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(54) **ORGANIC ELECTROLUMINESCENT MATERIAL CONTAINING IRIIDIUM, PREPARATION METHOD THEREOF AND ORGANIC ELECTROLUMINESCENT ELEMENT**

(57) Organic electroluminescent material containing iridium of the following general formula, in which R is C₁-C₈ alkyl, is provided. The preparation method of the

above organic electroluminescent material containing iridium and the organic electroluminescent element using the above organic electroluminescent material containing iridium are also provided.

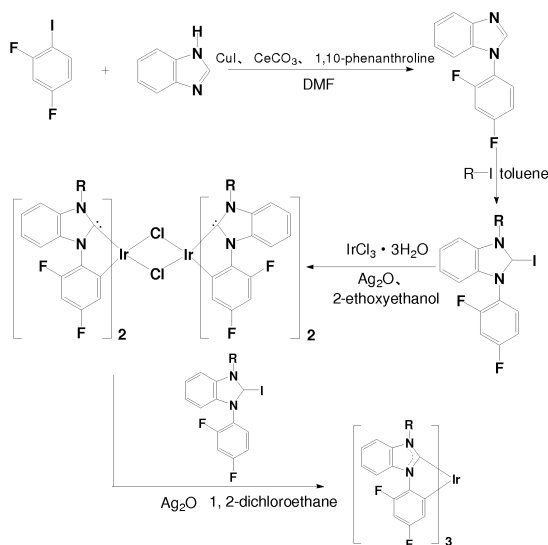


FIG. 1

Al
Buffer layer
Light emitting layer
ITO
glass

FIG. 3

Description

FIELD OF THE INVENTION

[0001] The present disclosure relates to organic electroluminescent technical fields, and more particularly relates to an iridium containing organic electroluminescent material, preparation method thereof and an organic electroluminescent element containing the iridium containing organic electroluminescent material.

BACKGROUND OF THE INVENTION

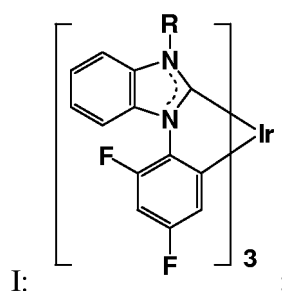
[0002] The organic electroluminescent (EL) is a luminous phenomenon in which the organic materials convert the electrical energy directly into light energy under an electric field. In early stage, due to such reasons as high voltage of the driver system, low luminous efficiency of the device, the research on organic electroluminescent was stagnated. In 1987, Tan et al (Kodak Corporation) invented 8 - hydroxyquinoline aluminum (Alq_3) as light-emitting materials, which can be made into a uniform, dense, high-quality thin film with aromatic diamine, such that the organic electroluminescent device was prepared with significantly increasing brightness and luminescent efficiency under low working voltage, and a research on new prologue electroluminescent materials was opened. However, due to the restriction of the spin statistics theory, the internal quantum efficiency of the fluorescent material was merely 25% in theory, thus it became a hot research directions in the field thereafter that how to make full use of the remaining 75% of the phosphorescence to achieve higher luminous efficiency. In 1997, Forrest et al discovered phosphorus electroluminescent phenomenon, and the internal quantum efficiency of the subsequently obtained organic electroluminescent material broke through the 25% limit, thus leading the research of the organic electroluminescent material into another new period.

[0003] In nowadays study of organic electroluminescent material, complexes of transition metal, such as complexes of iridium, ruthenium, platinum, etc., doped with small molecule have become a research focus. The advantages of the complexes are that they can obtain a high energy emitted from the triplet of their own, and the metal iridium (III) compounds, because of the good stability, mild reaction conditions in the synthesis process, and the high electroluminescent properties, have occupied the dominant position in the subsequent study. Nevertheless, conventional iridium containing organic electroluminescent material, such as bis [2 - (2,4 - difluorophenyl-yl) pyridine-N, C^2] (pyridine-formic acid) combined iridium (FIrpic), bis [2 - (2,4 - difluoro-3 - cyanophenyl) pyridine-N, C^2] (four pyrazole boron) iridium (Fir6) and the like, have a poor internal quantum efficiency and electroluminescent efficiency, thus limiting the development of the research on organic electroluminescent technology.

SUMMARY OF THE INVENTION

[0004] In view of this, it is necessary to provide an iridium containing organic electroluminescent material having higher internal quantum efficiency and electroluminescence efficiency and a preparation method thereof.

[0005] An iridium containing organic electroluminescent material is represented by the following formula I:

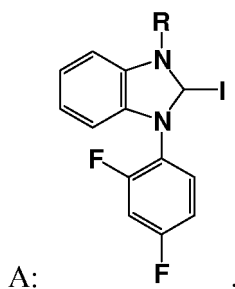


wherein R is $\text{C}_1\text{-C}_8$ alkyl.

[0006] The iridium containing organic electroluminescent material molecule contains benzimidazolyl with electron-transporting function, and the benzimidazolyl is also carried with alkyl group, fluorophenyl, such that it can significantly improve the electron injection and transport capacity, and has high internal quantum efficiency and electroluminescent efficiency. In addition, the molecule further contains 1 - (2,4 - di fluorophenyl) -3 - substituted benzimidazole ligand, therefore the solubility of the compounds can be regulated by changing the length of 3 - position of alkyl chain, thus the applicability is enhanced.

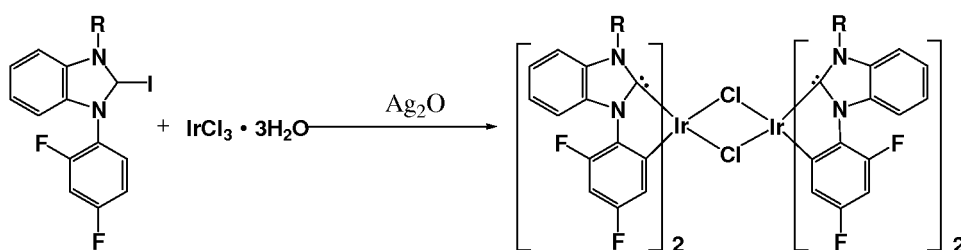
[0007] A preparation method of an iridium containing organic electroluminescent material comprises the following steps:

[0008] step one: preparing a compound A represented by the following formula:



wherein R is C₁-C₈ alkyl;

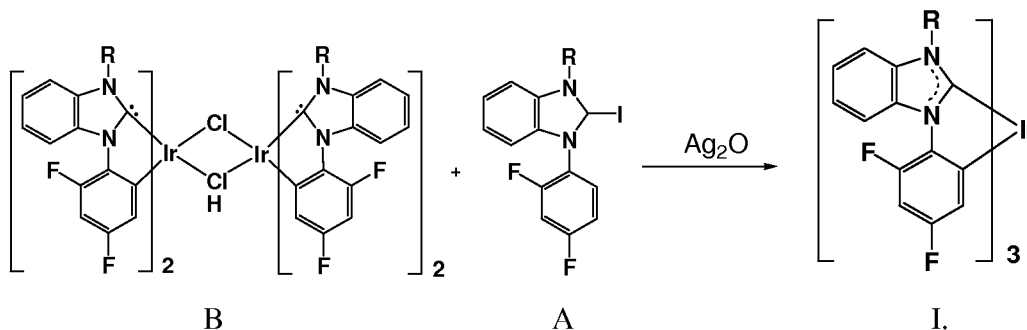
[0009] step two: performing reaction between compound A and Iridium trichloride trihydrate in a solvent under anaerobic condition in presence of Ag₂O catalyst to obtain a bridge compound B; the reaction equation being:



A

B, and

[0010] step three: performing ligands interchange reaction between bridge compound B and compound A in a solvent under anaerobic condition in presence of Ag₂O catalyst to obtain the compound I; the reaction equation being:



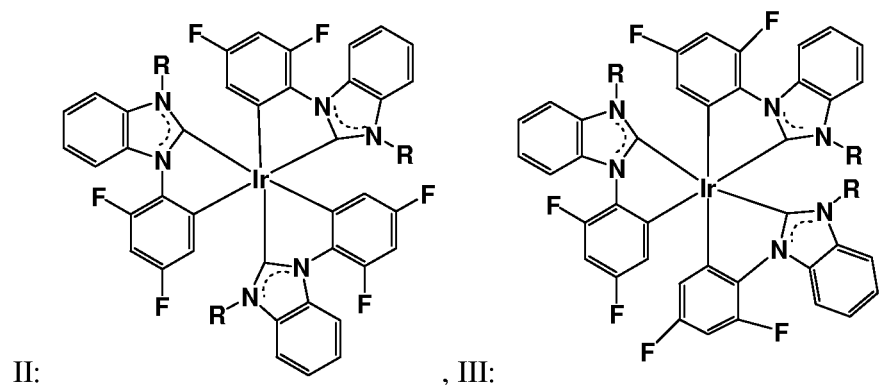
[0011] Preferably, the solvent in step two is 2-ethoxyethanol, and the reaction temperature is from 100°C to 150°C; the solvent in step three is 1,2-dichloroethane, and the reaction temperature is from 90°C to 150°C.

[0012] Preferably, the step two further comprises separation and purification steps: an obtained mixture after the reaction between compound A and iridium trichloride trihydrate is firstly concentrated under reduced pressure; the concentrate is then applied to silica gel column chromatography for 2 to 3 times using dichloromethane as eluent, and the purified compound B is obtained.

[0013] Preferably, the step three further comprises separation and purification steps:

[0014] firstly, the reaction product containing the compound I is concentrated under reduced pressure to obtain a concentrated product containing Compound I;

[0015] then, the concentrated product is applied to silica gel column chromatography using dichloromethane as eluent to obtain a solid mixture containing isomer II and isomer III;

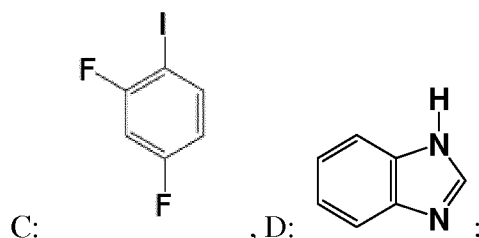


[0016] the solid mixture is applied to silica gel column chromatography using a mixture solution containing ethyl acetate and n-hexane in a volume ratio of 1:4 as eluant to obtain a purified compound III and separation residual liquid;

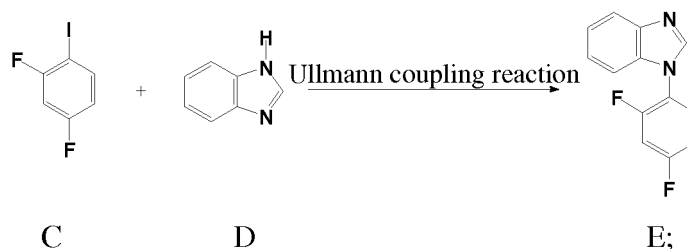
[0017] finally, the separation residual liquid is applied to silica gel column chromatography using a mixture solution containing ethyl acetate and n-hexane in a volume ratio of 2: 3 as eluant to obtain purified compound II.

[0018] Preferably, a preparation method of the compound A comprises the following steps:

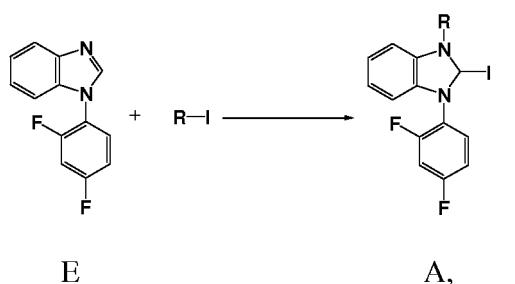
[0019] step one, providing compound C and D represented by the following formulas,



[0020] step two, performing Ullmann coupling reaction between the compound C and the compound D under anaerobic condition in presence of catalyst to obtain compound E, the reaction equation being:



[0021] step three, reacting the compound E with an alkyl iodide in a solvent to obtain the compound A, the reaction equation being:



[0022] Wherein R-I is alkyl iodide, R is C₁-C₈ alkyl.

[0023] Preferably, in step two the reaction temperature of the Ullmann coupling reaction is from 100°C to 180°C, the catalyst is a mixed catalyst composed of copper iodide, 1, 10- phenanthroline and cesium carbonate, the solvent is N, N- dimethylformamide; the solvent in step three is toluene, the reaction temperature is from 25°C to 45°C.

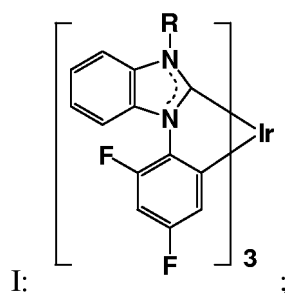
[0024] Preferably, the step two further comprises steps of separation and purification of compound E: an obtained mixture of the Ullmann coupling reaction is vacuum concentrated; ethyl acetate solution was added to the concentrate to produce a precipitate; the precipitate is separated by filtration and is washed with ethyl acetate, and the filtrate was collected; the filtrate is finally concentrated and is applied to silica gel column chromatography using a mixture solution containing ethyl acetate and n- hexane in a volume ratio of 2: 3 as eluant, and the purified compound E is obtained.

[0025] Preferably, the step three further comprises steps of separation and purification of compound A: the crude reaction product of step three is filtrated, the filtrated precipitate is washed with toluene and dried to obtain the purified compound A.

[0026] The preparation method described above is simple, easy to operate, low equipment requirements, and can be widely used.

[0027] Furthermore, it is necessary to provide an organic electroluminescent element having higher internal quantum efficiency and electroluminescence efficiency.

[0028] An organic electroluminescent element comprises a light emitting layer, wherein the light emitting layer contains the compound I represented by the following formula I:



wherein R is C₁-C₈ alkyl.

[0029] The compound I has an improving compatibility with a host material in the light emitting layer of the organic electroluminescence element, thus it can be widely used as a doped object in light emitting layer to prepare a blue or white phosphorus electroluminescent element. Since the light-emitting layer containing the iridium containing organic electroluminescent material has high internal quantum efficiency and the electroluminescent efficiency, the electroluminescent element has a high energy conversion efficiency and luminous efficiency.

BRIEF DESCRIPTION OF THE DRAWINGS

[0030] FIG. 1 is a flowchart of a preparation method of an embodiment of an organic electroluminescent material;

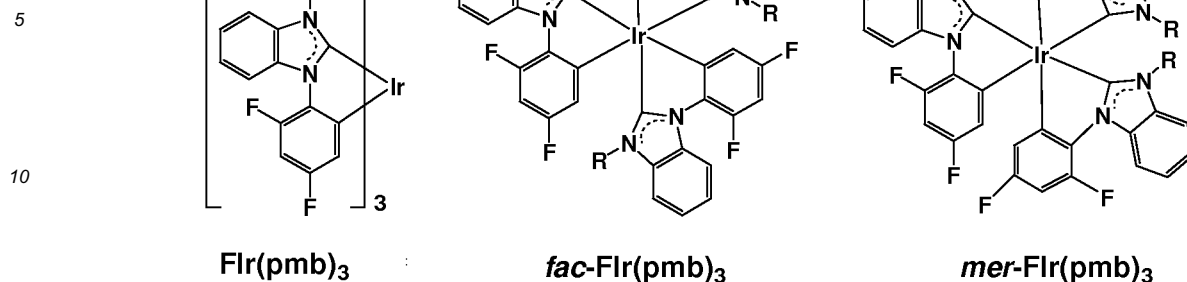
[0031] FIG. 2 is an emission spectra of the luminescent material in Example 8;

[0032] FIG. 3 is a schematic view of the organic electroluminescent device in Example 8.

DETAILED DESCRIPTION

[0033] The iridium-containing organic electroluminescent material and its preparation method and application will be further described in connection with the accompanying drawings and specific embodiments.

[0034] Metal organic complexes of iridium (Ir) is a phosphorescent light emitting material having a short phosphorescence lifetime (1- 14μs) . An embodiment of an iridium containing organic electroluminescent material is represented by formula $\text{Ir}(\text{pmb})_3$, which includes two isomers, i.e. *fac*- $\text{Ir}(\text{pmb})_3$ and *mer*- $\text{Ir}(\text{pmb})_3$, wherein F represents two fluorine atoms carried by specific functional groups, pmb represents 1- (2, 4- di fluorophenyl)- 3- alkyl imidazolyl, 3-position substituent is an alkyl group of C₁- C₈. The specific structural formulas are shown as follows:



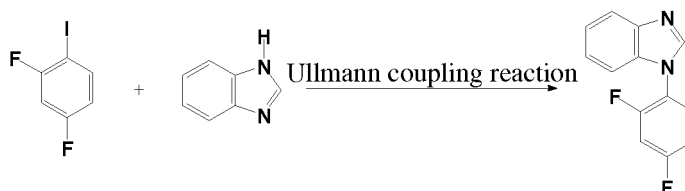
15 **[0035]** Wherein R is C₁-C₈ alkyl.

[0036] The embodiment of the iridium containing organic electroluminescent material molecule contains benzimidazolyl with electron-transporting function, and the benzimidazolyl is also carried with alkyl group, fluorophenyl, such that it can significantly improve the electron injection and transport capacity, and has high internal quantum efficiency and electroluminescent efficiency. In addition, the molecule further contains 1 - (2,4 - di fluorophenyl) -3 - substituted benzimidazole ligand, therefore the solubility of the compounds can be regulated by changing the length of 3 - position of alkyl chain, thus the applicability is enhanced. The iridium containing organic electroluminescent material has an improving compatibility with a host material in the light emitting layer of the organic electroluminescence element, thus it can be widely used as a doped object in light emitting layer to prepare a blue or white phosphorus electroluminescent element.

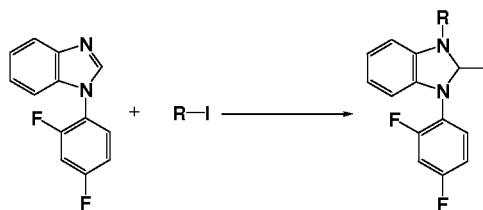
25 **[0037]** Referring to FIG.1, a first embodiment of a preparation method of the iridium containing organic electroluminescent material specifically includes the following steps:

[0038] The following steps are carried out under anaerobic conditions (e.g. N₂ or inert gas atmosphere, etc.).

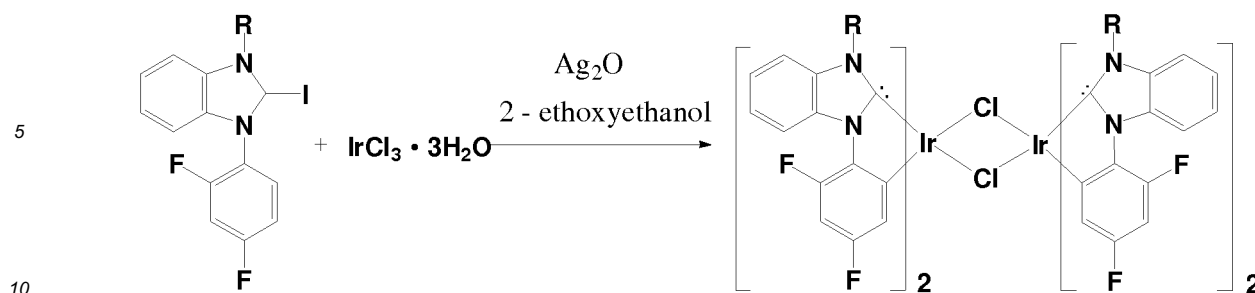
30 **[0039]** Step S1: In a solvent of N, N- dimethyl formamide (DMF), benzimidazole, and 2, 4- difluoro- iodobenzene are subjected to a Ullmann coupling reaction in presence of a mixed catalyst containing copper iodide (CuI), 1, 10- phenanthroline, and cesium carbonate (CeCO₃) at a temperature from 100°C to 180°C for the, to obtain 1- (2, 4- difluorophenyl) benzimidazole. The reaction equation is shown as follows:



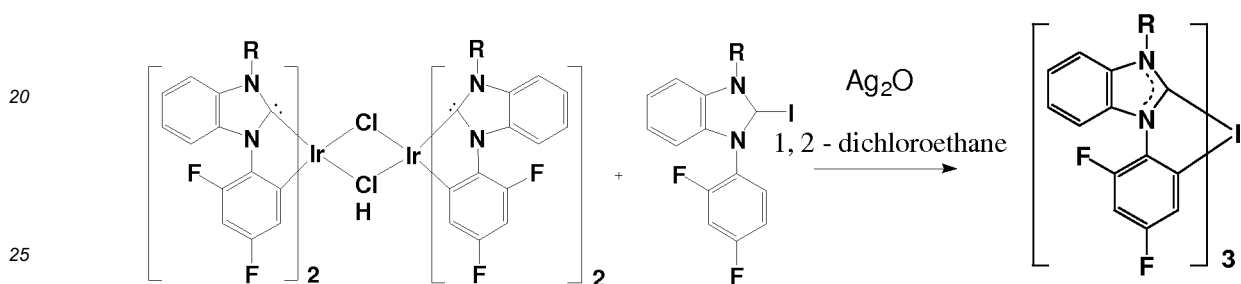
[0040] Step S2: the 1 - (2,4 - difluorophenyl) benzimidazole is reacted with alkyl iodide in a solvent of toluene at a temperature from 100°C to 150°C to obtain 1 - (2,4 - di fluorophenyl) -3 - alkyl iodide, the reaction equation is shown as follows:



[0041] Step S3: In a reaction system using 2- ethoxyethanol as the solvent, the obtained 1- (2, 4- di fluorophenyl)- 3- alkyl iodide is reacted with iridium trichloride trihydrate in presence of silver oxide at a temperature from 100°C to 150°C to obtain a bridge compound (Fpmb)₂Ir (μ- Cl)₂Ir (Fpmb)₂, the reaction equation is shown as follows:



[0042] Step S4: In a reaction system using 1, 2- dichloroethane as the solvent, a ligands interchange reaction is performed between compound 1- (2, 4- di fluorophenyl)- 3- alkyl iodide and the bridge compound (Fpmb)₂Ir (μ- Cl)₂Ir (Fpmb)₂, in presence of silver oxide at a temperature from 90°C to 150°C to obtain the object product FIr (pmb)₃, the reaction equation is shown as follows:



[0043] Step S5: highly purified *mer*- FIr (pmb)₃ and the *fac*- FIr (pmb)₃ can be obtained after subsequent separation and purification operations.

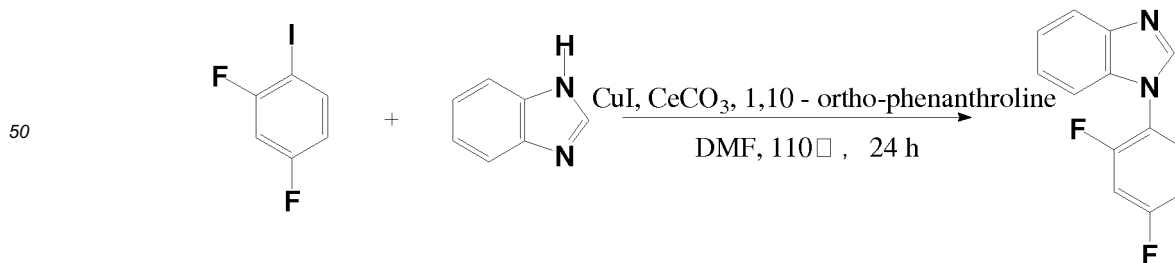
[0044] The preparation method described above is simple, easy to operate, low equipment requirements, and can be widely used.

[0045] Specific Examples are described as follows:

[0046] **Example 1:** the synthesis of tris (1 - (2,4 - difluorophenyl)-yl) -3 - methyl - benzimidazole) iridium.

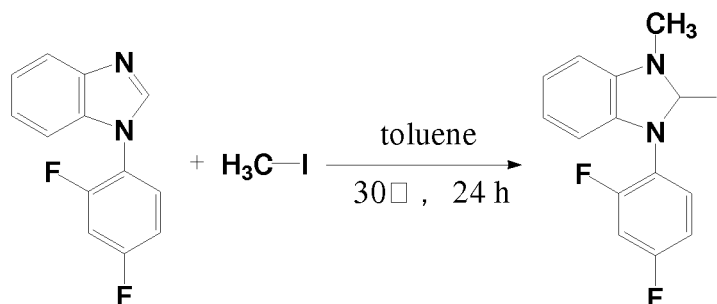
[0047] (1) the synthesis of 1- (2, 4- di fluorophenyl)- 3- methylbenzimidazole iodide.

[0048] 0.16 g (0.836 mmol) of CuI, 1.20 g (10.15 mmol) of benzimidazole and 5.70 g (17.50 mmol) of cesium carbonate (CeCO₃) were successively added into a 50ml round bottom flask wrapped by aluminum foil, after introducing nitrogen for 15 minutes, 1 mL (8.36 mmol) of 2,4 - difluoro-iodobenzene, 0.30 g (1.67 mmol) of 1,10 - ortho-phenanthroline and 25 mL of anhydrous N, N- dimethylformamide (DMF) were successively added to the nitrogen stream to form a reaction mixture; after 30 minutes of continually introducing nitrogen to the reaction mixture, the system was heated in oil bath to 110°C and stirred for 24 hours; after the reaction was cooled to room temperature, it was concentrated in vacuum, and 10 mL of ethyl acetate was added to the concentrate, the precipitate was removed by filtering, the concentrate was then washed with 30mL of ethyl acetate, the filtrate was concentrated; the filtrate was applied to silica gel column chromatography using a mixture solution containing ethyl acetate and n-hexane in a volume ratio of 2:3 as eluant, and 0.942g of 1 - (2,4 - di fluorophenyl) - benzimidazole in a form of yellow liquid was obtained with the yield of 48%.



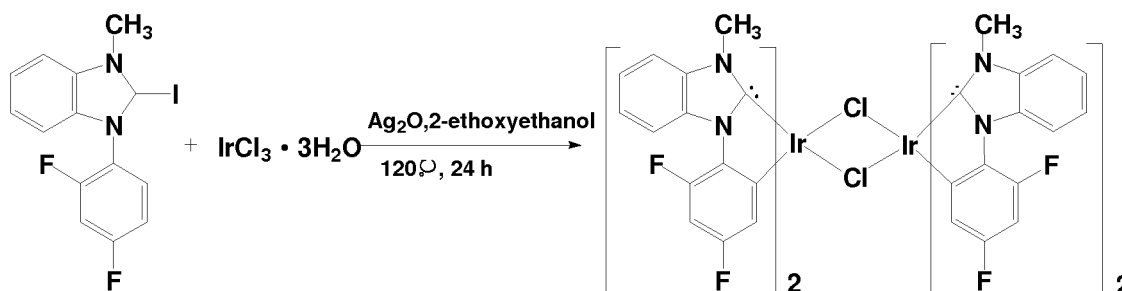
[0049] Under a protection of nitrogen, 1.26 g (8.830 mmol) of methyl iodide was added to an aluminum foil wrapped 25 mL round bottom flask containing 0.924 g (4.013 mmol) of 1 - (2,4 - di fluorophenyl) - benzimidazole, and 15 mL of toluene, the system was stirred at 30°C for 24 hours and white precipitate was generated; the precipitate was washed

with 20 mL of toluene and dried to obtain 0.882g of 1 - (2,4 - di fluorophenyl) -3 - methyl iodide in a form of white solid with yield of 59%. The detection data of the product is as follows: ^1H NMR (400 MHz, CDCl_3 , ppm): 9.32 (s, 1H), 8.31-8.13 (m, 3H), 7.78-7.66 (m, 4H), 4.52 (s, 3H).



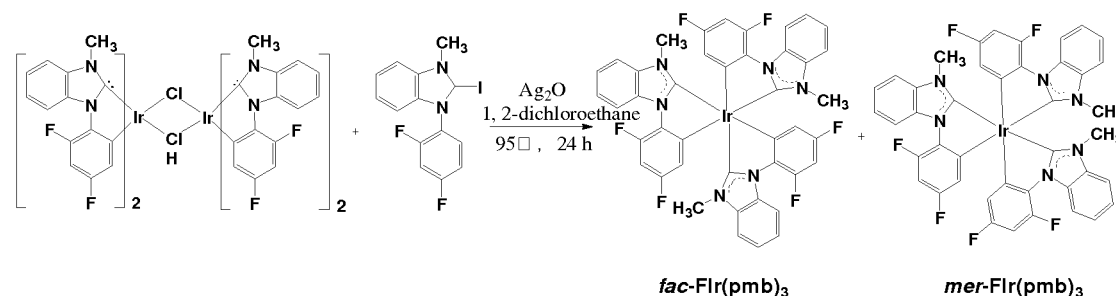
[0050] (2) The synthesis of bridge compound $(\text{Fpmb})_2\text{Ir}(\mu\text{-Cl})_2\text{Ir}(\text{Fpmb})_2$.

[0051] Under a protection of nitrogen, 7.44 g (20.0 mmol) of 1 - (2,4-di fluorophenyl) -3 - methylbenzimidazole iodide, 5.56 g (24 mmol) of silver oxide (Ag_2O), 1.77 g (5 mmol) of trihydratediridium chloride and 50 mL of 2-ethoxyethanol were successively added into a 100ml round bottom flask wrapped by aluminum foil, the mixture was heated and stirred in oil bath at 120°C for 24 hours. After the mixture was cooled to room temperature, it was concentrated under reduced pressure. The concentrate was then applied to silica gel column chromatography for 2 times using dichloromethane as eluent, and 0.582g of product in a form of slightly yellow solid was obtained with a yield of 16.3%. The detection data of the product is as follows: ^1H NMR (400 MHz, CDCl_3 , ppm): 8.33 (s, 4H), 8.14 (d, 4H), 7.81 (d, 4H), 7.75 (m, 4H), 7.67 (m, 4H), 7.38 (d, 4H), 4.49 (s, 12H).



[0052] (3) The synthesis of final products *mer*- $\text{Flr}(\text{pmb})_3$ and *fac*- $\text{Flr}(\text{pmb})_3$.

[0053] Under a protection of nitrogen, 0.114 g (0.49 mmol) of silver oxide and 0.365 g (0.98 mmol) of 1- (2, 4- di fluorophenyl)- 3- methyl iodide, 0.582 g (0.41 mmol) of bridge compound and 30 mL of 1, 2- dichloroethane were successively added into a 50ml round bottom flask wrapped by aluminum foil, the mixture was heated and stirred in oil bath at 95°C for 24 hours. After the mixture was cooled to room temperature, it was concentrated under reduced pressure. The concentrate was then applied to silica gel column chromatography for 2 times using dichloromethane as eluent, and 0.74g of white solid was obtained with the total yield of 98%. The product was applied to silica gel column chromatography using a mixture solution containing ethyl acetate and n- hexane in a volume ratio of 1: 4 as eluant, eluted repeatedly to obtain 0.507g of *mer*- $\text{Flr}(\text{pmb})_3$ with a yield of 67%; the separation residual liquid was applied to silica gel column chromatography using a mixture solution containing ethyl acetate and n- hexane in a volume ratio of 40: 60 as eluant, eluted repeatedly to obtain 0.159g of *fac*- $\text{Flr}(\text{pmb})_3$ with a yield of 21 %.



[0054] The detection data of the final product is as follows:

[0055] *fac*-Flr (pmb)₃:

[0056] ¹H NMR (400 MHz, CDCl₃, ppm) : 8.24 (s, 3H), 8.07 (d, 3H), 7.76 (m, 3H), 7.61 (m, 3H), 7.43 (d, 3H), 6.91 (d, 3H), 3.95 (s, 9H) .

[0057] *mer*-Flr (pmb)₃:

[0058] ¹H NMR (400 MHz, CDCl₃, ppm) : 8.31 (d, 1H), 8.28 (d, 1H), 8.23 (d, 1H), 7.85 (d, 1H), 7.82 (d, 1H), 7.75 (d, 1H), 7.45- 6.51 (m, 12H), 3.96 (s, 3H), 3.87 (s, 3H), 3.75 (s, 3H) .

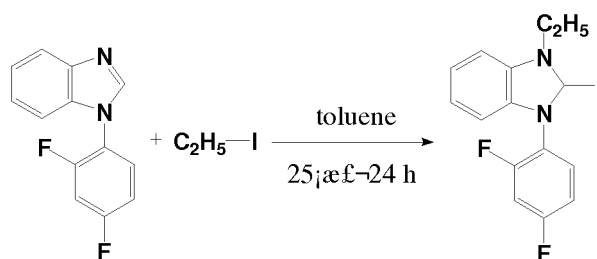
[0059] At a temperature of 77K in 2- methyl- tetrahydrofuran solution (~ 10⁻⁵mol/L), *fac*- Flr (pmb)₃ has a main emission peak at 376 nm in the emission spectrum and a shoulder peak at 396nm; the *mer*- Flr (pmb)₃ has a main emission peak at 378 nm and a shoulder peak at 398nm.

[0060] **Example 2:** the synthesis of tris (1 - (2,4 - difluorophenyl-yl) -3 - ethyl - benzimidazole) iridium.

[0061] (1) the synthesis of 1- (2, 4- di fluorophenyl)- 3- methylbenzimidazole iodide.

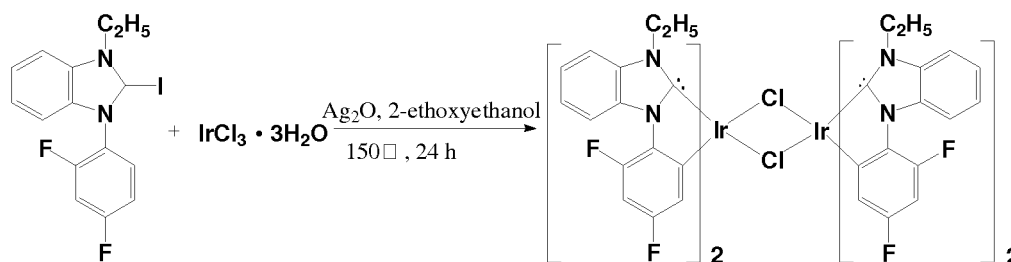
[0062] The synthesis of 1 - (2,4 - difluorophenyl) benzimidazole was identical to that in Example 1.

[0063] Under a protection of nitrogen, 1.377 g (8.830 mmol) of ethyl iodide was added to an aluminum foil wrapped 25 mL round bottom flask containing 0.924 g (4.013 mmol) of 1 - (2,4 - di fluorophenyl) - benzimidazole, and 15 mL of toluene, the system was stirred at 25°C for 24 hours and white precipitate was generated; the precipitate was washed with 20 mL of toluene and dried to obtain 0.883g of 1 - (2,4 - di fluorophenyl) -3 - methyl iodide in a form of white solid with yield of 57%. The detection data of the product is as follows: ¹H NMR (400 MHz, CDCl₃, ppm): 9.31 (s, 1H), 8.27-8.11 (m, 3H), 7.76-7.64 (m, 4H), 4.43 (m, 2H), 2.45(m, 3H).



[0064] (2) The synthesis of bridge compound (Fpmb)₂Ir (μ- Cl)₂Ir (Fpmb)₂.

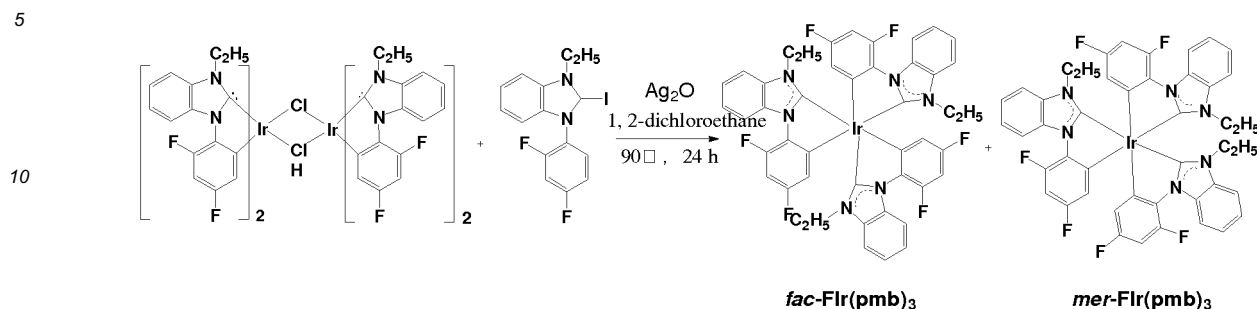
[0065] Under a protection of nitrogen, 7.43 g (20.0 mmol) of 1 - (2,4 - di fluorophenyl) -3 - ethyl iodide, 5.56 g (24 mmol) of silver oxide (Ag₂O), 1.77 g (5 mmol) of trihydratediridium chloride and 50 mL of 2-ethoxyethanol were successively added into a 100ml round bottom flask wrapped by aluminum foil, the mixture was heated and stirred in oil bath at 150°C for 24 hours. After the mixture was cooled to room temperature, it was concentrated under reduced pressure. The concentrate was then applied to silica gel column chromatography for 2 times using dichloromethane as eluent, and 0.594g of product in a form of slightly yellow solid was obtained with a yield of 16%. The detection data of the product is as follows: ¹H NMR (400 MHz, CDCl₃, ppm): 8.31 (s, 4H), 8.11 (d, 4H), 7.78 (d, 4H), 7.62 (m, 4H), 7.53 (m, 4H), 7.31 (d, 4H), 4.41 (m, 8H), 2.12 (m, 12H).



[0066] (3) The synthesis of final products *mer*- Flr (pmb)₃ and *fac*- Flr (pmb)₃.

[0067] Under a protection of nitrogen, 0.114 g (0.49 mmol) of silver oxide and 0.378 g (0.98 mmol) of 1- (2, 4- di fluorophenyl)- 3- ethyl iodide, 0.582 g (0.41 mmol) of bridge compound and 30 mL of 1, 2- dichloroethane were successively added into a 50ml round bottom flask wrapped by aluminum foil, the mixture was heated and stirred in oil bath at 90°C for 24 hours. After the mixture was cooled to room temperature, it was concentrated under reduced pressure. The concentrate was then applied to silica gel column chromatography for 2 times using dichloromethane as eluent, and 0.77g of white solid was obtained with the total yield of 97%. The product was applied to silica gel column chromatography using a mixture solution containing ethyl acetate and n- hexane in a volume ratio of 20: 80 as eluant, eluted repeatedly

to obtain 0.522g of *mer*-Flr (pmb)₃ with a yield of 66%; the separation residual liquid was applied to silica gel column chromatography using a mixture solution containing ethyl acetate and n-hexane in a volume ratio of 2: 3 as eluant, eluted repeatedly to obtain 0.166g of *fac*-Flr (pmb)₃ with a yield of 21 %.



15 [0068] The detection data of the final product is as follows:

[0069] *fac*-Flr (pmb)₃:

[0070] ¹H NMR (400 MHz, CDCl₃, ppm) : 8.20 (s, 3H), 8.05 (d, 3H), 7.74 (m, 3H), 7.54 (m, 3H), 7.13 (d, 3H), 6.85 (d, 3H), 3.87 (m, 6H), 2.11 (m, 9H) .

20 [0071] *mer*-Flr (pmb)₃:

[0072] ¹H NMR (400 MHz, CDCl₃, ppm) : 8.30 (d, 1H), 8.26 (d, 1H), 8.21 (d, 1H), 7.84 (d, 1H), 7.81 (d, 1H), 7.72 (d, 1H), 7.41- 6.46 (m, 12H), 3.91- 3.72 (m, 6H), 2.19- 2.03 (m, 9H) .

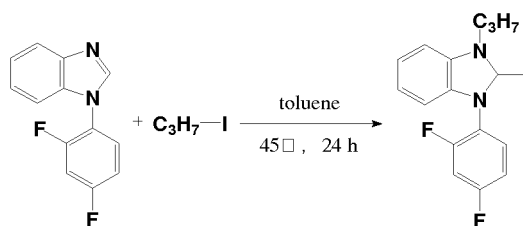
[0073] At a temperature of 77K in 2- methyl- tetrahydrofuran solution (~10⁻⁵mol/L), *fac*-Flr (pmb)₃ has a main emission peak at 377 nm in the emission spectrum and a shoulder peak at 397nm; the *mer*-Flr (pmb)₃ has a main emission peak at 379 nm and a shoulder peak at 399nm.

25 [0074] **Example 3:** the synthesis of tris (1 - (2,4 - di fluorophenyl) -3 - propyl - benzimidazole) iridium.

[0075] (1) the synthesis of 1 - (2, 4- di fluorophenyl)- 3- propyl benzimidazole iodide.

[0076] The synthesis of 1 - (2,4 - difluorophenyl) benzimidazole was identical to that in Example 1.

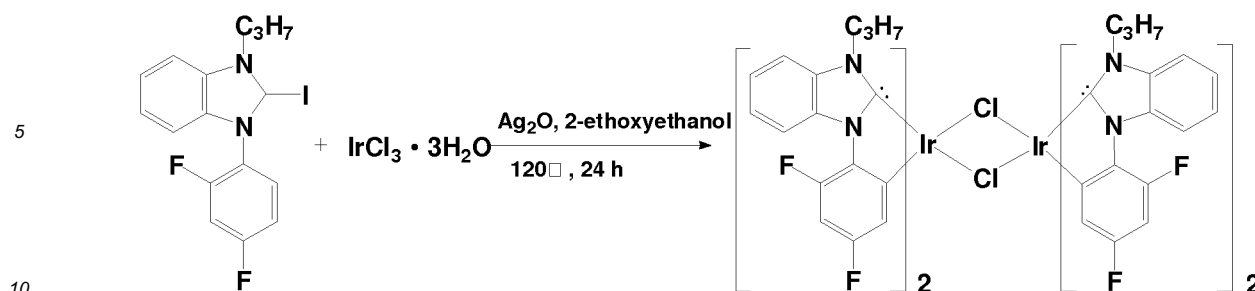
30 [0077] Under a protection of nitrogen, 1.50 g (8.830 mmol) of propyl iodide was added to an aluminum foil wrapped 25 mL round bottom flask containing 0.924 g (4.013 mmol) of 1 - (2,4 - di fluorophenyl) - benzimidazole, and 15 mL of toluene, the system was stirred at 45°C for 24 hours and white precipitate was generated; the precipitate was washed with 20 mL of toluene and dried to obtain 0.932g of white solid with yield of 58%. The detection data of the product is as follows: ¹H NMR (400 MHz, CDCl₃, ppm): 9.32 (s, 1H), 8.26-8.10 (m, 3H), 7.78-7.66 (m, 4H), 4.43 (m, 2H), 2.60-1.43 (m, 5H).



45 [0078] (2) The synthesis of bridge compound (Fpmb)₂Ir (μ- Cl)₂Ir (Fpmb)₂.

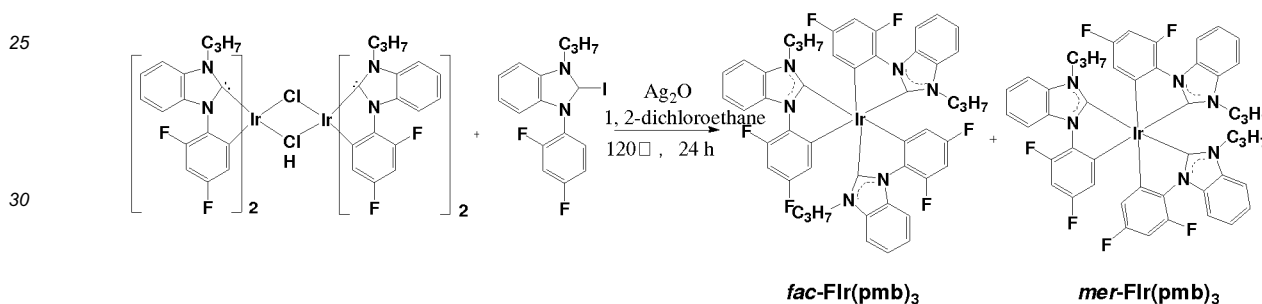
[0079] Under a protection of nitrogen, 8.00 g (20.0 mmol) of 1 - (2,4 - di fluorophenyl) -3 - propyl iodide, 5.56 g (24 mmol) of silver oxide (Ag₂O), 1.77 g (5 mmol) of trihydratediridium chloride and 50 mL of 2-ethoxyethanol were successively added into a 100ml round bottom flask wrapped by aluminum foil, the mixture was heated and stirred in oil bath at 120°C for 24 hours. After the mixture was cooled to room temperature, it was concentrated under reduced pressure.

50 The concentrate was then applied to silica gel column chromatography for 2 times using dichloromethane as eluent, and 0.609g of product in a form of slightly yellow solid was obtained with a yield of 15.8%. The detection data of the product is as follows: ¹H NMR (400 MHz, CDCl₃, ppm): 8.25 (s, 4H), 8.08 (d, 4H), 7.72 (d, 4H), 7.56 (m, 4H), 7.43 (m, 4H), 7.26 (d, 4H), 4.34 (m, 8H), 2.51-1.31 (m, 20H).



[0080] (3) The synthesis of final products *mer*-Flr(pmb)₃ and *fac*-Flr(pmb)₃.

[0081] Under a protection of nitrogen, 0.114 g (0.49 mmol) of silver oxide and 0.392 g (0.98 mmol) of 1-(2,4-difluorophenyl)-3-propyl iodide, 0.582 g (0.41 mmol) of bridge compound and 30 mL of 1,2-dichloroethane were successively added into a 50ml round bottom flask wrapped by aluminum foil, the mixture was heated and stirred in oil bath at 120°C for 24 hours. After the mixture was cooled to room temperature, it was concentrated under reduced pressure. The concentrate was then applied to silica gel column chromatography for 2 times using dichloromethane as eluent, and 0.79g of white solid was obtained with the total yield of 96%. The product was applied to silica gel column chromatography using a mixture solution containing ethyl acetate and n-hexane in a volume ratio of 20:80 as eluant, eluted repeatedly to obtain 0.50g of *mer*-Flr(pmb)₃ with a yield of 63%; the separation residual liquid was applied to silica gel column chromatography using a mixture solution containing ethyl acetate and n-hexane in a volume ratio of 2:3 as eluant, eluted repeatedly to obtain 0.174g of *fac*-Flr(pmb)₃ with a yield of 22%.



[0082] The detection data of the final product is as follows:

[0083] *fac*-Flr(pmb)₃:

[0084] ¹H NMR (400 MHz, CDCl₃, ppm) : 8.13 (s, 3H), 8.01 (d, 3H), 7.71 (m, 3H), 7.45 (m, 3H), 7.11 (d, 3H), 6.83 (d, 3H), 3.81 (m, 6H), 2.13-1.31 (m, 15H) .

[0085] *mer*-Flr(pmb)₃:

[0086] ¹H NMR (400 MHz, CDCl₃, ppm) : 8.21 (d, 1H), 8.16 (d, 1H), 8.11 (d, 1H), 7.85 (d, 1H), 7.82 (d, 1H), 7.75 (d, 1H), 7.45-6.51 (m, 12H), 3.27-3.20 (m, 6H), 2.19-0.98 (m, 15H) .

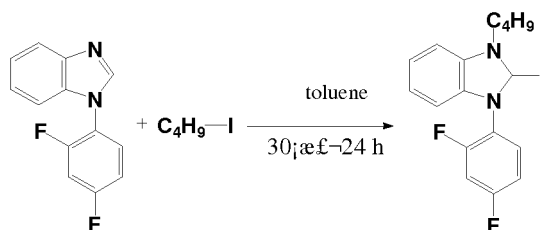
[0087] At a temperature of 77K in 2-methyl-tetrahydrofuran solution (~10⁻⁵mol/L), *fac*-Flr(pmb)₃ has a main emission peak at 377 nm in the emission spectrum and a shoulder peak at 397nm; the *mer*-Flr(pmb)₃ has a main emission peak at 379 nm and a shoulder peak at 399nm.

[0088] **Example 4:** the synthesis of tris (1-(2,4-difluorophenyl)-3-butyl-benzimidazole) iridium.

[0089] (1) the synthesis of 1-(2,4-difluorophenyl)-3-butyl benzimidazole iodide.

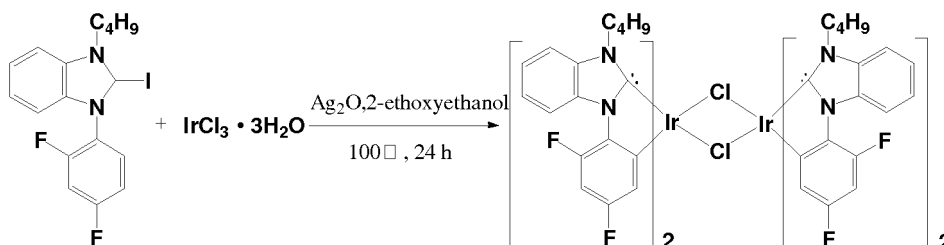
[0090] The synthesis of 1-(2,4-difluorophenyl) benzimidazole was identical to that in Example 1.

[0091] Under a protection of nitrogen, 1.625 g (8.830 mmol) of butyl iodide was added to an aluminum foil wrapped 25 mL round bottom flask containing 0.924 g (4.013 mmol) of 1-(2,4-difluorophenyl)-benzimidazole, and 15 mL of toluene, the system was stirred at 30°C for 24 hours and white precipitate was generated; the precipitate was washed with 20 mL of toluene and dried to obtain 0.931g of white solid with yield of 56%. The detection data of the product is as follows: ¹H NMR (400 MHz, CDCl₃, ppm): 9.30 (s, 1H), 8.23-8.07 (m, 3H), 7.76-7.64 (m, 3H), 4.44 (m, 2H), 1.23-2.62 (m, 7H).



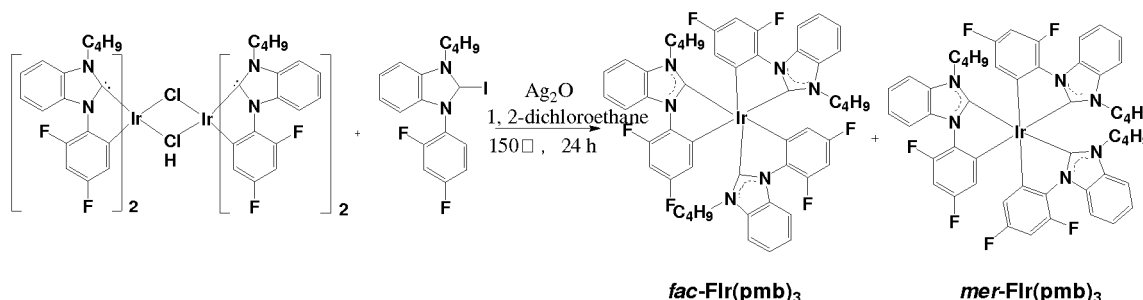
[0092] (2) The synthesis of bridge compound $(\text{Fpmb})_2\text{Ir}(\mu\text{-Cl})_2\text{Ir}(\text{Fpmb})_2$.

[0093] Under a protection of nitrogen, 8.25 g (20.0 mmol) of 1-(2,4-difluorophenyl)-3-butyl iodide, 5.56 g (24 mmol) of silver oxide (Ag_2O), 1.77 g (5 mmol) of trihydrated iridium chloride and 50 mL of 2-ethoxyethanol were successively added into a 100ml round bottom flask wrapped by aluminum foil, the mixture was heated and stirred in oil bath at 100°C for 24 hours. After the mixture was cooled to room temperature, it was concentrated under reduced pressure. The concentrate was then applied to silica gel column chromatography for 2 times using dichloromethane as eluent, and 0.627g of product in a form of slightly yellow solid was obtained with a yield of 15.7%. The detection data of the product is as follows: ^1H NMR (400 MHz, CDCl_3 , ppm): 8.22 (s, 4H), 7.95 (d, 4H), 7.70 (d, 4H), 7.46 (m, 4H), 7.34 (m, 4H), 7.21 (d, 4H), 4.25 (m, 8H), 2.42-1.21 (m, 28H).



[0094] (3) The synthesis of final products *mer*- $\text{Flr}(\text{pmb})_3$ and *fac*- $\text{Flr}(\text{pmb})_3$.

[0095] Under a protection of nitrogen, 0.114 g (0.49 mmol) of silver oxide and 0.406 g (0.98 mmol) of 1-(2,4-difluorophenyl)-3-butyl iodide, 0.582 g (0.41 mmol) of bridge compound and 30 mL of 1,2-dichloroethane were successively added into a 50ml round bottom flask wrapped by aluminum foil, the mixture was heated and stirred in oil bath at 150°C for 24 hours. After the mixture was cooled to room temperature, it was concentrated under reduced pressure. The concentrate was then applied to silica gel column chromatography for 2 times using dichloromethane as eluent, and 0.84g of white solid was obtained with the total yield of 98%. The product was applied to silica gel column chromatography using a mixture solution containing ethyl acetate and n-hexane in a volume ratio of 20:80 as eluent, eluted repeatedly to obtain 0.551g of *mer*- $\text{Flr}(\text{pmb})_3$ with a yield of 64%; the separation residual liquid was applied to silica gel column chromatography using a mixture solution containing ethyl acetate and n-hexane in a volume ratio of 40:60 as eluant, eluted repeatedly to obtain 0.181g of *fac*- $\text{Flr}(\text{pmb})_3$ with a yield of 21%.



[0096] The detection data of the final product is as follows:

[0097] *fac*- $\text{Flr}(\text{pmb})_3$:

[0098] ^1H NMR (400 MHz, CDCl_3 , ppm) : 8.11 (s, 3H), 7.96 (d, 3H), 7.68 (m, 3H), 7.36 (m, 3H), 7.03 (d, 3H), 6.78 (d, 3H), 3.71 (m, 6H), 2.11-0.98 (m, 21H) .

[0099] *mer*- $\text{Flr}(\text{pmb})_3$:

[0100] ^1H NMR (400 MHz, CDCl_3 , ppm) : 8.21 (d, 1H), 8.14 (d, 1H), 8.02 (d, 1H), 7.81 (d, 1H), 7.77 (d, 1H), 7.67 (d, 1H), 7.44-6.53 (m, 12H), 3.27-3.11 (m, 6H), 2.19-0.97 (m, 21H) .

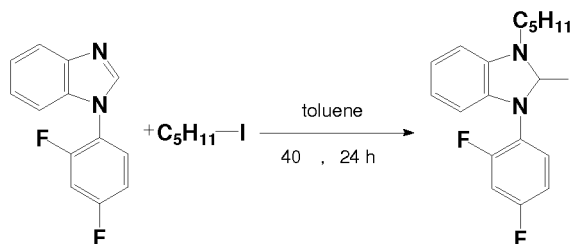
[0101] At a temperature of 77K in 2-methyl-tetrahydrofuran solution ($\sim 10^{-5}$ mol/L), *fac*-Flr (pmb)₃ has a main emission peak at 378 nm in the emission spectrum and a shoulder peak at 398 nm; the *mer*-Flr (pmb)₃ has a main emission peak at 379 nm and a shoulder peak at 399 nm.

[0102] **Example 5:** the synthesis of tris(1-(2,4-difluorophenyl)-3-pentylbenzimidazole) iridium.

[0103] (1) the synthesis of 1-(2,4-difluorophenyl)-3-pentylchroman iodide.

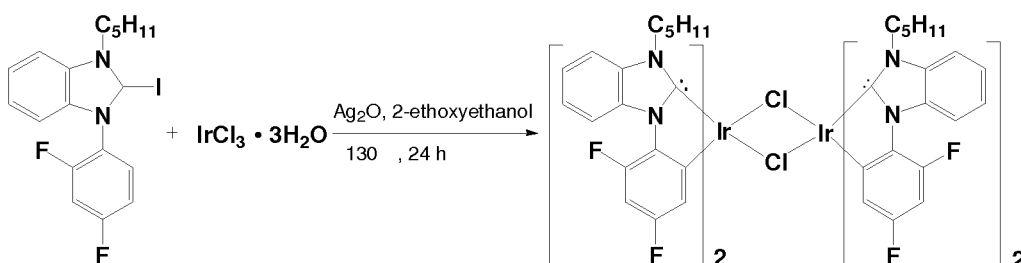
[0104] The synthesis of 1-(2,4-difluorophenyl)benzimidazole was identical to that in Example 1.

[0105] Under a protection of nitrogen, 1.748 g (8.830 mmol) of iodopentane was added to an aluminum foil wrapped 25 mL round bottom flask containing 0.924 g (4.013 mmol) of 1-(2,4-difluorophenyl)-benzimidazole, and 15 mL of toluene, the system was stirred at 40°C for 24 hours and white precipitate was generated; the precipitate was washed with 20 mL of toluene and dried to obtain 0.882 g of white solid with yield of 59%. The detection data of the product is as follows: ¹H NMR (400 MHz, CDCl₃, ppm): 9.30 (s, 1H), 8.21-7.97 (m, 3H), 7.75-7.63 (m, 3H), 4.43 (m, 3H), 1.16-2.45 (m, 9H).



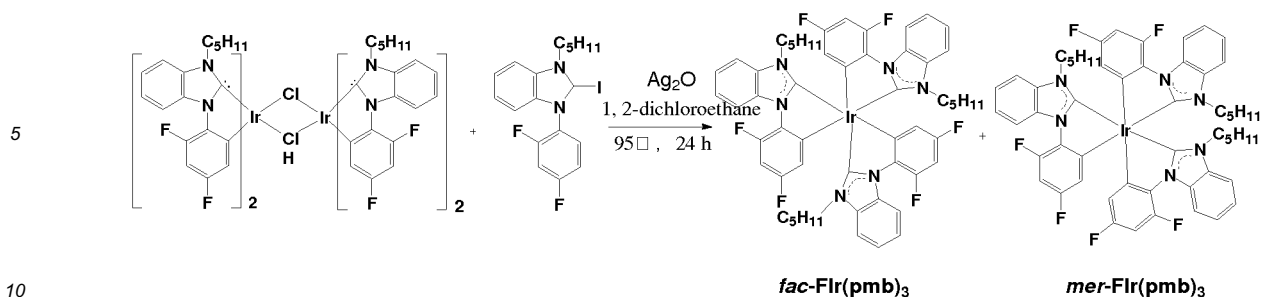
[0106] (2) The synthesis of bridge compound (Fpmb)₂Ir (μ-Cl)₂Ir (Fpmb)₂.

[0107] Under a protection of nitrogen, 8.27 g (20.0 mmol) of 1-(2,4-difluorophenyl)-3-pentylchroman iodide, 5.56 g (24 mmol) of silver oxide (Ag₂O), 1.77 g (5 mmol) of trihydrated iridium chloride and 50 mL of 2-ethoxyethanol were successively added into a 100 mL round bottom flask wrapped by aluminum foil, the mixture was heated and stirred in oil bath at 130°C for 24 hours. After the mixture was cooled to room temperature, it was concentrated under reduced pressure. The concentrate was then applied to silica gel column chromatography for 2 times using dichloromethane as eluent, and 0.64 g of product in a form of slightly yellow solid was obtained with a yield of 15.5%. The detection data of the product is as follows: ¹H NMR (400 MHz, CDCl₃, ppm): 8.18 (s, 4H), 7.91 (d, 4H), 7.68 (d, 4H), 7.43 (m, 4H), 7.30 (m, 4H), 7.14 (d, 4H), 4.21 (m, 8H), 2.38-0.97 (m, 36H).



[0108] (3) The synthesis of final products *mer*-Flr (pmb)₃ and *fac*-Flr (pmb)₃.

[0109] Under a protection of nitrogen, 0.114 g (0.49 mmol) of silver oxide and 0.42 g (0.98 mmol) of 1-(2,4-difluorophenyl)-3-pentylchroman iodide, 0.582 g (0.41 mmol) of bridge compound and 30 mL of 1,2-dichloroethane were successively added into a 50 mL round bottom flask wrapped by aluminum foil, the mixture was heated and stirred in oil bath at 95°C for 24 hours. After the mixture was cooled to room temperature, it was concentrated under reduced pressure. The concentrate was then applied to silica gel column chromatography for 2 times using dichloromethane as eluent, and 0.85 g of white solid was obtained with the total yield of 95%. The product was applied to silica gel column chromatography using a mixture solution containing ethyl acetate and n-hexane in a volume ratio of 20:80 as eluent, eluted repeatedly to obtain 0.564 g of *mer*-Flr (pmb)₃ with a yield of 63%; the separation residual liquid was applied to silica gel column chromatography using a mixture solution containing ethyl acetate and n-hexane in a volume ratio of 2:3 as eluent, eluted repeatedly to obtain 0.162 g of *fac*-Flr (pmb)₃ with a yield of 19%.



[0110] The detection data of the final product is as follows:

[0111] *fac*-FIr(pmb)₃:

[0112] ¹H NMR (400 MHz, CDCl₃, ppm) : 8.11 (s, 3H), 7.94 (d, 3H), 7.68 (m, 3H), 7.23 (m, 3H), 6.97 (d, 3H), 6.65 (d, 3H), 3.70 (m, 6H), 2.13- 0.98 (m, 27H) .

[0113] *mer*-FIr(pmb)₃:

[0114] ¹H NMR (400 MHz, CDCl₃, ppm) : 8.21 (d, 1H), 8.13 (d, 1H), 8.01 (d, 1H), 7.80 (d, 1H), 7.71 (d, 1H), 7.61 (d, 1H), 7.45- 6.51 (m, 12H), 3.20- 3.11 (m, 6H), 2.19- 0.98 (m, 27H) .

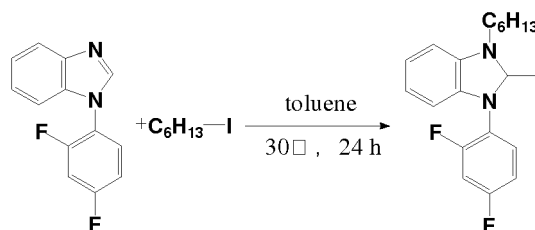
[0115] At a temperature of 77K in 2- methyl- tetrahydrofuran solution (~10⁻⁵mol/L), *fac*-FIr(pmb)₃ has a main emission peak at 379 nm in the emission spectrum and a shoulder peak at 399nm; the *mer*-FIr(pmb)₃ has a main emission peak at 380 nm and a shoulder peak at 400nm.

[0116] **Example 6:** the synthesis of tris (1 - (2,4 - difluorophenyl-yl) -3 - hexyl - benzimidazole) iridium.

[0117] (1) the synthesis of 1- (2, 4- di fluorophenyl)- 3- methylbenzimidazole iodide.

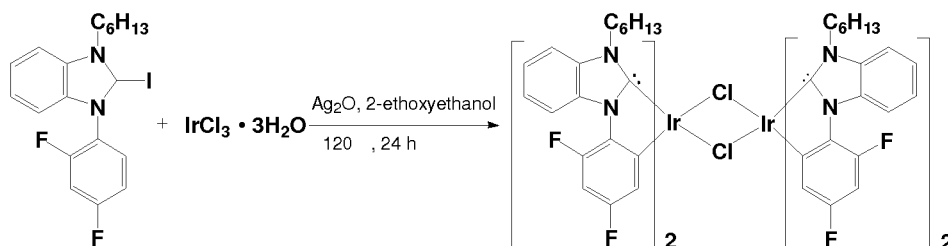
[0118] The synthesis of 1 - (2,4 - difluorophenyl) benzimidazole was identical to that in Example 1.

[0119] Under a protection of nitrogen, 1.871 g (8.830 mmol) of iodoheptane was added to an aluminum foil wrapped 25 mL round bottom flask containing 0.924 g (4.013 mmol) of 1 - (2,4 - di fluorophenyl) - benzimidazole, and 15 mL of toluene, the system was stirred at 30°C for 24 hours and white precipitate was generated; the precipitate was washed with 20 mL of toluene and dried to obtain 0.882g white solid with yield of 59%. The detection data of the product is as follows: ¹H NMR (400 MHz, CDCl₃, ppm): 9.31 (s, 1H), 8.21-7.96 (m, 3H), 7.72-7.61 (m, 3H), 4.41 (m, 3H), 1.12-2.36 (m, 11H).



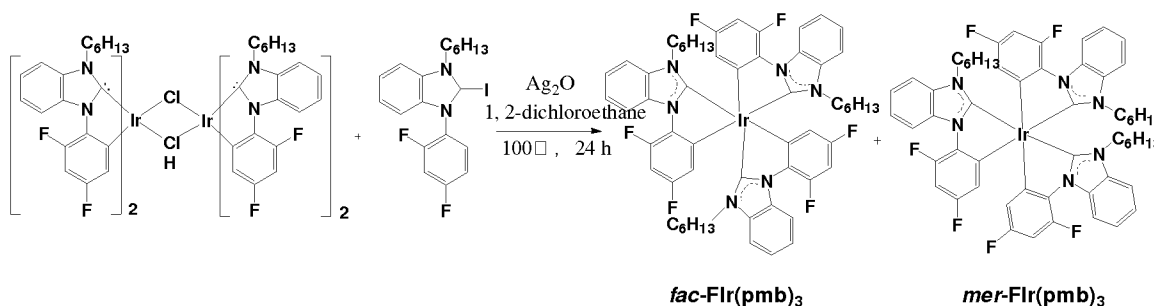
[0120] (2) The synthesis of bridge compound (Fpmb)₂Ir(μ-Cl)₂Ir(Fpmb)₂.

[0121] Under a protection of nitrogen, 8.85 g (20.0 mmol) of 1- (2, 4- di fluorophenyl)- 3- hexylbenzotriazole iodide, 5.56 g (24 mmol) of silver oxide (Ag₂O), 1.77 g (5 mmol) of trihydratediridium chloride and 50 mL of 2- ethoxyethanol were successively added into a 100ml round bottom flask wrapped by aluminum foil, the mixture was heated and stirred in oil bath at 120°C for 24 hours. After the mixture was cooled to room temperature, it was concentrated under reduced pressure. The concentrate was then applied to silica gel column chromatography for 2 times using dichloromethane as eluent, and 0.662g of product in a form of slightly yellow solid was obtained with a yield of 15.8%. The detection data of the product is as follows: ¹H NMR (400 MHz, CDCl₃, ppm) : 8.17 (s, 4H), 7.84 (d, 4H), 7.55 (d, 4H), 7.36 (m, 4H), 7.23 (m, 4H), 7.05 (d, 4H), 4.13 (m, 8H), 2.21- 0.98 (m, 44H) .



[0122] (3) The synthesis of final products *mer*-Flr (pmb)₃ and *fac*-Flr (pmb)₃.

[0123] Under a protection of nitrogen, 0.114 g (0.49 mmol) of silver oxide and 0.433 g (0.98 mmol) of 1- (2, 4- di fluorophenyl)- 3- hexylbenzotriazole iodide, 0.582 g (0.41 mmol) of bridge compound and 30 mL of 1, 2- dichloroethane were successively added into a 50ml round bottom flask wrapped by aluminum foil, the mixture was heated and stirred in oil bath at 100°C for 24 hours. After the mixture was cooled to room temperature, it was concentrated under reduced pressure. The concentrate was then applied to silica gel column chromatography for 2 times using dichloromethane as eluent, and 0.864g of white solid was obtained with the total yield of 93%. The product was applied to silica gel column chromatography using a mixture solution containing ethyl acetate and n- hexane in a volume ratio of 20: 80 as eluant, eluted repeatedly to obtain 0.604g of *mer*- Flr (pmb)₃ with a yield of 65%; the separation residual liquid was applied to silica gel column chromatography using a mixture solution containing ethyl acetate and n- hexane in a volume ratio of 2: 3 as eluant, eluted repeatedly to obtain 0.186g of *fac*- Flr (pmb)₃ with a yield of 20%.



[0124] The detection data of the final product is as follows:

[0125] *fac*- Flr (pmb)₃:

[0126] ¹H NMR (400 MHz, CDCl₃, ppm) : 8.10 (s, 3H), 7.88 (d, 3H), 7.70 (m, 3H), 7.24 (m, 3H), 6.87 (d, 3H), 6.65 (d, 3H), 3.71 (m, 6H), 2.15- 0.98 (m, 33H) .

[0127] *mer*- Flr (pmb)₃:

[0128] ¹H NMR (400 MHz, CDCl₃, ppm) : 8.19 (d, 1H), 8.17 (d, 1H), 8.08 (d, 1H), 7.85 (d, 1H), 7.81 (d, 1H), 7.68 (d, 1H), 7.44- 6.52 (m, 12H), 3.20- 3.12 (m, 6H), 2.16- 0.98 (m, 33H) .

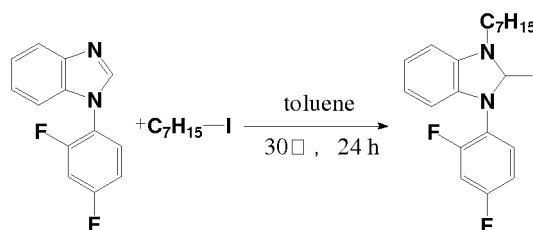
[0129] At a temperature of 77K in 2- methyl- tetrahydrofuran solution (~10⁻⁵mol/L), *fac*- Flr (pmb)₃ has a main emission peak at 379 nm in the emission spectrum and a shoulder peak at 399nm; the *mer*- Flr (pmb)₃ has a main emission peak at 381 nm and a shoulder peak at 401nm.

[0130] **Example 7:** the synthesis of tris (1 - (2,4 - di fluorophenyl) -3 - heptyl - benzimidazole) iridium.

[0131] (1) the synthesis of 1- (2, 4- di fluorophenyl)- 3- heptylphenoxy iodide.

[0132] The synthesis of 1 - (2,4 - difluorophenyl) benzimidazole was identical to that in Example 1.

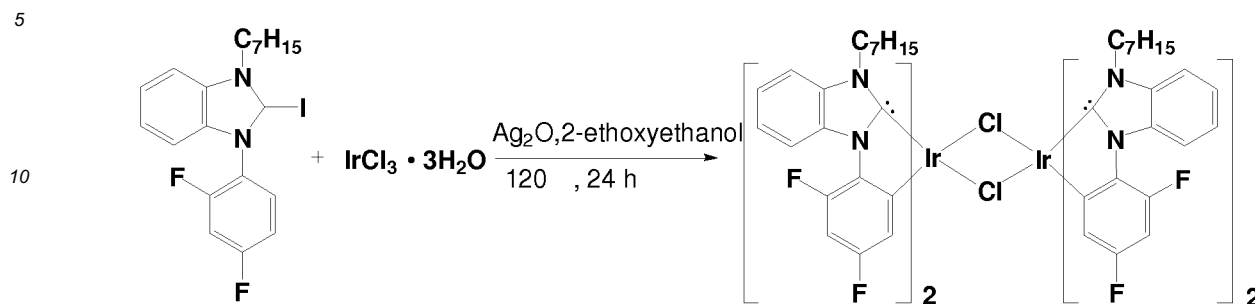
[0133] Under a protection of nitrogen, 1.994 g (8.830 mmol) of iodoheptane was added to an aluminum foil wrapped 25 mL round bottom flask containing 0.924 g (4.013 mmol) of 1 - (2,4 - di fluorophenyl) - benzimidazole, and 15 mL of toluene, the system was stirred at 30°C for 24 hours and white precipitate was generated; the precipitate was washed with 20 mL of toluene and dried to obtain 0.882g of white solid with yield of 59%. The detection data of the product is as follows: ¹H NMR (400 MHz, CDCl₃, ppm): 9.29 (s, 1H), 8.21-7.94 (m, 3H), 7.71-7.60 (m, 3H), 4.40 (m, 3H), 1.08-2.24 (m, 13H).



[0134] (2) The synthesis of bridge compound (Fpmb)₂Ir (μ- Cl)₂Ir (Fpmb)₂.

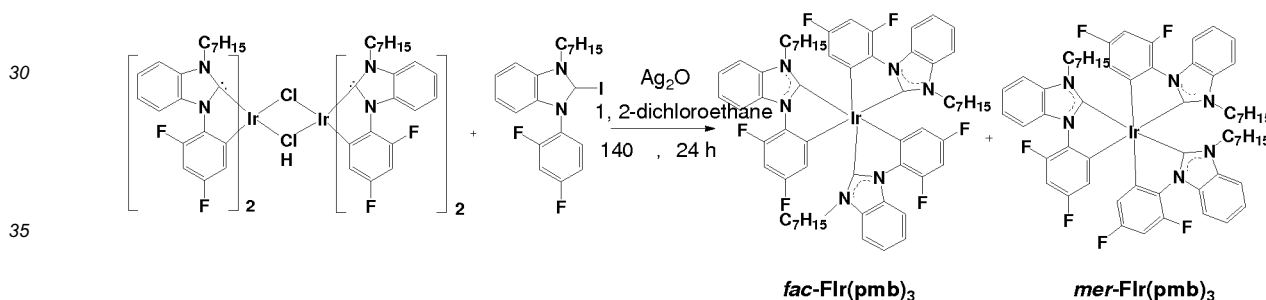
[0135] Under a protection of nitrogen, 9.13 g (20.0 mmol) of 1 - (2,4 - di fluorophenyl) -3 - heptylphenoxy iodide, 5.56 g (24 mmol) of silver oxide (Ag₂O), 1.77 g (5 mmol) of trihydrediridium chloride and 50 mL of 2-ethoxyethanol were successively added into a 100ml round bottom flask wrapped by aluminum foil, the mixture was heated and stirred in oil bath at 120°C for 24 hours. After the mixture was cooled to room temperature, it was concentrated under reduced pressure. The concentrate was then applied to silica gel column chromatography for 2 times using dichloromethane as

eluent, and 0.666g of product in a form of slightly yellow solid was obtained with a yield of 15.1%. The detection data of the product is as follows: ^1H NMR (400 MHz, CDCl_3 , ppm): 8.15 (s, 4H), 7.81 (d, 4H), 7.54 (d, 4H), 7.31 (m, 4H), 7.22 (m, 4H), 6.98 (d, 4H), 4.01 (m, 8H), 2.14-0.89 (m, 52H).



[0136] (3) The synthesis of final products *mer*-Flr (pmb)₃ and *fac*-Flr (pmb)₃.

[0137] Under a protection of nitrogen, 0.114 g (0.49 mmol) of silver oxide and 0.447 g (0.98 mmol) of 1- (2, 4- di fluorophenyl)- 3- heptylphenoxy iodide, 0.582 g (0.41 mmol) of bridge compound and 30 mL of 1, 2- dichloroethane were successively added into a 50ml round bottom flask wrapped by aluminum foil, the mixture was heated and stirred in oil bath at 140°C for 24 hours. After the mixture was cooled to room temperature, it was concentrated under reduced pressure. The concentrate was then applied to silica gel column chromatography for 2 times using dichloromethane as eluent, and 0.887g of white solid was obtained with the total yield of 92%. The product was applied to silica gel column chromatography using a mixture solution containing ethyl acetate and n- hexane in a volume ratio of 20: 80 as eluant, eluted repeatedly to obtain 0.578g of *mer*- Flr (pmb)₃ with a yield of 60%; the separation residual liquid was applied to silica gel column chromatography using a mixture solution containing ethyl acetate and n- hexane in a volume ratio of 2: 3 as eluant, eluted repeatedly to obtain 0.202g of *fac*- Flr (pmb)₃ with a yield of 21 %.



[0138] The detection data of the final product is as follows:

[0139] *fac*- Flr (pmb)₃:

[0140] ^1H NMR (400 MHz, CDCl_3 , ppm) : 8.09 (s, 3H), 7.87 (d, 3H), 7.66 (m, 3H), 7.25 (m, 3H), 6.86 (d, 3H), 6.67 (d, 3H), 3.73 (m, 6H), 2.14- 0.97 (m, 39H) . (B) *mer*- Flr (pmb)₃:

[0141] ^1H NMR (400 MHz, CDCl_3 , ppm) : 8.15 (d, 1H), 8.08 (d, 1H), 7.97 (d, 1H), 7.76 (d, 1H), 7.71 (d, 1H), 7.62 (d, 1H), 7.45- 6.51 (m, 12H), 3.20- 3.01 (m, 6H), 2.11- 0.98 (m, 39H) .

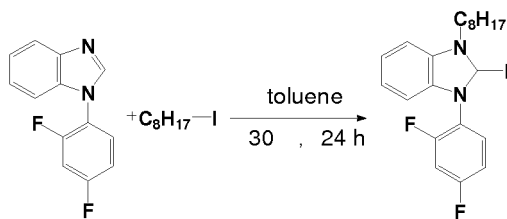
[0142] At a temperature of 77K in 2- methyl- tetrahydrofuran solution ($\sim 10^{-5}$ mol/L), *fac*- Flr (pmb)₃ has a main emission peak at 379 nm in the emission spectrum and a shoulder peak at 399nm; the *mer*- Flr (pmb)₃ has a main emission peak at 382 nm and a shoulder peak at 402nm.

[0143] **Example 8:** the synthesis of tris(1 - (2,4 - di fluorophenyl) -3 - octyl - benzimidazole) iridium.

[0144] (1) the synthesis of 1- (2, 4- di fluorophenyl)- 3- octyl benzimidazol iodide.

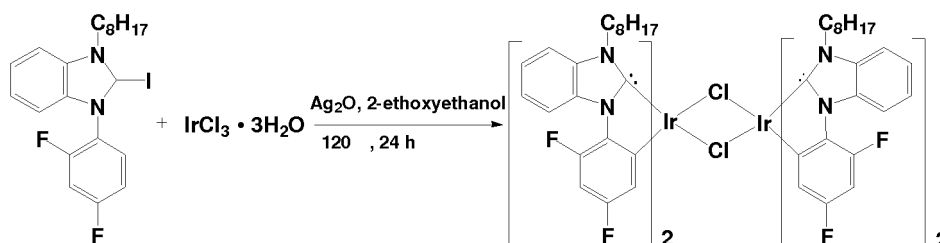
[0145] The synthesis of 1 - (2,4 - difluorophenyl) benzimidazole was identical to that in Example 1.

[0146] Under a protection of nitrogen, 2.117 g (8.830 mmol) of iodo-octane was added to an aluminum foil wrapped 25 mL round bottom flask containing 0.924 g (4.013 mmol) of 1 - (2,4 - di fluorophenyl) - benzimidazole, and 15 mL of toluene, the system was stirred at 30°C for 24 hours and white precipitate was generated; the precipitate was washed with 20 mL of toluene and dried to obtain 0.882g of white solid with yield of 59%. The detection data of the product is as follows: ^1H NMR (400 MHz, CDCl_3 , ppm): 9.28 (s, 1H), 8.17-7.90 (m, 3H), 7.71-7.62 (m, 3H), 4.39 (s, 3H), 1.05-2.18 (m, 15H).



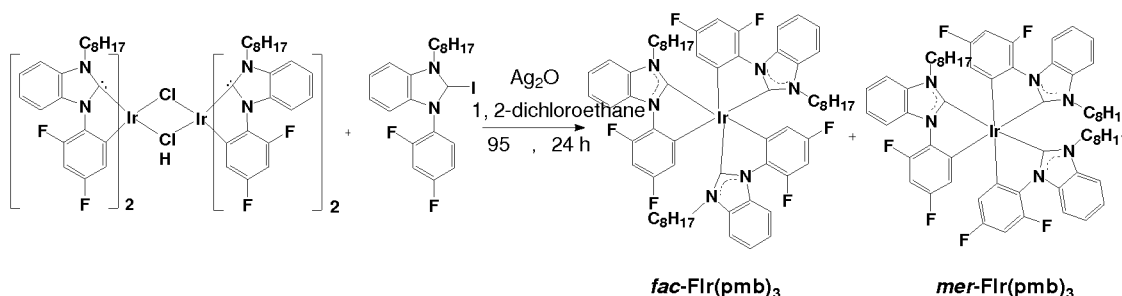
[0147] (2) The synthesis of bridge compound $(\text{Fpmb})_2\text{Ir}(\mu\text{-Cl})_2\text{Ir}(\text{Fpmb})_2$.

[0148] Under a protection of nitrogen, 9.41 g (20.0 mmol) of 1-(2,4-difluorophenyl)-3-octyl iodide, 5.56 g (24 mmol) of silver oxide (Ag_2O), 1.77 g (5 mmol) of trihydrated iridium chloride and 50 mL of 2-ethoxyethanol were successively added into a 100 mL round bottom flask wrapped by aluminum foil, the mixture was heated and stirred in oil bath at 120 °C for 24 hours. After the mixture was cooled to room temperature, it was concentrated under reduced pressure. The concentrate was then applied to silica gel column chromatography for 2 times using dichloromethane as eluent, and 0.692 g of product in a form of slightly yellow solid was obtained with a yield of 15.2%. The detection data of the product is as follows: ^1H NMR (400 MHz, CDCl_3 , ppm): 8.14 (s, 4H), 7.76 (d, 4H), 7.51 (d, 4H), 7.31 (m, 4H), 7.21 (m, 4H), 6.87 (d, 4H), 3.91 (m, 8H), 2.12-0.89 (m, 60H).



[0149] (3) The synthesis of final products *mer*- $\text{Flr}(\text{pmb})_3$ and *fac*- $\text{Flr}(\text{pmb})_3$.

[0150] Under a protection of nitrogen, 0.114 g (0.49 mmol) of silver oxide and 0.461 g (0.98 mmol) of 1-(2,4-difluorophenyl)-3-octyl iodide, 0.582 g (0.41 mmol) of bridge compound and 30 mL of 1,2-dichloroethane were successively added into a 50 mL round bottom flask wrapped by aluminum foil, the mixture was heated and stirred in oil bath at 95 °C for 24 hours. After the mixture was cooled to room temperature, it was concentrated under reduced pressure. The concentrate was then applied to silica gel column chromatography for 2 times using dichloromethane as eluent, and 0.908 g of white solid was obtained with the total yield of 91%. The product was applied to silica gel column chromatography using a mixture solution containing ethyl acetate and n-hexane in a volume ratio of 20:80 as eluent, eluted repeatedly to obtain 0.589 g of *mer*- $\text{Flr}(\text{pmb})_3$ with a yield of 59%; the separation residual liquid was applied to silica gel column chromatography using a mixture solution containing ethyl acetate and n-hexane in a volume ratio of 2:3 as eluent, eluted repeatedly to obtain 0.18 g of *fac*- $\text{Flr}(\text{pmb})_3$ with a yield of 18%.



[0151] The detection data of the final product is as follows:

[0152] *fac*- $\text{Flr}(\text{pmb})_3$:

[0153] ^1H NMR (400 MHz, CDCl_3 , ppm): 8.02 (s, 3H), 7.86 (d, 3H), 7.64 (m, 3H), 7.25 (m, 3H), 6.84 (d, 3H), 6.61 (d, 3H), 3.51 (m, 6H), 2.15-0.96 (m, 45H).

[0154] *mer*- $\text{Flr}(\text{pmb})_3$:

[0155] ^1H NMR (400 MHz, CDCl_3 , ppm): 8.15 (d, 1H), 8.13 (d, 1H), 8.05 (d, 1H), 7.75 (d, 1H), 7.67 (d, 1H), 7.58 (d, 1H), 7.41-6.53 (m, 12H), 3.20-3.02 (m, 6H), 2.19-0.96 (m, 45H).

[0156] At a temperature of 77K in 2-methyl-tetrahydrofuran solution ($\sim 10^{-5}$ mol/L), *fac*-Flr (pmb)₃ has a main emission peak at 380 nm in the emission spectrum and a shoulder peak at 400 nm. *mer*-Flr (pmb)₃ has a main emission peak at 382 nm and a shoulder peak at 402 nm.

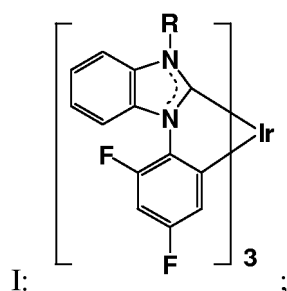
[0157] (4) The structure of an organic electroluminescent element is shown in FIG. 3 using Flr (pmb)₃ of the present embodiment as a doped object in the light-emitting layer.

[0158] The element includes ITO/Flr (pmb)₃/LiF/Al, i.e. it is formed by depositing indium tin oxide (ITO) on a glass substrate with a sheet resistance of 10-20 Ω /sq as a transparent anode; preparing a Flr (pmb)₃ of the present embodiment on the ITO as a light-emitting layer by spin coating technique; and then vacuum depositing LiF on the light-emitting layer as a buffer layer; and finally depositing metal Al on the buffer layer using vacuum coating technology as a cathode of the element. Since the light-emitting layer containing an iridium-containing organic electroluminescent material has high internal quantum efficiency and the electroluminescent efficiency, the electroluminescent element has a high energy conversion efficiency and luminous efficiency.

[0159] Although the invention has been described in language specific to structural features and/or methodological acts, it is to be understood that the invention defined in the appended claims is not necessarily limited to the specific features or acts described. Rather, the specific features and acts are disclosed as sample forms of implementing the claimed invention.

Claims

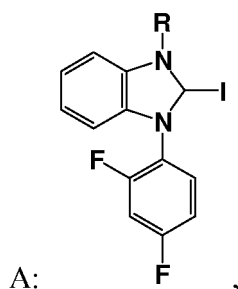
1. An iridium containing organic electroluminescent material, represented by the following formula I:



wherein R is C₁-C₈ alkyl.

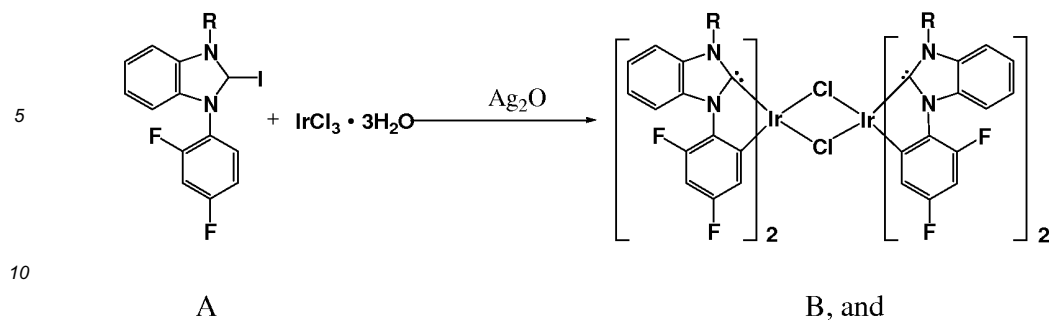
2. A preparation method of an iridium containing organic electroluminescent material, comprising the following steps:

step one: preparing a compound A represented by the following formula:

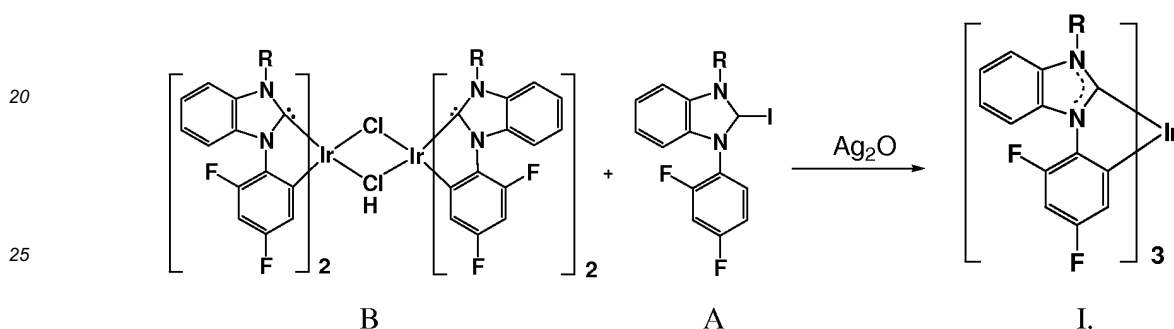


wherein R is C₁-C₈ alkyl;

step two: performing reaction between compound A and trihydrate iridium trichloride in a solvent under an anaerobic condition in presence of Ag₂O catalyst to obtain a bridge compound B; the reaction equation being:

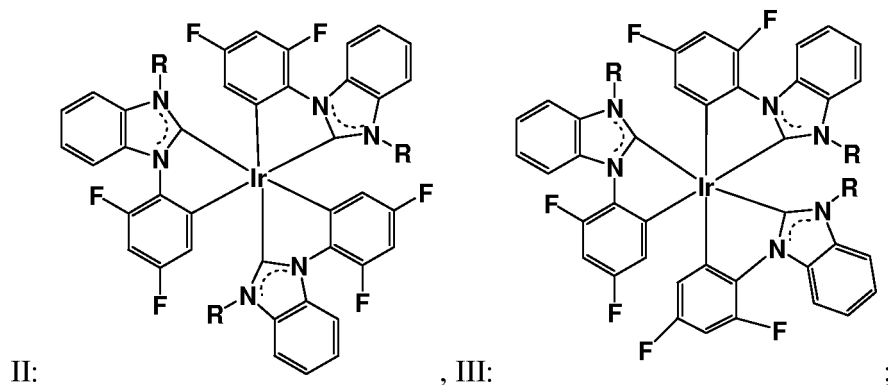


step three: performing ligands interchange reaction between bridge compound B and compound A in a solvent under an anaerobic condition in presence of Ag_2O catalyst to obtain the compound I; the reaction equation being:



3. The preparation method according to claim 2, wherein the solvent in step two is 2-ethoxyethanol, and the reaction temperature is from 100°C to 150°C; the solvent in step three is 1, 2-dichloroethane, and the reaction temperature is from 90°C to 150°C.
4. The preparation method according to claim 2, wherein the step two further comprises separation and purification steps: an obtained mixture after the reaction between compound A and iridium trichloride trihydrate is firstly concentrated under reduced pressure; the concentrate is then applied to silica gel column chromatography for 2 to 3 times using dichloromethane as eluent, and the purified compound B is obtained.
5. The preparation method according to claim 2, wherein the step three further comprises separation and purification steps:

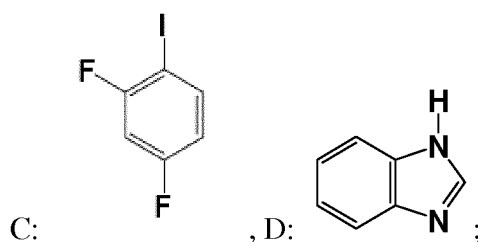
firstly, the reaction product containing the compound I is concentrated under reduced pressure to obtain a concentrated product containing compound I;
then, the concentrated product is applied to silica gel column chromatography using dichloromethane as eluent to obtain a solid mixture containing isomer II and isomer III;



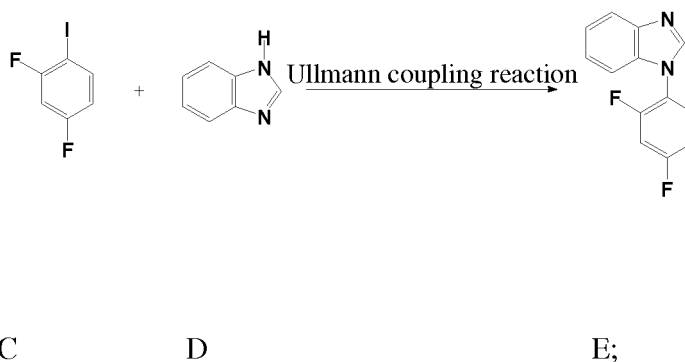
the solid mixture is applied to silica gel column chromatography using a mixture solution containing ethyl acetate and n-hexane in a volume ratio of 1:4 as eluant to obtain a purified compound III and separation residual liquid; finally, the separation residual liquid is applied to silica gel column chromatography using a mixture solution containing ethyl acetate and n-hexane in a volume ratio of 2:3 as eluant to obtain purified compound II.

6. The preparation method according to claim 2, wherein a preparation method of the compound A comprises the following steps:

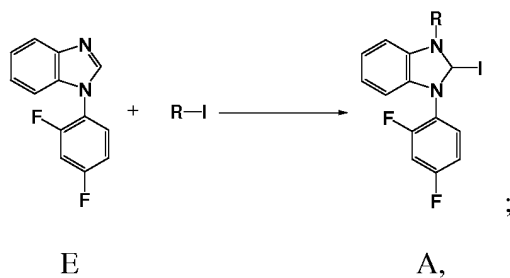
step one, providing compound C and D represented by the following formulas,



step two, performing Ullmann coupling reaction between the compound C and the compound D under anaerobic condition in presence of catalyst to obtain compound E, the reaction equation being:

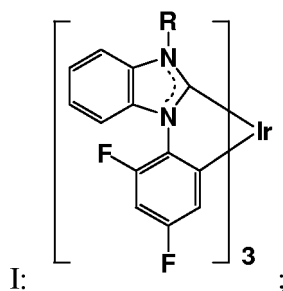


step three, reacting the compound E with an alkyl iodide in a solvent to obtain the compound A, the reaction equation being:



Wherein R-I is alkyl iodide, R is C₁-C₈ alkyl.

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7. The preparation method according to claim 6, wherein in step two the reaction temperature of the Ullmann coupling reaction is from 100°C to 180°C, the catalyst is a mixed catalyst composed of copper iodide, 1, 10-phenanthroline and cesium carbonate, the solvent is N, N-dimethylformamide; the solvent in step three is toluene, the reaction temperature is from 25°C to 45°C.
- 20
8. The preparation method according to claim 6, wherein the step two further comprises steps of separation and purification of compound E: an obtained mixture of the Ullmann coupling reaction is vacuum concentrated; ethyl acetate solution was added to the concentrate to produce a precipitate; the precipitate is separated by filtration and is washed with ethyl acetate, and the filtrate was collected; the filtrate is finally concentrated and is applied to silica gel column chromatography using a mixture solution containing ethyl acetate and n-hexane in a volume ratio of 2: 3 as eluant, and the purified compound E is obtained.
- 25
9. The preparation method according to claim 6, wherein the step three further comprises steps of separation and purification of compound A: the crude reaction product of step three is filtrated, the filtrated precipitate is washed with toluene and dried to obtain the purified compound A.
- 30
10. An organic electroluminescent element, comprising a light emitting layer, wherein the light emitting layer contains the compound I represented by the following formula I:



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wherein R is C₁-C₈ alkyl.

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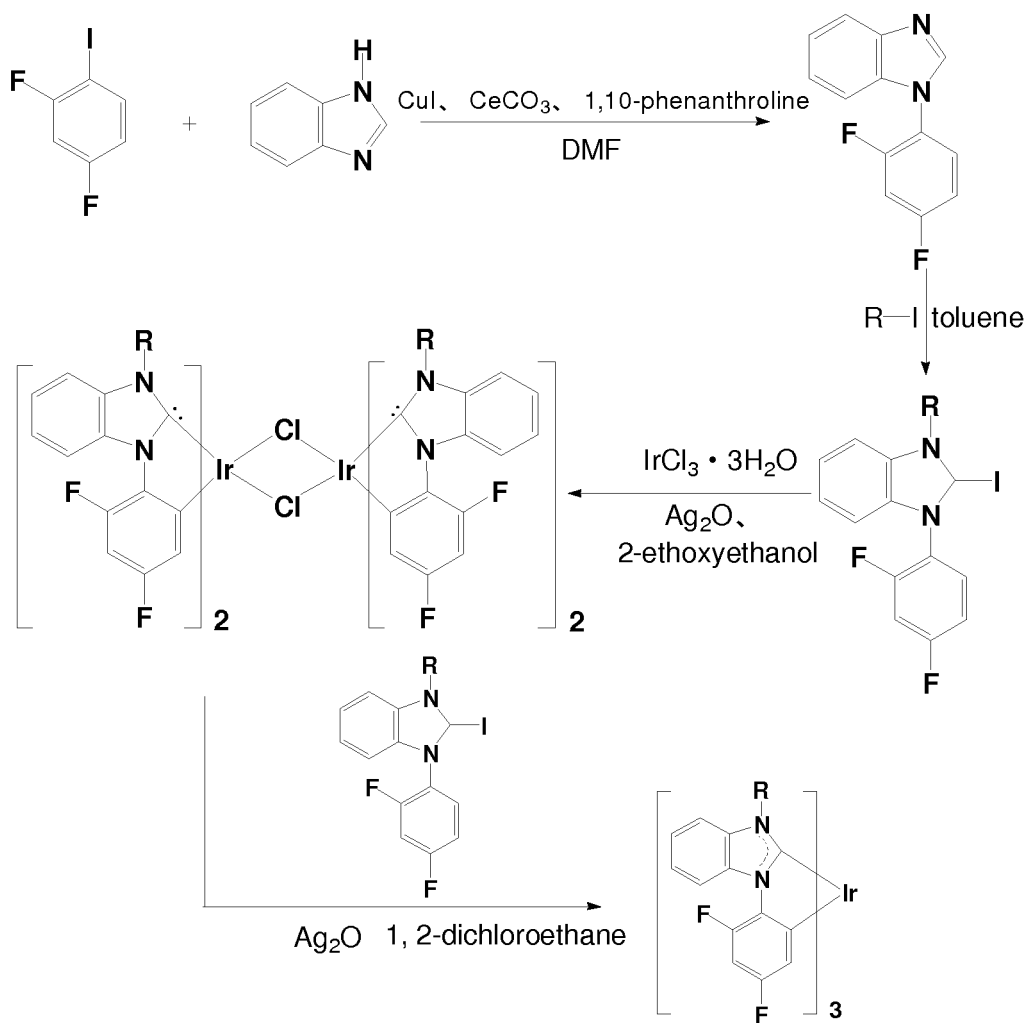


FIG. 1

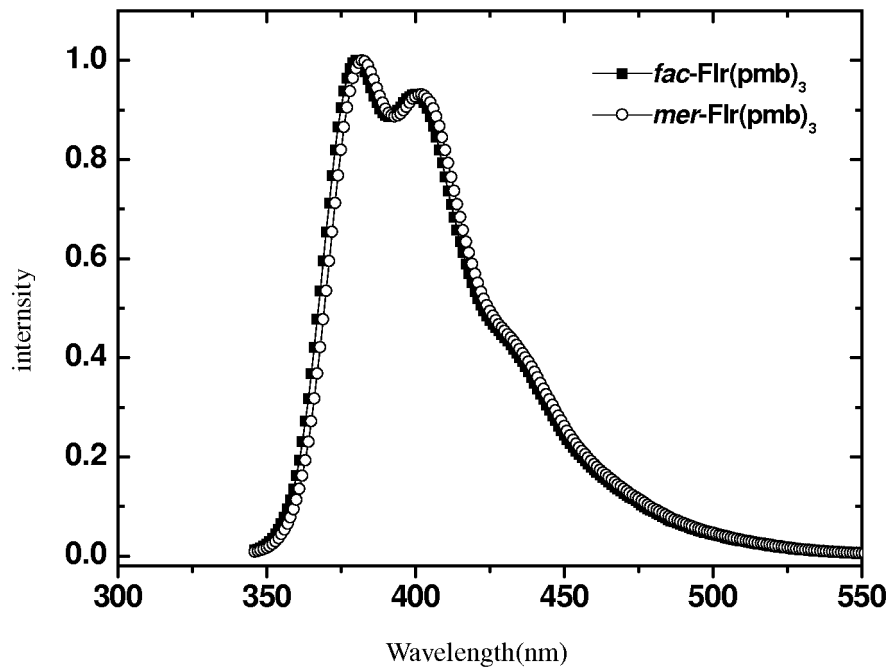


FIG. 2

Al
Buffer layer
Light emitting layer
ITO
glass

FIG. 3

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2010/079147

A. CLASSIFICATION OF SUBJECT MATTER

C09K11/06 (2006.01) i

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)

IPC: C09K

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)

See extra sheet

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US7154114B2 (UNIVERSAL DISPLAY CORPORATION), 26 December 2006 (26.12.2006) , see column 19 in description, claim 6	1, 10
A	US7154114B2 (UNIVERSAL DISPLAY CORPORATION), 26 December 2006 (26.12.2006) , see column 19 in description, claim 6	2-9
A	US7598388B2 (THE UNIVERSITY OF SOUTHERN CALIFORNIA), 06 October 2009 (06.10.2009), see examples 2 and 4	2-9

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

* Special categories of cited documents:	“T” later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
“A” document defining the general state of the art which is not considered to be of particular relevance	“X” document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
“E” earlier application or patent but published on or after the international filing date	“Y” document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
“L” document which may throw doubts on priority claim (S) or which is cited to establish the publication date of another citation or other special reason (as specified)	“&” document member of the same patent family
“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	

Date of the actual completion of the international search
03 August 2011 (03.08.2011)Date of mailing of the international search report
01 Sep. 2011 (01.09.2011)Name and mailing address of the ISA/CN
The State Intellectual Property Office, the P.R.China
6 Xitucheng Rd., Jimen Bridge, Haidian District, Beijing, China
100088
Facsimile No. 86-10-62019451Authorized officer
WANG Ying
Telephone No. (86-10)62086304

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2010/079147

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

WPI;EPODOC;CNKI;IEEE;CNPAT;STN (REG, CAPLUS, CASREACT) iridium, electroluminescent, light emitting, fluorescence

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

PCT/CN2010/079147

Patent Documents referred in the Report	Publication Date	Patent Family	Publication Date
US7154114B2	26.12.2006	US20050260447A1	24.11.2005
		US 20050260441A1	24.11.2005
		US 7491823B2	17.02.2009
		US 20060024522A1	02.02.2006
		US 7393599B2	01.07.2008
		WO 2005113704A2	01.12.2005
		WO 2005113704A3	17.08.2006
US7598388B2	06.10.2009	US 20050258742A1	24.11.2005
		US 20050260441A1	24.11.2005
		US 7491823B2	17.02.2009
		US 20060024522A1	02.02.2006
		US 7393599B2	01.07.2008
		WO 2005113704A2	01.12.2005
		WO 2005113704A3	17.08.2006

Form PCT/ISA /210 (patent family annex) (July 2009)

专利名称(译)	含铱的有机电致发光材料，其制备方法和有机电致发光元件		
公开(公告)号	EP2644680A1	公开(公告)日	2013-10-02
申请号	EP2010860033	申请日	2010-11-25
[标]申请(专利权)人(译)	海洋王照明科技股份有限公司		
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当前申请(专利权)人(译)	海洋王照明科技股份有限公司.		
[标]发明人	ZHOU MINGJIE WANG PING ZHANG JUANJUAN LIANG LUSHENG		
发明人	ZHOU, MINGJIE WANG, PING ZHANG, JUANJUAN LIANG, LUSHENG		
IPC分类号	C09K11/06 C07F15/00 H05B33/14		
CPC分类号	H01L51/0085 C07F15/0033 C09K11/06 C09K2211/1007 C09K2211/1011 C09K2211/1044 C09K2211/185 H05B33/10 H05B33/14		
代理机构(译)	MICHALSKI HÜTTERMANN & PARTNERPATENTANWÄLTE		
外部链接	Espacenet		

摘要(译)

提供含有下列通式的铱的有机电致发光材料，其中R是C1-C8烷基。还提供了使用上述含铱的有机电致发光材料制备含铱的有机电致发光材料和有机电致发光元件的方法。

