Trends in Research and Development of OLED technology with blooming generations of emitters

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Organic light emitting diode (OLED) technology has drawn the attention of commercial communities due to its potential application in next-generation displays and revealed a market value of USD 38.4 billion in 2022. Over the past few decades, OLED technology has been studied and researched from both materials and device points of view. However, the material development has undergone several dimensions based on molecular architecture.

According to the spin rule, the singlet and triplet emission ratio is 1:3, whereas singlet emission is only utilized in earlier first-generation fluorescence emitters. The efficiencies are limited due to its theoretical limitation of internal quantum efficiency (IQE) of 25%. To obtain a theoretical maximum (100%) of IQE, heavy metal ligand-mediated second-generation phosphorescence emitters are investigated using expensive noble metals, such as iridium (Ir) and platinum (Pt). Compared to the first-generation, second-generation emitters exhibited excellent device performances in all demandable aspects for commercial applications. Unfortunately, such metal-ligand complex emitters had to pass through the cost-effectiveness hurdle in mass production.

To overcome such issues, in 2012, Adachi et al.[1] brought up an interesting phenomenon known as thermally activated delayed fluorescence (TADF) emitters using donor-acceptor building blocks in a single module. With lowering energy difference between singlet and triplet levels, 100% IQE is achievable by activating the reverse intersystem crossing (RISC) channel. Although third-generation TADF emitters have paved a path to achieving high efficiencies using in-expensive organic molecules, color purity has become an issue when applying ultra-high definition (UHD) displays.

Recently, Hatakeyama et al.[2] proposed new strategy of emitter design using boron atom embedded poly aromatic hydrocarbons (PAHs). Since frontier molecular orbitals are localized and delocalized on different atoms, the emitters are called multi-resonance (MR) emitters. Although these emitters possess TADF properties, their application has become wider in hyper-fluorescence (HF) OLEDs. To fulfill the requirements and high demands by the BT2020 UHD, utilizing both singlet and triplet excitons in TADF-sensitized HF (TSH) and phosphor-sensitized fluorescence (PSF) systems is a supreme technology marching toward further steps while giving room for the research communities.

1. Zhang, Q. *et al.* Design of efficient thermally activated delayed fluorescence materials for pure blue organic light emitting diodes. *J. Am. Chem. Soc.* **134**, 14706–14709 (2012).

2. Hatakeyama, T. *et al.* Ultrapure Blue Thermally Activated Delayed Fluorescence Molecules: Efficient HOMO-LUMO Separation by the Multiple Resonance Effect. *Adv. Mater.* **28**, 2777–2781 (2016).