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(54) PHOSPHORESCENT OLED AND HOLE TRANSPORTING MATERIALS FOR PHOSPHORESCENT OLEDS

PHOSPHORESZENTE OLED UND LOCHTRANSPORTMATERIALIEN FÜR PHOPHORESZENTE OLED

DIODE ÉLECTROLUMINESCENTE ORGANIQUE PHOSPHORESCENTE ET MATIÈRES DE TRANSPORT DE TROUS POUR DIODES ÉLECTROLUMINESCENTES PHOSPHORESCENTES

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Description

[0001] The present invention relates to phosphorescent organic light-emitting devices, and to compounds which may be used in such devices, especially in hole transporting and/or electron blocking layers thereof.

[0002] In OLEDs, the electroluminescence (EL) characteristic of certain organic materials is used. In EL devices, an application of a voltage creates suitable charge carriers which form, if re-combined, activated conditions, which return into the basic condition by emission of light. For improving the efficiency, the organic light-emitting diodes very often have, amongst the emission layer, also charge transporting layers which are responsible for transport of negative and positive charge carriers into the emission layer. These charge transporting layers are grouped, depending on the charge carrier transported, into hole conductors and electron conductors. A quite similar set of layers is known for photovoltaic devices, such as organic solar cells. Organic semiconducting devices having several layers can be produced by known methods, for example evaporation under vacuum or deposition from solution.

[0003] In other words, in case of organic light-emitting diodes, light is produced and emitted by the injection of charge carriers, electrons from one side, holes from the other, from the contacts into adjacent organic layers as a result of an externally applied voltage, subsequent formation of excitons (electron-hole pairs) in an active zone, and radiant recombination of these excitons.

[0004] The most usual OLED structure with the positive electrode (anode) adjacent to the substrate is schematically depicted on Fig. 1, wherein the numbers 1-9 stand for the following layers:

1. Substrate
2. Base electrode, hole-injecting (positive pole), usually transparent
3. Hole-injecting layer
4. Hole-transporting layer (HTL)
5. Light-emitting layer (EL)
6. Electron-transporting layer (ETL)
7. Electron-injecting layer
8. Cover electrode (usually a metal with low work function, electron-injecting (negative pole))
9. Encapsulation, to shut out ambient influence.

[0005] While the foregoing represents the most typical case, often several layers may be omitted, or else one layer may be combined for several properties.

[0006] An important property of organic semiconducting materials is their conductivity. The conductivity of a thin layer sample can be measured by, for example, the so-called two-point method. At this, a voltage is applied to the thin layer and the current flowing through the layer is measured. The measured resistance, respectively conductivity, results by considering the geometry of the contacts and the thickness of the layer of the sample.

[0007] In an OLED, the operational voltage (or, more exactly, the overall electrical resistance) is given not only by resistances and thicknesses of particular layers, but also by energetic barriers for charge carrier injection from a particular layer to the adjacent one. The power efficiency of the device (conversion of the electrical power in the light flux at the given wavelength or in the given colour range) depends on Joule losses given by the overall resistance and on the efficiency of conversion of charge carriers in photons, which depends on the charge carrier (electron-hole) balance and on the quantum efficiency of radiating recombination of the formed electron-hole pairs (excitons) in the device.

[0008] There is steady effort to develop materials and OLED designs which allow minimizing Joule losses, ensure the charge carrier balance and maximize the quantum efficiency. In minimizing Joule losses, significant improvement brought the design of special charge injecting layers and the introduction of electrically doped charge transporting layers. Specific charge injecting and blocking layers can also improve the charge carrier balance. Most important improvement in quantum efficiency brought an introduction of phosphorescent emitters, which allow exploiting not only singlet excitons, but also the triplet exciton states, which under normal circumstances statistically prevail in the exciton population.

[0009] In the prior art, a number of materials used for preparing hole transport layer and/or electron/exciton blocking layer is known.

[0010] JPH 5 105647 A discloses a phenylendiamine compound and a photosensitive material containing the same.

[0011] JP 2002 241352 A discloses an organic compound, an organic electroluminescent material and an organic electroluminescent element.

[0012] JP 2006 156635 A discloses an organic electroluminescent element and an indicating device.

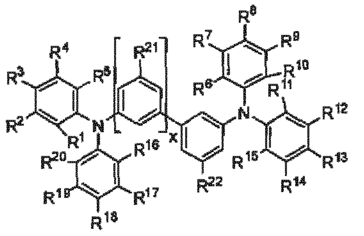
[0013] US 2004/214040 A1 discloses biphenyl derivatives and organic electroluminescent devices comprising the same.

[0014] However, despite impressive results in OLED performance achieved thank to previous material and design development, the OLED efficiency is still significantly below its theoretical limits and many other OLED-performance parameters like luminosity and lifetime can be also further improved.

[0015] It is therefore an object of the present invention to provide improved phosphorescent OLEDs having lower operating voltage and/or higher efficiency than devices using hole transporting and electron blocking matrices according to the state of the art. Another object of the invention is providing new compounds which can be used as matrix materials for hole-transporting layers and/or electron/exciton blocking layers which overcome the drawbacks of the prior art and can especially be used in phosphorescent OLEDs.

[0016] The above object is achieved in accordance with the subject-matter of the independent claims. Preferred embodiments result from the sub-claims.

[0017] This object is in particular achieved by an organic light emitting device comprising between anode and cathode at least one emitting layer comprising a phosphorescent emitter and at least one hole transporting and/or electron blocking layer comprising a compound represented by general formula (I)



wherein R^1-R^5 and R^{11}-R^{15} are independently selected from phenyl and hydrogen or the adjacent substituents are linked so that they form an aromatic ring, R^6-R^{10} and R^{16}-R^{20} are independently selected from hydrogen, C1-C20 alkyl or C3-C20 cycloalkyl, C1-C20 alkoxy or C3-C20 cycloalkyloxy, C7-C20 arylalkyl, C6-C20 aryl and C2-C20 heteroaryl,

x is an integer chosen from 0 and 1, wherein for x = 0, R^{22} is selected from hydrogen, C1-C20 alkyl or C3-C20 cycloalkyl, C1-C20 alkoxy or C3-C20 cycloalkyloxy, C7-C20 arylalkyl, C6-C20 aryl and C2-C20 heteroaryl, whereas for x = 1, R21 and R22 are independently selected from hydrogen, C1-C10 alkyl, C3-C10 cycloalkyl, C1-C10 alkoxy and C3-C10 cycloalkyloxy,

wherein the aromatic ring can be formed by

i) R^1 with R^2 as well as R^{11} with R^{12} or

ii) R^2 with R^3 as well as R^{12} with R^{13} and

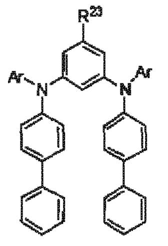
at least two of R^6 - R^{10} and at least two of R^{16}-R^{20} are methyl, or at least one of R^6-R^{10} and at least one of R^{16}-R^{20} is selected from C2-C20 alkyl, C3-C20 cycloalkyl, C1-C20 alkoxy, C3-C20 cycloalkyloxy, C7-C20 arylalkyl, C6-C20 aryl and C2-C20 heteroaryl.

[0018] The alkyl or alkoxy substituent can be saturated or unsaturated, straight or branched. The cycloalkyl or cycloalkoxy substituent may be saturated or unsaturated, monocyclic or polycyclic. The overall C atom count in a substituent includes possible alkyl substitution, branching and/or occurrence of cyclic structures within the substituent. It is advantageous, if the heteroaryl substituent is attached through a carbocyclic ring or through a five-membered heterocyclic ring containing up to three heteroatoms independently chosen from O, N and S. Preferably, the overall C atom count in the compound (I) does not exceed 150. More preferably, the overall C atom count in any group of substituents selected from R^1-R^5, R^6-R^{10}, R^{11}-R^{15}, R^{16}-R^{20}, that means of all the substituents bound to one of phenyl rings bound in the structure (I) to nitrogen atoms, does not exceed 20. Most preferably, the overall C atom count in any group of substituents selected from R^1-R^5, R^6-R^{10}, R^{11}-R^{15}, R^{16}-R^{20} does not exceed 12.

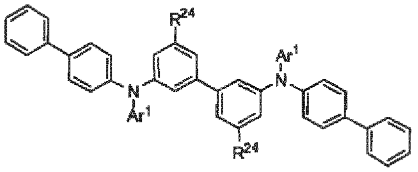
[0019] In the present invention, at least one of R^1-R^5 and at least one of R^{11}-R^{15} is phenyl, whereas other R^1-R^5 and R^{11}-R^{15} are hydrogen. In a preferred embodiment, at least two of R^6-R^{10} and at least two of R^{16}-R^{20} are methyl, or at least one of R^6-R^{10} and at least one of R^{16}-R^{20} is selected from C2-C20 alkyl, C3-C20 cycloalkyl, C1-C20 alkoxy, C3-C20 cycloalkyloxy, C7-C20 arylalkyl, C6-C20 aryl and C2-C20 heteroaryl. In more preferred embodiment, at least two of R^6-R^{10} and at least two of R^{16}-R^{20} are methyl, or at least one of R^6-R^{10} and at least one of R^{16}-R^{20} is selected from C2-C20 alkyl, C3-C20 cycloalkyl, C1-C20 alkoxy, C3-C20 cycloalkyloxy, C7-C20 arylalkyl, C6-C20 aryl and C2-C20 heteroaryl, whereas other R^6-R^{10} and R^{16}-R^{20} are hydrogen. In an even preferred embodiment, R^3 and R^{13} is phenyl and other substituents on R^3 and R^{13} bearing phenyl rings are hydrogen atoms. In another preferred embodiment, R^1-R^5

are the same as R^{11}-R^{15} and R^6-R^{10} are the same as R^{16}-R^{20}. In still another preferred embodiment, at least two of R^6-R^{10} and at least two of R^{16}-R^{20} are methyl, or at least one of R^6-R^{10} and at least one of R^{16}-R^{20} is selected from C2-C12 alkyl, C3-C12 cycloalkyl. More preferably, R^8 and R^{18} is tert-butyl or R^7, R^9, R^{17} and R^{19} is methyl. For x = 1, R^{21} and R^{22} are preferably independently selected from methyl or methoxy. More preferably, R^{21} and R^{22} are the same. Preferred are also all possible combinations of preferred embodiments mentioned above.

[0020] More preferred are the devices comprising embodiments of general structure (I) represented by general formula (II) or (III)



II

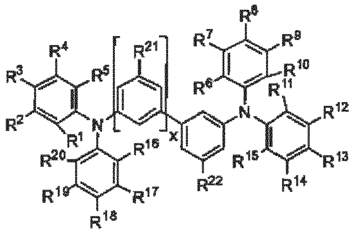


III

wherein Ar and Ar^1 are selected from 4-tert-butylphenyl, 3,5-dimethylphenyl and 2,4,6-trimethylphenyl, R^{23} has the same meaning as R^{22} defined above and R^{24} is hydrogen, C1-C10 alkyl, C3-C10 cycloalkyl, C1-C10 alkoxy and C3-C10 cycloalkyloxy.

[0021] Preferably, R^{23} is selected from C2-C20 alkyl, C3-C20 cycloalkyl, C1-C20 alkoxy, C3-C20 cycloalkyloxy, C7-C20 arylalkyl, C6-C20 aryl and C2-C20 heteroaryl. More preferably, R^{23} is selected from the group consisting of methyl, phenyl, 3,5-dimethylphenyl and 1,1'-biphenyl-4-yl. Preferably, R^{24} is C1-C4 alkyl or C1-C4 alkoxy. More preferably, R^{24} is selected from methyl and methoxy.

[0022] A further object is achieved by Compound represented by general formula (I)



wherein R^1-R^5 and R^{11}-R^{15} are independently selected from phenyl and hydrogen or the adjacent substituents are linked so that they form an aromatic ring,

x is an integer chosen from 0 and 1, wherein for x = 0, R^{22} is selected from hydrogen, C1-C20 alkyl or C3-C20 cycloalkyl, C1-C20 alkoxy or C3-C20 cycloalkyloxy, C7-C20 arylalkyl, C6-C20 aryl and C2-C20 heteroaryl, whereas for x = 1, R^{21} and R^{22} are independently selected from hydrogen, C1-C10 alkyl, C3-C10 cycloalkyl, C1-C10 alkoxy and C3-C10 cycloalkyloxy, wherein the aromatic ring can be formed by

i) R^1 with R^2 as well as R^{11} with R^{12} or

ii) R^2 with R^3 as well as R^{12} with R^{13}
and

iii) R^7 and R^9 as well as R^{17} and R^{19} are methyl whereas R^6, R^8 and R^{10} as well as R^{16}, R^{18} and R^{20} are hydrogen or

iv) R^8 and R^{18} are 1,1-dimethylethyl and R^6, R^7, R^9, R^{10} as well as R^{16}, R^{17}, R^{19} and R^{20} are hydrogen.

[0023] The alkyl or alkoxy substituent can be saturated or unsaturated, straight or branched. The cycloalkyl or cycloalkoxy substituent may be saturated or unsaturated, monocyclic or polycyclic. The overall C atom count in a substituent includes possible alkyl substitution, branching and/or occurrence of cyclic structures within the substituent. It is advantageous, if the heteroaryl substituent is attached through a carbocyclic ring or through a five-membered heterocyclic ring containing up to three heteroatoms independently chosen from O, N and S. Preferably, the overall C atom count in the compound (I) does not exceed 150. More preferably, the overall C atom count in any group of substituents selected from R^1-R^5, R^6-R^{10}, R^{11}-R^{15}, R^{16}-R^{20}, that means of all the substituents bound to one of phenyl rings bound in the structure (I) to nitrogen atoms, does not exceed 20. Most preferably, the overall C atom count in any group of substituents selected from R^1-R^5, R^6-R^{10}, R^{11}-R^{15}, R^{16}-R^{20} does not exceed 12.

[0024] More preferably, this object is achieved by new compounds of general formula (I) wherein

i) at least one of R^1-R^5 and at least one of R^{11}-R^{15} is C6-C20 aryl or C2-C20 heteroaryl or

ii) R^1 with R^2 as well as R^{11} with R^{12} form an aromatic ring or

iii) R^2 with R^3 as well as R^{12} with R^{13} form an aromatic ring

and
at least two of R^6-R^{10} and at least two of R^{16}-R^{20} are methyl, or at least one of R^6-R^{10} and at least one of R^{16}-R^{20} is selected from C2-C20 alkyl, C3-C20 cycloalkyl, C1-C20 alkoxy, C3-C20 cycloalkyloxy, C7-C20 arylalkyl, C6-C20 aryl and C2-C20 heteroaryl, whereas other R^6-R^{10} and R^{16}-R^{20} are H.

[0025] Even preferably, this object is achieved by new compounds of general formula (I) wherein
at least one of R^1-R^5 and at least one of R^{11}-R^{15} is C6-C20 aryl or C2-C20 heteroaryl;
at least two of R^6-R^{10} and at least two of R^{16}-R^{20} are methyl, or
at least one of R^6-R^{10} and at least one of R^{16}-R^{20} is selected from C2-C20 alkyl, C3-C20 cycloalkyl, C1-C20 alkoxy, C3-C20 cycloalkyloxy, C7-C20 arylalkyl, C6-C20 aryl and C2-C20 heteroaryl,
whereas other R^1-R^5, R^6-R^{10}, R^{11}-R^{15} and R^{16}-R^{20} are H.

[0026] Even more preferably, this object is achieved by new compounds of general formula (I) wherein
at least one of R^1-R^5 and at least one of R^{11}-R^{15} is phenyl;
at least two of R^5-R^{10} and at least two of R^{16}-R^{20} are methyl, or
at least one of R^6-R^{10} and at least one of R^{16}-R^{20} is selected from C2-C20 alkyl, C3-C20 cycloalkyl, C1-C20 alkoxy, C3-C20 cycloalkyloxy, C7-C20 arylalkyl, C6-C20 aryl and C2-C20 heteroaryl,
whereas other R^1-R^5, R^6-R^{10}, R^{11}-R^{15} and R^{16}-R^{20} are H.

[0027] Even more preferably, this object is achieved by new compounds of general formula (II) or (III) defined above, most preferably in their embodiments preferred above.

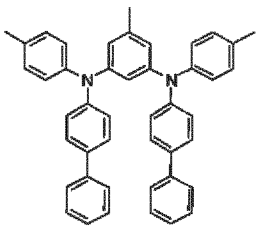
[0028] It is preferred that at least one layer containing the compound of formula (I) is electrically doped.

[0029] More preferably, the layer containing the compound of formula (I) has at least one doped portion and at least one portion which is less doped than the doped portion or is un-doped. In this embodiment, the less doped or undoped part of the layer serves as electron blocking layer.

[0030] In one yet preferred embodiment, the undoped part of the layer serves as both electron-blocking and triplet exciton blocking layer.

Detailed description of the invention

[0031] In a research striving to find new ways to approaching better OLEDs, it was surprisingly found by the authors that certain hole-transporting materials known for long, like



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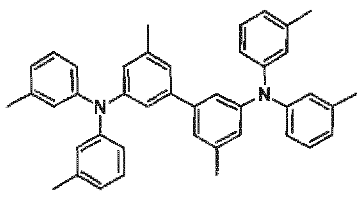
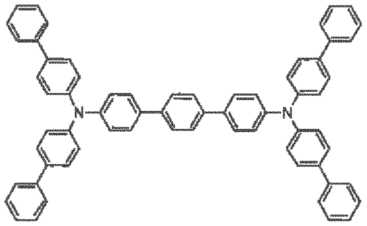
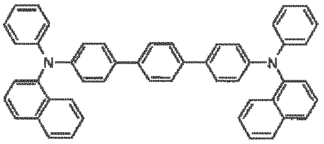


perform unexpectedly well when used in OLEDs comprising a phosphorescent emitter, whereas their performance in conventional fluorescent OLEDS is only moderate and no way achieves the level provided by established hole transporting matrix materials like



H-1

or



H-2

[0032] Further research helped clarifying relationships with the structure of the compounds tested and confirmed that the improvement is rather general. Table 1 shows the experimental results obtained by the procedure described in detail in the examples below. In the experimental OLEDs tested, the hole transporting layer was doped with a p-dopant, what is symbolized with the p-symbol in the substrate/HTL/EBL column. In the table, to the compounds showing voltage lower voltage than reference, negative values were assigned in the voltage column. Oppositely, a positive value in the voltage column shows unfavourable, higher average voltage observed at the set of devices comprising inventive compound in comparison with the average voltage measured on the set of reference devices prepared under the same conditions. In the efficiency column, the average efficiency of devices comprising an inventive compound higher than the average efficiency of comparative devices is positive, whereas unfavourable lower efficiency in comparison with reference has negative sign. The last column in the table shows the arithmetic difference between the value in the efficiency column and the value in the voltage column. The resulting value was used as a benchmark for assessing the overall performance. Its positive value in at least one from the three rows shows that at least in one application - if the compound was used as an EBL, as an HTL, or in both layers - shows that in this particular case, the percentage voltage improvement has overweighed the percentage efficiency decrease or, oppositely, that the percentage efficiency improvement overweighed the undesired voltage increase, or that there was an improvement in both properties. In fluorescent blue OLED, there was uniformly no particular (in at least one - efficiency or voltage - value) improvement at all for all compounds tested. Consequently, all overall performance values were strongly negative. Surprisingly, in the phosphorescent OLED, the only combination of the structural features of the substituents tested which unequivocally failed (afforded negative overall performance in all applications) was the R^{23} substituent defined as phenyl bearing at least one strongly electron withdrawing group. The gained knowledge was exploited for providing new hole transporting and electron-blocking matrix materials, particularly useful in OLEDs comprising triplet emitters.

Table 1

Compound tested	**Core substit.**	**Periphery s.**	**phosphorescent green**			
			substrate/HTL/EBL	voltage change [%]	Q eff change [%]	Q - voltage [%]
			ITO / p-H-1 / H-2 ITO / p-H-2 /H-2	-8 -8	-49 -50	-41 -42
			ITO / **p-H-1 / TCTA** ITO / p-TCTA / TCTA	0 +38	 +5	
			ITO / p-H-1 / **MPD-1** ITO / **p-MPD-1** / TCTA ITO / **p-MPD-1/ MPD-1**	-6 +6 -4	-5 +15 +11	1 9 15
			ITO / p-H-1 / **MPD-2** ITO / **p-MPD-2** / TCTA ITO / **p-MPD-2/ MPD-2**	-7 +1 -5	-47 +7 -44	-40 6 -39
			ITO / p-H-1 / **MPD-3** ITO / **p-MPD-3** / TCTA ITO / **p-MPD-3/ MPD-3**	-4 -1 -3	-46 +6 -40	-42 7 -37
			ITO / p-H-1 / **MPD-4**	-6	-4	2

(continued)

Compound tested	**Core substit.**	**Periphery s.**	**phosphorescent green**			
			substrate/HTL/EBL	voltage change [%]	Q eff change [%]	Q - voltage [%]
			ITO / **p-MPD-4** / TCTA	+1	+12	11
			ITO / **p-MPD-4/ MPD-4**	-5	0	5
			ITO / p-H-1 / **MPD-5**	-6	+1	7
			ITO / **p-MPD-5/** TCTA	+5	+13	8
			ITO / **p-MPD-5/ MPD-5**	-5	+13	18
			ITO / p-H-1 / **MPD-6**	-4	0	4
			ITO / **p-MPD-6** / TCTA	+5	+14	9
			ITO / p-MPD-6/ **MPD-6**	-3	+13	16
			ITO / p-H-1 / **MPD-7**	-8	-15	-7
			ITO / **p-MPD-7/** TCTA	+4	+10	6
			ITO / **p-MPD-7/ MPD-7**	-5	-4	1
			ITO / p-H-1 / **MPD-8**	-7	-9	-2
			ITO / **p-MPD-8** / TCTA	+10	+13	3
			ITO / **p-MPD-8/ MPD-8**	+2	+3	1
			ITO / p-H-1 / **MPD-9**	-6	-6	0
			ITO / **p-MPD-9** / TCTA	+6	+16	10
			ITO / **p-MPD-9/ MPD-9**	-5	+9	14
			ITO / p-H-1 / **MPD-10**	+3	+4	1
			ITO / **p-MPD-10**/TCTA	+14	+20	6
			ITO / **p-MPD-10/ MPD-10**	+18	+16	-2
			ITO / p-H-1 / **MPD-11**	+8	-7	-15
			ITO / **p-MPD-11** / TCTA	+18	+6	-12
			ITO / **p-MPD-11/ MPD-**11	+30	+3	-27
			ITO / p-H-1 / **MPD-12**	-5	-2	3
			ITO / **p-MPD-12/** TCTA	+16	+14	-2
			ITO / **p-MPD-12/ MPD-12**	+8	+12	4
			ITO / p-H-1 / **MPD-13**	-7	-5	2
			ITO / **p-MPD-13/** TCTA	-7	-5	2
			ITO / **p-MPD-13/ MPD-13**	-5	+8	13
			ITO / p-H-1 / **MPD-14**	-8	-13	-5
			ITO / **p-MPD-14** / TCTA	+2	+12	10
			ITO / **p-MPD-14/ MPD-14**	-6	-5	1
			ITO / p-H-1 / **MPD-15**	-7	-16	-9
			ITO / **p-MPD-15**/TCTA	+1	+9	8
			ITO / **p-MPD-15/ MPD-15**	-4	-9	-5
			ITO / p-H-1/ **MDAB-1**	-4	0	4
			ITO / **p-MDAB-1** / TCTA	+6	+14	8
			ITO / **p-MDAB-1** / **MDAB-1**	-2	+12	14
			ITO / p-H-1 / **MDAB-2**	-5	-1	4
			ITO / **p-MDAB-2/** TCTA	+8	+14	6
			ITO / **p-MDAB-2** / **MDAB-2**	-2	+13	15

(continued)

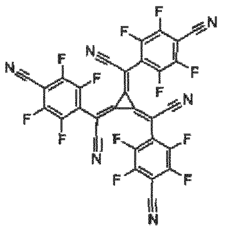
Compound tested	Core substit.	Periphery s.	phosphorescent green			
			substrate/HTL/EBL	voltage change [%]	Q eff change [%]	Q - voltage [%]
			ITO / p-H-1 / **MDAB-3**	-6	-5	1
			ITO / **p-MDAB-3** / TCTA	+2	+6	4
			ITO / **p-MDAB-3 MDAB-3**	-4	+4	8
			ITO / p-H-1 **/MDAB-4**	-4	-3	1
			ITO / **p-MDAB4/** TCTA	+13	+8	-5
			ITO / **p-MDAB-4 /MDAB-4**	+15	+7	-8
			ITO / p-H-1 / **MDAB-5**	-2	+1	3
			ITO / **p-MDAB-5** / TCTA	+19	+7	-12
			ITO / **p-MDAB-5 /MDAB-5**	+19	+8	-11

[0033] Additionally, it has been found that inventive compounds are advantageous also when used as hole transporting and/or electron blocking matrices in blue fluorescent OLEDs.

[0034] Emitting layer, electron transporting layer, hole blocking layer, electrodes

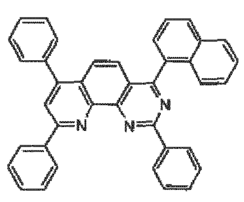
[0035] Other parts of the inventive phosphorescent light emitting device than the inventive hole transporting and/or electron blocking layer can be prepared in various designs and from various materials described in the scientific and patent literature.

[0036] In the examples, following supporting materials were used:



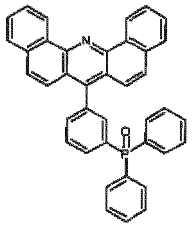
D1

as a p-dopant,



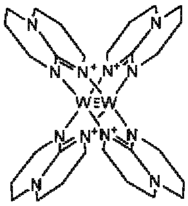
E-1

and



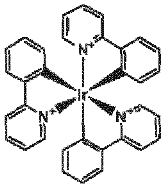
E2

as electron-transporting matrices,



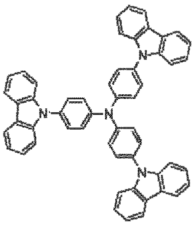
D2

as n-dopant,



Irppy

as the triplet emitter,



TCTA

as a known electron blocking matrix.

Description of drawings

[0037]

Figure 1: Schematic drawing of experimental bottom emitting phosphorescent OLED

Figure 2: a) Top view of deposition of layer 1 (p-doped inventive material (stripes), p-doped reference (dots), left; b) Top view of layer 2 after rotation of substrate by 90°, with the inventive material in the top row (fields A, C) and reference material in the bottom row (fields B, D).

Figure 3a - 3g: ^{1}H-NMR spectra of example compounds having formula (II) measured in CD_2Cl_2 solution, at 500.13 MHz, referenced to 5.31 ppm; 3a - MDAB-1, 3b - MDAB-2, 3c - MDAB-3, 3d - MDAB-4, 3e - MDAB-5, 3f - MDAB-6, 3g - MDAB-7.

Figure 4a - 4o: ^{1}H-NMR spectra of example compounds having formula (III) measured under the same conditions; 4a - MPD-1, 4b - MPD-2, 4c - MPD-3, 4d - MPD-4, 4e - MPD-5, 4f - MPD-6,4g - MPD-7, 4h - MPD-8, 4i - MPD-9, 4j - MPD-10, 4k - MPD-11, 41 - MPD-12, 4m - MPD-13, 4n - MPD-14, 4o - MPD-15.

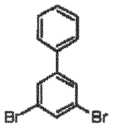
Examples

General procedure for 3,5-dibromophenylenes

[0038] 1,3,5-Tribromobenzene, the boronic acid and $Pd(PPh_3)_4$ were dissolved in a mixture of toluene and ethanol. A degassed 2M aqueous Na_2CO_3 solution was added. The mixture was refluxed for 18 hours. After cooling to room temperature the organic phase was separated from the aqueous one. The aqueous phase was extracted with toluene three times. The combined organic phases were evaporated to dryness and the residue was filtered over a pad of silica gel using dichloromethane (DCM) as eluent. After evaporating the solvents the crude product was purified by column chromatography on silica gel using hexane : DCM mixtures as an eluent. In thin layer chromatography (TLC), the upper main spot was identified as the desired product and the one below as the 3,5-disubstituted bromobenzene side product.

3,5-dibromo-1,1'-biphenyl

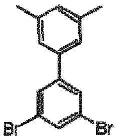
[0039]



1,3,5-tribromobenzene: 10.20 g (1.2 eq, 32.4 mmol)
phenylboronic acid: 3.30 g (1.0 eq, 27.1 mmol)
$Pd(PPh_3)_4$: 625 mg (2 mol%, 0.54 mmol)
toluene: 160 mL
ethanol: 54 mL
2M Na_2CO_3: 27 mL
Yield: 5.53 g (65%)
GC-MS: m/z = 310 / 312 / 314

3,5-dibromo-3',5'-dimethyl-1,1'-biphenyl

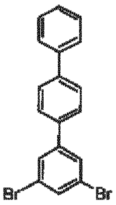
[0040]



1,3,5-tribromobenzene: 13.00 g (1.2 eq, 41.3 mmol)
3,5-dimethylphenylboronic acid: 5.16 g (1.0 eq, 34.4 mmol)
$Pd(PPh_3)_4$: 795 mg (2 mol%, 0.69 mmol)
toluene: 160 mL
ethanol: 68 mL
2M Na_2CO_3: 34 mL
Yield: 7.13 g (61%)
GC-MS: m/z = 338 / 340 / 342

3,5-dibromo-1,1'-4',1"-terphenyl

[0041]

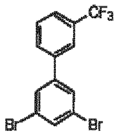


1,3,5-tribromobenzene: 10.00 g (1.2 eq, 31.77 mmol)
4-biphenylboronic acid: 5.24 g (1.0 eq, 26.47 mmol)
$Pd(PPh_3)_4$: 612 mg (2 mol%, 0.53 mmol)

toluene: 160 mL
ethanol: 52 mL
2M Na_2CO_3: 26 mL
Yield: 4.95 g (48%)
GC-MS: m/z = 386 / 388 / 390

3,5-dibromo-3'-(trifluoromethyl)-1,1'-biphenyl

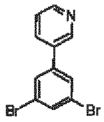
[0042]



1,3,5-tribromobenzene: 10.00 g (1.2 eq, 31.77 mmol)
3-(Trifluoromethyl)phenylboronic acid: 5.03 g (1.0 eq, 26.47 mmol)
$Pd(PPh_3)_4$: 611 mg (2 mol%, 0.53 mmol)
toluene: 160 mL
ethanol: 52 mL
2M Na_2CO_3: 26 mL
Yield: 5.57 g (56%)
GC-MS: m/z = 378 / 380 / 382

3-(3,5-dibromophenyl)pyridine

[0043]



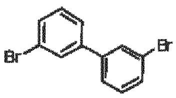
1,3,5-tribromobenzene: 10.00 g (1.2 eq, 31.77 mmol)
3-(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)pyridine: 5.43 g (1.0 eq, 26.47 mmol)
$Pd(PPh_3)_4$: 612 mg (2 mol%, 0.53 mmol)
toluene: 160 mL
ethanol: 52 mL
2M Na_2CO_3: 26 mL
Yield: 4.00 g (48%)
GC-MS: m/z = 311 / 313 / 315

General procedure for biphenyl based cores

[0044] The dibromo compound was solved in ether and the flask was shielded from light by aluminium foil. The solution was cooled to -80°C and butyllithium was added within 30 minutes. After butyllithium addition, the solution was kept at -80 °C for 90 minutes. Under vigorous stirring, copper(II) chloride was added in one shot. The solution was allowed to warm to room temperature and to stir overnight. TLC indicated consumption of the starting material and formation of a new product as the only component in the mixture. The mixture was washed three times with 10% aqueous NH_4OH, once with brine and once with water. The organic phase was dried over $MgSO_4$ and filtered through a pad of silica gel by using DCM/hexane 1:1. After evaporation of the solvents, the crude product was washed in boiling methanol for 15 minutes and then filtered and dried.

3,3'-dibromo-1,1'-biphenyl

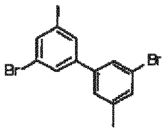
[0045]



3,5-dibromobenzene: 58.98 g (1.0 eq, 250 mmol)
n-Butyllithium, 2.5M in hexane: 100mL (1.0 eq, 250 mmol)
copper(II)chloride: 36,97 g (1.1 eq, 275 mmol)
diethylether: 800 mL
Yield: 22.06 g (56%)
GC-MS: m/z = 310 / 312 / 314

3,3'-dibromo-5,5'-dimethyl-1,1'-biphenyl

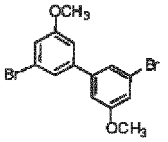
[0046]



3,5-dibromotoluene: 62.48 g (1.0 eq, 250 mmol)
n-Butyllithium, 2.5M in hexane: 100mL (1.0 eq, 250 mmol)
copper(II)chloride: 36,97 g (1.1 eq, 275 mmol)
diethylether: 800 mL
Yield: 22.1 g (52%)
GC-MS: m/z = 338 / 340 / 342

3,3'-dibromo-5,5'-dimetlroxy-1,1'-biphenyl

[0047]



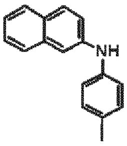
3,5-dibromoanisole: 16.40 g (1.0 eq, 61.7 mmol)
n-Butyllithium, 2.5M in hexane: 27mL (1.0 eq, 67.8 mmol)
copper(II)chloride: 9.12 g (1.1 eq, 67.8 mmol)
diethylether: 200 mL
Yield: 9.7 g (85%)
GC-MS: m/z = 370 / 372 / 374

General procedure for secondary amines

[0048] Under an inert atmosphere the bromoaryl component, palladium(II)acetate, cesium carbonate and 2,2'-bis(diphenylphosphino)-1,1'-binaphthyl (BINAP) were combined in a flask and dissolved in 1,4-dioxane. The primary arylamine component was added, followed by heating up the mixture to reflux and stirring for 18-48 hours. According to TLC the reaction was complete. The mixture was cooled to room temperature and filtered through a pad of silica gel. After washing with DCM and evaporation of the solvent the crude product was purified by column chromatography (SiO_2, hexane:DCM mixtures). The combined fractions were evaporated to dryness and the resulting solid was recrystalized from hexane to yield the desired product.

N-(p-tolyl)naphthalen-2-amine

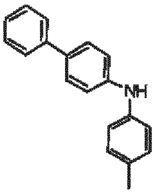
[0049]



2-bromonaphthalene: 15 g (1.0 eq, 72.44 mmol)
p-toluidine: 11.6 g (1.5 eq, 108.6 mmol)
palladium(II)acetate: 488 mg (3.0 mol.%, 2.17 mmol)
BINAP: 2.0 g (4.5 mol.%, 3.26 mmol)
cesium carbonate: 47.20 g (2.0 eq, 144.9 mmol)
dioxane: 150 mL
Yield: 11.4 g (67 %)
GC-MS: m/z = 233

N-(4-(methyl)phenyl)-[1,1'-biphenyl]-4-amine

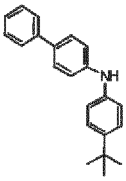
[0050]



4-bromobiphenyl: 20.0 g (1.0 eq, 85.8 mmol)
4-toluidine: 9.65 g (1.05 eq, 90.1 mmol)
palladium(II)acetate: 578 mg (3.0 mol.%, 2.6 mmol)
BINAP: 2.40 g (4.5 mol.%, 3.9 mmol)
cesium carbonate: 39.14 g (1.4 eq, 120.1 mmol)
dioxane: 200 mL
Yield: 19.20 g (86 %)
EI-MS: m/z = 259

N-(4-(tert-butyl)phenyl)-[1,1'-biphenyl]-4-amine

[0051]

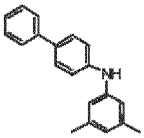


4-bromobiphenyl: 20 g (1.0 eq, 85.8 mmol)
4-(*tert*-butyl)aniline: 15.36 g (1.2 eq, 102.9 mmol)
palladium(II)acetate: 578 mg (3.0 mol.%, 2.57 mmol)
BINAP: 2.4 g (4.5 mol.%, 3.86 mmol)
cesium carbonate: 55.90 g (2.0 eq, 171.6 mmol)
dioxane: 220 mL
Yield: 13.9 g (54%)

GC-MS: m/z = 301

N-(3,5-dimethylphenyl)-[1,1'-biphenyl]-4-amine

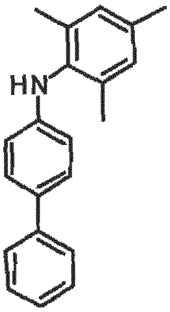
[0052]



4-bromobiphenyl: 30.00 g (1.0 eq, 128.70 mmol)
3,5-dimethylaniline: 16.38 g (1.05 eq, 135.10 mmol)
palladium(II)acetate: 867 mg (3.0 mol.%, 3.86 mmol)
BINAP: 3.60 g (4.5 mol.%, 5.79 mmol)
cesium carbonate: 58.70 g (1.4 eq, 180.00 mmol)
dioxane: 300 mL
Yield: 21.34 g (60 %)
GC-MS: m/z = 273

N-mesityl-[1,1'-biphenyl]-4-amine

[0053]



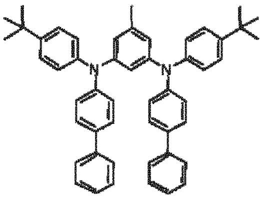
4-bromobiphenyl: 20.00 g (1.0 eq, 85.8 mmol)
mesitylamine: 12.18 g (1.05 eq, 90.1 mmol)
palladium(II)acetate: 578 mg (3.0 mol.%, 2.57 mmol)
BINAP: 2.40 g (4.5 mol.%, 3.86 mmol)
cesium carbonate: 39.13 g (1.4 eq, 120.1 mmol)
dioxane: 200 mL
Yield: 12.53 g (51 %)
GC-MS: m/z = 287

General procedure for tertiary amines of the 3,5-diaminophenylene class

[0054] Under an inert atmosphere, the secondary amine, the dibromo compound, bis(dibenzylidenaceton)palladium, tri-*tert*-butylphosphine and potassium-*tert*-butoxide were combined in a flask and solved in toluene. The mixture was stirred at 80°C for 80 minutes and then cooled to room temperature. TLC indicated complete consumption of the starting materials. The mixture was filtered through a pad of silica gel, washed with a 1:2 mixture of DCM/hexane and evaporated to dryness. The crude product was stirred in boiling methanol. After cooling to room temperature, the mixture was filtered to yield the product. In case TLC indicated still some impurities, column chromatography was used. Finally, all tertiary amines were purified by gradient sublimation under high vacuum (10^{-6} mbar) condition.

N1,N3-di([1,1'-biphenyl]-4-yl)-N1,N3-bis(4-(tert-butyl)phenyl)-5-methylbenzene-1,3-diamine (MPD-1)

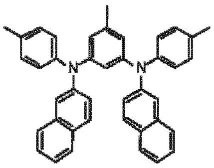
[0055]



3,5-dibromotoluene: 2.8 g (1.0 eq, 11.2 mmol)
N-(4-(tert-butyl)phenyl)-[1,1'-biphenyl]-4-amine: 7.1 g (2.1 eq, 23.6 mmol)
bis(dibenzylidenaceton)palladium: 129 mg (2 mol.%, 0.22 mmol)
tri-*tert*-butylphosphine: 68 mg (3 mol.%, 0.34 mmol)
potassium-*tert*-butoxide: 3.77 g (3.0 eq, 33.6 mmol)
toluene: 220 mL
Yield: 7.03 g (91 %)
HPLC-MS: m/z = 691 [M+H$^+$]

5-methyl-N1,N3-di(naphthalen-2-yl)-N1,N3-di-p-tolylbenzene-1,3-diamine (MPD-2) (comparative example)

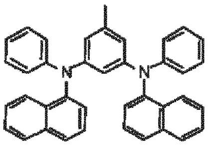
[0056]



3,5-dibromotoluene: 2.0 g (1.0 eq, 8.0 mmol)
N-(p-tolyl)naphthalen-2-amine: 3.92 g (2.1 eq, 16.8 mmol)
bis(dibenzylidenaceton)palladium: 92 mg (2.0 mol.%, 0.16 mmol)
tri-*tert*-butylphosphine: 49 mg (3 mol.%, 0.24 mmol)
potassium-*tert*-butoxide: 2.69 g (3.0 eq, 24 mmol)
toluene: 130 mL
Yield: 3.95 g (70 %)
HPLC-MS: m/z = 555 [M+H$^+$]

5-methyl-N1,N3-di(naphthalen-1-yl)-N1,N3-diphenylbenzene-1,3-diamine (MPD-3) (comparative example)

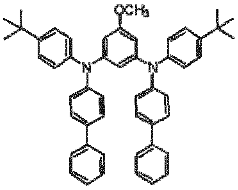
[0057]



3,5-dibromotoluene: 5.0 g (1.0 eq, 20.0 mmol)
N-phenylnaphthalen-1-amine: 9.21 g (2.1 eq, 42.0 mmol)
bis(dibenzylidenaceton)palladium: 230 mg (2 mol%, 0.40 mmol)
tri-*tert*-butylphosphine: 121 mg (3 mol.%, 0.60 mmol)
potassium-*tert*-butoxide: 6.73 g (3.0 eq, 60.0 mmol)
toluene: 150 mL
Yield: 9.31 g (88 %)
HPLC-MS: m/z = 527 [M+H$^+$]

N1,N3-di([1,1'-biphenyl]-4-yl)-N1,N3-bis(4-(tert-butyl)phenyl)-5-methoxybenzene-1,3-diamine (MPD-4)

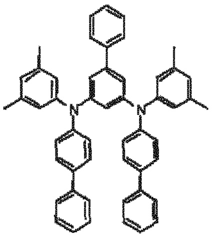
[0058]



3,5-dibromoanisole: 2.00 g (1.0 eq, 7.50 mmol)
N-(4-(tert-butyl)phenyl)-[1,1'-biphenyl]-4-amine: 4.76 g (2.1 eq, 15.8 mmol)
bis(dibenzylidenaceton)palladium: 86 mg (2.0 mol%, 0.15 mmol)
tri-*tert*-butylphosphine: 46 mg (3 mol.%, 0.23 mmol)
potassium-tert-butoxide: 2.52 g (3.0 eq, 22.5 mmol)
toluene: 130 mL
Yield: 5.08 g (96 %)
HPLC-MS: m/z = 707 [M+H$^+$]

N3,N5-di([1,1'-biphenyl]-4-yl)-N3,N5-bis(3,5-dimethylphenyl)-[1,1'-biphenyl]-3,5-diamine (MPD-5)

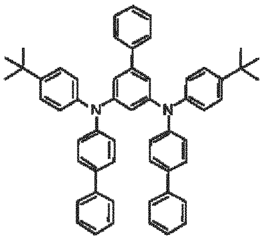
[0059]



3,5-dibromo-1,1'-biphenyl: 1.9 g (1.0 eq, 6.1 mmol)
N-(3,5-dimethylphenyl)-[1,1'-biphenyl]-4-amine: 3.5 g (2.1 eq, 12.8 mmol)
bis(dibenzylidenaceton)palladium: 70 mg (2 mol.%, 0.12 mmol)
tri-*tert*-butylphosphine: 37 mg (3 mol.%, 0.18 mmol)
potassium-*tert*-butoxide: 2.05 g (3.0 eq, 18.3 mmol)
toluene: 150 mL
Yield: 2.94 g (69 %)
HPLC-MS: m/z = 719 [M+Na$^+$]

N3,N5-di([1,1'-biphenyl]-4-yl)-N3,N5-bis(4-(tert-butyl)phenyl)-[1,1'-biphenyl]-3,5-diamine (MPD-6)

[0060]

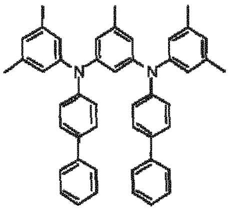


3,5-dibromo-1,1'-biphenyl: 1.80 g (1.0 eq, 5.8 mmol)
N-(4-(tert-butyl)phenyl)-[1,1'-biphenyl]-4-amine: 3.65 g (2.1 eq, 12.1 mmol)

bis(dibenzylidenaceton)palladium: 66 mg (2 mol.%, 0.12 mmol)
tri-*tert*-butylphosphine: 35 mg (3 mol.%, 0.17 mmol)
potassium-*tert*-butoxide: 1.94 g (3.0 eq, 17.3 mmol)
toluene: 150 mL
Yield: 4.17 g (96 %)
HPLC-MS: m/z = 775 [M+Na$^+$]

N1,N3-di([1,1'-biphenyl]-4-yl)-N1,N3-bis(3,5-dimethylphenyl)-5-methylbenzene-1,3-diamine (MPD-7)

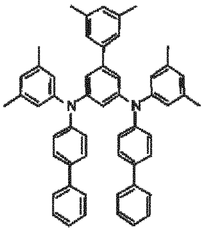
[0061]



3,5-dibromotoluene: 1.52 g (1.0 eq, 6.1 mmol)
N-(3,5-dimethylphenyl)-[1,1'-biphenyl]-4-amine: 3.50 g (2.1 eq, 12.8 mmol)
bis(dibenzylidenaceton)palladium: 70 mg (2 mol.%, 0.12 mmol)
tri-*tert*-butylphosphine: 37 mg (3 mol.%, 0.18 mmol)
potassium-*tert*-butoxide: 2.05 g (3.0 eq, 18.3 mmol)
toluene: 150 mL
Yield: 3.42 g (78 %)
HPLC-MS: m/z = 657 [M+Na$^+$]

N3,N5-di([1,1'-biphenyl]-4-yl)-N3,N5-bis(3,5-dimethylphenyl)-3',5'-dimethyl-[1,1'-biphenyl]-3,5-diamine (MPD-8)

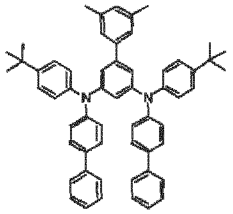
[0062]



3,5-dibromo-3',5'-dimethyl-1,1'-biphenyl: 2.00 g (1.0 eq, 5.88 mmol)
N N-(3,5-dimethylphenyl)-[1,1'-biphenyl]-4-amine: 3.38 g (2.1 eq, 12.4 mmol)
bis(dibenzylidenaceton)palladium: 68 mg (2 mol.%, 0.12 mmol)
tri-*tert*-butylphosphine: 36 mg (3 mol.%, 0.18 mmol)
potassium-*tert*-butoxide: 1.98 g (3.0 eq, 17.6 mmol)
toluene: 120 mL
Yield: 4.02 g (94 %)
HPLC-MS: m/z = 747 [M+Na$^+$]

N3,N5-di([1,1'-biphenyl]-4-yl)-N3,N5-bis(4-(tert-butyl)phenyl)-3',5'-dimethyl-[1,1'-biphenyl]-3,5-diamine (MPD-9)

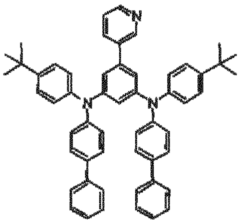
[0063]



3,5-dibromo-3',5'-dimethyl-1,1'-biphenyl: 2.00 g (1.0 eq, 5.88 mmol)
N-(4-(tert-butyl)phenyl)-[1,1'-biphenyl]-4-amine: 3.72 g (2.1 eq, 12.4 mmol)
bis(dibenzylidenaceton)palladium: 68 mg (2 mol.%, 0.12 mmol)
tri-*tert*-butylphosphine: 36 mg (3 mol.%, 0.18 mmol)
potassium-*tert*-butoxide: 1.98 g (3.0 eq, 17.6 mmol)
toluene: 120 mL
Yield: 4.43 g (97 %)
HPLC-MS: m/z = 803 [M+Na$^+$]

N1,N3-di([1,1'-biphenyl]-4-yl)-N1,N3-bis(4-(tert-butyl)phenyl)-5-(pyridin-3-yl)benzene-1,3-diamine (MPD-10)

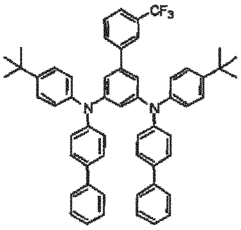
[0064]



3-(3,5-dibromophenyl)pyridine: 1.50 g (1.0 eq, 4.8 mmol)
N-(4-(tert-butyl)phenyl)-[1,1'-biphenyl]-4-amine: 3.0 g (2.1 eq, 10.1 mmol)
bis(dibenzylidenaceton)palladium: 55 mg (2 mol.%, 0.10 mmol)
tri-*tert*-butylphosphine: 29 mg (3 mol.%, 0.14 mmol)
potassium-*tert*-butoxide: 1.62 g (3.0 eq, 14.4 mmol)
toluene: 120 mL
Yield: 2.40 g (66 %)
HPLC-MS: m/z = 754 [M+H]$^+$

N3,N5-di([1,1'-biphenyl]-4-yl)-N3,N5-bis(4-(tert-butyl)phenyl)-3'-(trifluoromethyl)-[1,1'-biphenyl]-3,5-diamine (MPD-11)

[0065]

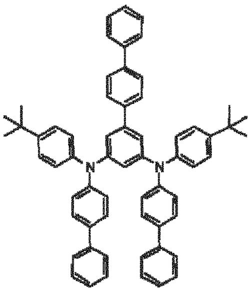


3,5-dihromo-3'-(trifluorometbyl)-1,1'-biphenyl: 1.82 g (1.0 eq, 4.8 mmol)
N-(4-(tert-butyl)phenyl)-[1,r-biphenyl]-4-amine: 3.0 g (2.1 eq, 10.1 mmol)
bis(dibenzylidenaceton)palladium: 55 mg (2 mol.%, 0.10 mmol)
tri-*tert*-butylphosphine: 29 mg (3 mol.%, 0.14 mmol)
potassium-*tert*-butoxide: 1.62 g (3.0 eq, 14.4 mmol)
toluene: 120 mL

Yield: 3.29 g (84 %)
HPLC-MS: m/z = 843 [M+Na$^+$]

N3,N5-di([1,1'-biphenyl]-4-yl)-N3,N5-bis(4-(tert-butyl)phenyl)-[1,1':4',1"-terphenyl]-3,5-diamine (MPD-12)

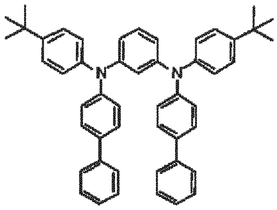
[0066]



3,5-dibromo-1,1':4',1"-terphenyl: 1.86 g (1.0 eq, 4.8 mmol)
N-(4-(tert-butyl)phenyl)-[1,1'-biphenyl]-4-amine: 3.03 g (2.1 eq, 10.1 mmol)
bis(dibenzylidenaceton)palladium: 55 mg (2 mol.%, 0.10 mmol)
tri-*tert*-butylphosphine: 29 mg (3 mol.%, 0.14 mmol)
potassium-*tert*-butoxide: 1.62 g (3.0 eq, 14.4 mmol)
toluene: 120 mL
Yield: 3.20 g (80 %)
HPLC-MS: m/z = 851 [M+Na$^+$]

N1,N3-di([1,1'-biphenyl]-4-yl)-N1,N3-bis(4-(tert-butyl)phenyl)benzene-1,3-diamine (MPD-13)

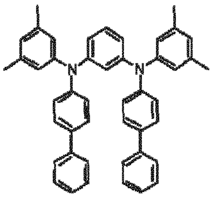
[0067]



3,5-dibromobenzene: 2.5 g (1.0 eq, 10.6 mmol)
N-(4-(tert-butyl)phenyl)-[1,1'-biphenyl]-4-amine: 6.70 g (2.1 eq, 22.26 mmol)
bis(dibenzylidenaceton)palladium: 121 mg (2 mol.%, 0.21 mmol)
tri-*tert*-butylphosphine: 64 mg (3 mol.%, 0.32 mmol)
potassium-*tert*-butoxide: 3.57 g (3.0 eq, 31.8 mmol)
toluene: 180 mL
Yield: 6.70 g (94 %)
ESI-MS: m/z = 677 [M+H$^+$]

N1,N3-di([1,1'-biphenyl]-4-yl)-N1,N3-bis(3,5-dimethylphenyl)benzene-1,3-diamine (MPD-14)

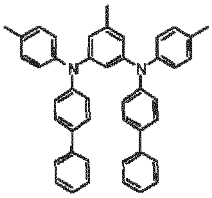
[0068]



3,5-dibromobenzene: 2.5 g (1.0 eq, 10.6 mmol)
N-(3,5-dimethylphenyl)-[1,1'-biphenyl]-4-amine: 6.08 g (2.1 eq, 22.26 mmol)
bis(dibenzylidenaceton)palladium: 122 mg (2 mol.%, 0.21 mmol)
tri-*tert*-butylphosphine: 64 mg (3 mol.%, 0.32 mmol)
potassium-*tert*-butoxide: 3.57 g (3.0 eq, 31.8 mmol)
toluene: 180 mL
Yield: 5.42 g (82 %)
ESI-MS: m/z = 621 [M+H$^+$]

N1,N3-di([1,1'-biphenyl]-4-yl)-5-methyl-N1,N3-di-p-tolylbenzene-1,3-diamine (MPD-15)

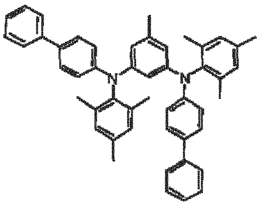
[0069]



3,5-dibromotoluene: 2.5 g (1.0 eq, 10.0 mmol)
N-(4-(methyl)phenyl)-[1,1'-biphenyl]-4-amine: 5.45 g (2.1 eq, 21.00 mmol)
bis(dibenzylidenaceton)palladium: 115 mg (2 mol.%, 0.20 mmol)
tri-*tert*-butylphosphine: 61 mg (3 mol.%, 0.30 mmol)
potassium-tert-butoxide: 3.37 g (3.0 eq, 30.0 mmol)
toluene: 180 mL
Yield: 4.95 g (81 %).
ESI-MS: m/z = 607 [M+H$^+$]

N1,N3-di([1,1'-biphenyl]-4-yl)-N1,N3-dimesityl-5-methylbenzene-1,3 -diamine (MPD-16)

[0070]



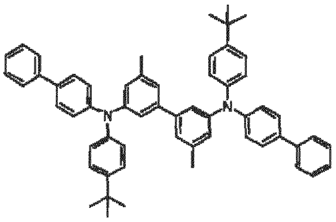
3,5-dibromotoluene: 16.60 g (1.0 eq, 66.4 mmol)
N-mesityl-[1,1'-biphenyl]-4-amine: 40.1 g (2.1 eq, 139.5 mmol)
bis(dibenzylidenaceton)palladium: 764 mg (2 mol.%, 1.3 mmol)
tri-*tert*-butylphosphine: 404 mg (3 mol.%, 2.00 mmol)
potassium-*tert*-butoxide: 22.36 g (3.0 eq, 199.3 mmol)
toluene: 400 mL
Yield: 22.3 g (51 %)
HPLC-MS: m/z = 663 [M+H$^+$]

General procedure for tertiary amines of the 3,3'-diaminobiphenylene class

[0071] The dibromo compound, the secondary amine, bis(dibenzylidenaceton)palladium, tri-tert-butylphosphine and potassium-tert-butoxide were combined in a flask and solved in toluene. The mixture was stirred at 80°C until TLC indicated complete consumption of the starting materials. The mixture was filtered through a pad of silica gel, washed with DCM and evaporated to dryness. The crude solid was washed in boiling methanol and filtered afterwards. This sequence was repeated with hot hexane and hot acetone to yield the desired product finally.

N3,N3'-di([1,1'-biphenyl]-4-yl)-N3,N3'-bis(4-(tert-butyl)phenyl)-5,5'-dimethyl-[1,1'-biphenyl]-3,3'-diamine (MDAB-1)

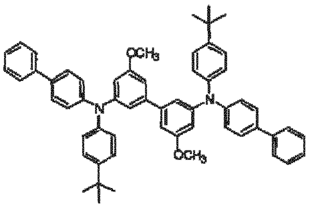
[0072]



3,3'-dibromo-5,5'-dimethyl,1,1'-biphenyl: 2.00 g (1.0 eq, 5.88 mmol)
N-(4-(tert-butyl)phenyl)-[1,1'-biphenyl]-4-amine: 3.90 g (2.1 eq, 12.9 mmol)
bis(dibenzylidenaceton)palladium: 68 mg (2.0 mol.%, 0.12 mmol)
tri-*tert*-butylphosphine: 36 mg (3.0 mol.%, 0.18 mmol)
potassium-*tert*-butoxide: 1.98 g (3.0 eq, 17.6 mmol)
toluene: 150 mL
Yield: 2.27 g (49 %)
HPLC-MS: m/z = 781 [M+H$^+$]

N3,N3',di([1,1'-biphenyl]-4-yl)-N3,N3'-bis(4-(tert-butyl)phenyl)-5,5'-dimethoxy-[1,1'-biphenyl]-3,3'-diamine (MDAB-2)

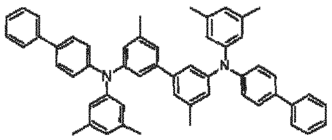
[0073]



3,3'-dibromo-5,5'-dimethoxy-1,1'-biphenyl: 2.00 g (1.0 eq, 5.88 mmol)
N-(4-(tert-butyl)phenyl)-[1,1'-biphenyl]-4-amine: 3.56 g (2.2 eq, 11.8 mmol)
bis(dibenzylidenaceton)palladium: 62 mg (2.0 mol.%, 0.11 mmol)
tri-tert-butylphosphine: 33 mg (3.0 mol.%, 0.16 mmol)
potassium-*tert*-butoxide: 1.81 g (3.0 eq, 16.1 mmol)
toluene: 130 mL
Yield: 3.33 g (76 %)
HPLC-MS: m/z = 835 [M+Na$^+$]

N3,N3'-di([1,1'-biphenyl]-4-yl)-N3,N3'-bis(3,5-dimethylphenyl)-5,5'-dimethyl-[1,1'-biphenyl]-3,3'-diamine (MDAB-3)

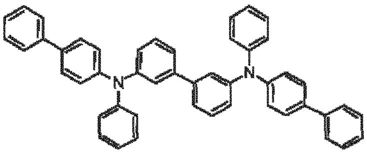
[0074]



3,3'-dibromo-5,5'-dimethyl-1,1'-biphenyl: 5.43g (1.0 eq, 15.96 mmol)
N-(3,5-dimethylphenyl)-[1,1'-biphenyl]-4-amine: 9.61 g (2.1 eq, 33.51 mmol)
bis(dibenzylidenaceton)palladium: 184 mg (2.0 mol.%, 0.32 mmol)
tri-*tert*-butylphosphine: 202 mg (3.0 mol.%, 0.48 mmol)
potassium-tert-butoxide: 5.37 g (3.0 eq, 47.88 mmol)
toluene: 250 mL
Yield: 10.56 g (91 %)
HPLC-MS: m/z = 747 [M+Na$^+$]

N3,N3'-di([1,1'-biphenyl]-4-yl)-N3,N3'-diphenyl-[1,1'-biphenyl]-3,3'-diamine (MDAB-4)

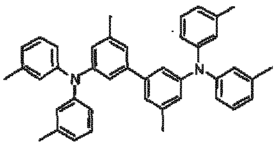
[0075]



3,3'-dibromo-1,1'-biphenyl: 3.39 g (1.0 eq, 10.88 mmol)
N-(3,5-dimethylphenyl)-[1,1'-biphenyl]-4-amine: 5.60 g (2.1 eq, 22.84 mmol)
bis(dibenzylidenaceton)palladium: 125 mg (2.0 mol.%, 0.22 mmol)
tri-*tert*-butylphosphine: 66 mg (3.0 mol.%, 0.33 mmol)
potassium-*tert*-butoxide: 3.66 g (3.0 eq, 32.6 mmol)
toluene: 190 mL
Yield: 6.8 g (97 %)
EI-MS: m/z = 640

5,5'-dimethyl-N3,N3,N3',N3'-tetra-m-tolyl-[1,1'-biphenyl]-3,3'-diamine (MDAB-5)

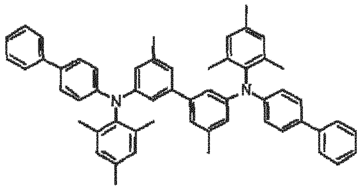
[0076]



3,3'-dibromo-5,5'-dimethyl-1,1'-biphenyl: 2.50g (1.0 eq, 7.35 mmol)
-3,3'-dimethyldiphenylamine: 3.05 g (2.1 eq, 15.44 mmol)
bis(dibenzylidenaceton)palladium: 85 mg (2.0 mol.%, 0.15 mmol)
tri-*tert*-butylphosphine: 45 mg (3.0 mol.%, 0.22 mmol)
potassium-*tert*-butoxide: 2.50 g (3.0 eq, 22.05 mmol)
toluene: 180 mL
Yield: 2.8 g (66 %)
EI-MS: m/z = 572

N3,N3'-di([1,1'-biphenyl]-4-yl)-N3,N3'-dimesityl-5,5'-dimethyl-[1,1'-biphenyl]-3,3'-diamine (MDAB-6)

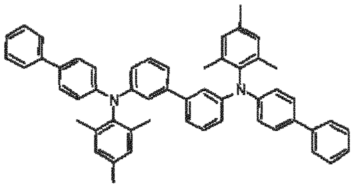
[0077]



3,5-dibromo-3',5'-dimethyl-1,1'-biphenyl: 20.00 g (1.0 eq, 58.8 mmol)
N-mesityt-[1,1'-biphenyl]-4-amine: 35.50 g (2.1 eq, 123.5 mmol)
bis(dibenzylidenaceton)palladium: 676 mg (2 mol.%, 1.20 mmol)
tri-*tert*-butylphosphine: 364 mg (3 mol.%, 1.80 mmol)
potassium-tert-butoxide: 19.80 g (3.0 eq, 176.4 mmol)
toluene: 700 mL
Yield: 27.1 g (61 %)
HPLC-MS: m/z = 753 [M+H$^+$]

N3,N3'-di([1,1'-biphenyl]-4-yl)-N3,N3'-dimesityl-[1,1'-biphenyl]-3,3'-diamine (MDAB-7)

[0078]



3,5-dibromo-1,1'-biphenyl: 5.17 g (1.0 eq, 16.59 mmol)
N-mesityl-[1,1'-biphenyl]4-amine: 10.00 g (2.1 eq, 34.79 mmol)
bis(dibenzylidenaceton)palladium: 190 mg (2 mol.%, 0.33 mmol)
tri-*tert*-hutylphosphine: 100 mg (3 mol.%, 0.50 mmol)
potassium-*tert*-butoxide: 5.58 g (3.0 eq, 49.77 mmol)
toluene: 230 mL
Yield: 8.7 g (72 %)
EI-MS: m/z = 724

OLED preparation and testing

[0079] Performance testing of the new materials was carried out in bottom emitting phosphorescent organic light emitting diodes (OLED). The diodes were processed in vacuum via vapor thermal deposition of organic materials (active layers) and metals (electrodes). Shadow mask techniques were used to structure the devices (active matrix, electrodes). Four OLEDs are prepared on one substrate with an active area of 6.70 mm^2 each. 16 identical indium tin oxide (ITO) substrates were processed at once in a 4x4 array placed on a table which is pivotable around its vertical axe. Using shutters, each of these 16 substrates can be covered by different set of organic layers.
The ITO substrates were cleaned and put into a vapor thermal deposition unit in the 4x4 array. A reference p-doped layer (e.g. H-1 doped with D1; molar ratio (97:3) was deposited on half of these substrates for a final film thickness of 30 nm. On the other half of the plate, the studied inventive material was codeposited with the same p-dopant at the same 97:3 molar ratio and thickness. After a rotation of the plate by 90°, the second (electron blocking) layer is deposited on top of the first layer. Here, half the plate is covered with 10 nm of the reference compound (e.g., TCTA) and the other half with the same inventive material as used in the first layer (see figure 1). The reference devices (figure 1, field D) were thus always processed together with the devices comprising the inventive materials. This approach allows assessing performance of new material in comparison with the reference independent from possible day-to-day variations of deposition rates, vacuum quality or other tool performance parameters. As each field contains 16 identically prepared OLEDs and the performance parameters were estimated for each of these 16 OLEDs, statistical evaluation of the obtained experimental results unequivocally showed the statistical significance of the observed average values reported in the Table 1.

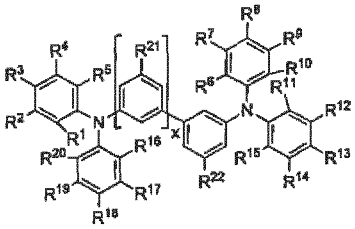
The subsequent phosphorescent green emission layer (Merck_TMM004:Irrpy at molar ratio 9:1) was deposited with a thickness of 20 nm, followed by 10 nm Merck_TMM004 as a hole blocking layer and 50 nm E-1 layer doped with D2 (matrix to dopant molar ratio 9:1). The cathode was prepared by vacuum deposition of 100 nm aluminum layer.

[0080] Bottom emitting blue fluorescent OLEDs were prepared on ITO substrates and tested analogously, with a difference that Sun Fine Chem (SFC, Korea) host ABH113 and blue emitter NUBD370 were codeposited in the weight ratio 97:3 as a 20 nm thick emitting layer, followed by 36 nm thick electron transporting layer consisting of 60 weigt % E2 and 40 weight % lithium 8-hygroxyquinoline salt (LiQ). The 100 nm aluminium cathode was deposited on top of the electron transporting layer.

[0081] In comparison with devices comprising H-2 in the same hole transporting and/or electron blocking layer, the devices comprising inventive compounds showed improvement in terms of the overall performance score Q as defined in the Table 1 in the range 3-22 %.

Claims

1. Organic light emitting device comprising between anode (3) and cathode (2) at least one emitting layer (5) comprising a phosphorescent emitter and at least one hole transporting and/or electron blocking layer (4) comprising a compound represented by general formula (I)



I

wherein R^1-R^5 and R^{11}-R^{15} are independently selected from phenyl and hydrogen or the adjacent substituents are linked so that they form an aromatic ring, R^6-R^{10} and R^{16}-R^{20} are independently selected from hydrogen, C1-C20 alkyl or C3-C20 cycloalkyl, C1-C20 alkoxy or C3-C20 cycloalkyloxy, C7-C20 arylalkyl, C6-C20 aryl and C2-C20 heteroaryl,
x is an integer chosen from 0 and 1, wherein for x = 0, R^{22} is selected from hydrogen, C1-C20 alkyl or C3-C20 cycloalkyl, C1-C20 alkoxy or C3-C20 cycloalkyloxy, C7-C20 arylalkyl, C6-C20 aryl and C2-C20 heteroaryl, whereas for x = 1, R^{21} and R^{22} are independently selected from hydrogen, C1-C10 alkyl, C3-C10 cycloalkyl, C1-C10 alkoxy and C3-C10 cycloalkyloxy,
wherein the aromatic ring can be formed by

i) R^1 with R^2 as well as R^{11} with R^{12} or
ii) R^2 with R^3 as well as R^{12} with R^{13} and

at least two of R^6 - R^{10} and at least two of R^{16}-R^{20} are methyl, or at least one of R^6-R^{10} and at least one of R^{16}-R^{20} is selected from C2-C20 alkyl, C3-C20 cycloalkyl, C1-C20 alkoxy, C3-C20 cycloalkyloxy, C7-C20 arylalkyl, C6-C20 aryl and C2-C20 heteroaryl.

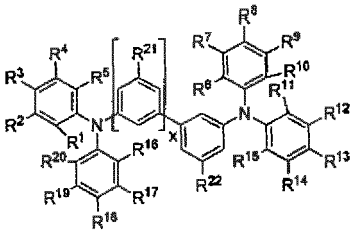
2. Device according to claim 1 wherein x = 1 and R^{21} and R^{22} are independently selected from methyl or methoxy.

3. Device according to any of claims 1-2 wherein x = 1 and R^{21} and R^{22} are the same.

4. Device according to any of claims 1-3 wherein at least one layer containing the compound of formula (I) is electrically doped.

5. Device according to claim 4 wherein the layer containing compound of formula (I) has at least one doped portion and at least one portion which is less doped than the doped portion or is undoped.

6. Compound represented by general formula (I)

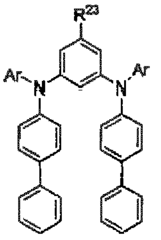


I

wherein R^1-R^5 and R^{11}-R^{15} are independently selected from phenyl and hydrogen or the adjacent substituents are linked so that they form an aromatic ring,
x is an integer chosen from 0 and 1, wherein for x = 0, R^{22} is selected from hydrogen, C1-C20 alkyl or C3-C20 cycloalkyl, C1-C20 alkoxy or C3-C20 cycloalkyloxy, C7-C20 arylalkyl, C6-C20 aryl and C2-C20 heteroaryl, whereas for x = 1, R^{21} and R^{22} are independently selected from hydrogen, C1-C10 alkyl, C3-C10 cycloalkyl, C1-C10 alkoxy and C3-C10 cycloalkyloxy, wherein the aromatic ring can be formed by

i) R^1 with R^2 as well as R^{11} with R^{12} or
ii) R^2 with R^3 as well as R^{12} with R^{13}
and
iii) R^7 and R^9 as well as R^{17} and R^{19} are methyl whereas R^6, R^8 and R^{10} as well as R^{16}. R^{18} and R^{20} are hydrogen or
iv) R^8 and R^{18} are 1,1-dimethylethyl and R^6, R^7, R^9, R^{10} as well as R^{16}, R^{17}, R^{19} and R^{20} are hydrogen.

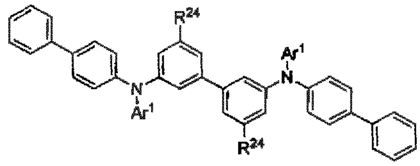
7. Compound according to claim 6 represented by formula (II)



II

wherein R^{23} is hydrogen, C1-C20 alkyl or C3-C20 cycloalkyl, C1-C10 alkoxy or C3-C20 cycloalkyloxy, C7-C20 arylalkyl, C6-C20 aryl and C2-C20 heteroaryl and Ar is selected from 4-tert-butylphenyl, 3,5-dimethylphenyl.

8. Compound according to claim 6 represented by formula (III)

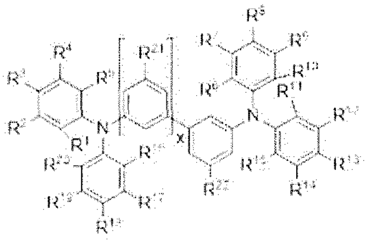


III

wherein Ar^1 is selected from 4-tert-butylphenyl and 3,5-dimethylphenyl, and R^{24} is selected from C1-C10 alkyl, C3-C10 cycloalkyl, C1-C10 alkoxy and C3-C10 cycloalkyloxy.

Patentansprüche

1. Organische lichtemittierende Vorrichtung, umfassend, zwischen Anode (3) und Kathode (2), zumindest eine emittierende Schicht (5), die einen phosphoreszierenden Emitter und zumindest eine Lochtransport- und/oder elektronenblockende Schicht (4), die eine Verbindung umfasst, die durch die allgemeine Formel (I) dargestellt ist



I ,

wobei R^1-R^5 und R^{11}-R^{15} unabhängig aus Phenyl und Wasserstoff ausgewählt sind oder die benachbarten Substituenten so verbunden sind, dass sie einen aromatischen Ring bilden, R^6-R^{10} und R^{16}-R^{20} unabhängig ausgewählt sind aus Wasserstoff, C1-C20-Alkyl oder C3-C20-Cycloalkyl, C1-C20-Alkoxy oder C3-C20-Cycloalkyloxy, C7-C20-Arylalkyl, C6-C20-Aryl und C2-C20-Heteroaryl,
x eine ganze Zahl, ausgewählt aus 0 und 1, ist, wobei für x = 0, R^{22} ausgewählt ist aus Wasserstoff, C1-C20-Alkyl oder C3-C20-Cycloalkyl, C1-C20-Alkoxy oder C3-C20-Cycloalkyloxy, C7-C20-Arylalkyl, C6-C20-Aryl und C2-C20-Heteroaryl, wobei für x = 1, R^{21} und R^{22} unabhängig ausgewählt sind aus Wasserstoff, C1-C10-Alkyl, C3-C10-Cycloalkyl, C1-C10-Alkoxy und C3-C10-Cycloalkyloxy,
wobei der aromatische Ring gebildet werden kann durch

i) R^1 mit R^2 sowie R^{11} mit R^{12} oder
ii) R^2 mit R^3 sowie R^{12} mit R^{13} und

zumindest zwei der R^6-R^{10} und zumindest zwei der R^{16}-R^{20} Methyl sind oder zumindest einer von R^6-R^{10} und zumindest einer von R^{16}-R^{20} ausgewählt ist aus C2-C20-Alkyl, C3-C20-Cycloalkyl, C1-C20-Alkoxy, C3-C20-Cycloalkyloxy, C7-C20-Arylalkyl, C6-C20-Aryl und C2-C20-Heteroaryl,

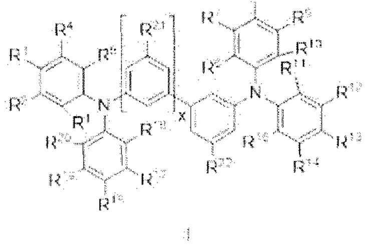
2. Vorrichtung nach Anspruch 1, wobei x = 1 und R^{21} und R^{22} unabhängig aus Methyl oder Methoxy ausgewählt sind.

3. Vorrichtung nach einem der Ansprüche 1-2, wobei x = 1 und R^{21} und R^{22} gleich sind.

4. Vorrichtung nach einem der Ansprüche 1-3, wobei zumindest eine Schicht, die die Verbindung der Formel (I) enthält, elektrisch dotiert ist.

5. Vorrichtung nach Anspruch 4, wobei die Schicht, die die Verbindung der Formel (I) enthält, zumindest einen dotierten Teil und zumindest einen Teil hat, der weniger dotiert ist als der dotierte Teil oder der undotiert ist.

6. Verbindung, dargestellt durch die allgemeine Formel (I)

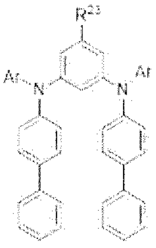


I ,

wobei R^1-R^5 und R^{11}-R^{15} unabhängig ausgewählt sind aus Phenyl und Wasserstoff oder die benachbarten Substituenten so verbunden sind, dass sie einen aromatischen Ring bilden,
x eine ganze Zahl, ausgewählt aus 0 und 1, ist, wobei für x = 0, R^{22} ausgewählt ist aus Wasserstoff, C1-C20-Alkyl oder C3-C20-Cycloalkyl, C1-C20-Alkoxy oder C3-C20-Cycloalkyloxy, C7-C20-Arylalkyl, C6-C20-Aryl und C2-C20-Heteroaryl, wobei für x = 1, R^{21} und R^{22} unabhängig ausgewählt sind aus Wasserstoff, C1-C10-Alkyl, C3-C10-Cycloalkyl, C1-C10-Alkoxy und C3-C10-Cycloalkyloxy, wobei der aromatische Ring gebildet werden kann durch

i) R^1 mit R^2 sowie R^{11} mit R^{12} oder
ii) R^2 mit R^3 sowie R^{12} mit R^{13}
und
iii) R^7 und R^9 sowie R^{17} und R^{19} Methyl sind, wobei R^6, R^8 und R^{10} sowie R^{16}, R^{18} und R^{20} Wasserstoff sind oder
iv) R^8 und R^{18} 1,1-Dimethylethyl sind und R^6, R^7, R^9, R^{10} sowie R^{16}, R^{17}, R^{19} und R^{20} Wasserstoff sind.

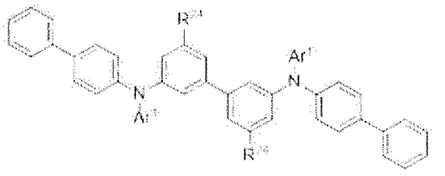
7. Verbindung nach Anspruch 6, dargestellt durch die Formel (II)



II ,

wobei R^{23} Wasserstoff, C1-C20-Alkyl oder C3-C20-Cycloalkyl, C1-C10-Alkoxy oder C3-C20-Cycloalkyloxy, C7-C20-Arylalkyl, C6-C20-Aryl und C2-C20-Heteroaryl ist und Ar ausgewählt ist aus 4-tert-Butylphenyl, 3,5-Dimethylphenyl.

8. Verbindung nach Anspruch 6, dargestellt durch die Formel (III)

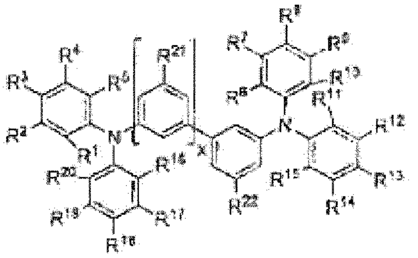


III ,

wobei Ar^1 ausgewählt ist aus 4-tert-Butylphenyl und 3,5-Dimethylphenyl und R^{24} ausgewählt ist aus C1-C10-Alkyl, C3-C10-Cycloalkyl, C1-C10-Alkoxy und C3-C10-Cycloalkyloxy.

Revendications

1. Dispositif organique électroluminescent comprenant entre une anode (3) et une cathode (2) au moins une couche d'émission (5) comprenant un émetteur phosphorescent et au moins une couche de transport de trous et/ou une couche de blocage d'électrons (4) comprenant un composé représenté par la formule générale (I)



I

dans laquelle R^1 à R^5 et R^{11} à R^{15} sont indépendamment choisis parmi le phényle et l'hydrogène ou les substituants adjacents sont liés de sorte qu'ils forment un noyau aromatique, R^6 à R^{10} et R^{16} à R^{20} sont

indépendamment choisis parmi l'hydrogène, un groupe alkyle en C1-C20 ou cycloalkyle en C3-C20, un groupe alcoxy en C1-C20 ou cycloalcoxy en C3-C20, un groupe arylalkyle en C7-C20, un groupe aryle en C6-C20 et hétéroaryle en C2-C20,
x représente un nombre entier choisi parmi 0 et 1, dans laquelle pour x = 0, R^{22} est choisi parmi l'hydrogène, un groupe alkyle en C1-C20 ou cycloalkyle en C3-C20, un groupe alcoxy en C1-C20 ou cycloalcoxy en C3-C20, un groupe arylalkyle en C7-C20, un groupe aryle en C6-C20 et hétéroaryle en C2-C20, alors que pour x = 1, R^{21} et R^{22} sont indépendamment choisis parmi l'hydrogène, un groupe alkyle en C1-C10, un groupe cycloalkyle en C3-C20, un groupe alcoxy en C1-C10 et un groupe cycloalcoxy en C3-C20, dans laquelle le noyau aromatique peut être formé

i) par R^1 avec R^2 ainsi que par R^{11} avec R^{12} ou
ii) par R^2 avec R^3 ainsi que par R^{12} avec R^{13} et

au moins deux parmi R^6 à R^{10} est au moins deux parmi R^{16} à R^{20} représentent le méthyle, ou au moins un parmi R^6 à R^{10} est au moins un parmi R^{16} à R^{20} est choisi parmi un groupe alkyle en C2-C20, un groupe cycloalkyle en C3-C20, un groupe alcoxy en C1-C20, un groupe cycloalcoxy en C3-C20, un groupe un groupe arylalkyle en C7-C20, un groupe aryle en C6-C20 et un groupe hétéroaryle en C2-C20.

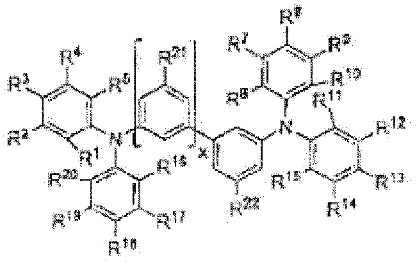
2. Dispositif selon la revendication 1, dans lequel x =1 et R^{21} et R^{22} sont indépendamment choisis parmi le méthyle ou le méthoxy.

3. Dispositif selon la revendication 1 ou la revendication 2, dans lequel x =1 et R^{21} et R^{22} sont les mêmes.

4. Dispositif selon l'une quelconque des revendications 1 à 3, dans lequel au moins une couche contenant le composé répondant à la formule générale (I) est électriquement dopé.

5. Dispositif selon la revendication 4, dans lequel la couche contenant le composé répondant à la formule (I) comporte au moins une partie dopée et au moins une partie qui est moins dopée que la partie dopée ou est non dopée.

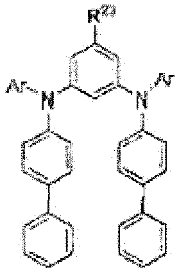
6. Composé représenté par la formule générale (I)



dans laquelle R^1 à R^5 et R^{11} à R^{15} sont indépendamment choisis parmi le phényle et l'hydrogène ou les substituants adjacents sont liés de sorte qu'ils forment un noyau aromatique,
x représente un nombre entier choisi parmi 0 et 1, dans laquelle pour x = 0, R^{22} est choisi parmi l'hydrogène, un groupe alkyle en C1-C20 ou cycloalkyle en C3-C20, un groupe alcoxy en C1-C20 ou cycloalcoxy en C3-C20, un groupe arylalkyle en C7-C20, un groupe aryle en C6-C20 et hétéroaryle en C2-C20, alors que pour x = 1, R^{21} et R^{22} sont indépendamment choisis parmi l'hydrogène, un groupe alkyle en C1-C10, un groupe cycloalkyle en C3-C20, un groupe alcoxy en C1-C10 et un groupe cycloalcoxy en C3-C20, dans laquelle le noyau aromatique peut être formé

i) par R^1 avec R^2 ainsi que par R^{11} avec R^{12} ou
ii) par R^2 avec R^3 ainsi que par R^{12} avec R^{13} et
iii) par R^7 avec R^9 ainsi que par R^{17} avec R^{19} qui représentent le méthyle tandis que R^6, R^8 et R^{10} ainsi que R^{16}, R^{18} et R^{20} représentent l'hydrogène ou
iv) par R^8 avec R^{18} qui représentent le 1,1-diméthyléthyle et R^6, R^7, R^9 et R^{10} ainsi que par R^{16}, R^{17}, R^{19} et R^{20} qui représentent l'hydrogène.

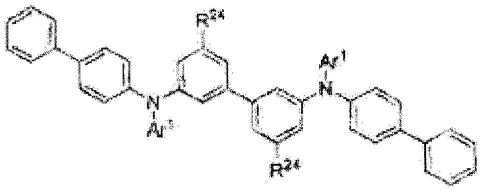
7. Composé selon la revendication 6, représenté par la formule (II)



II

dans laquelle R^{23} représente l'hydrogène, un groupe alkyle en C1-C20 ou cycloalkyle en C3-C20, un groupe alcoxy en C1-C20 ou cycloalcoxy en C3-C20, un groupe arylalkyle en C7-C20, un groupe aryle en C6-C20 et hétéroaryle en C2-C20 et Ar est choisi parmi le 4-tert-butylphényle, le 3,5-diméthylphényle.

8. Composé selon la revendication 6, représenté par la formule (III)



III

dans laquelle Ar^1 est choisi parmi le 4-tert-butylphényle et le 3,5-diméthylphényle, et R^{24} est choisi parmi un groupe alkyle en C1-C10, un groupe cycloalkyle en C3-C10, un groupe un groupe alcoxy en C1-C10 et un groupe cycloalcoxy en C3-C10.

Fig. 1

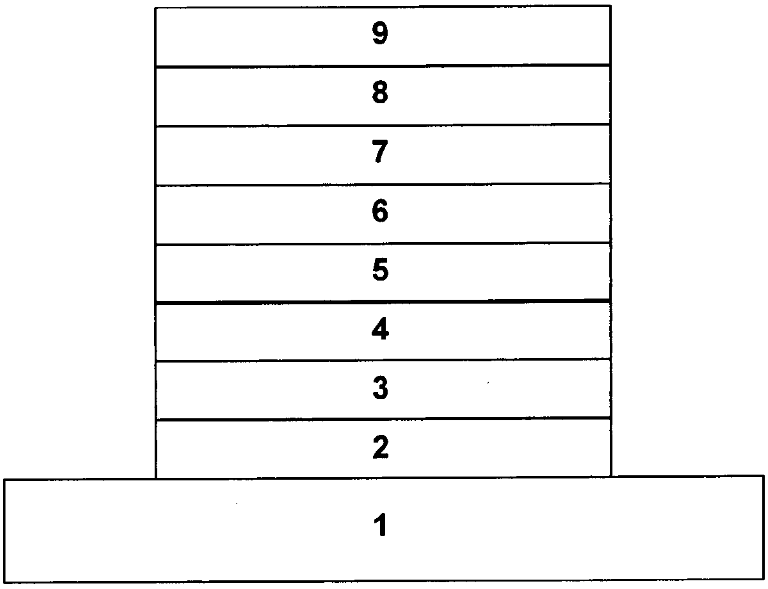
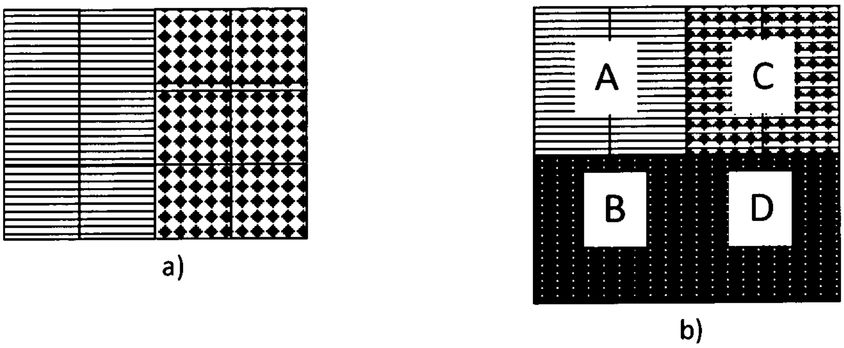


Fig. 2



a)

b)

Fig. 3a

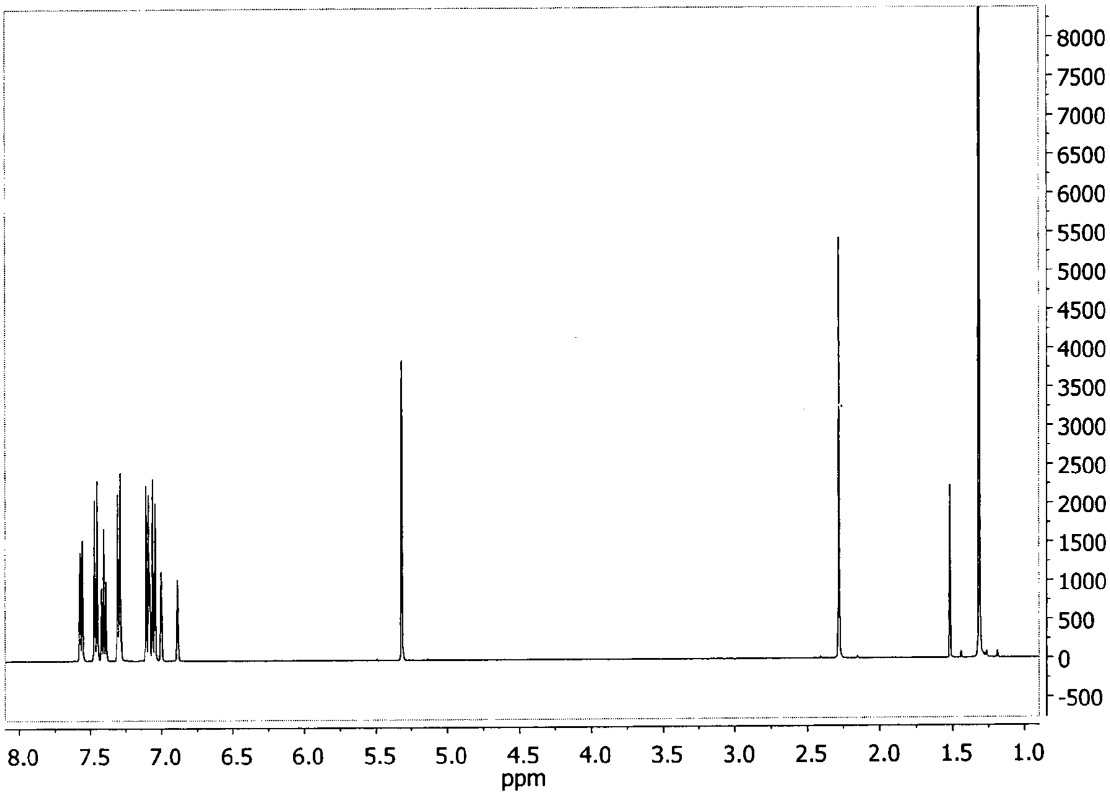

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Fig. 3b

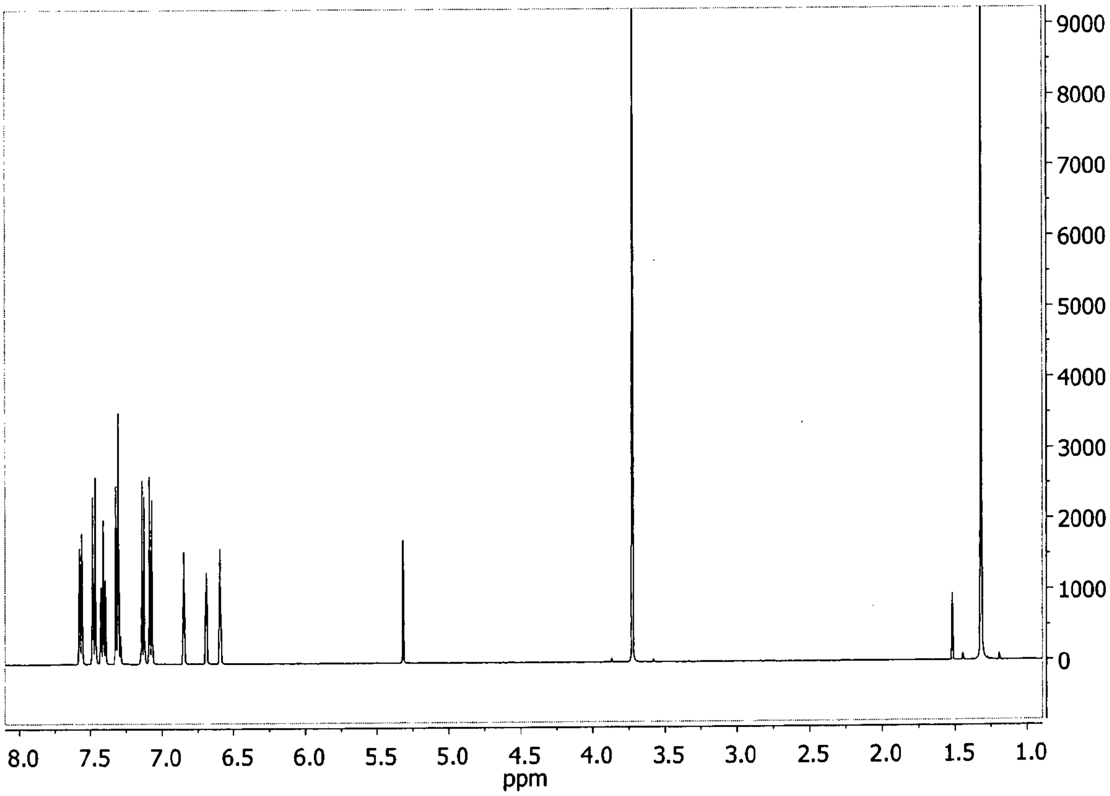
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Fig. 3c

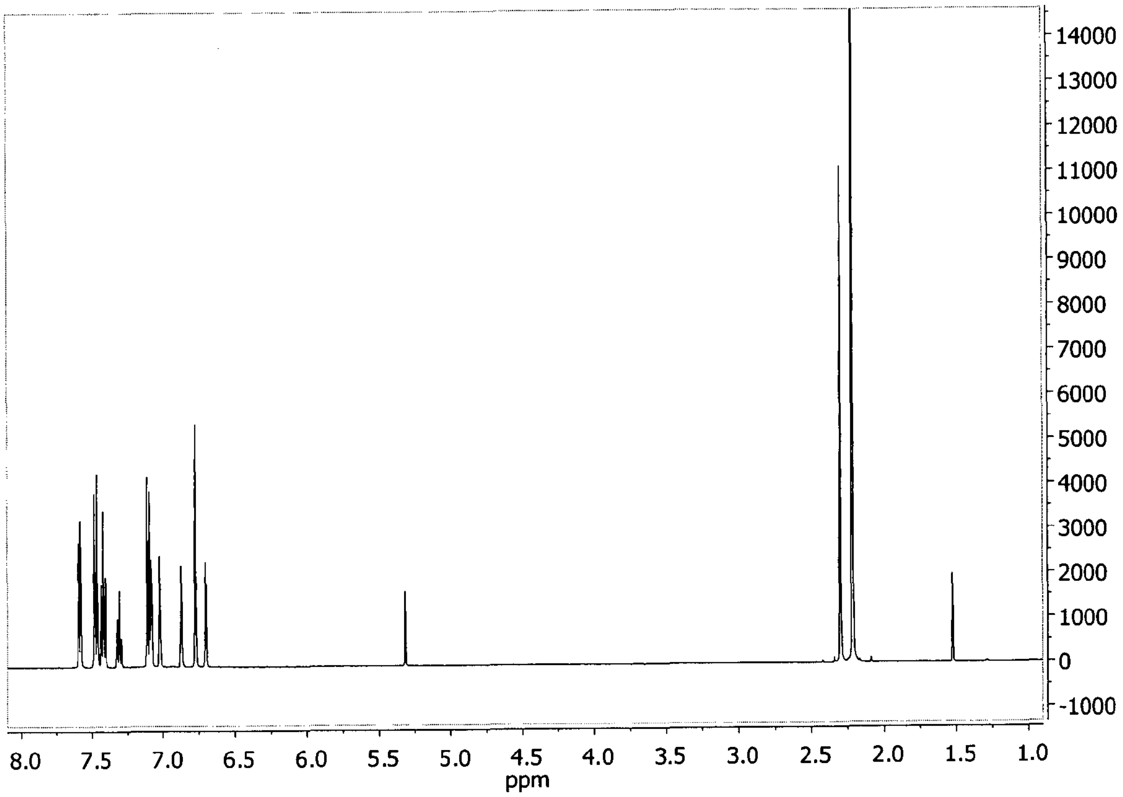
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Fig. 3d

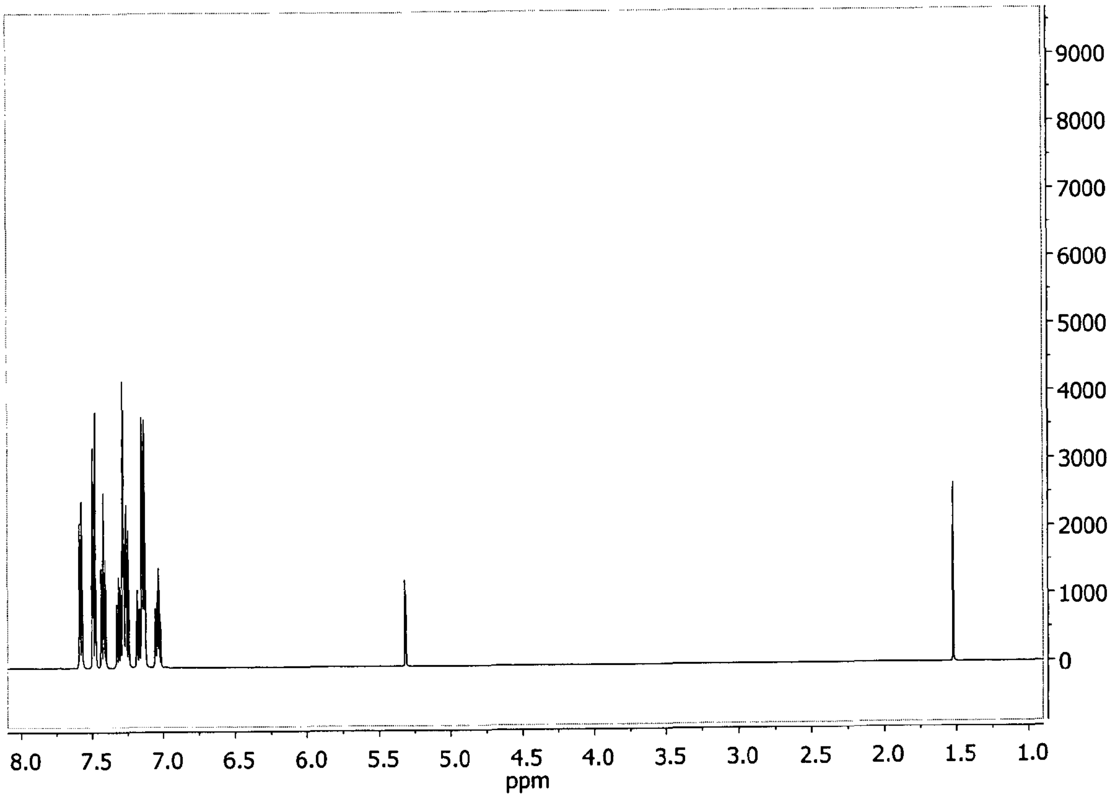
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Fig. 3e

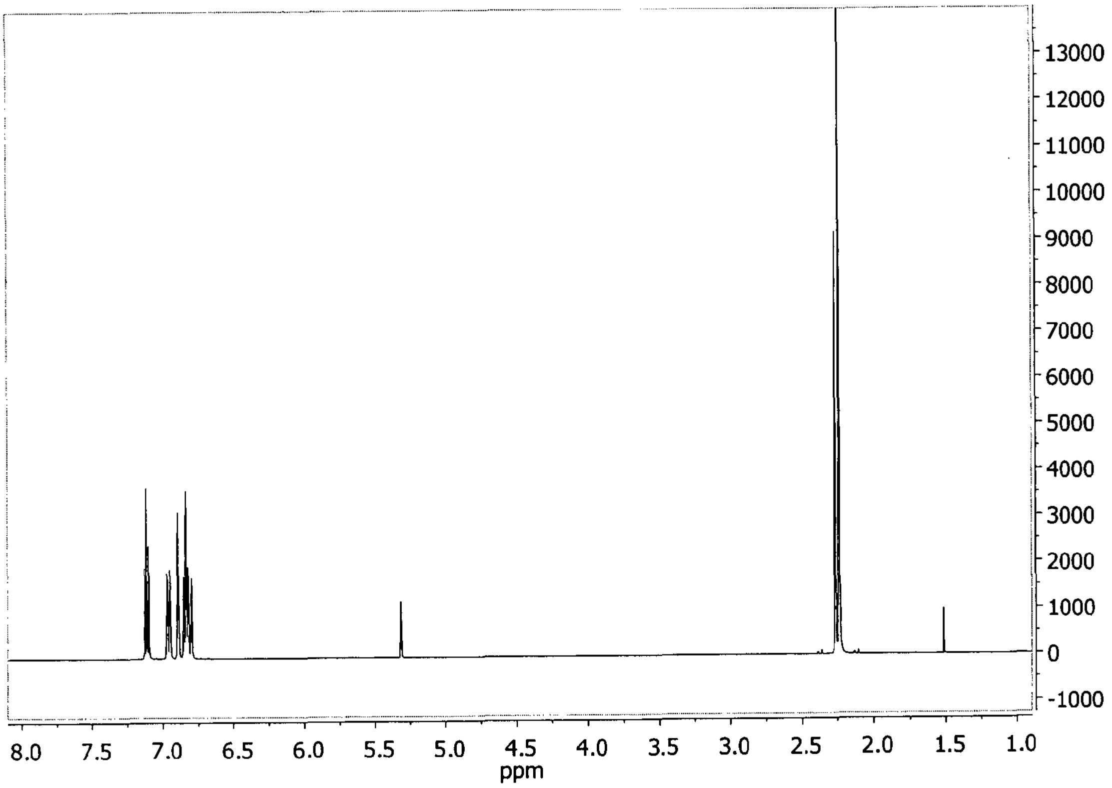
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Fig. 3f

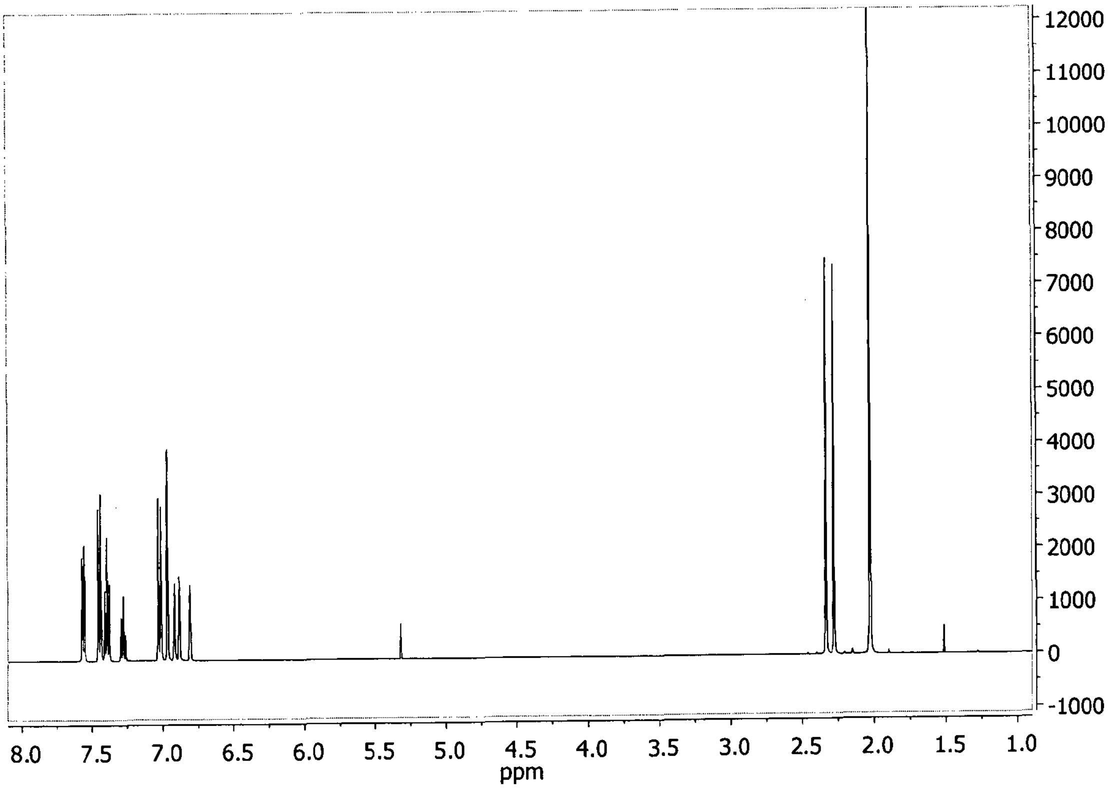
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Fig. 3g

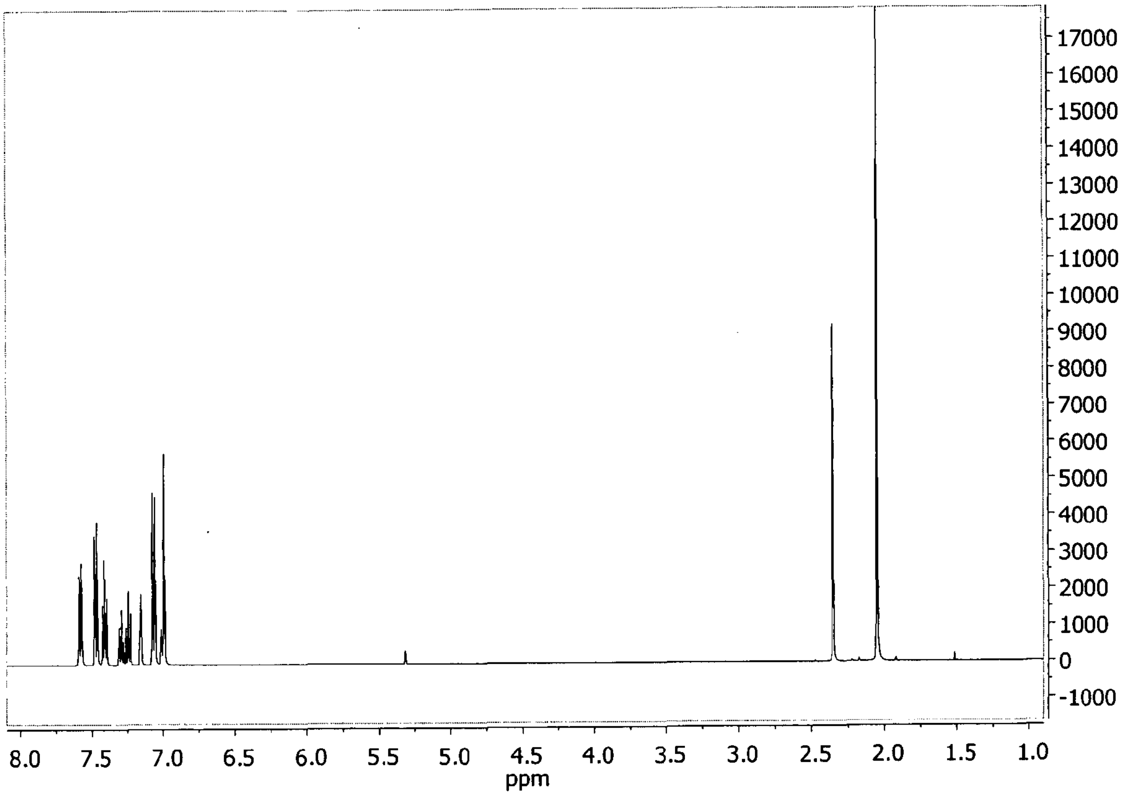
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Fig. 4a

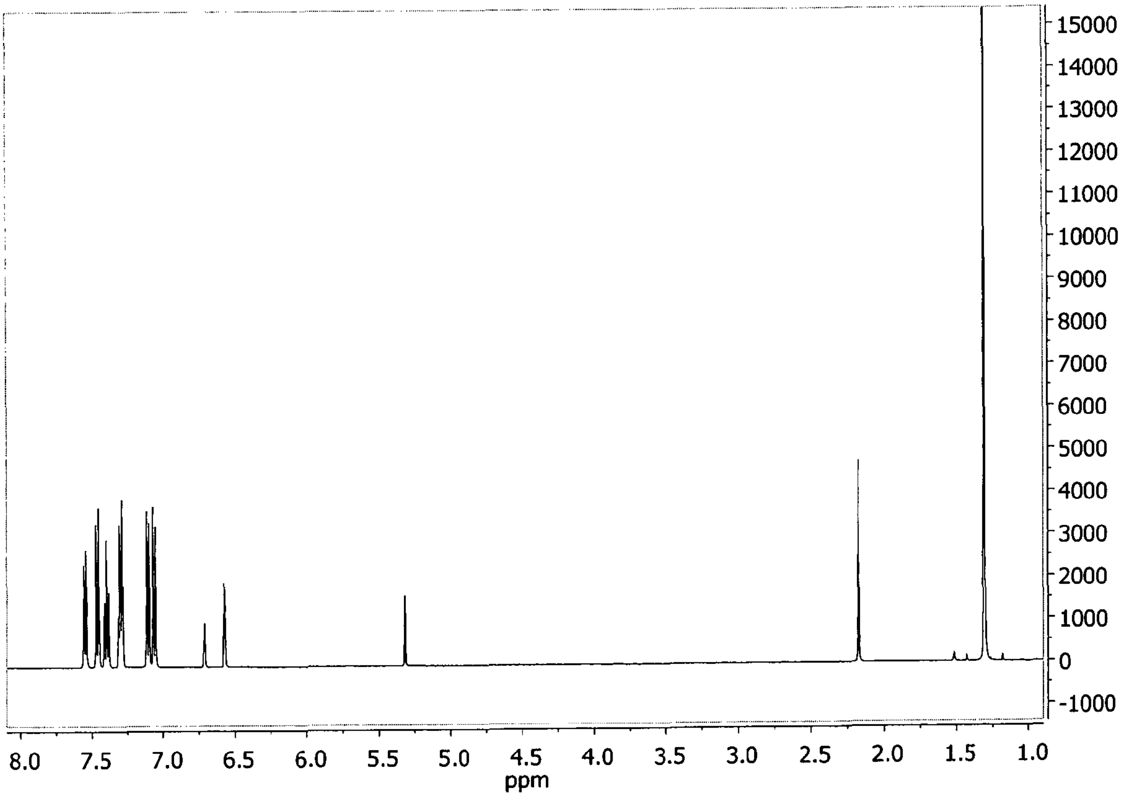
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Fig. 4b

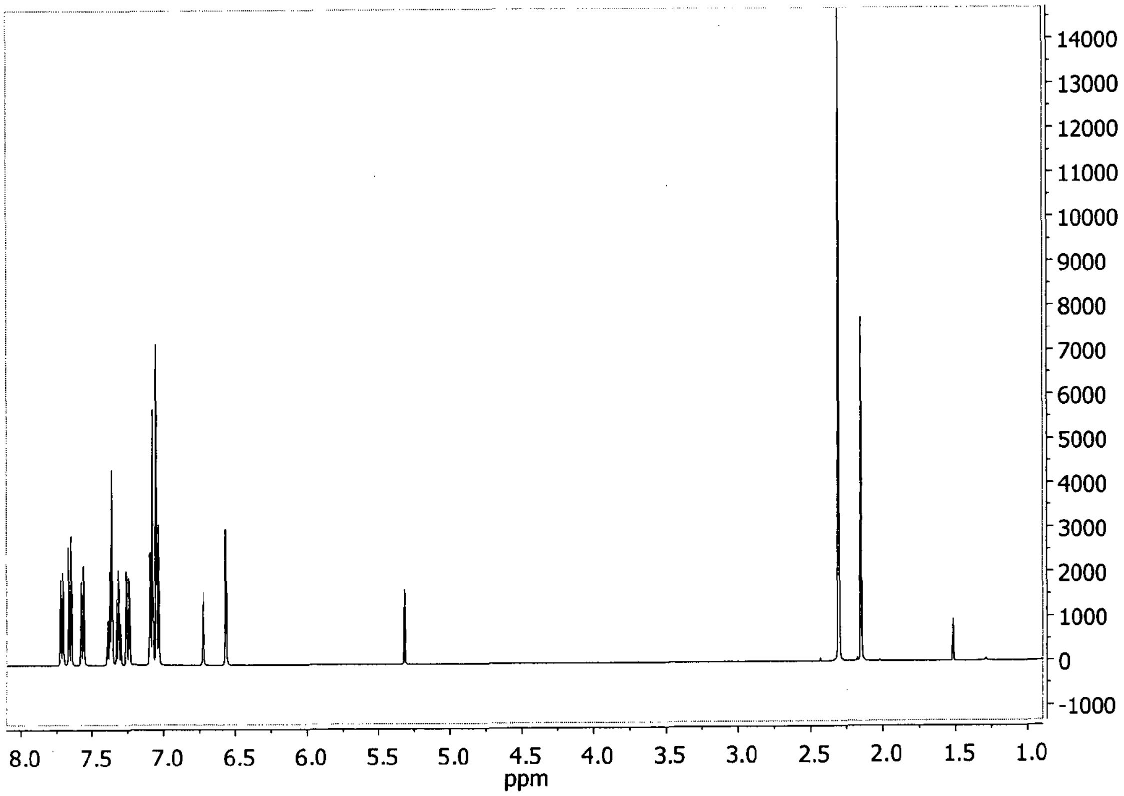
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Fig. 4c

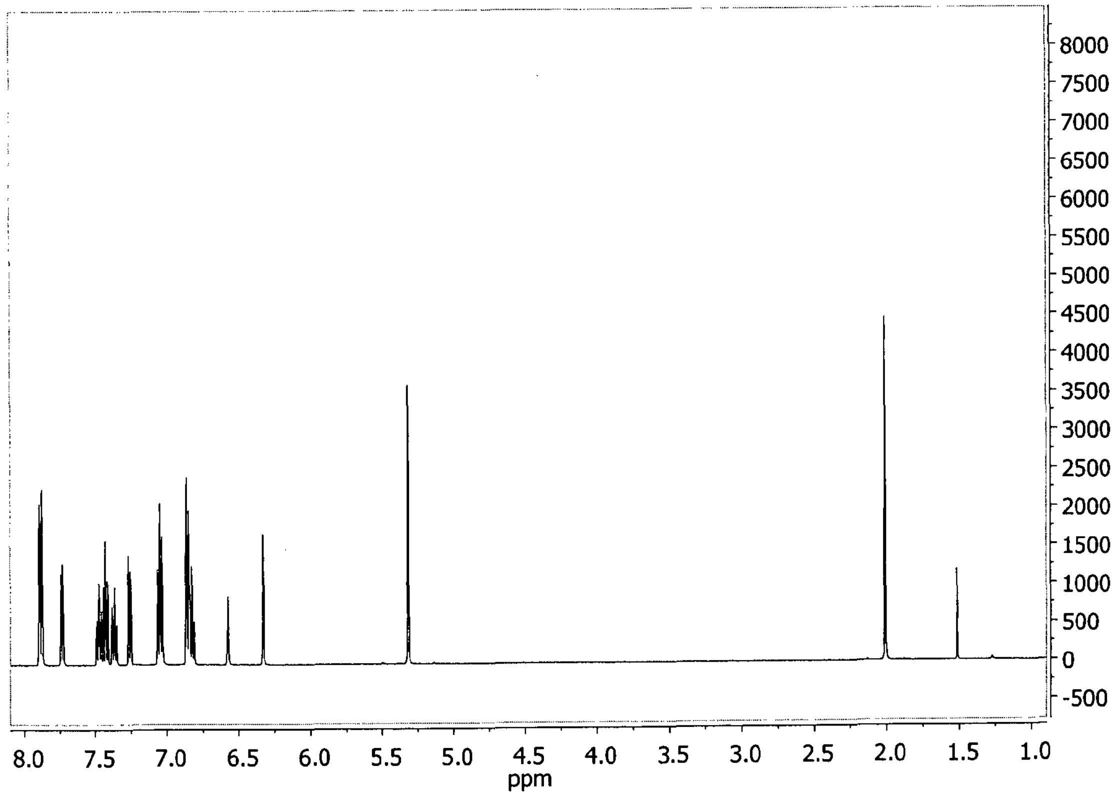
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Fig. 4d

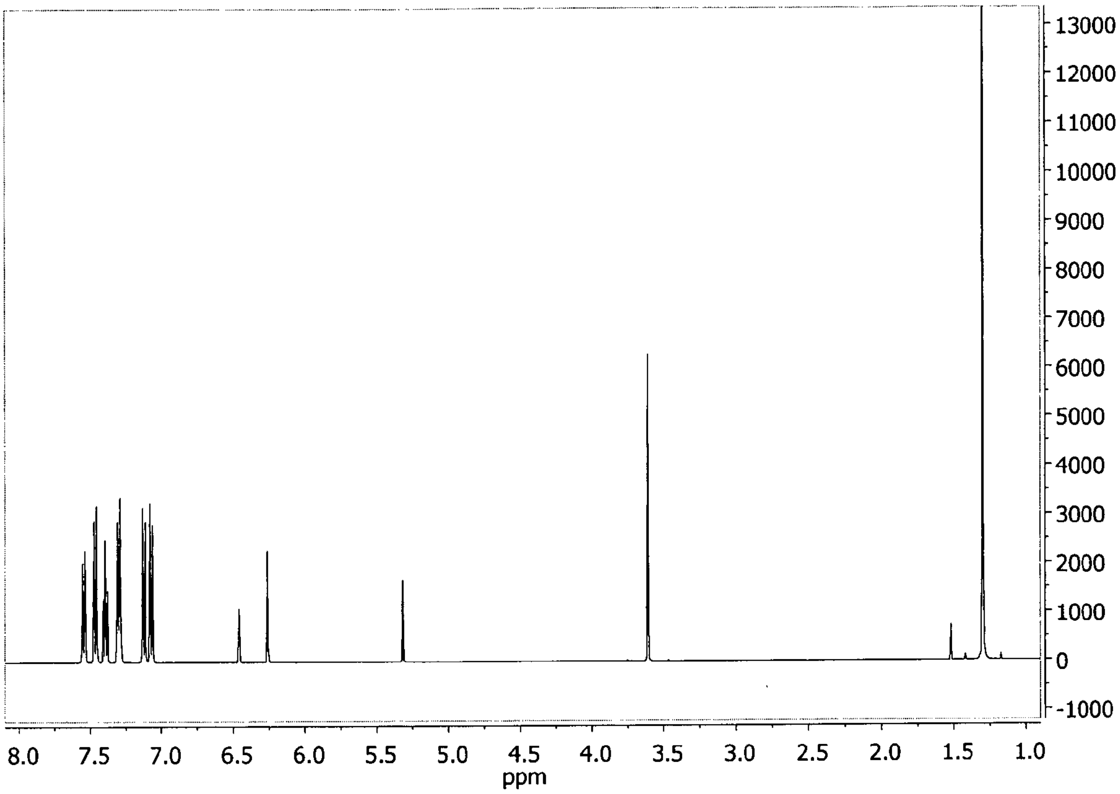
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Fig. 4e

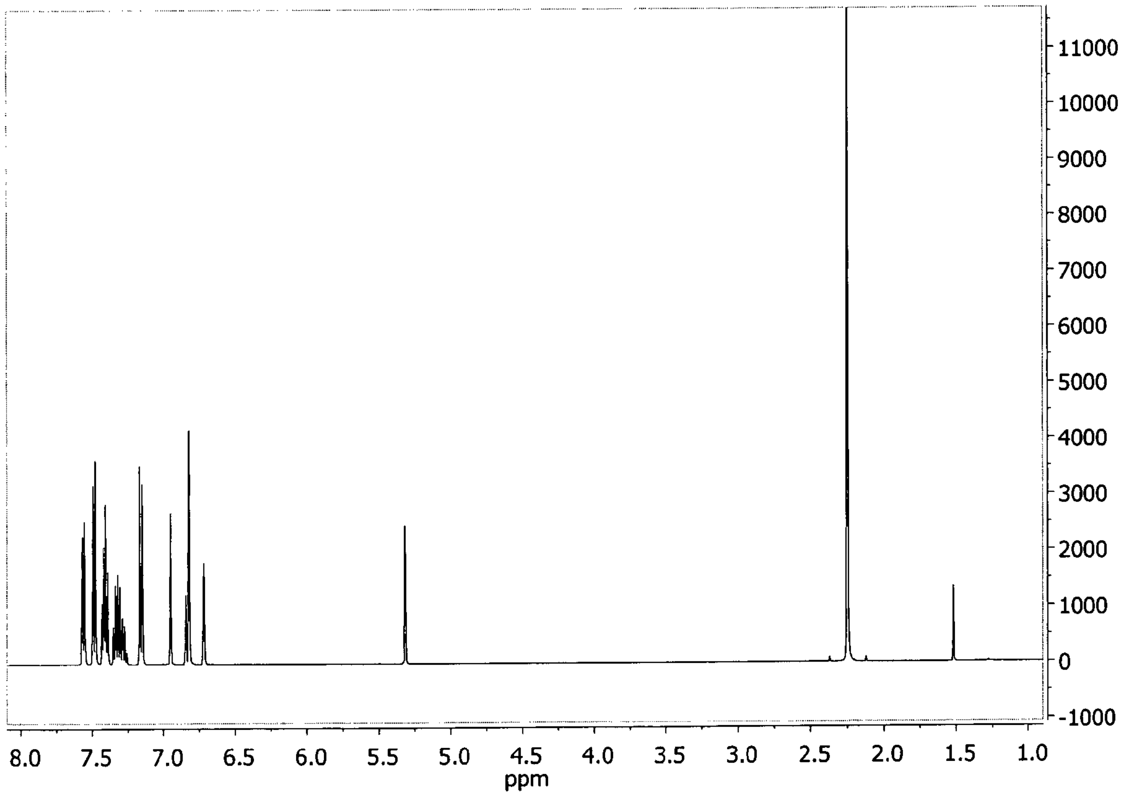
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Fig. 4f

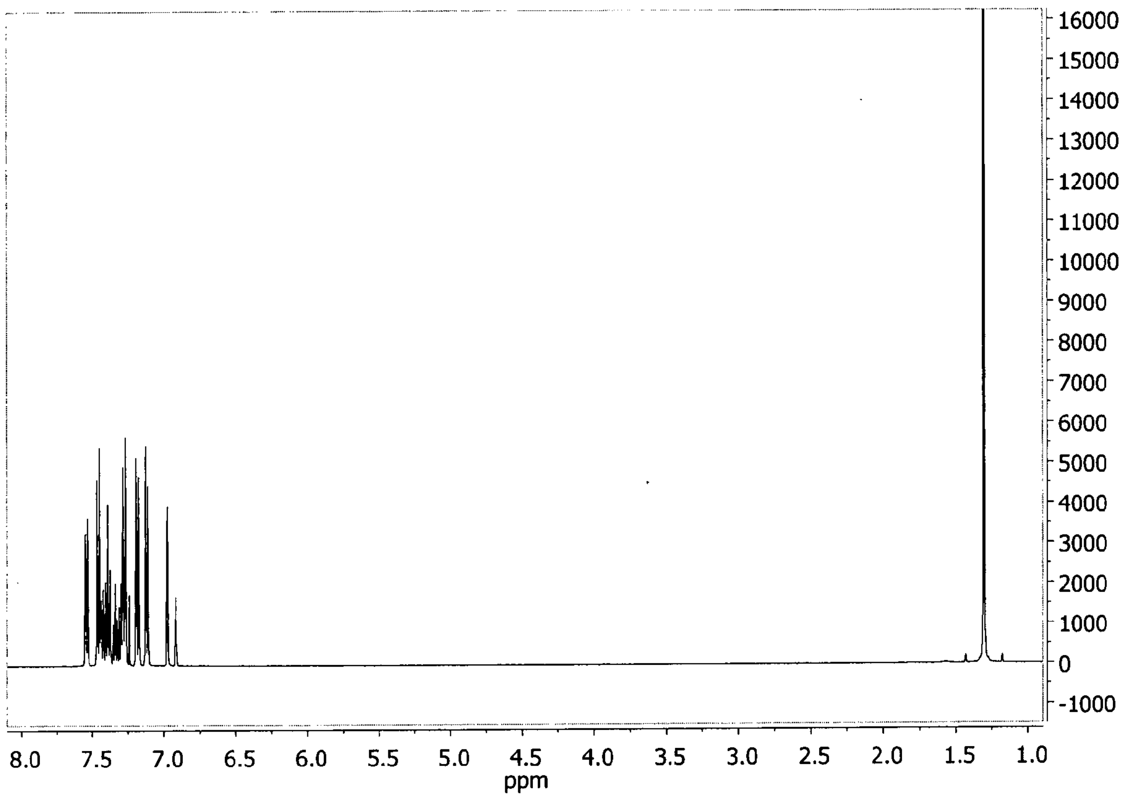
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Fig. 4g

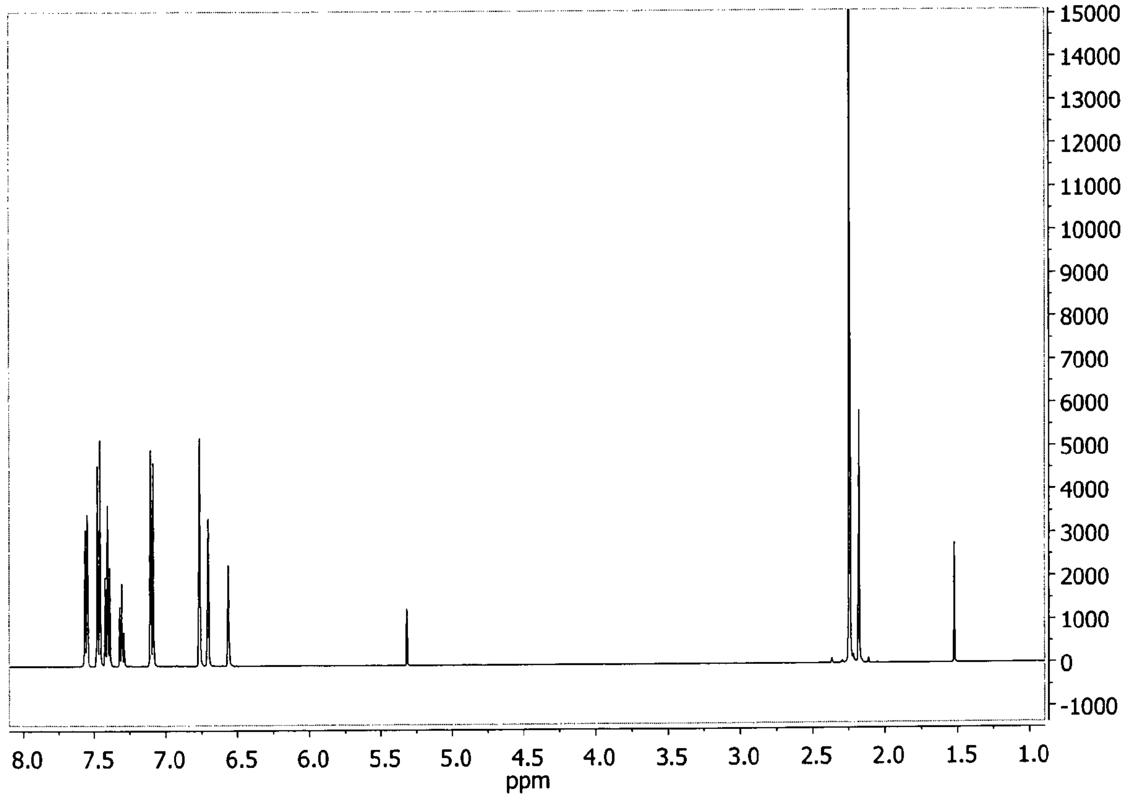
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Fig. 4h

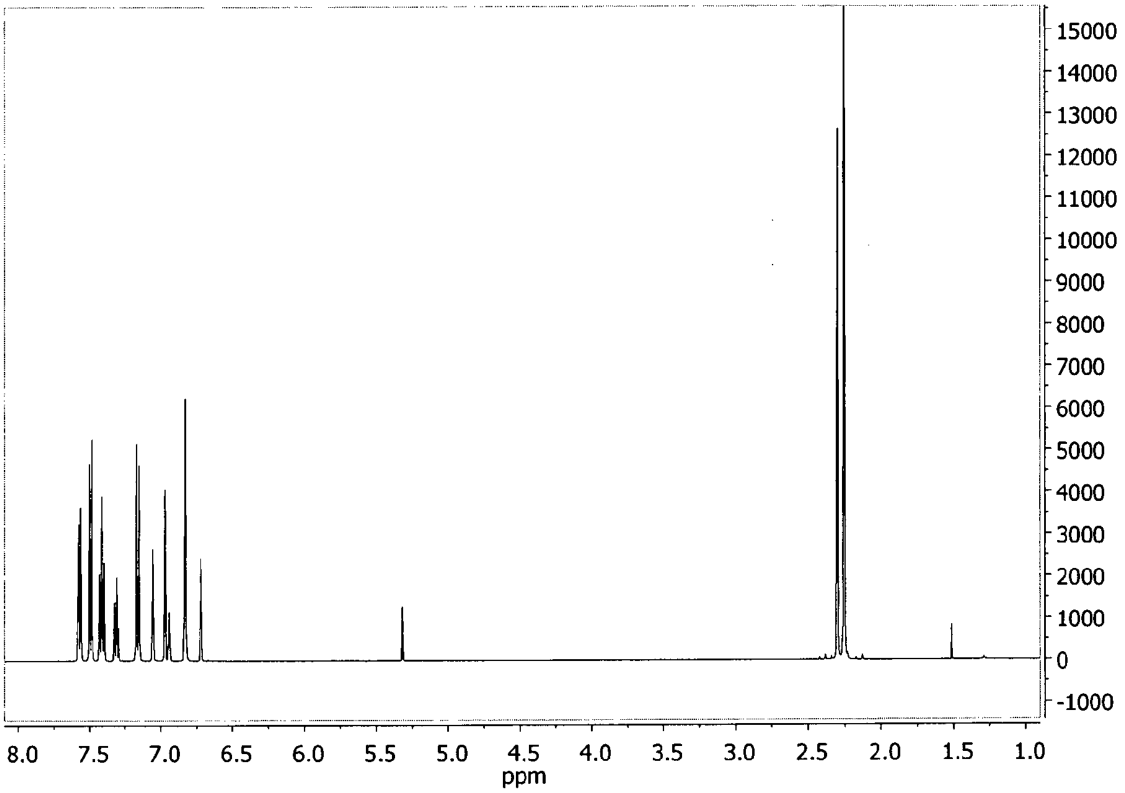
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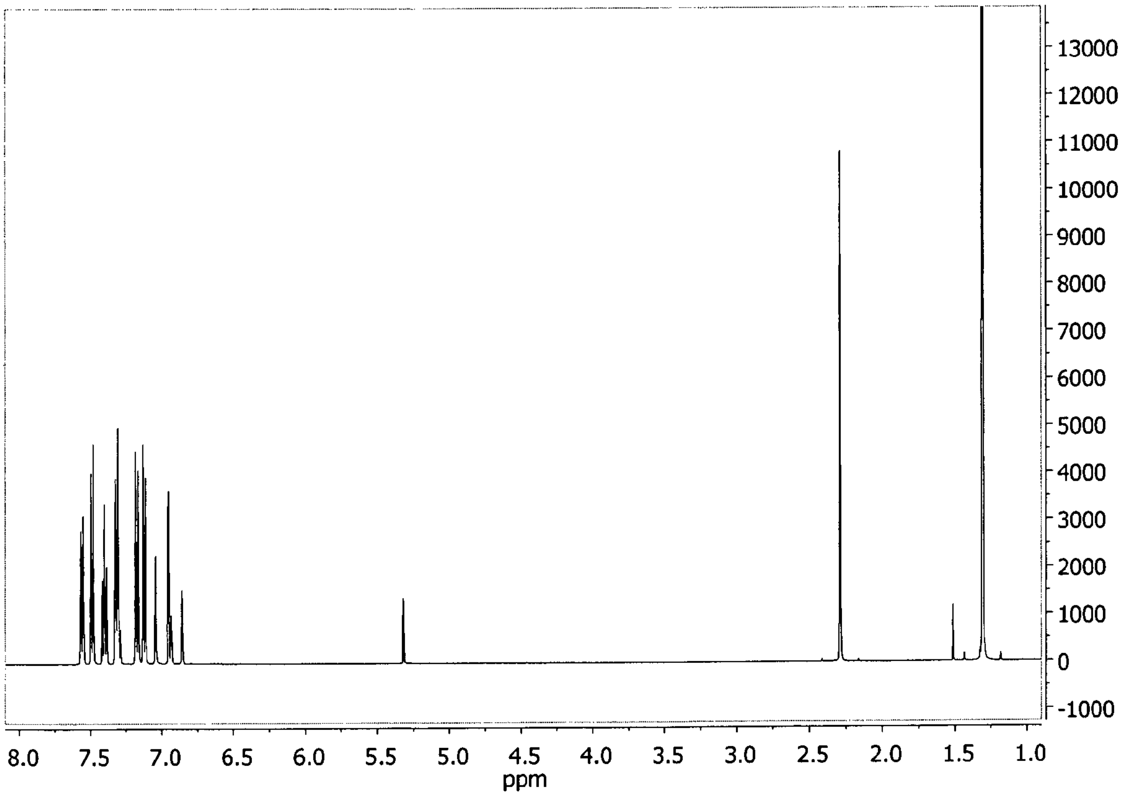
Fig. 4i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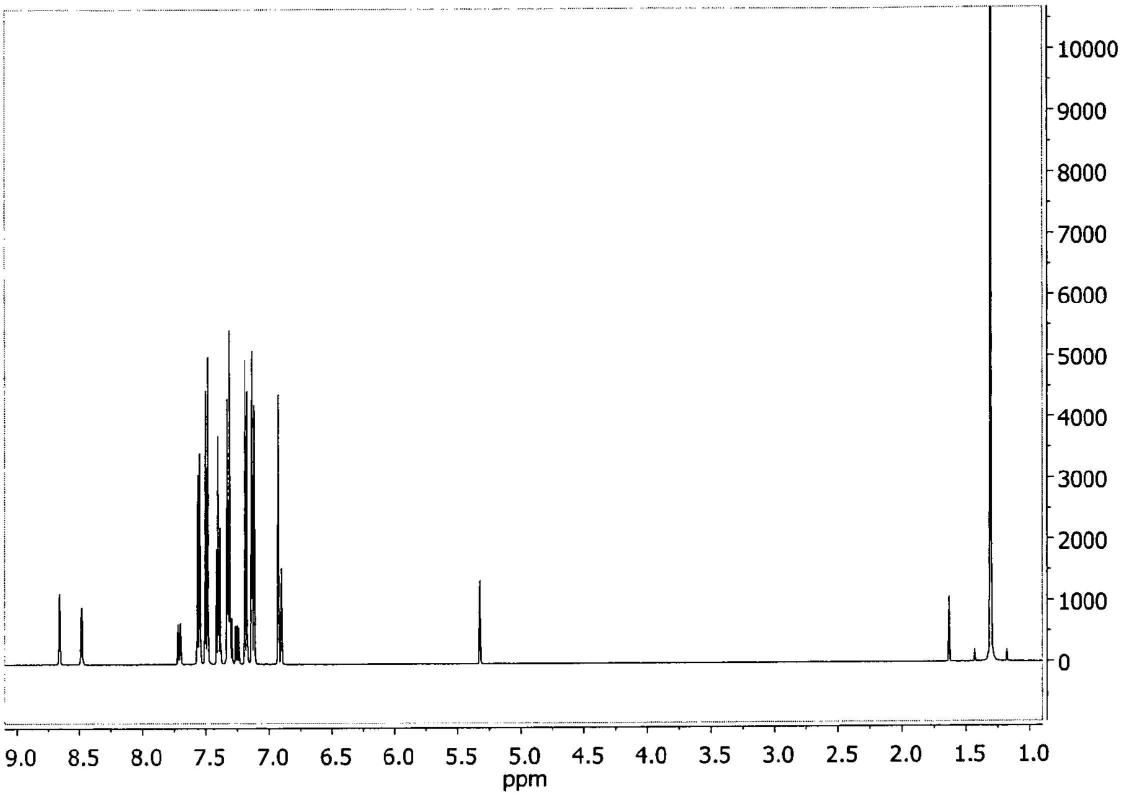
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
-1000
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
ppm

Fig. 4j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2000
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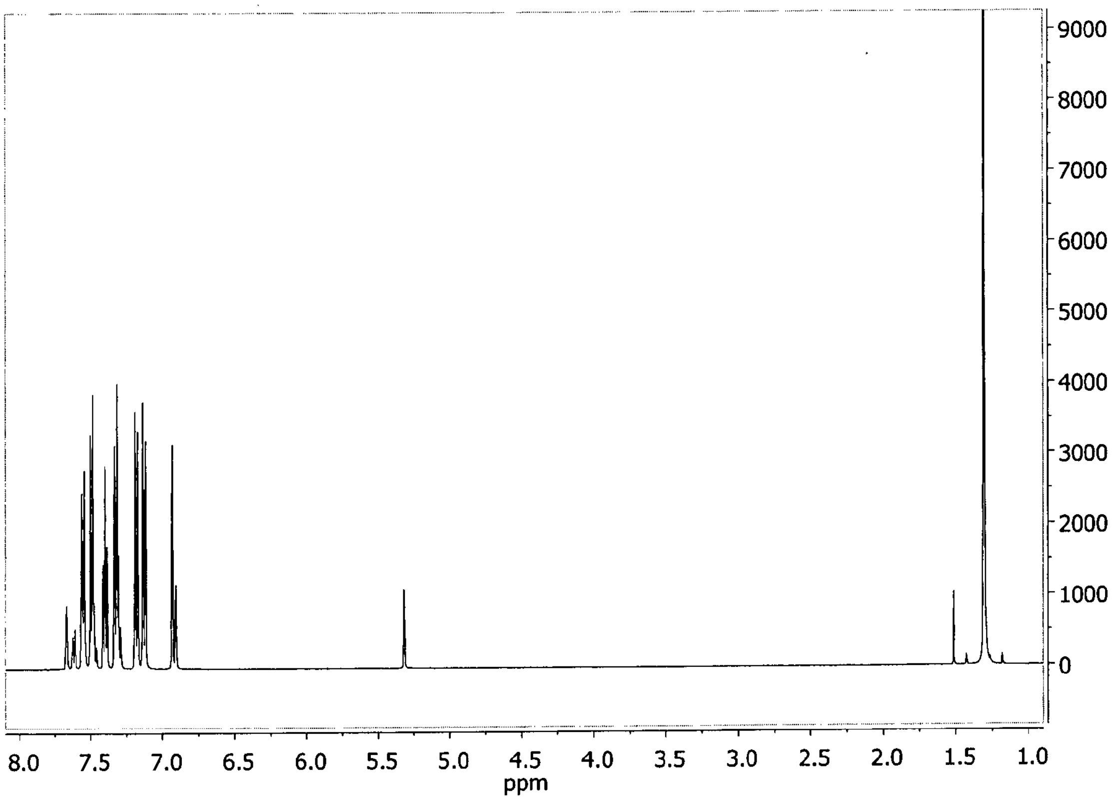
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
ppm

Fig. 4k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7.0
6.5
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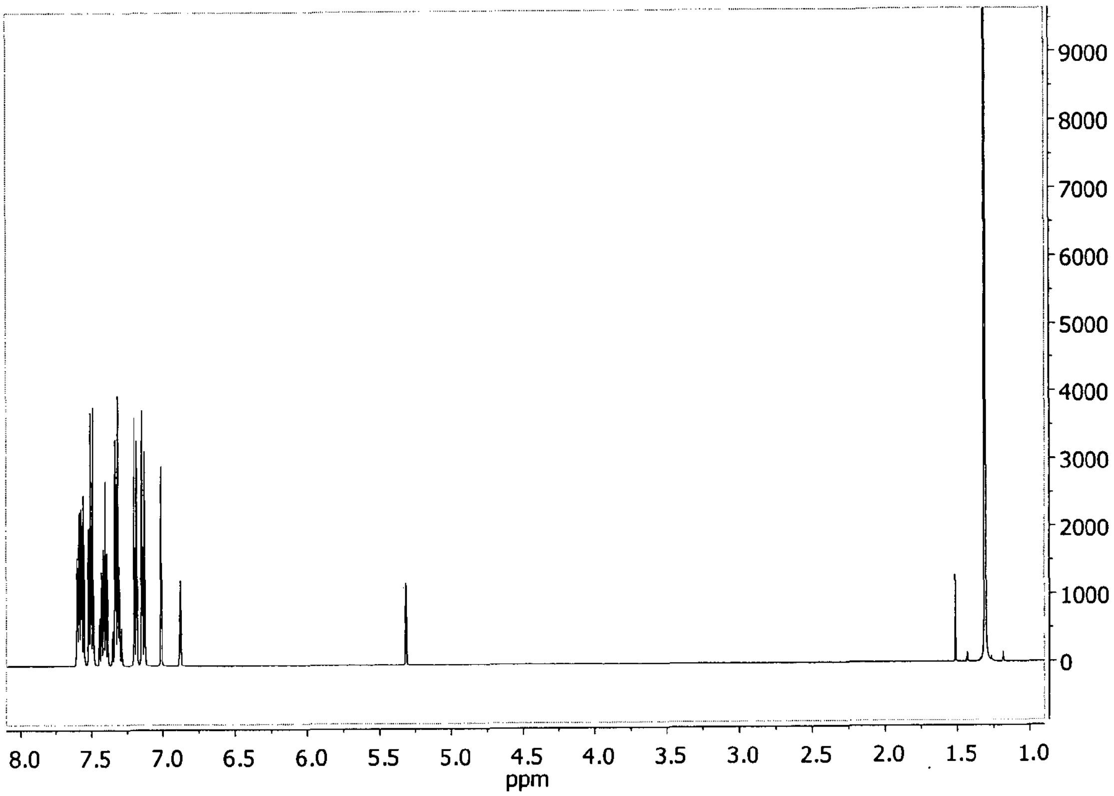
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
ppm

Fig. 4l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4000
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2000
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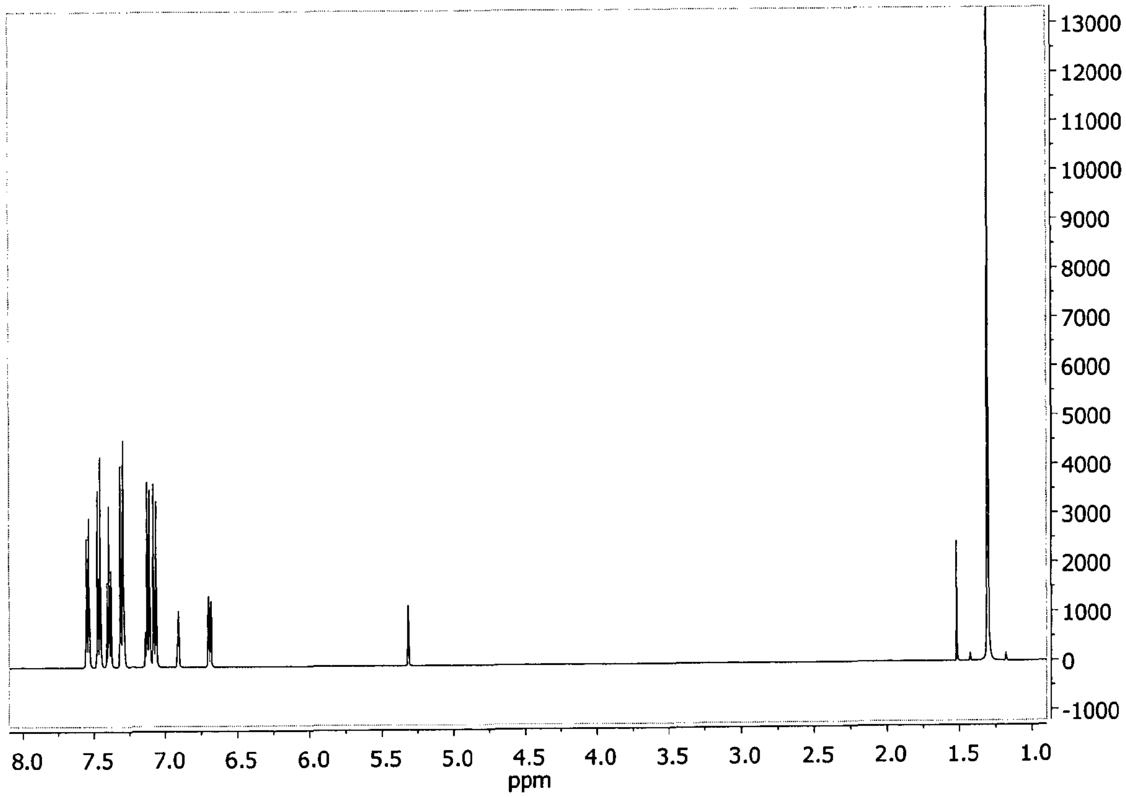
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
ppm

Fig. 4m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11000
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4000
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-1000
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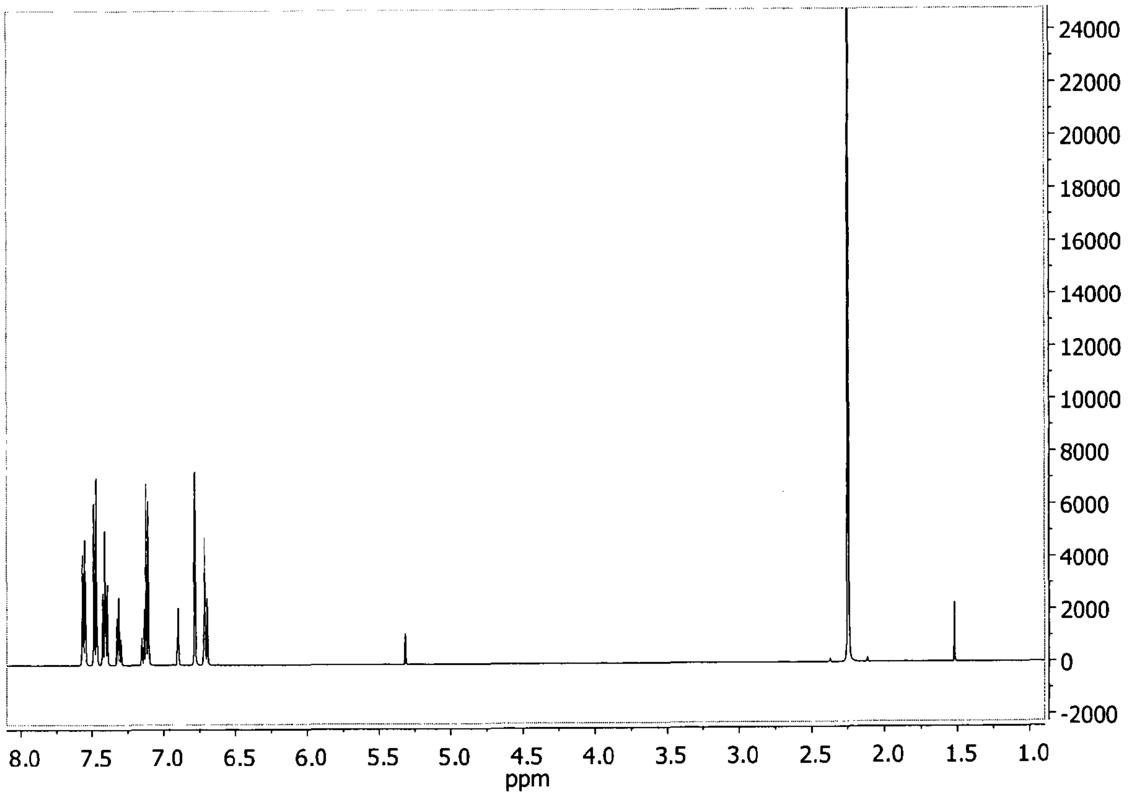
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
ppm

Fig. 4n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22000
20000
18000
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14000
12000
10000
8000
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4000
2000
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-2000
8.0
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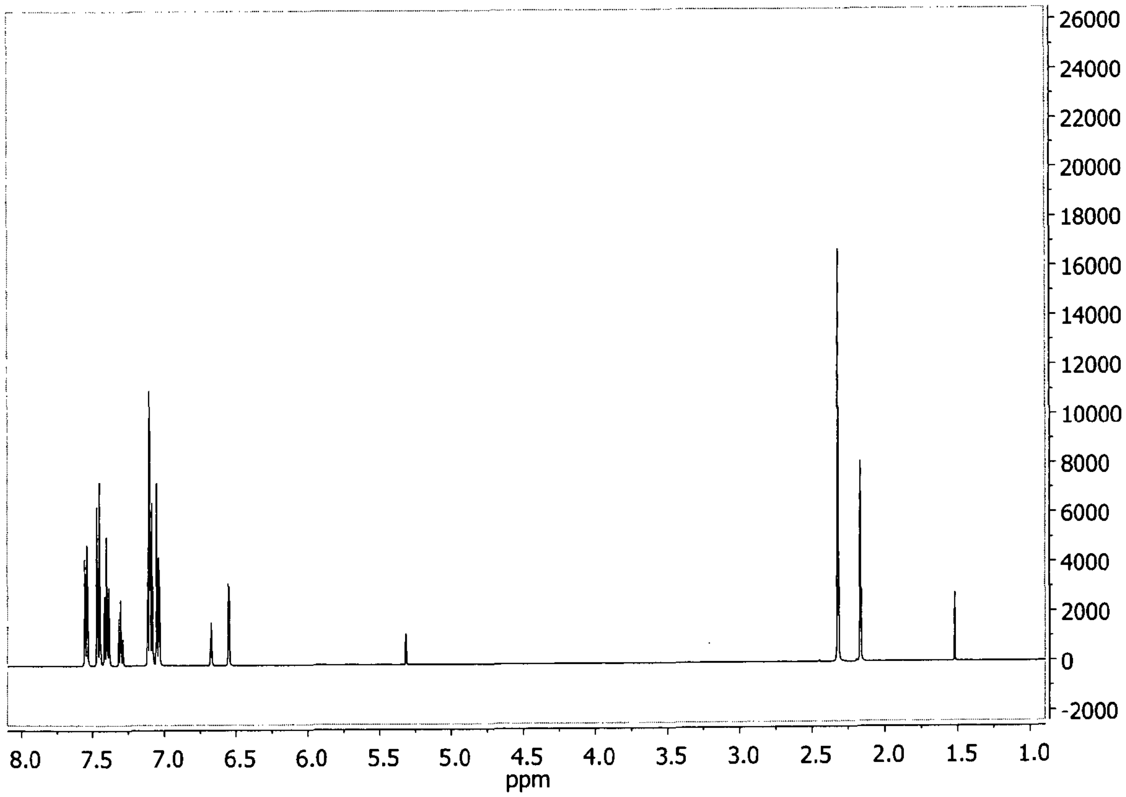
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
ppm

Fig. 4o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22000
20000
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16000
14000
12000
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6000
4000
2000
0
-2000
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7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
ppm

REFERENCES CITED IN THE DESCRIPTION

Patent documents cited in the description

- JP 2002241352 A **[0011]**
- JP 2006156635 A **[0012]**
- US 2004214040 A1 **[0013]**

专利名称(译)	磷光OLED和磷光性OLED的孔传输材料		
公开(公告)号	EP2909872B1	公开(公告)日	2020-01-08
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[标]申请(专利权)人(译)	诺瓦莱德公开股份有限公司		
申请(专利权)人(译)	Novaled公司GMBH		
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发明人	ZÖLLNER, MIKE WUTKE, JENS BURKHARDT, MARTIN		
IPC分类号	H01L51/54 H01L51/52 C07C211/54 C07C211/56		
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优先权	2012188828 2012-10-17 EP		
其他公开文献	EP2909872A1		
外部链接	Espacenet		

摘要(译)

本发明涉及磷光有机发光二极管（OLED），其包括空穴传输或空穴传输以及电子阻挡层，该电子阻挡层包括N，N，N′，N′-四芳基-亚苯基-3，5-。 二胺或N，N，N'，N'-四芳基-1,1'-联苯-3,3'-二胺基质化合物和对新的N，N，N'，N'-四芳基取代的间亚芳基二胺化合物有用 作为磷光OLED中的空穴传输和电子阻挡层基质。