings indicated above, \( q = 0, 1, 2, 3, 4, 5 \) or 6, preferably \( 0, 1, 2, 3 \) or 4, 
\( X = CR2, \text{NR, S1R2, O, S, C=0 or P=0,} \) preferably \( \text{CR2, NR, O or S,} \) and 
\( r = 0 \) or 1, preferably 0.

In the present application, the term polymer is taken to mean both polymeric compounds, oligomeric compounds and dendrimers. The polymeric compounds according to the invention preferably contain 10 to 10000, particularly preferably 10 to 5000 and very particularly preferably 10 to 2000 structural units (i.e. recurring units). The oligomeric compounds according to the invention preferably contain 3 to 9 structural units. The branching factor of the polymers here is between 0 (linear polymer, no branching points) and 1 (fully branched dendrimer).

The polymers according to the invention preferably have a molecular weight \( M_w \) in the range from 1000 to 2000000 g/mol, particularly preferably a molecular weight \( M_w \) in the range from 10000 to 1500000 g/mol and very particularly preferably a molecular weight \( M_w \) in the range from 50000 to 1000000 g/mol. The molecular weight \( M_w \) is determined by means of GPC (= gel permeation chromatography) against an internal polystyrene standard.

The polymers according to the invention are either conjugated, partially conjugated or non-conjugated polymers. Preference is given to conjugated or partially conjugated polymers.

The structural units of the formula (XI) can in accordance with the invention be incorporated into the main chain or into the side chain of the polymer. However, the structural units of the formula (XI) are preferably incorporated into the main chain of the polymer. In the case of incorporation into the side
chain of the polymer, the structural units of the formula (XI) can be either monovalent or divalent, i.e. they have either one or two bonds to adjacent structural units in the polymer.

"Conjugated polymers" in the sense of the present application are polymers which contain principally sp²-hybridised (or optionally also sp-hybridised) carbon atoms in the main chain, which may also be replaced by correspondingly hybridised heteroatoms. In the simplest case, this means the alternating presence of double and single bonds in the main chain, but polymers containing units such as, for example, a meta-linked phenylene are also intended to be regarded as conjugated polymers in the sense of this application. "Principally" means that naturally (spontaneously) occurring defects which result in conjugation interruptions do not devalue the term "conjugated polymer". The term conjugated polymers is likewise applied to polymers having a conjugated main chain and non-conjugated side chains. Furthermore, the term conjugated is likewise used in the present application if the main chain contains, for example, arylamine units, arylphosphine units, certain heterocycles (i.e. conjugation via N, O or S atoms) and/or organometallic complexes (i.e. conjugation via the metal atom). An analogous situation applies to conjugated dendrimers. By contrast, units such as, for example, simple alkyl bridges, (thio)ether, ester, amide or imide links are clearly defined as non-conjugated segments.

A partially conjugated polymer in the present application is intended to be taken to mean a polymer which contains conjugated regions which are separated from one another by non-conjugated sections, specific conjugation interrupters (for example spacer groups) or branches, for example in which relatively long conjugated sections in the main chain are interrupted by non-conjugated sections, or which contains relatively long conjugated sections in the side chains of a polymer which is non-conjugated in the main chain. Conjugated and partially conjugated polymers may also contain conjugated, partially conjugated or non-conjugated dendrimers.

The term "dendrimer" in the present application is intended to be taken to mean a highly branched compound built up from a multifunctional centre (core), to which branched monomers are bonded in a regular structure, so
that a tree-like structure is obtained. Both the core and also the monomers here can adopt any desired branched structures which consist both of purely organic units and also organometallic compounds or coordination compounds. "Dendrimer" here is generally intended to be understood as described, for example, by M. Fischer and F. Vogtle (Angew. Chem., Int. Ed. 1999, 38, 885).

The term "structural unit" in the present application is taken to mean a unit which, starting from a monomer unit which contains at least two, preferably two, reactive groups, is incorporated into the polymer backbone as a part thereof by reaction with bond formation and is thus present in the polymer prepared as linked recurring unit.

The term "mono- or polycyclic, aromatic ring system" in the present application is taken to mean an aromatic ring system having 6 to 60, preferably 6 to 30 and particularly preferably 6 to 24 aromatic ring atoms, which does not necessarily contain only aromatic groups, but instead in which a plurality of aromatic units may also be interrupted by a short non-aromatic unit (< 10% of the atoms other than H, preferably < 5% of the atoms other than H), such as, for example, an sp³-hybridised C atom or O or N atom, a CO group, etc. Thus, for example, systems such as, for example, 9,9'-spirobifluorene, 9,9-diarylfluorene and 9,9-dialkylfluorene are also intended to be taken to be aromatic ring systems.

The aromatic ring systems may be mono- or polycyclic, i.e. they may contain one ring (for example phenyl) or a plurality of rings, which may also be condensed (for example naphthyl) or covalently linked (for example biphenyl), or contain a combination of condensed and linked rings.

Preferred aromatic ring systems are, for example, phenyl, biphenyl, terphenyl, [1,1':3',1"]terphenyl-2'-yl, quaterphenyl, naphthyl, anthracene, binaphthyl, phenanthrene, dihydrophenanthrene, pyrene, dihydropyrene, chrysene, perylene, tetracene, pentacene, benzopyrene, fluorene, indene, indenofluorene and spirobifluorene.
The term "mono- or polycyclic, heteroaromatic ring system" in the present application is taken to mean an aromatic ring system having 5 to 60, preferably 5 to 30 and particularly preferably 5 to 24 aromatic ring atoms, where one or more of these atoms is (are) a heteroatom. The "mono- or polycyclic, heteroaromatic ring system" does not necessarily contain only aromatic groups, but instead may also be interrupted by a short non-aromatic unit (<10% of the atoms other than H, preferably <5% of the atoms other than H), such as, for example, an sp³-hybridised C atom or O or N atom, a CO group, etc.

The heteroaromatic ring systems may be mono- or polycyclic, i.e. they may contain one ring or a plurality of rings, which may also be condensed or covalently linked (for example pyridylphenyl), or contain a combination of condensed and linked rings. Preference is given to fully conjugated heteroaryl groups.

Preferred heteroaromatic ring systems are, for example, 5-membered rings, such as pyrrole, pyrazole, imidazole, 1,2,3-triazole, 1,2,4-triazole, tetrazole, furan, thiophene, selenophene, oxazole, isoxazole, 1,2-thiazole, 1,3-thiazole, 1,2,3-oxadiazole, 1,2,4-oxadiazole, 1,2,5-oxadiazole, 1,3,4-oxadiazole, 1,2,3-thiadiazole, 1,2,4-thiadiazole, 1,2,5-thiadiazole, 1,3,4-thiadiazole, 6-membered rings, such as pyridine, pyridazine, pyrimidine, pyrazine, 1,3,5-triazine, 1,2,4-triazine, 1,2,3-triazine, 1,2,4,5-tetrazine, 1,2,3,4-tetrazine, 1,2,3,5-tetrazine, or groups having a plurality of rings, such as carbazole, indenocarbazole, indole, isoindole, indolizine, indazole, benzimidazole, benzotriazole, purine, naphthimidazole, phenanthrimidazole, pyrimidinamide, pyrazinimidazole, quinoxalimidazole, benzoxazole, naphthoxazole, anthraoxazole, phenanthrooxazole, isoxazole, benzothiazole, benzo-furan, isobenzofuran, dibenzofuran, quinoline, isoquinoline, pteridine, benzo-5,6-quinoline, benzo-6,7-quinoline, benzo-7,8-quinoline, benzoisoquinoline, acridine, phenothiazine, phenoxazine, benzopyridazine, benzopyrimidine, quinoxaline, phenazine, naphthyridine, azacarbazole, benzo-carboline, phenanthridine, phenanthroline, thieno[2,3b]thiophene, thieno-[3,2b]thiophene, dithienothiophene, isobenzothiophene, dibenzothiophene, benzothiadiazothiophene or combinations of these groups.
The mono- or polycyclic, aromatic or heteroaromatic ring system may be unsubstituted or substituted. Substituted in the present application means that the mono- or polycyclic, aromatic or heteroaromatic ring system contains one or more substituents \( R \).

\( R \) is on each occurrence preferably, identically or differently, \( H, D, F, Cl, Br, I, \) \( N(R^1)_2, CN, NO_2, Si(R^1)_3, B(OR^1)_2, C(=O)R^1, P(=O)(R^1)_2, S(=O)R^1, \) \( S(=O)2R^1, OSO_2R^1 \), a straight-chain alkyl, alkoxy or thioalkoxy group having 1 to 40 C atoms or an alkenyl or alkynyl group having 2 to 40 C atoms or a branched or cyclic alkyl, alkoxy or thioalkoxy group having 3 to 40 C atoms, each of which may be substituted by one or more radicals \( R^1 \), one or more non-adjacent \( \text{CH}_2 \) groups may be replaced by \( R^1C=CR^1, C≡C, Si(R^1)_2, C=0, C=S, C=NR^1, P(=O)(R^1)_2, SO, SO_2, NR^1, O, S \) or \( \text{CONR}^1 \) and where one or more H atoms may be replaced by \( D, F, Cl, Br, I \) or \( CN \), or an aromatic or heteroaromatic ring system having 5 to 60 aromatic ring atoms, which may in each case be substituted by one or more radicals \( R^1 \), or an aryloxy or heteroaryloxy group having 5 to 60 aromatic ring atoms, which may be substituted by one or more radicals \( R^1 \), or an aralkyl or heteroaralkyl group having 5 to 60 aromatic ring atoms, which may be substituted by one or more radicals \( R^1 \), or a diarylamino group, diheteroarylamino group or arylheteroarylamino group having 10 to 40 aromatic ring atoms, which may be substituted by one or more radicals \( R^1 \); two or more radicals \( R \) here may also form a mono- or polycyclic, aliphatic, aromatic and/or benzo-fused ring system with one another.

\( R \) is on each occurrence particularly preferably, identically or differently, \( H, D, F, Cl, Br, I, N(R^1)_2, Si(R^1)_3, B(OR^1)_2, C(=O)R^1, P(=O)(R^1)_2, \) a straight-chain alkyl or alkoxy group having 1 to 20 C atoms or an alkenyl or alkynyl group having 2 to 20 C atoms or a branched or cyclic alkyl or alkoxy group having 3 to 20 C atoms, each of which may be substituted by one or more radicals \( R^1 \), where one or more non-adjacent \( \text{CH}_2 \) groups may be replaced by \( R^1C=CR^1, C≡C, Si(R^1)_2, C=0, C=S, C=NR^1, P(=O)(R^1)_2, \) \( NR^1, O \) or \( \text{CONR}^1 \) and where one or more H atoms may be replaced by \( F, Cl, Br \) or \( I \), or an aromatic or heteroaromatic ring system having 5 to 30 aromatic ring atoms, which may in each case be substituted by one or more radicals \( R^1 \), or an aryloxy or heteroaryloxy group having 5 to 30 aromatic ring atoms, which may be
substituted by one or more radicals \( R^1 \), or an aralkyl or heteroaralkyl group having 5 to 30 aromatic ring atoms, which may be substituted by one or more radicals \( R^1 \), or a diarylamino group, diheteroarylamino group or arylheteroarylamino group having 10 to 20 aromatic ring atoms, which may be substituted by one or more radicals \( R^1 \); two or more radicals \( R \) here may also form a mono- or polycyclic, aliphatic, aromatic and/or benzo-fused ring system with one another.

\( R \) is on each occurrence very particularly preferably, identically or differently, \( H \), a straight-chain alkyl or alkoxy group having 1 to 10 C atoms or an alkenyl or alkynyl group having 2 to 10 C atoms or a branched or cyclic alkyl or alkoxy group having 3 to 10 C atoms, each of which may be substituted by one or more radicals \( R^1 \), where one or more non-adjacent \( CH_2 \) groups may be replaced by \( R^1C=CR^1, C=C=0, C=NR^1, N=O \) or \( CONR^1 \), or an aromatic or heteroaromatic ring system having 5 to 20 aromatic ring atoms, which may in each case be substituted by one or more radicals \( R^1 \), or an aryloxy or heteroaryloxy group having 5 to 20 aromatic ring atoms, which may be substituted by one or more radicals \( R^1 \), or an aralkyl or heteroaralkyl group having 5 to 20 aromatic ring atoms, which may be substituted by one or more radicals \( R^1 \), or a diarylamino group, diheteroarylamino group or arylheteroarylamino group having 10 to 20 aromatic ring atoms, which may be substituted by one or more radicals \( R^1 \); two or more radicals \( R \) here may also form a mono- or polycyclic, aliphatic, aromatic and/or benzo-fused ring system with one another.

\( R^1 \) is on each occurrence preferably, identically or differently, \( H \), \( D \), \( F \) or an aliphatic hydrocarbon radical having 1 to 20 C atoms, an aromatic and/or a heteroaromatic hydrocarbon radical having 5 to 20 C atoms, in which, in addition, one or more \( H \) atoms may be replaced by \( F \); two or more substituents \( R^1 \) here may also form a mono- or polycyclic, aliphatic or aromatic ring system with one another.

\( R^1 \) is on each occurrence particularly preferably, identically or differently, \( H \), \( D \) or an aliphatic hydrocarbon radical having 1 to 20 C atoms, an aromatic and/or a heteroaromatic hydrocarbon radical having 5 to 20 C atoms; two or
more substituents $R^1$ here may also form a mono- or polycyclic, aliphatic or aromatic ring system with one another.

$R^1$ is on each occurrence very particularly preferably, identically or differently, $H$ or an aliphatic hydrocarbon radical having 1 to 10 C atoms, an aromatic and/or a heteroaromatic hydrocarbon radical having 5 to 10 C atoms.

In one embodiment, the at least one structural unit of the formula (XI) of the polymer is characterised in that $A r^3$ is substituted by $A r^4$ in one of the two ortho positions, and $A r^3$ is additionally linked to $A r^4$ in the meta position that is adjacent to the substituted ortho position.

The structural unit of the formula (XI) thus preferably has the structure of the following formula (Xlb):

![Formula](attachment:formula.png)

where $A r^1$, $A r^2$, $A r^3$, $A r^4$ and $R$ can adopt the meanings indicated above,

$m = 0, 1, 2, 3$ or $4$,

$n = 0, 1, 2$ or $3$,

$X = CR_2$, $NR$, $S_1R_2$, $O$, $S$, $C=0$ or $P=0$, preferably $CR_2$, $NR$, $O$ or $S$, and

$s$ and $t$ are each 0 or 1, where the sum ($s + t$) = 1 or 2, preferably 1.

In a preferred embodiment, the at least one structural unit of the formula (XI) is selected from the structural units of the following formulae (XII), (XIII) and (XIV):
where $\text{Ar}^1$, $\text{Ar}^2$, $\text{Ar}^4$ and $\text{R}$ can adopt the meanings indicated above,

$m = 0, 1, 2, 3$ or $4$,

$n = 0, 1, 2$ or $3$, and

$X = \text{CR}2$, NR, S1R2, O, S, C=0 or P=0, preferably CR2, NR, O or S.

In a particularly preferred embodiment, the at least one structural unit of the formula (XII) is selected from the structural unit of the following formula (XV):
where $A_{r1}$, $A_{r2}$, $R$ and $m$ can adopt the meanings indicated above, and $p = 0, 1, 2, 3, 4$ or $5$.

Examples of preferred structural units of the formula (XV) are depicted in the following table:

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</table>

where $A_{r1}$, $A_{r2}$, $R$, $m$, $n$ and $p$ can adopt the meanings indicated above, and $k = 0, 1$ or $2$.

In a further particularly preferred embodiment, the at least one structural unit of the formula (XIII) is selected from the structural unit of the following formula (XVI):
where \( \text{Ar}^1, \text{Ar}^2, R, m \) and \( n \) can adopt the meanings indicated above.

Examples of preferred structural units of the formula (XVI) are depicted in the following table:

<table>
<thead>
<tr>
<th>(XVIa)</th>
<th>(XVIb)</th>
<th>(XVIc)</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.png" alt="Image" /></td>
<td><img src="image2.png" alt="Image" /></td>
<td><img src="image3.png" alt="Image" /></td>
</tr>
<tr>
<td>(XVId)</td>
<td>(XVIe)</td>
<td>(XVIf)</td>
</tr>
<tr>
<td><img src="image4.png" alt="Image" /></td>
<td><img src="image5.png" alt="Image" /></td>
<td><img src="image6.png" alt="Image" /></td>
</tr>
</tbody>
</table>

where \( \text{Ar}^1, \text{Ar}^2, R, m, n \) and \( p \) can adopt the meanings indicated above.

In still a further particularly preferred embodiment, the at least one structural unit of the formula (XIV) is selected from the structural unit of the following formula (XVII):

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where $A_{r1}, A_{r2}, R, m$ and $n$ can adopt the meanings indicated above.

Examples of preferred structural units of the formula (XVII) are depicted in the following table:

where $A_{r1}, A_{r2}, R, m, n$ and $p$ can adopt the meanings indicated above.

In a very particularly preferred embodiment, the at least one structural unit of the formula (XV) is selected from the structural unit of the following formula (XVIII):
where $R$, $m$ and $p$ can adopt the meanings indicated above.

Examples of preferred structural units of the formula (XVIII) are depicted in the following table:
where $R$, $k$, $m$, $n$ and $p$ can adopt the meanings indicated above.

In a further very particularly preferred embodiment, the at least one structural unit of the formula (XVI) is selected from the structural unit of the following formula (XIX):

where $R$, $X$, $m$ and $n$ can adopt the meanings indicated above.

Examples of preferred structural units of the formula (XIX) are depicted in the following table:

<table>
<thead>
<tr>
<th>(XIXa)</th>
<th>(XIXb)</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image" alt="Diagram" /></td>
<td><img src="image" alt="Diagram" /></td>
</tr>
</tbody>
</table>
where \( R, m, n \) and \( p \) can adopt the meanings indicated above, and 
\( v = 1 \) to 20, preferably 1 to 10.

In still a further very particularly preferred embodiment, the at least one 
structural unit of the formula (XVII) is selected from the structural unit of the 
following formula (XX):

where \( R, X, m \) and \( n \) can adopt the meanings indicated above.
Examples of preferred structural units of the formula (XX) are depicted in the following table:

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image" alt="XXa" /></td>
<td><img src="image" alt="XXb" /></td>
<td><img src="image" alt="XXc" /></td>
</tr>
</tbody>
</table>

where R, m and n can adopt the meanings indicated above.

In the formulae (XVIII), (XIX) and (XX), and their preferred embodiments of the formulae (XVIIIa) to (XVIIIh), (XIXa) to (XIXg) and (XXa) to (XXc), dashed lines represent the bonds to the adjacent structural units in the polymer. They can be arranged here, independently of one another, identically or differently, in the ortho-, meta- or para-position, preferably identically in the ortho-, meta- or para-position, particularly preferably in the meta- or para-position and very particularly preferably in the para-position.

The proportion of structural units of the formula (XI), (XII), (XIII), (XIV), (XV), (XVI), (XVII), (XVIII), (XIX) or (XX) in the polymer is in the range from 1 to 100 mol%.

In one embodiment, the polymer contains only one structural unit of the formula (XI), (XII), (XIII), (XIV), (XV), (XVI), (XVII), (XVIII), (XIX) or (XX), i.e. its proportion in the polymer is 100 mol%. In this case, the polymer is a homopolymer.

In a second embodiment, the proportion of structural units of the formula (XI), (XII), (XIII), (XIV), (XV), (XVI), (XVII), (XVIII), (XIX) or (XX) in the polymer is in the range from 50 to 95 mol%, particularly preferably in the range from 60 to 95 mol%, based on 100 mol% of all copolymerisable monomers which are present as structural units in the polymer, i.e. that the polymer, besides one or more structural units of the formula (XI), (XII), (XIII), (XIV), (XV), (XVI), (XVII), (XVIII), (XIX) and/or (XX), also contains
further structural units which are different from the structural units of the
formulae (XI), (XII), (XIII), (XIV), (XV), (XVI), (XVII), (XVIII), (XIX) and/or
(XX).

In a third embodiment, the proportion of structural units of the formula (XI),
(XII), (XIII), (XIV), (XV), (XVI), (XVII), (XVIII), (XIX) or (XX) in the polymer is
in the range from 5 to 50 mol%, particularly preferably in the range from 25
to 50 mol%, based on 100 mol% of all copolymerisable monomers which
are present as structural units in the polymer, i.e. that the polymer, besides
one or more structural units of the formula (XI), (XII), (XIII), (XIV), (XV),
(XVI), (XVII), (XVIII), (XIX) and/or (XX), also contains further structural units
which are different from the structural units of the formulae (XI), (XII), (XIII),
(XIV), (XV), (XVI), (XVII), (XVIII), (XIX) and (XX).

These structural units, which are different from the structural units of the
formulae (XI), (XII), (XIII), (XIV), (XV), (XVI), (XVII), (XVIII), (XIX) and (XX),
are, inter alia, those as disclosed and extensively listed in WO 02/077060
A1 and in WO 2005/014689 A2. The further structural units can originate,
for example, from the following classes:

group 1: units which influence the hole-injection and/or hole-transport
properties of the polymers;

group 2: units which influence the electron-injection and/or electron-
transport properties of the polymers;

group 3: units which have combinations of individual units from group 1
and group 2;

group 4: units which modify the emission characteristics to such an extent
that electrophosphorescence can be obtained instead of electro-
fluorescence;

group 5: units which improve transfer from the singlet state to the triplet
state;
group 6: units which influence the emission colour of the resultant polymers;

Preferred polymers according to the invention are those in which at least one structural unit has charge-transport properties, i.e. which contain units from group 1 and/or 2.

Structural units from group 1 which have hole-injection and/or hole-transport properties are, for example, triarylamine, benzidine, tetraaryl-para-phenylenediamine, triarylphosphine, phenothiazine, phenoxazine, dihydrophenazine, thianthrene, dibenzo-para-dioxin, phenoxathiyn, carbazole, azulene, thiophene, pyrrole and furan derivatives and further O-, S- or N-containing heterocycles.

Preferred structural units from group 1 are the structural units of the following formulae (1a) to (1q):
In the formulae (1a) to (1q), the dashed lines represent possible bonds to the adjacent structural units in the polymer. If two dashed lines are present, the meanings indicated above.
in the formulae, the structural unit has one or two, preferably two, bonds to adjacent structural units. If three dashed lines are present in the formulae, the structural unit has one, two or three, preferably two, bonds to adjacent structural units. If four dashed lines are present in the formulae, the structural unit has one, two, three or four, preferably two, bonds to adjacent structural units. They can be arranged here, independently of one another, identically or differently, in the ortho-, meta- or para-position.

Structural units from group 2 which have electron-injection and/or electron-transport properties are, for example, pyridine, pyrimidine, pyridazine, 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.

It may be preferred for the polymers to contain units from group 3 in which structures which influence the hole mobility and structures which increase the electron mobility (i.e. units from group 1 and 2) are bonded directly to one another or to contain structures which increase both the hole mobility and the electron mobility. Some of these units can serve as emitters and shift the emission colour into the green, yellow or red. Their use is thus suitable, for example, for the generation of other emission colours from originally blue-emitting polymers.

Structural units of group 4 are those 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 structural units which contain elements of groups 8 to 10 (Ru, Os, Rh, Ir, Pd, Pt). Suitable structural units for the polymers here are, for example, various complexes, as described, for example, in WO 02/068435 A1, WO 02/081488 A1, EP 1239526 A2 and

Structural units of group 5 are those which improve transfer from the singlet state to the triplet state and which, employed in support of the structural elements of group 4, improve the phosphorescence properties of these structural elements. Suitable for this purpose are, in particular, carbazole and bridged carbazole dimer units, as described, for example, in WO 2004/070772 A2 and WO 2004/13468 A1. Also suitable for this purpose are ketones, phosphine oxides, sulfoxides, sulfones, silane derivatives and similar compounds, as described, for example, in WO 2005/040302 A1.

Structural units of group 6, besides those mentioned above, are those which have at least one further aromatic structure or another conjugated structure which do not fall under the above-mentioned groups, i.e. which have only little influence on the charge-carrier mobilities, are not organo-metallic complexes or do not influence singlet-triplet transfer. Structural elements of this type can influence the emission colour of the resultant polymers. Depending on the unit, they can therefore also be employed as emitters. Preference is given here to aromatic structures having 6 to 40 C atoms or also tolan, stilbene or bistrylarylene derivatives, each of which may be substituted by one or more radicals R. Particular preference is given here to the incorporation of 1,4- or 9,10-anthrylene, 1,6-, 2,7- or 4,9-pyrenylene, 3,9- or 3,10-perylenylene, 4,4'-tolanylene, 4,4'-stilbenylene, benzothiadiazole and corresponding oxygen derivatives, quinoxaline, phenothiazine, phenoxazine, dihydrophenazine, bis(thiophenyl)arylene, oligo(thiophenylene), phenazine, rubrene, pentacene or perylene derivatives, which are preferably substituted, or preferably conjugated push-pull systems (systems which are substituted by donor and acceptor substituents) or systems such as squarines or quinacridones, which are preferably substituted.

Structural units of group 7 are units which contain aromatic structures having 6 to 40 C atoms, which are typically used as polymer backbone. These are, for example, 4,5-dihydroxyrene derivatives, 4,5,9,10-tetrahydroxyprene derivatives, fluorene derivatives, 9,9'-spirobiocfluorene derivatives, phen-
anthrene derivatives, 9,10-dihydrophenanthrene derivatives, 5,7-dihydro-
dibenzoxepine derivatives and cis- and trans-indenofluorene derivatives,
but also 1,2-, 1,3- or 1,4-phenylene, 1,2-, 1,3- or 1,4-naphthyne, 2,2',
3,3'- or 4,4'-biphenylylene, 2,2", 3,3"- or 4,4"-terphenylylene, 2,2', 3,3'- or
4,4'-bi-1,1'-naphthylyene or 2,2"", 3,3"- or 4,4""-quaterphenylylene deriv-
avies.

Preferred structural units from group 7 are the structural units of the follow-
ing formulae (7a) to (7o):

\[
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\text{(7a)} & \text{(7b)} & \text{(7c)} \\
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\begin{tikzpicture}
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\end{array} \\
\hline
\text{(7d)} & \text{(7e)} & \text{(7f)} \\
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\text{(7g)} & \text{(7h)} & \text{(7i)} \\
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\end{array}
\]
where $R$, $k$, $m$, $n$ and $p$ can adopt the meanings indicated above.

In the formulae (7a) to (7o), the dashed lines represent possible bonds to the adjacent structural units in the polymer. If two dashed lines are present in the formulae, the structural unit has one or two, preferably two, bonds to adjacent structural units. If four or more dashed lines are present in the formulae (formulae (7g), (7h) and (7j)), the structural units have one, two, three or four, preferably two, bonds to adjacent structural units. They can be arranged here, independently of one another, identically or differently, in the ortho-, meta- or para-position.

Structural units of group 8 are those which influence the film morphology and/or the rheological properties of the polymers, such as, for example, siloxanes, alkyl chains or fluorinated groups, but also particularly rigid or flexible units, liquid-crystal-forming units or crosslinkable groups.

Preference is given to polymers which simultaneously, besides structural units of the formula (XI), (XII), (XIII), (XIV), (XV), (XVI), (XVII), (XVIII), (XIX) and/or (XX), additionally also contain one or more units selected from groups 1 to 8. It may likewise be preferred for more than one further structural unit from a group to be present simultaneously.
Preference is given here to polymers which, besides at least one structural unit of the formula (XI), (XII), (XIII), (XIV), (XV), (XVI), (XVII), (XVIII), (XIX) and/or (XX), also contain units from group 7.

It is likewise preferred for the polymers to contain units which improve the charge transport or the charge injection, i.e. units from group 1 and/or 2.

It is furthermore particularly preferred for the polymers to contain structural units from group 7 and units from group 1 and/or 2.

The polymers are either homopolymers comprising structural units of the formula (XI), (XII), (XIII), (XIV), (XV), (XVI), (XVII), (XVIII), (XIX) or (XX) or copolymers. The polymers may be linear or branched, preferably linear. Copolymers may, besides one or more structural units of the formula (XI), (XII), (XIII), (XIV), (XV), (XVI), (XVII), (XVIII), (XIX) and/or (XX), potentially have one or more further structures from the above-mentioned groups 1 to 8.

The copolymers can contain random, alternating or block-like structures or also have a plurality of these structures in an alternating manner. The copolymers according to the invention particularly preferably contain random or alternating structures. The copolymers are particularly preferably random or alternating copolymers. The way in which copolymers having block-like structures can be obtained and what further structural elements are particularly preferred for this purpose is described, for example, in detail in WO 2005/014688 A2.

The thicknesses of the positive hole transport layers 5R, 5G, and 5B, which are not particularly limited, are preferably in the range of 15 nm to 25 nm.

Furthermore, the thickness t of the positive hole transport layer 7 is 2 nm or less, preferably in the range of 0.1 nm to 1.5 nm, more preferably in the range of 0.1 nm to 1 nm, and most preferably in the range of 0.1 nm to 0.9 nm. In this manner, in the light emitting elements 1R and 1G, since the positive hole transport layer 7 provided among the light emitting functional
layers 6R and 6G and the light emitting functional layer 6B is extremely thin, the carrier (electrons) can be delivered from the light emitting functional layer 6B to the light emitting functional layers 6R and 6G. Therefore, the light emitting functional layers 6R and 6G can be allowed to selectively emit light without allowing the light emitting functional layer 6B to emit light in the light emitting elements 1R and 1G. Further, since the positive hole transport layer 7 is extremely thin, it is possible to suppress increases in the driving voltage of the light emitting elements 1R, 1G, and 1B caused by the positive hole transport layer 7 being provided among the light emitting functional layers 6R and 6G and the light emitting functional layer 6B.

Here, since the constituent material of the positive hole transport layer 7 has the electron blocking property as described above, it is possible for the light emitting functional layer 6B to effectively emit light by using the electron blocking property of the positive hole transport layer 7 in the light emitting element 1B. In contrast, in the light emitting elements 1R and 1G, when the electron blocking property of the positive hole transport layer 7 is exceedingly high, the light emitting functional layers 6R and 6G do not emit light or the light emission efficiency is considerably decreased. Therefore, it is extremely useful to decrease the electron blocking property of the positive hole transport layer 7 in the light emitting elements 1R and 1G by making the thickness of the positive hole transport layer 7 extremely small.

In contrast, when the thickness t of the positive hole transport layer 7 is exceedingly small, there is a tendency that the above-described effect generated by providing the positive hole transport layer 7 becomes extremely small. In contrast, when the thickness t of the positive hole transport layer 7 is exceedingly large, the driving voltage of the light emitting elements 1R and 1G becomes drastically large (light emission efficiency becomes drastically low) or a desired color of light emission
cannot be obtained because the light emitting functional layer 6B emits light in the light emitting elements 1R and 1G.

[Light emitting functional layer]

The light emitting functional layer 6R is provided in contact with the positive hole transport layer 5R. In addition, the light emitting functional layer 6G is provided in contact with the positive hole transport layer 5G. Further, the light emitting functional layer 6B is provided in contact with the positive hole transport layer 7.

The light emitting functional layers 6R, 6G, and 6B are respectively configured by containing light emitting materials. Examples of the light emitting materials, which are not particularly limited, include various kinds of fluorescent materials and phosphorescent materials, and one or more kinds of these can be used in combination. The light emitting functional layer 6R uses a red fluorescent material or a red phosphorescent material as a light emitting material, the light emitting functional layer 6G uses a green fluorescent material or a green phosphorescent material as a light emitting material, and the light emitting functional layer 6B uses a blue fluorescent material or a blue phosphorescent material as a light emitting material.

Examples of the red fluorescent material, which are not particularly limited as long as the materials emit red fluorescence, include a perylene derivative such as a diindenoperylene derivative, an europium complex, a benzopyran derivative, a rhodamine derivative, a benzothioxanthene derivative, a porphyrin derivative, Nile Red, 2-(1,1-dimethylethyl)-6-(2,3,6,7-tetrahydro-1,1,7,7-tetramethyl-1H,5H-benzo(ij)quinolizin-9-yl)ethenyl)-4H-pyran-4H-ylidene)propanedinitrile (DCJTB), 4-(dicyanomethylene)-2-methyl-6-(p-dimethylaminostyryl)-4H-pyran (DCM), and ADS1 RE (manufactured by American Dye Source Co., Ltd.).
Examples of the red phosphorescent material, which are not particularly limited as long as the materials emit red phosphorescence, include iridium complexes such as Bt2Ir(acac)(Bis(2-phenylbenzothiazolato-N,C2')Iridium(III)(acetylacetonate)), and Btp2Ir(acac)(Bis(2,2'-benzothienyl)-pyridinato-N,C3)Iridium(acetylacetonate)), and platinum complexes such as PtOEP(2,3,7,8, 12,13,17,18-Octaethyl-2 1H,23H-porphine, platinum(II)).

Examples of the green fluorescent material, which are not particularly limited as long as the materials emit green fluorescence, include quinacridone such as a coumarin derivative or a quinacridone derivative and a derivative thereof; 9,10-bis[(9-ethyl-3-carbazole)-vinylenyl]-anthracene, poly(9,9-dihexyl-2,7-vinylenefluorenylene), poly[(9,9-dioctyl fluorene-2,7-diyl)-co-(1,4-diphenylene-vinylene-2-methoxy-5-(2-ethylhexyloxy)benzene]], poly[(9,9-dioctyl-2,7-divinylenefluorenylene)-ortho-co-(2-methoxy-5-(2-ethoxyhexyloxy)-1,4-phenylene]), and ADS109GE (manufactured by American Dye Source Co., Ltd.).

Examples of the green phosphorescent material, which are not particularly limited as long as the materials emit green phosphorescence, include iridium complexes such as Ir(ppy)3(Fac-tris(2-phenyipyridine)iridium) and Ppy2Ir(acac)(Bis(2-phenyl-pyridinato-N-C2)Iridium(acetylacetone)).

Examples of the blue fluorescent material, which are not particularly limited as long as the materials emit blue fluorescence, include a distyryldiamine derivative such as a distyryldiamine-based compound; a fluoranthene derivative, a pyrene derivative, perylene, a perylene derivative, an anthracene derivative, a benzoazole derivative, a benzothiazole derivative, a benzoimidazole derivative, a chrysene derivative, a phenanthrene derivative, a distyrylbenezene derivative, tetrphenyl butadiene, 4,4'-bis(9-ethyl-3-carbazovinylene)-1,1'-biphenyl(BCzVBi), poly[(9,9-dioctylfluorene-2,7-diyl)-co-(2,5-dimethoxybenzene-1,4-diyl)], poly[(9,9-dihexyloxyfluorene-2,7-diyl)-ortho-co-(2-methoxy-5-(2-ethoxyhexyloxy)phenylene-1,4-diyl]), and
Examples of the blue phosphorescent material, which are not particularly limited as long as the materials emit blue phosphorescence, include iridium complexes such as Flrpic(Iridium-bis(4,6-difluorophenyl-pyridinato-N,C2)-picolinate), Ir(pmb)3(Iridium-tris(1-phenyl-3-methylbenzimidazolin-2-ylidene-C,C(2)'), FlrN4(Iridium(III)bis(4,6-difluorophenylpyridinato)(5-(pyridin-2-yl)tetrazolate)), and Flrtaz(Iridium(III)bis(4,6-difluorophenylpyridinato)(5-(pyridine-2-yl)-1,2,4-triazolate)).

In addition, the light emitting functional layers 6R, 6G, and 6B may contain host materials to which light emitting materials are added as guest materials in addition to the above-described light emitting materials. The host material has a function of generating excitons by recombining positive holes and electrons and of exciting a light emitting material by moving (forster movement or dexter movement) the energy of the excitons to the light emitting material. In a case where such a host material is used, the light emitting material which is the guest material can be used by being doped to the host material as a dopant.

Examples of the host material, which are not particularly limited as long as the materials exhibit the above-described function with respect to a light emitting material to be used, include low molecular weight host materials such as TDAPB(1,3,5-tris-(N,N-bis-(4-methoxy-phenyl)aminophenyl)-benzene), CBP(4,4'-bis(9-dicarbazolyl)2,2'-biphenyl), BAlq(Bis-(2-methyl-8-quinolinolate)-4-(phenylphenolate)aluminium), mCP(N,N-dicarbazolyl-3,5-benzene: CBP derivative), CDBP(4,4'-bis(9-carbazolyl)-2,2'-dimethyl-biphenyl), DCB(N,N'-Dicarbazolyl-1 ,4-dimethene-benzene), P06(2,7-bis(diphenylphosphineoxide)9,9-dimethylfluorene), SimCP(3,5-bis(9-carbazolyl)tetraphenylsilane), and UGH3(W-bis(triphenylsilyl)benzene), and one or more kinds of these can be used in combination.
It is preferable that the constituent materials of the light emitting functional layers 6R and 6G be soluble in a solvent in which the constituent materials of the above-described positive hole transport layers 5R and 5G are soluble. In this manner, the light emitting functional layers 6R and 6G and the positive hole transport layers 5R and 5G can be formed by the liquid phase process using the same solvent. That is, when the light emitting functional layers 6R and 6G are formed by the liquid phase process, a solvent which is the same used when the positive hole transport layers 5R and 5G are formed by the liquid phase process can be used. As a result, adhesion or affinity of the interface between the light emitting functional layers 6R and 6G and the positive hole transport layers 5R and 5G can be improved and transportability of the carrier (positive hole) from the positive hole transport layers 5R and 5G to the light emitting functional layers 6R and 6G can be improved.

Further, the constituent materials of the light emitting functional layers 6R and 6G are preferably configured of low molecular weight materials as main materials and more preferably configured of low molecular weight guest materials and low molecular weight host materials as main materials. In this manner, it is possible to compensate for the decrease in the light emission efficiency of the light emitting elements 1R and 1G due to the positive hole transport layer 7 being provided by improving the light emission efficiency of the light emitting functional layer 6R and 6G. As a result, the light emission of the light emitting elements 1R and 1G and the light emitting element 1B can be excellently balanced. From this point of view, the content of the low molecular weight materials in the light emitting functional layers 6R and 6G is preferably 60 wt% or more, more preferably 80 wt% or more, and most preferably 90 wt% or more.
The thicknesses of the respective light emitting functional layers 6R, 6G, and 6B, which are not particularly limited, are preferably in the range of 5 nm to 100 nm and more preferably in the range of 10 nm to 50 nm.

5 [Electron transport layer]
The electron transport layer 8 has a function of transporting electrons injected from the cathode 10 through the electron injection layer 9 to the light emitting functional layer 6B.

10 Examples of the constituent material (electron transport material) of the electron transport layer 8 include BAlq, OXD-1(1,3,5-tri(5-(4-tert-butylphenyl)-1,3,4-oxadiazole)), BCP (Bathocuproine), PBD(2-(4-biphenyl)-5-(4-tert-butylphenyl)-1,2,4-oxadiazole), TAZ(3-(4-biphenyl)-5-(4-tert-butylphenyl)-1,2,4-triazole), DPVBi(4,4'-bis(1,1-bis-diphenylethenyl)biphenyl), BND(2,5-bis(1-naphthyl)-1,3,4-oxadiazole), DTVBi(4,4'-bis(1,1-bis(4-methyphenyl)ethenyl)biphenyl), BBD(2,5-bis(4-biphenyryl)-1,3,4-oxadiazole), tris(8-quinolinolato)aluminum (Alq3), an oxadiazole derivative, an oxazole derivative, a phenanthroline derivative, an anthraquino-dimethane derivative, a benzoquinone derivative, a naphthoquinone derivative, an anthraquinone derivative, a tetracyanoanthraquinodimethane derivative, a fluorene derivative, a diphenylidicyanoethylene derivative, a diphenoquinone derivative, and a hydroxyl quinoline derivative, and one or more kinds of these can be used in combination.

15 The thickness of the electron transport layer 8, which is not particularly limited, is preferably in the range of 1 nm to 100 nm and more preferably in the range of 5 nm to 50 nm.

20 In addition, the electron transport layer 8 can be omitted depending on the constituent material or the thickness of another layer.

25 [Electron injection layer]
The electron injection layer 9 has a function of improving electron injection efficiency from the cathode 10.

Examples of the constituent material (electron injection material) of the electron injection layer 9 include various inorganic insulation materials and various inorganic semiconductor materials.

Examples of the inorganic insulation material include an alkali metal chalcogenide (an oxide, a sulfide, a selenide, or a telluride), an alkaline-earth metal chalcogenide, a halide of an alkali metal and a halide of an alkaline-earth metal, and one or more kinds of these can be used in combination. The electron injection property can be further improved by constituting the electron injection layer with these as main materials. Particularly, the light emitting element 1 can obtain high brightness by constituting the electron injection layer 9 with these materials because an alkali metal compound (alkali metal chalcogenide, a halide of an alkali metal, or the like) has an extremely small work function.

Examples of the alkali metal chalcogenide include U2O, LiO, Na2S, Na2Se, and NaO. The examples of the alkaline-earth metal chalcogenide include CaO, BaO, SrO, BeO, BaS, MgO, and CaSe. Examples of the halide of an alkali metal include CsF, LiF, NaF, KF, LiCl, KCl, and NaCl. Examples of the halide of an alkaline-earth metal include CaF2, BaF2, SrF2, MgF2, and BeF2.

In addition, examples of the inorganic semiconductor material include an oxide, a nitride, or an oxynitride including at least one element among Li, Na, Ba, Ca, Sr, Yb, Al, Ga, In, Cd, Mg, Si, Ta, Sb, and Zn, and one or more kinds of these can be used in combination.
The thickness of the electron injection layer 9, which is not particularly limited, is preferably in the range of 0.01 nm to 10 nm and more preferably in the range of 0.1 nm to 10 nm.

Further, the electron injection layer 9 can be omitted depending on the constituent material or the thickness of another layer.

[Cathode]
The cathode 10 is an electrode that injects electrons into the electron transport layer 8 through the electron injection layer 9. As the constituent material of the cathode 10, it is preferable to use a material having a small work function.

Examples of the constituent material of the cathode 10 include Li, Mg, Ca, Sr, La, Ce, Er, Eu, Sc, Y, Yb, Ag, Cu, Al, Cs, and Rb, or an alloy containing these, and one or more kinds of these can be used in combination (for example, a laminate or the like of multiple layers).

Particularly, in a case of using an alloy as the constituent material of the cathode 10, an alloy containing stable metal elements such as Ag, Al, and Cu or an alloy such as MgAg, AlLi, or CuLi is preferably used. The electron injection efficiency and the stability of the cathode 10 can be improved by means of using such an alloy as the constituent material of the cathode 10.

Moreover, since the light emitting element 1 of the present embodiment is the bottom emission type, the cathode 10 may not have optical transparency. In the case where the light emitting element 1 is the bottom emission type, metals or alloys such as Al, Ag, AlAg, and AlNd are preferably used as the constituent material of the cathode 10. The electron injection efficiency and the stability of the cathode 10 can be improved by means of using such metals or alloys as the constituent materials of the cathode 10.
The thickness of the cathode 10 in the case of the bottom emission type, which is not particularly limited, is preferably in the range of 50 nm to 1000 nm and more preferably in the range of 100 nm to 500 nm.

In addition, in the case where the light emitting element 1 is the top emission type, metals or alloys such as MgAg, MgAl, MgAu, and AlAg are preferably used as the constituent materials of the cathode 10. The electron injection efficiency and the stability of the cathode 10 can be improved while securing the optical transparency of the cathode 10 by means of using such metals or alloys as the constituent materials of the cathode 10.

The thickness of the cathode 10 in the case of the top emission type, which is not particularly limited, is preferably in the range of 1 nm to 50 nm and more preferably in the range of 5 nm to 20 nm.

According to the light emitting device 100 configured in the above-described manner, the respective positive hole transport layers 5R, 5G, and 5B and the light emitting functional layers 6R and 6G can be respectively formed for each of the elements using the liquid phase process and the positive hole transport layer 7 and the light emitting functional layer 6B are respectively formed in the light emitting elements 1R, 1G, and 1B in common using the vapor phase process. Therefore, the light emitting elements 1R, 1G, and 1B can be effectively produced.

When the light emitting elements 1R, 1G, and 1B are formed in this manner, the positive hole transport layer 7 formed using the vapor phase process which is the same as that of the light emitting functional layer 6B can be provided between the positive hole transport layer 5B and the light emitting functional layer 6B in the light emitting element 1B, and thus an electrical barrier related to movement of the carrier between the positive hole transport layer 5B and the light emitting functional layer 6B can be
lowered when compared to a case in which the positive hole transport layer 5B is directly laminated on the light emitting functional layer 6B which is produced by a production method different from that of the positive hole transport layer 5B. Therefore, the carrier (positive hole) is smoothly transported to the light emitting functional layer 6B so that the light emission efficiency can be improved.

On the other hand, in the light emitting elements 1R and 1G, since the positive hole transport layer 7 provided between the light emitting functional layers 6R and 6G and the light emitting functional layer 6B is extremely thin, the carrier (electrons) can be delivered from the light emitting functional layer 6B to the light emitting functional layers 6R and 6G. Therefore, the light emitting functional layers 6R and 6G can be allowed to selectively emit light without allowing the light emitting functional layer 6B to emit light in the light emitting elements 1R and 1G.

Further, since the positive hole transport layer 7 is extremely thin, it is possible to suppress increases in the driving voltage of the light emitting elements 1R, 1G, and 1B caused by providing the positive hole transport layer 7.

For the reason described above, in the light emitting device 100 which includes a plurality of light emitting elements 1R, 1G, and 1B having luminescent colors different from one another, it is possible to improve the light emission efficiency of the respective light emitting elements 1R, 1G, and 1B and to effectively produce the light emitting device 100.

[Method of producing light emitting device]
Hereinafter, an example of a method of producing the above-described light emitting device 100 will be described.
Figs. 2A to 4C are views for describing the method of producing the light emitting device illustrated in Fig. 1. Hereinafter, each process will be sequentially described.

(1) Firstly, the circuit substrate 20 is prepared, the anodes 3R, 3G, and 3B are formed on the circuit substrate 20, and then the partition 31 is formed as illustrated in Fig. 2A.

After film formation is performed on the circuit substrate 20 with an electrode material using a vapor phase film formation method such as a deposition method or a CVD method, the anodes 3R, 3G, and 3B can be obtained by performing patterning on the electrode material using etching or the like.

Further, the partition 31 can be formed by performing patterning on the anodes 3R, 3G, and 3B using a photolithography method such that the anodes 3R, 3G, and 3B are exposed.

Here, the constituent material of the partition 31 can be selected in consideration of heat resistance, liquid repellency, ink solvent resistance, and adhesion to the circuit substrate 20 or the like. Specifically, examples of the partition 31 include an acrylic resin, a polyimide resin, an organic material such as an epoxy resin, and an inorganic material such as SiO2.

In addition, after the anodes 3R, 3G, and 3B and the partition 31 are formed, the surfaces of the anodes 3R, 3G, and 3B and the partition 31 may be subjected to an oxygen plasma treatment. In this manner, it is possible to apply a lyophilic property to the surfaces of the anodes 3R, 3G, and 3B, to remove (wash) organic matter adhered to the surfaces of the anodes 3R, 3G, and 3B and the partition 31, and to adjust the work function in the peripheries of the surfaces of the anodes 3R, 3G, and 3B.
Here, as conditions of the oxygen plasma treatment, for example, a plasma power of approximately 100 W to 800 W, an oxygen gas flow rate of approximately 50 ml/min to 100 ml/min, a transporting speed of approximately 0.5 mm/sec to 10 mm/sec of members (anodes 3R, 3G, and 3B) to be treated, and a temperature of approximately 70°C to 90°C of the circuit substrate 20 are preferable.

In addition, it is preferable to perform a plasma treatment on fluorine-based gas such as CF₄ as treatment gas after the oxygen plasma treatment. In this manner, the fluorine-based gas reacts only with the surface of the partition 31 made of a photosensitive resin which is an organic material and repels a liquid. Accordingly, it is possible to reduce unnecessary wet-spreading of the liquid applied to the inside of the partition 31.

(2) Next, as illustrated in Fig. 2B, an ink 4a for forming the positive hole injection layer is applied to the respective anodes 3R, 3G, and 3B in the partition 31 from an ink jet head 200.

The ink 4a allows the constituent materials of the positive hole injection layers 4R, 4G, and 4B or a precursor thereof to be dissolved in a solvent or to be dispersed in a dispersion medium. Examples of the solvent or the dispersion medium include various inorganic solvents, various organic solvents, and a mixed solvent containing these.

Subsequently, the positive hole injection layers 4R, 4G, and 4B are formed as illustrated in Fig. 2C by drying (removing the solvent or removing the dispersion medium) the ink 4a on the anode 3 and performing a heat treatment as needed.

Drying can be performed by leaving the ink as it is in an atmospheric pressure or in a reduced pressure atmosphere, and carrying out a heat treatment, or spraying inert gas, but it is preferable to heat and dry the ink
in an oven at an atmospheric pressure in a temperature range of 150°C to 250°C for 5 minutes to 30 minutes after drying at a reduced pressure is performed for 10 minutes to 1 hour in a vacuum of 5 Pa or less. Accordingly, the positive hole injection layers 4R, 4G, and 4B which are flat and have excellent characteristics can be formed.

As described above, the positive hole injection layers 4R, 4G, and 4B are formed by the liquid phase process using the ink 4a.

(3) Next, as illustrated in Fig. 2D, an ink 5a for forming the positive hole transport layer is applied to the respective positive hole injection layers 4R and 4G in the partition 31 from an ink jet head 200.

The ink 5a allows the constituent materials of the positive hole transport layers 5R and 5G or a precursor thereof to be dissolved in a solvent or to be dispersed in a dispersion medium. Examples of the solvent or the dispersion medium include various inorganic solvents, various organic solvents, and a mixed solvent containing these.

Subsequently, the positive hole transport layers 5R and 5G are formed as illustrated in Fig. 3A by drying (removing the solvent or removing the dispersion medium) the ink 5a on the positive hole injection layers 4R and 4G and performing a heat treatment as needed.

Drying can be performed by leaving the ink as it is in an atmospheric pressure or in a reduced pressure atmosphere, and carrying out a heat treatment, or spraying inert gas, but it is preferable to heat and dry the ink in an oven in a nitrogen atmosphere in a temperature range of 150°C to 250°C for 5 minutes to 30 minutes after drying at a reduced pressure is performed for 10 minutes to 1 hour in a vacuum of 5 Pa or less. Accordingly, the positive hole transport layers 5R and 5G which are flat and have excellent characteristics can be formed.
As described above, the positive hole transport layers $5R$ and $5G$ are formed by the liquid phase process using the ink $5a$.

(4) Next, as illustrated in Fig. 3B, inks $6a$ and $6b$ for forming the light emitting functional layer are applied to the respective positive hole transport layers $5R$ and $5G$ in the partition 31 from an ink jet head 200.

The ink $6a$ allows the constituent material of the light emitting functional layer $6R$ or a precursor thereof to be dissolved in a solvent or to be dispersed in a dispersion medium. The ink $6b$ allows the constituent material of the light emitting functional layer $6G$ or a precursor thereof to be dissolved in a solvent or to be dispersed in a dispersion medium. Examples of the solvent or the dispersion medium include various inorganic solvents, various organic solvents, and a mixed solvent containing these.

Subsequently, the light emitting functional layers $6R$ and $6G$ are formed as illustrated in Fig. 3C by drying (removing the solvent or removing the dispersion medium) the inks $6a$ and $6b$ on the positive hole transport layers $5R$ and $5G$ and performing a heat treatment as needed.

Drying can be performed by leaving the ink as it is in an atmospheric pressure or in a reduced pressure atmosphere, and carrying out a heat treatment, or spraying inert gas, but it is preferable to heat and dry the ink in an oven in a nitrogen atmosphere in a temperature range of 150°C to 250°C for 5 minutes to 30 minutes after drying at a reduced pressure is performed for 10 minutes to 1 hour in a vacuum of 5 Pa or less. Accordingly, the light emitting functional layers $6R$ and $6G$ which are flat and have excellent characteristics can be formed.

As described above, the light emitting functional layers $6R$ and $6G$ are formed by the liquid phase process using the inks $6a$ and $6b$. 
Next, as illustrated in Fig. 3D, an ink 5b for forming the positive hole transport layer 5B is applied to the positive hole injection layer 4B in the partition 31 from an ink jet head 200.

The ink 5b allows the constituent material of the positive hole transport layer 5B or a precursor thereof to be dissolved in a solvent or to be dispersed in a dispersion medium. Examples of the solvent or the dispersion medium include various inorganic solvents, various organic solvents, or a mixed solvent containing these.

Subsequently, the positive hole transport layer 5B is formed as illustrated in Fig. 4A by drying (removing the solvent or removing the dispersion medium) the ink 5b on the positive hole injection layer 4B and performing a heat treatment as needed.

Drying can be performed by leaving the ink as it is in an atmospheric pressure or in a reduced pressure atmosphere, and carrying out a heat treatment, or spraying inert gas, but it is preferable to heat and dry the ink in an oven in a nitrogen atmosphere in a temperature range of 150°C to 250°C for 5 minutes to 30 minutes after drying at a reduced pressure is performed for 10 minutes to 1 hour in a vacuum of 5 Pa or less.

Accordingly, the positive hole transport layer 5B which is flat and has excellent characteristics can be formed.

As described above, the positive hole transport layer 5B is formed by the liquid phase process using the ink 5b.

(6) Next, as illustrated in Fig. 4B, the positive hole transport layer 7, the light emitting functional layer 6B, the electron transport layer 8, the electron injection layer 9, and the cathode 10 are formed on the light emitting functional layers 6R and 6G and the positive hole transport layer 5B in this
order so as to cover the light emitting functional layers and the positive hole injection layer across the partition 31.

The positive hole transport layer 7, the light emitting functional layer 6B, the electron transport layer 8, the electron injection layer 9, and the cathode 10 can be respectively formed by the vapor phase process using a dry plating method such as vacuum deposition or the like.

(7) Finally, as illustrated in Fig. 4C, the sealing substrate 40 is adhered to the cathode 10 through the resin layer 32 (sealing layer). In this manner, the light emitting device 100 can be obtained.

As described above, the respective positive hole transport layers 5R, 5G, and 5B and the light emitting functional layers 6R and 6G can be respectively formed for each of the elements using the liquid phase process and the positive hole transport layer 7 and the light emitting functional layers 6B are respectively formed in the light emitting elements 1R, 1G, and 1B in common using the vapor phase process. Therefore, the light emitting elements 1R, 1G, and 1B can be effectively produced.

[Electronic equipment]

Fig. 5 is a perspective view illustrating the configuration of a mobile (or laptop) personal computer to which the electronic equipment of the present invention is applied.

In the figure, a personal computer 1100 is configured of a main body 1104 including a keyboard 1102 and a display unit 1106 including a display section, and the display unit 1106 is rotatably supported by the main body 1104 through a hinge structure.

In the personal computer 1100, the display section included in the display unit 1106 is configured of the above-described light emitting device 100.
Fig. 6 is a perspective view illustrating the configuration of a mobile phone (including a PHS) to which the electronic equipment of the present invention is applied.

In the figure, a mobile phone 1200 includes a plurality of operation buttons 1202, an earpiece 1204, a mouthpiece 1206, and a display section.

In the mobile phone 1200, the display section is configured of the above-described light emitting device 100.

Fig. 7 is a perspective view illustrating the configuration of a digital still camera to which the electronic equipment of the present invention is applied. In addition, connections with external devices are simply illustrated in the figure.

Here, whereas a general camera exposes a silver salt photographic film by an optical image of a subject, a digital still camera 1300 generates an imaging signal (image signal) by photoelectrically converting the optical image of the subject through an imaging element such as a Charge Coupled Device (CCD).

A display section is provided on a back surface of a case (body) 1302 in the digital still camera 1300, and is configured so that display is performed based on the imaging signal from the CCD, and functions as a finder which displays the subject as an electronic image.

In the digital still camera 1300, the display section is configured of the above-described light emitting device 100.

A circuit substrate 1308 is disposed in the case. A memory in which an imaging signal can be stored (memory) is disposed in the circuit substrate 1308.
In addition, a light receiving unit 1304 containing an optical lens (imaging optical system) or a CCD is provided on the front surface side (back surface side in the configuration illustrated in the figure) of the case 1302.

When a photographer verifies a subject image displayed on the display section and presses down a shutter button 1306, the imaging signal of the CCD is transferred to and stored in the memory of the circuit substrate 1308.

In addition, in the digital still camera 1300, a video signal output terminal 1312 and an input and output terminal 1314 for data communication are provided on the side surface of the case 1302. Further, as illustrated in the figure, a TV monitor 1430 and a personal computer 1440 are respectively connected to the video signal output terminal 1312 and the input and output terminal 1314 for data communication as needed. Furthermore, the imaging signal stored in the memory of the circuit substrate 1308 is configured to be output to the TV monitor 1430 and the personal computer 1440 by a predetermined operation.

The electronic equipment of the present invention has excellent reliability.

In addition, the electronic equipment of the present invention can be applied to, for example, a TV, a video camera, a view finder type video tape recorder, a monitor direct view type video tape recorder, a laptop personal computer, a car navigation system, a pager, an electronic organizer (having communication function), an electronic dictionary, an electronic calculator, an electronic game machine, a word processor, a workstation, a videophone, a TV monitor for security, electronic binoculars, a POS terminal, equipment including a touch panel (for example, a cash dispenser of a financial institution or an automatic ticket vending machine), medical equipment (for example, an electronic thermometer, a blood pressure...
meter, a blood glucose meter, an ECG display device, an ultrasonic
diagnostic device, or an endoscopic display device), a fish finder, various
measurement equipment, meters (for example, meters of a vehicle, an
aircraft, and a ship), a flight simulator, various monitors, and a projection
type display device such as a projector in addition to the personal computer
(mobile personal computer) in Fig. 5, the mobile phone in Fig. 6, and the
digital still camera in Fig. 7.

Hereinbefore, the light emitting device and the electronic equipment of the
present invention have been described with reference to the embodiments
illustrated in the figures, but the present invention is not limited thereto.
Working examples: Part A

Next, examples of the present invention will be described in detail.

(1. Production of light emitting element)

[Example 1]
First, a transparent glass substrate having a thickness of 0.5 mm was prepared. Next, ITO electrodes (a first anode, a second anode, and a third anode) having a thickness of 100 nm were formed on the substrate as respective pixel electrodes of RGB pixels using a sputtering method. Subsequently, an insulation layer made of an acrylic resin was formed, and a partition (bank) was formed by performing patterning on the insulation layer so as to expose the respective ITO electrodes using a photolithography method.

In addition, the substrate was subjected to an oxygen plasma treatment and an argon plasma treatment after the substrate was immersed in acetone and then 2-propanol, and washed with ultrasonic waves. These plasma treatments were performed at a plasma power of 100 w, at a gas flow rate of 20 seem, and for a treatment time of 5 seconds in a state in which the respective substrates were heated at 70°C to 90°C.

Next, an ink for forming a positive hole injection layer was filled in the respective partitions of the RGB pixels using an ink jet method, applied to the ITO electrodes, dried at a reduced pressure, and then subjected to a heat treatment (firing), thereby forming a positive hole injection layer having a thickness of 50 nm.

Here, as the ink for forming the positive hole injection layer, a 0.5 wt% aqueous dispersion of a mixture of PEDOT:PSS was used. Further, firing was performed in an atmospheric pressure at a temperature of 200°C for 10 minutes.
Next, an ink for forming a positive hole transport layer was filled in the respective partitions of the RG pixels using an ink jet method, applied to the positive hole injection layer, dried at a reduced pressure, and then subjected to a heat treatment (firing), thereby forming positive hole transport layers (first and third positive hole transport layers) having a thickness of 20 nm.

Here, as the ink for forming a positive hole transport layer, a tetramethyl benzene solution containing 1.5 wt% of TFB (poly(9,9-dioctyl-fluorene-co-N-(4-butylphenyl)-diphenylamine)) was used. In addition, firing was performed in a glove box filled with nitrogen at a temperature of 200°C for 30 minutes.

Next, an ink for forming a light emitting functional layer was filled in the respective partitions of the RG pixels using an ink jet method, applied to the positive hole transport layer, dried at a reduced pressure, and then subjected to a heat treatment (firing), thereby forming light emitting functional layers (first and third light emitting functional layers) having a thickness of 20 nm.

Here, as the ink for forming a light emitting functional layer, a tetramethyl benzene solution (concentration of 1.2 wt%) in which CBP(4,4'-bis(9-dicarbazoyl)-2,2'-biphenyl) and Ir(ppy)3(Fac-tris(2-phenylpyridine)iridium) are mixed with each other at a weight ratio of 90:10 is formed. In addition, drying was performed at a reduced pressure for 10 minutes in a vacuum degree of 5 Pa or less. Further, firing was performed in a glove box filled with nitrogen at a temperature of 220°C for 10 minutes.

Next, an ink for forming a positive hole transport layer was filled in the partition of B pixels using an ink jet method, applied to the positive hole injection layer, dried at a reduced pressure, and then subjected to a heat
treatment (firing), thereby forming a positive hole transport layer (second positive hole transport layer) having a thickness of 20 nm.

Here, as the ink for forming a positive hole transport layer, a CHB (cyclohexylbenzene) solution containing a-NPD at a concentration of 0.3 wt% which is a low molecular weight positive hole transport material was used. Further, firing was performed in a glove box filled with nitrogen at a temperature of 160°C for 10 minutes.

Next, film formation was performed across the RGB pixels with a material for forming a positive hole transport layer (material for forming an intermediate layer) by deposition, thereby forming a positive hole transport layer (common positive hole transport layer (intermediate layer)) having a thickness of 1 nm.

Here, as the material for forming a positive hole transport layer (material for forming an intermediate layer), a-NPD which is a low molecular weight positive hole transport material was used.

Next, film formation was performed across the RGB pixels with a material for forming a light emitting functional layer by deposition, thereby forming a light emitting functional layer (second light emitting functional layer) having a thickness of 20 nm.

Here, as the material for forming a light emitting functional layer, a material in which 10 parts by mass of Flrpic was doped on 90 parts by mass of CBP(4,4′-bis(9-dicarbazoyl)-2,2′-biphenyl) was used. In addition, drying was performed at a reduced pressure for 10 minutes in a vacuum degree of 5 Pa or less.
Next, film formation was performed on a second light emitting functional layer with Alq3 by a vacuum deposition method, thereby forming an electron transport layer having a thickness of 20 nm.

Next, film formation was performed on an electron transport layer with lithium fluoride (LiF) by a vacuum deposition method, thereby forming an electron injection layer having a thickness of 1 nm.

Next, film formation was performed on an electron injection layer with Al by a vacuum deposition method, thereby forming a cathode made of Al with a thickness of 200 nm.

In the above-described process, a light emitting device including RGB pixels (first to third light emitting elements) was produced.

[Example 2]
A light emitting device was produced in the same manner as that of Example 1 described above except that a mixed material (a mixed ratio of 50:50 in terms of a mass ratio) of a-NPD which is a low molecular weight positive hole transport material and TFB (poly(9,9-diocetyl-fluorene-co-N-(4-butylphenyl)-diphenylamine)) which is a high molecular weight positive hole transport material was used as a material for forming a positive hole transport layer (second positive hole transport layer) of B pixels.

[Example 3]
A light emitting device was produced in the same manner as that of Example 1 described above except that RG pixels were coated with the ink for forming a light emitting functional layer, B pixels were coated with the ink for forming a positive hole transport layer, and drying and firing were respectively performed on these pixels.
A light emitting device was produced in the same manner as that of Example 2 described above except that RG pixels were coated with the ink for forming a light emitting functional layer, B pixels were coated with the ink for forming a positive hole transport layer, and drying and firing were respectively performed on these pixels.

[Example 5]
A light emitting device was produced in the same manner as that in Example 1 described above except that 3-phenoxytoluene was used as a solvent for each of the ink for forming a light emitting functional layer used for RG pixels and the ink for forming a positive hole transport layer used for B pixels.

[Example 6]
A light emitting device was produced in the same manner as that of Example 2 described above except that 3-phenoxytoluene was used as a solvent for each of the ink for forming a light emitting functional layer used for RG pixels and the ink for forming a positive hole transport layer used for B pixels.

[Example 7]
A light emitting device was produced in the same manner as that of Example 3 described above except that 3-phenoxytoluene was used as a solvent for each of the ink for forming a light emitting functional layer used for RG pixels and the ink for forming a positive hole transport layer used for B pixels.

[Example 8]
A light emitting device was produced in the same manner as that of Example 4 described above except that 3-phenoxytoluene was used as a solvent for each of the ink for forming a light emitting functional layer used
for RG pixels and the ink for forming a positive hole transport layer used for B pixels.

[Example 9]
A light emitting device was produced in the same manner as that of Example 1 described above except that the thickness of the common positive hole transport layer (intermediate layer) was set to 1.5 nm.

[Example 10]
A light emitting device was produced in the same manner as that of Example 1 described above except that the thickness of the common positive hole transport layer (intermediate layer) was set to 2 nm.

(Comparative Example 1)
A light emitting device was produced in the same manner as that of Example 1 described above except that the thickness of the common positive hole transport layer (intermediate layer) was set to 3 nm.

(Comparative Example 2)
A light emitting device was produced in the same manner as that of Example 1 described above except that the formation of the common positive hole transport layer (intermediate layer) was omitted.

(2. Evaluation)
When the lifetime (LT50) of the light emitting elements of RGB pixels was measured in the light emitting devices of respective Examples and respective Comparative Examples which were produced in the above-described manner, the lifetime between the light emitting elements of R pixels and G pixels and the light emitting elements of B pixels are excellently balanced in the light emitting devices of respective Examples and the lifetime of the light emitting elements of respective pixels were
excellent when compared to the light emitting devices of respective Comparative Examples.

The result of measuring the lifetime of the light emitting elements of G pixels in the light emitting devices of Examples 1, 9, and 10 and Comparative Examples 1 and 2 are shown in Fig. 8A. In addition, the result of measuring the lifetime of the light emitting elements of B pixels in the light emitting devices of Examples 1 and 10 and Comparative Examples 1 and 2 are shown in Fig. 8B.

Further, the light emitting device of Example 2 had high light emission efficiency of the light emitting elements of G pixels when compared to the light emitting device of Example 1.

**Working examples: Part B**

Preparation of solution-based OLEDs

The production of solution-based OLEDs of this type has already been described many times in the literature, for example in WO 2004/037887. Also the production of vacuum-based OLEDs has already been described many times, for example in WO 2004/05891 1. In the examples, which are described in the following, within one OLED, layers are applied either solution-based or vacuum-based, wherein the processing including the red and green light-emitting layer is carried out from solution and whereas the subsequent layers (common blue emitting layer, hole blocking layer and electron transport layer) are processed in vacuum. The above-described general processes are adapted and/or combined to the conditions (variation of thicknesses, materials) of the present application.

The structure of the red and green emitting elements is as follows:
- substrate
- ITO (50 nm)
- Hole injection layer (20 nm for green and 60 nm for red elements)
- Hole transport layer (HTL) (20 nm)
- Emission layer (EML) (60 nm)
- Common blue emitting layer (BCL) (20 nm)
- Electron transport layer (ETL) (20 nm)
- Cathode

The structure of the blue emitting elements is as follows:
- substrate
- ITO (50 nm)
- Hole injection layer (20 nm)
- Hole transport layer (HTL) (40 nm)
- Emission layer (BCL) (20 nm)
- Electron transport layer (ETL) (20 nm)
- Cathode

Between the emission layer and the common blue emitting layer in case of the green and red emitting element, and between the positive hole transporting layer and the common blue layer in case of the blue emitting element, a common hole transport layer, which can be also called a "surface improvement layer (SIL)", is introduced. The comparative examples, mentioned in the following, do not have such a common hole transport layer.

Glass plates coated with structured ITO (indium tin oxide) in a thickness of 50 nm serve as substrate. These are coated with PEDOTPSS for better processing. PEDOTPSS (Poly(3,4-ethylenedioxy-2,5-thiophen) : Polystyrolsulfonat) is purchased from Heraeus Precious Metals GmbH & Co. KG, Germany. The spin coating of PEDOTPSS is carried out from water in air. Subsequently PEDOTPSS is dried on air by heating at 180°C for 10 minutes, to remove residues of water. The hole-transport layer and the emission layer are applied to these coated glass plates. The used hole-transport layer is cross-linkable. A hole transport polymer of the following structure is used for the red and green pixel, which can be synthesized according to WO 2010/097155.
The hole transport polymer is dissolved in toluene. The typical solids content of such solutions is about 5 g/l if, as here, the layer thickness of 20 nm which is typical for a device is to be achieved by means of spin coating. The layers are applied by spin coating in an inert-gas atmosphere, in the present case argon, and dried by heating at 180°C for 60 minutes.

The red and emission layer is always composed of at least one matrix material (host material) and an emitting dopant (emitter). Furthermore, mixtures of a plurality of matrix materials and co-dopants may occur. An expression such as H1 (40%) : H2 (40%) : D4 (20%) here means that material H1 is present in the emission layer in a proportion by weight of 40%, that material H2 is present in the emission layer in a proportion by weight of 40% and dopant D4 is present in the emission layer in a proportion by weight of 20%. The mixture for the emission layer is dissolved in toluene or optionally in chlorbenzene. The typical solids content of such solutions is about 18 g/l if, as here, the layer thickness of 60 nm which is typical for a device is to be achieved by means of spin coating. The layers are applied by spin coating in an inert-gas atmosphere, in the present case argon, and dried by heating at 160°C for 10 minutes. The matrix materials which are used in the working examples of the present invention are shown in table 1.

The materials for the common blue emission layer as well as the electron transport layer are formed by thermal evaporation in a vacuum chamber. Here, e.g. the electron transport layer may consist of more than one material, which are mixed with one another in a certain proportion by volume by co-evaporation. An expression such as ETM1:ETM2 (50%:50%) here means that materials ETM1 and ETM2 are present in the layer in a proportion by volume of 95%:5%. The materials which are used in the working examples of the present invention are shown in table 1.
The cathode is formed by the thermal evaporation of an aluminium layer with a thickness of 100 nm.

The OLEDs are characterised by standard methods. For this purpose, the electroluminescence spectra, current/voltage/luminous density characteristic lines (IUL characteristic lines) assuming Lambert emission characteristics and the (operating) lifetime are determined. The IUL characteristic lines are used to determine characteristic numbers such as the operating voltage (in V) and the external quantum efficiency (in %) at a certain luminance. LT80 @ 10000 cd/m² is the lifetime by which the OLED has dropped from an initial luminance of 10000 cd/m² to 80% of the initial intensity, i.e. to 8000 cd/m².

The optoelectronic characteristics of the different OLEDs are summarized in tables 12 to 17. The examples Comp_R, Comp_G, Comp_B, as well as Comp_B2-6 are comparative examples according to the prior art, the examples E_R, E_G, E_B as well as E_B2-8 show data of OLEDs with the used materials and the inventive layer composition.

In the following some examples are explained in detail, to point out the advantages of the materials as used in the present invention. Nevertheless, it should be pointed out, that is is only a selection of the data as shown in tables 12 to 17.

The described common hole transport layer (surface improvement layer (SIL)), together with the claimed composite layer of at least one polymer and at least one small molecular weight compound leads to improved OLED performance for blue pixels within a blue common layer OLED device. Compared to a device without a common hole transport layer, efficiency and lifetime are both increased once the common hole transport layer is included.

As shown in example E_B and comparative example Comp_B lifetime is more than doubled (20h vs. 9h), efficiency is increased by more than 10% and driving voltage at 1000cd/m² is reduced from 4.3 V to 4.1 V for the blue
pixel. For the red and green pixels, efficiency is only slightly reduced (less than 3%). Lifetime of the red and green pixels is reduced as a compromise to achieve better blue performance.

All mentioned material combinations show such positive effect on blue pixel performance. Red and green pixel performance is only slightly reduced.

Table 1: Structural formulae of the materials used in the OLED
Table 2: Structural formulae of the materials used in the common positive hole transport layer

Table 3: Structural formulae of the polymers used in the positive hole transport layers of the OLEDs

Table 4: Mixtures of polymers and SIL-materials used in the positive hole transport layers of the OLEDs

Other mixing ratios than 50:50 of polymer and corresponding SIL material can be used to increase processability/printability.
In the following the device examples are shown. For clarity reasons, the layers with are always the same (HIL, HTL, BCL, ETL, cathode and anode) are not explicitly mentioned. The complete structure of the different pixel consists of:

<table>
<thead>
<tr>
<th>Ex.</th>
<th>HIL Thickness</th>
<th>HTL Thickness</th>
<th>EML Thickness</th>
<th>SIL Thickness</th>
<th>BCL Thickness</th>
<th>ETL Thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red Pixel PEDOT:PS S 60 nm HTM Polymer 20 nm H1:H2:D1:D2 (39:45:6:10) 60 nm</td>
<td>-/SIL 1 nm</td>
<td>H3:D3 (95:5) 20 nm</td>
<td>ETM1:ETM2 (50%:50%) 20 nm</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Green Pixel PEDOT:PS S 20 nm HTM Polymer 20 nm H1:H2:D4 (40:40:20)</td>
<td>-/SIL 1 nm</td>
<td>H3:D3 (95:5) 20 nm</td>
<td>ETM1:ETM2 (50%:50%) 20 nm</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blue Pixel PEDOT:PS S 20 nm HTL 40 nm</td>
<td>---</td>
<td>-/SIL 1 nm</td>
<td>H3:D3 (95:5) 20 nm</td>
<td>ETM1:ETM2 (50%:50%) 20 nm</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 5: Exemplary structure of the RGB Pixel

<table>
<thead>
<tr>
<th>Ex.</th>
<th>HTL Thickness</th>
<th>EML Thickness</th>
<th>SIL Thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Comp_R</td>
<td>HTM Polymer 20 nm H1:H2:D1:D2 (39:45:6:10) 60 nm</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Comp_G</td>
<td>HTM Polymer 20 nm H1:H2:D4 (40:40:20) 60 nm</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Comp_B</td>
<td>HTL_ref 40 nm</td>
<td>---</td>
<td>---</td>
</tr>
</tbody>
</table>

Table 6: RGB pixel without common hole transport layer (SIL)

<table>
<thead>
<tr>
<th>Ex.</th>
<th>HTL Thickness</th>
<th>EML Thickness</th>
<th>SIL Thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>E_R</td>
<td>HTM Polymer 20 nm H1:H2:D1:D2 (39:45:6:10) 60 nm</td>
<td>SIL 1 nm</td>
<td></td>
</tr>
<tr>
<td>E_G</td>
<td>HTM Polymer 20 nm H1:H2:D2 (40:40:20) 60 nm</td>
<td>SIL 1 nm</td>
<td></td>
</tr>
<tr>
<td>E_B</td>
<td>HTL_ref 40 nm</td>
<td>---</td>
<td>SIL 1 nm</td>
</tr>
</tbody>
</table>

Table 7: RGB pixel with common hole transport layer (SIL)
<table>
<thead>
<tr>
<th>Ex.</th>
<th>HTL Thickness</th>
<th>EML Thickness</th>
<th>SIL Thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Comp_B</td>
<td>HTL_ref 40 nm</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Comp_B2</td>
<td>HTL_a 40 nm</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Comp_B3</td>
<td>HTL_b 40 nm</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Comp_B4</td>
<td>HTL_c 40 nm</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Comp_B5</td>
<td>HTL_d 40 nm</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Comp_B6</td>
<td>HTL_e 40 nm</td>
<td>---</td>
<td>---</td>
</tr>
</tbody>
</table>

Table 8: Comparative examples; blue pixel without common hole transport layer (SIL)

<table>
<thead>
<tr>
<th>Ex.</th>
<th>HTL Thickness</th>
<th>EML Thickness</th>
<th>SIL Thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>E_B</td>
<td>HTL_ref 40 nm</td>
<td>---</td>
<td>SIL1 1 nm</td>
</tr>
<tr>
<td>E_B6</td>
<td>HTL_ref 40 nm</td>
<td>---</td>
<td>SIL3 1 nm</td>
</tr>
</tbody>
</table>

Table 9: Device examples, blue pixel with common hole transport layer (SIL) (same positive hole transport layer, different common hole transport layer)

<table>
<thead>
<tr>
<th>Ex.</th>
<th>HTL Thickness</th>
<th>EML Thickness</th>
<th>SIL Thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>E_B2</td>
<td>HTL_a 40 nm</td>
<td>---</td>
<td>SIL1 1 nm</td>
</tr>
<tr>
<td>E_B3</td>
<td>HTL_b 40 nm</td>
<td>---</td>
<td>SIL1 1 nm</td>
</tr>
<tr>
<td>E_B4</td>
<td>HTL_c 40 nm</td>
<td>---</td>
<td>SIL1 1 nm</td>
</tr>
</tbody>
</table>

Table 10: Device examples, blue pixel with common hole transport layer (different hole transport layer, same common hole transport layer)
<table>
<thead>
<tr>
<th>Ex.</th>
<th>HTL Thickness</th>
<th>EML Thickness</th>
<th>SIL Thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>E_B7</td>
<td>HTL_d 40nm</td>
<td>—</td>
<td>SIL2 1nm</td>
</tr>
<tr>
<td>E_B8</td>
<td>HTL_e 40nm</td>
<td>—</td>
<td>SIL4 1nm</td>
</tr>
</tbody>
</table>

Table 11: Device examples, blue pixel with common hole transport layer (SIL-molecule also in positive hole transport layer, same polymer)

<table>
<thead>
<tr>
<th>Exp.</th>
<th>Voltage at 1000 cd/m² (V)</th>
<th>Efficiency at 1000 cd/m²</th>
<th>CIE x/y at 1000 cd/m²</th>
<th>LT80 at 10,000 cd/m² [h]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Comp_R</td>
<td>7.1</td>
<td>13.2%</td>
<td>0.652/0.343</td>
<td>10</td>
</tr>
<tr>
<td>Comp_G</td>
<td>4.5</td>
<td>15.1%</td>
<td>0.321/0.634</td>
<td>87</td>
</tr>
<tr>
<td>Comp_B</td>
<td>4.3</td>
<td>5.3%</td>
<td>0.140/0.102</td>
<td>9</td>
</tr>
</tbody>
</table>

Table 12: RGB pixel without common hole transport layer (SIL)

<table>
<thead>
<tr>
<th>Exp.</th>
<th>Voltage at 1000 cd/m² (V)</th>
<th>Efficiency at 1000 cd/m²</th>
<th>CIE x/y at 1000 cd/m²</th>
<th>LT80 at 10,000 cd/m² [h]</th>
</tr>
</thead>
<tbody>
<tr>
<td>E_R</td>
<td>6.7</td>
<td>12.9%</td>
<td>0.652/0.342</td>
<td>7</td>
</tr>
<tr>
<td>E_G</td>
<td>4.6</td>
<td>14.9%</td>
<td>0.324/0.631</td>
<td>23</td>
</tr>
<tr>
<td>E_B</td>
<td>4.1</td>
<td>6.1%</td>
<td>0.140/0.109</td>
<td>20</td>
</tr>
</tbody>
</table>

Table 13: RGB pixel with common hole transport layer (SIL)

<table>
<thead>
<tr>
<th>Exp.</th>
<th>Voltage at 1000 cd/m² (V)</th>
<th>Efficiency at 1000 cd/m²</th>
<th>CIE x/y at 1000 cd/m²</th>
<th>LT80 at 10,000 cd/m² [h]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Comp_B</td>
<td>4.3</td>
<td>5.3%</td>
<td>0.140/0.102</td>
<td>9</td>
</tr>
<tr>
<td>Comp_B2</td>
<td>4.7</td>
<td>7.2%</td>
<td>0.140/0.112</td>
<td>14</td>
</tr>
<tr>
<td>Comp_B3</td>
<td>4.8</td>
<td>7.9%</td>
<td>0.138/0.115</td>
<td>19</td>
</tr>
<tr>
<td>Comp_B4</td>
<td>4.7</td>
<td>7.1%</td>
<td>0.141/0.110</td>
<td>15</td>
</tr>
<tr>
<td>Comp_B5</td>
<td>4.1</td>
<td>5.6%</td>
<td>0.140/0.105</td>
<td>10</td>
</tr>
<tr>
<td>Comp_B6</td>
<td>4.2</td>
<td>5.4%</td>
<td>0.141/0.102</td>
<td>11</td>
</tr>
</tbody>
</table>

Table 14: Comparative examples, blue pixel without common hole transport layer (SIL)
### Table 15: Device examples, blue pixel with common hole transport layer (SIL) (same positive hole transport layer, different common hole transport layer)

<table>
<thead>
<tr>
<th>Exp.</th>
<th>Voltage at 1000 cd/m² (V)</th>
<th>Efficiency at 1000 cd/m²</th>
<th>CIE x/y at 1000 cd/m²</th>
<th>LT80 at 10.000 cd/m² [h]</th>
</tr>
</thead>
<tbody>
<tr>
<td>E_B</td>
<td>4.1</td>
<td>6.1%</td>
<td>0.140/0.109</td>
<td>20</td>
</tr>
<tr>
<td>E_B5</td>
<td>4.1</td>
<td>6.2%</td>
<td>0.141/0.109</td>
<td>20</td>
</tr>
<tr>
<td>E_B6</td>
<td>4.4</td>
<td>5.7%</td>
<td>0.139/0.110</td>
<td>18</td>
</tr>
</tbody>
</table>

### Table 16: Device examples, blue pixel with common hole transport layer (SIL) (different positive hole transport layer, same common hole transport layer)

<table>
<thead>
<tr>
<th>Exp.</th>
<th>Voltage at 1000 cd/m² (V)</th>
<th>Efficiency at 1000 cd/m²</th>
<th>CIE x/y at 1000 cd/m²</th>
<th>LT80 at 10.000 cd/m² [h]</th>
</tr>
</thead>
<tbody>
<tr>
<td>E_B2</td>
<td>4.5</td>
<td>8.5%</td>
<td>0.140/0.110</td>
<td>21</td>
</tr>
<tr>
<td>E_B3</td>
<td>4.7</td>
<td>9.3%</td>
<td>0.139/0.112</td>
<td>22</td>
</tr>
<tr>
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### Table 17: Device examples, blue pixel with common hole transport layer (SIL) (SIL-molecule also in positive hole transport layer, same polymer)

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[Reference Signs List]
1 Light emitting element
1B Light emitting element
1G Light emitting element
1R Light emitting element
3 Anode
3B Anode
3G Anode
3R Anode
4B Positive hole injection layer
4G Positive hole injection layer
4R Positive hole injection layer
4a Ink
5B Positive hole transport layer
5G Positive hole transport layer
5R Positive hole transport layer
5a Ink
5b Ink
6B Light emitting functional layer
6G Light emitting functional layer
6R Light emitting functional layer
6a Ink
6b Ink
7 Positive hole transport layer
8 Electron transport layer
9 Electron injection layer
10 Cathode
20 Circuit substrate
21 Substrate
22 Interlayer insulation film
23 Switching element
24 Wiring
31 Partition
32 Resin layer
40 Sealing substrate
100 Light emitting device
100R Sub pixel
100G Sub pixel
100B Sub pixel
200 Ink jet head
231 Semiconductor layer
10 Gate insulation layer
232 Gate electrode
233 Gate electrode
234 Source electrode
235 Drain electrode
1100 Personal computer
1102 Keyboard
1104 Main body
1106 Display unit
1200 Mobile phone
1202 Operation button
1204 Earpiece
1206 Mouthpiece
1300 Digital still camera
1302 Case
1304 Light receiving unit
1306 Shutter button
1308 Circuit substrate
1312 Video signal output terminal
1314 Input and output terminal
1430 TV monitor
1440 Personal computer
Claims

1. A light emitting device comprising:
a first light emitting element which includes a first anode, a common
cathode, a first positive hole transport layer that is provided between
the first anode and the common cathode, and a first light emitting
functional layer that is provided between the first positive hole
transport layer and the common cathode in a state of being in contact
with the first positive hole transport layer; and

a second light emitting element which includes a second anode, the
common cathode, a second positive hole transport layer that is
provided between the second anode and the common cathode, a
common positive hole transport layer that is provided between the
second positive hole transport layer and the common cathode in a
state of being in contact with the second positive hole transport layer,
and

a second light emitting functional layer that is provided between
the common positive hole transport layer and the common cathode in
a state of being in contact with the common positive hole transport
layer,

wherein the common positive hole transport layer is provided between
the common cathode and the first light emitting functional layer in a
state of being in contact with the first light emitting functional layer,
and

the thickness of the common positive hole transport layer is 2 nm or
less.

2. The light emitting device according to claim 1,
wherein the first positive hole transport layer, the first light emitting
functional layer, and the second positive hole transport layer are
respectively formed using a liquid phase process, and

the common positive hole transport layer and the second light emitting
functional layer are formed using a vapor phase process.
3. The light emitting device according to claim 1 or 2, wherein the first positive hole transport layer is configured using a high molecular weight positive hole transport material, and the second positive hole transport layer and the common positive hole transport layer are respectively configured using a low molecular weight positive hole transport material.

4. The light emitting device according to claim 3, wherein the second positive hole transport layer and the common positive hole transport layer comprise as a low molecular weight positive hole transport material a triarylamine compound having three aromatic or heteroaromatic ring systems.

5. The light emitting device according to claim 4, wherein the triarylamine compound has the following formula (I):

\[
\begin{align*}
\text{Ar}^1 & \quad \text{N} \\
\text{Ar}^2 & \quad \text{Ar}^3
\end{align*}
\]

where

- \( \text{Ar}^1 \) to \( \text{Ar}^3 \) is on each occurrence, in each case identically or differently, a mono- or polycyclic, aromatic or heteroaromatic ring system having 5 to 60 aromatic ring atoms, which may be substituted by one or more radicals \( R; \)

- \( R \) is on each occurrence, identically or differently, \( \text{H}, \text{D}, \text{F}, \text{Cl}, \text{Br}, \text{I}, \text{N} (\text{R}^1)_{2}, \text{CN}, \text{NO}_2, \text{Si} (\text{R}^1)_3, \text{B}(\text{OR}^1)_2, \text{C} (=\text{O}) \text{R}^1, \text{P}(=\text{O}) (\text{R}^1)_2, \text{S} (=\text{O}) \text{R}^1, \text{S} (=\text{O})_2 \text{R}^1, \text{OSO}_2 \text{R}^1, \text{a straight-chain alkyl, alkoxy or thioalkoxy group having 1 to 40 C atoms or a branched or cyclic alkyl, alkoxy or thioalkoxy group having 3 to 40 C atoms, each of} \)
which may be substituted by one or more radicals \( R^1 \), where one or more non-adjacent CH2 groups may be replaced by \( R^1 \)C=CR1, C≡C, Si(R1)2, C=0, C=S, C=NR1, P(=0)(R1), SO, SO2, NR1, O, S or CONR1 and where one or more H atoms may be replaced by D, F, Cl, Br, I or CN, or a mono- or polycyclic, aromatic or heteroaromatic ring system having 5 to 60 aromatic ring atoms, which may in each case be substituted by one or more radicals \( R^1 \), or an aryloxy or heteroaryloxy group having 5 to 60 aromatic ring atoms, which may be substituted by one or more radicals \( R^1 \), or an aralkyl or heteroaralkyl group having 5 to 60 aromatic ring atoms, which may be substituted by one or more radicals \( R^1 \), or a diarylamino group, diheteroarylamino group or arylheteroarylamino group having 10 to 40 aromatic ring atoms, which may be substituted by one or more radicals \( R^1 \), or a crosslinkable group Q, where two or more radicals \( R \) may also form a mono- or polycyclic, aliphatic, aromatic and/or benzo-fused ring system with one another;

\[ R^1 \]

is on each occurrence, identically or differently, H, D, F or an aliphatic hydrocarbon radical having 1 to 20 C atoms, an aromatic and/or a heteroaromatic hydrocarbon radical having 5 to 20 C atoms, in which, in addition, one or more H atoms may be replaced by F; where two or more substituents \( R^1 \) may also form a mono- or polycyclic, aliphatic or aromatic ring system with one another.

6. The light emitting device according to any one of claims 1 to 5, wherein the second positive hole transport layer is configured by containing a material having a characteristic which is the same as or approximate to a characteristic of a constituent material of the common positive hole transport layer.

7. The light emitting device according to any one of claims 3 to 6, wherein the second positive hole transport layer is configured
comprising beside the low molecular weight positive hole transport material also a high molecular weight positive hole transport material.

8. The light emitting device according to claim 7, wherein the high molecular weight positive hole transport material is a polymer which contains at least one structural unit of the following formula (XI):

\[
\text{Ar}^3
\]

\[
\text{N}
\]

\[
\text{---Ar}^{1,2}---
\]

where

\(\text{Ar}^1\) to \(\text{Ar}^3\) is on each occurrence, in each case identically or differently, a mono- or polycyclic, aromatic or heteroaromatic ring system having 5 to 60 aromatic ring atoms, which may be substituted by one or more radicals \(R\);

\(R\) is on each occurrence, identically or differently, \(H, D, F, Cl, Br, I, N(R^1)_2, CN, NO2, Si(R^1)_3, B(OR^1)_2, C(=O)R^1, P(=O)(R^1)_2, S(O)R^1, S(=O)2R^1, \text{OSO}_2R^1, \) a straight-chain alkyl, alkox y or thioalkoxy group having 1 to 40 C atoms or a branched or cyclic alkyl, alkox y or thioalkoxy group having 3 to 40 C atoms, each of which may be substituted by one or more radicals \(R^1\), where one or more non-adjacent \(\text{CH}_2\) groups may be replaced by \(\text{R}^1\text{C} = \text{CR}^1\), \(\text{C} = \text{C}, \text{Si}(\text{R}^1)_2, \text{C} = 0, \text{C} = \text{S}, \text{C} = \text{NR}^1, P(=O)(R^1), \text{SO}, \text{SO}_2, \text{NR}^1, \text{O}, \text{S} \) or \(\text{CONR}^1\) and where one or more H atoms may be replaced by \(\text{D, F, Cl, Br, I or CN, or a mono- or polycyclic, aromatic or heteroaromatic ring system having 5 to 60 aromatic ring atoms, which may in each case be substituted by one or more radicals }\)\(R^1\), or an arylox y or heteroarylox y group having 5 to 60 aromatic ring atoms, which may be substituted by one or more radicals \(R^1\), or an aralkyl or heteroaralkyl group having 5 to 60 aromatic ring atoms, which may be substituted by one or more radicals \(R^1\), or a diarylamino group, diheteroarylamino group or
arylheteroarylamino group having 10 to 40 aromatic ring atoms, which may be substituted by one or more radicals $R^1$, where two or more radicals $R$ may also form a mono- or polycyclic, aliphatic, aromatic and/or benzo-fused ring system with one another;

$R^1$ is on each occurrence, identically or differently, $H$, $D$, $F$ or an aliphatic hydrocarbon radical having 1 to 20 C atoms, an aromatic and/or a heteroaromatic hydrocarbon radical having 5 to 20 C atoms, in which, in addition, one or more $H$ atoms may be replaced by $F$; where two or more substituents $R^1$ may also form a mono- or polycyclic, aliphatic or aromatic ring system with one another; and

the dashed lines represent bonds to adjacent structural units in the polymer.

9. The light emitting device according to any one of claims 1 to 8, wherein the constituent material of the common positive hole transport layer has an electron blocking property.

10. The light emitting device according to any one of claims 1 to 9, wherein a constituent material of the first light emitting functional layer is configured of a low molecular weight material as a main material.

11. The light emitting device according to any one of claims 1 to 10, wherein the thickness of the common positive hole transport layer is 1 nm or less.

12. The light emitting device according to any one of claims 1 to 11, further comprising:

a third light emitting element which includes a third anode, the common cathode, a third positive hole transport layer that is provided between the third anode and the common cathode, and a third light
emitting functional layer that is provided between the third positive hole transport layer and the common cathode in a state of being in contact with the third positive hole transport layer, wherein the common positive hole transport layer is in contact with the third light emitting functional layer, and the first light emitting element, the second light emitting element, and the third light emitting element have luminescent colors which are different from one another.

13. The light emitting device according to claim 12, wherein the luminescent color of the first light emitting element is red, the luminescent color of the second light emitting element is blue, and the luminescent color of the third light emitting element is green.

14. Electronic equipment which includes the light emitting device according to any one of claims 1 to 13.
Fig. 8(a)

Green element life time

Life time (LT50) Standard value

Layer thickness of the common hole transport layer (nm)

Fig. 8(b)

Blue element life time

Life time (LT50) Standard value

Layer thickness of the common hole transport layer (nm)
## A. CLASSIFICATION OF SUBJECT MATTER

**INV.** H01L51/50

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

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

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<td><strong>US 2012/025225 Al (ODA TOSHIHI R0 [JP])</strong>&lt;br&gt;2 February 2012 (2012-02-02)&lt;br&gt;paragraph [0237] - paragraph [0260]; figure 5; example 1&lt;br&gt;paragraph [0312] - paragraph [0332]; figure 8&lt;br&gt;paragraph [0047] - paragraph [0162]; figures 1-4</td>
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Further documents are listed in the continuation of Box C.

See patent family annex.

* Special categories of cited documents:
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  - "O" document referring to an oral disclosure, use, exhibition or other means
  - "P" document published prior to the international filing date but later than the priority date claimed

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Name and mailing address of the ISA:

European Patent Office, P.B. 5818 Patentlaan 2<br>NL-2280 HV Rijswijk<br>Tel. (+31-70) 340-2040,<br>Fax. (+31-70) 340-3016

Authorized officer:

Konradsson, Ásgeir
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