High efficiency mer-iridium complexes for organic light-emitting diodes†

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We have developed a new process at high vacuum (5 × 10⁻⁵ Torr) and high temperature (300 °C) to produce meridional iridium complexes from the dimer; interestingly, mer-Ir(m-ppy)₃ overthrow the concept of poor efficiency and shows excellent efficiency which is almost equal to that of fac-Ir(ppy)₃, fac-Ir(m-ppy)₃ and (ppy)₂Ir(acac).

In the past decade, great progress has been made in organic light-emitting diodes (OLEDs). Electroluminescence from small molecules based on light-emitting diodes figures in the history of flat panel display. Recently, highly efficient OLEDs using phosphorescent dyes such as 2,3,7,8,12,13,17,18-octethyl-21H,23H-porphine platinum (PorOP), iridium(n) fac-tris(2-phenylpyridinato-N,C²) (Ir(ppy)₃), iridium(n) bis(2-phenylpyridinato-N,C²)acetacrylate (ppy)₂Ir(acac), and their derivatives have been reported. Both fac-Ir(ppy)₃ and (ppy)₂Ir(acac) exhibit green emission with high external quantum efficiency. By employing triplet-based phosphorescent dye in OLEDs, where both singlet and triplet excited states participate, the external quantum efficiency can reach as high as 8 ~ 15%, notedly. This result may improve the photophysics properties of mer-Ir(m-ppy)₃, and thus it could show better efficiency for OLEDs. The blue shift of mer-Ir(m-ppy)₃ and red shift of mer-Ir(ppy)₃ indicate that the emission color is tunable according to the position of the substitution in the meridional type iridium complexes.

Devices were fabricated by high vacuum (10⁻⁶ Torr) thermal evaporation on pre-cleaned indium-tin-oxide (ITO) glass substrate.

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Fig. 1 Chemical structure of iridium complexes.

Fig. 2 PL spectra of iridium complexes in CH₂Cl₂.
with the following structures: ITO/NPB (50 nm)/CBP: 6% dopant (30 nm)/BCP (10 nm)/AlQ (30 nm)/Al. With a base pressure of \( \sim 1 \times 10^{-6} \) Torr, the organic and metal cathode layers were grown successively. In this device, 4,4′-bis(N-(1-naphthyl)-N-phenylamino)benzophenyl (NPB) acted as a hole transport layer, 2,9-dimethyl-4,7-diphenyl-1,10-phenanthroline (BCP) as a hole blocking layer, tris-(8-hydroxyquinoline)aluminium(III) (AlQ3) as an electron transport layer, 4,4′-bis(N-carbazolyl)biphenyl (CBP) as the host material, and iridium complexes as the dopant. The corresponding CIE (Commission International de L’Eclairage) chromaticity coordinates are \( \x \approx 0.35, y \approx 0.60 \) for fac-Ir(ppy)$_3$, \( \x = 0.35, y = 0.60 \) for fac-Ir(ppy)$_3$, \( \x = 0.31, y = 0.62 \) for mer-Ir(m-ppy)$_3$, \( \x = 0.33, y = 0.60 \) for (ppy)$_2$Ir(acac), \( \x = 0.42, y = 0.59 \) for mer-Ir(ppy)$_3$, and \( \x = 0.31, y = 0.59 \) for mer-Ir(m-ppy)$_3$. All five devices show green to yellow-green emissions, and mer-Ir(ppy)$_3$ shows the same tendency in PL spectrum data.

Electrophosphorescence and photophosphorescence data for iridium complexes are summarized in Table 1.

The peak wavelength of the EL spectrum for the devices using fac-Ir(ppy)$_3$, fac-Ir(m-ppy)$_3$, (ppy)$_2$Ir(acac), mer-Ir(ppy)$_3$, and mer-Ir(m-ppy)$_3$, was 516, 511, 524, 564 and 508 nm, respectively. The EL spectrum for each device was almost coincident with the corresponding PL spectrum. Although fac-Ir(ppy)$_3$ shows the best luminance efficiency and power efficiency at low current density, (ppy)$_2$Ir(acac) exhibits the best brightness, luminance efficiency and power efficiency at a high current density. Similar to the demonstration of last year,1513 mer-Ir(ppy)$_3$ shows the yellow-green emission and poor performance among these complexes. Although mer-Ir(m-ppy)$_3$ is meridional type, its photophysics properties are different from mer-Ir(ppy)$_3$, mer-Ir(m-ppy)$_3$ shows the best brightness of 35249 cd m$^{-2}$ luminance efficiency of 17.62 cd A$^{-1}$ and power efficiency 4.01 lm W$^{-1}$ at a high current density of \( J = 200 \) mA cm$^{-2}$, which are almost the same as for fac-Ir(ppy)$_3$, fac-Ir(m-ppy)$_3$, and (ppy)$_2$Ir(acac). We speculate that when we introduced a methyl group to the \( para \) position of 2-phenylpyridine, the MLCT energy level of the iridium complex decreased. Then, energy transfer from the host to the mer-Ir(ppy)$_3$ occurs more efficiently than to the mer-Ir(m-ppy)$_3$.

In conclusion, we have developed a simple procedure to prepare novel iridium complexes with 2-phenyl-4-methylpyridine ligands. Marvellously, mer-Ir(m-ppy)$_3$ shows excellent performance comparable to fac-Ir(ppy)$_3$, fac-Ir(m-ppy)$_3$, and (ppy)$_2$Ir(acac). This result opens up a new direction in developing novel emitters for OLEDs.

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### Notes and references