Design for High Efficiency and Wide Color Gamut BT.2020 OLEDs

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ABSTRACT

Hyperfluorescence™ (HF), combines the advantages of TADF and fluorescence, is known as the most promising OLED emitting technology. HF enables high internal quantum efficiency (IQE) and a narrowband emission (< 25 nm) can be simultaneously possessed in one OLED emitting system. Incorporating with our original Materials Informatic System, Kyumatic, Kyulux has successfully developed materials for BT.2020 color gamut and attained unparalleled HF performance. At this conference, we will report our latest HF progress towards BT.2020 spec.

1 Introduction

Over the past decades, OLEDs have attracted lots of attention in the display industry because of their distinguishing features such as thin, lightweight, fast responsive time, low power consumption as well as excellent color contrast performance. But, an OLED device cannot achieve compelling performance without incorporating a suitable emitting technology. Fluorescence and phosphorescence have been the dominant emitting technologies of the OLED market, and many efforts have strived to the device engineering to further performance enhancement. However, due to the intrinsic quantum confinement, both technologies can hardly simultaneously 100% fulfill the growing stringent demands of the display market, attaining high efficiency and long operational lifetime at a satisfying color purity without compromising viewing angle. Hence, a new OLED emitting technology comprehending all these criteria for red, green and blue colors has been a desperate desire.

Hyperfluorescence™ (HF), a hybrid of thermally activated delayed fluorescence (TADF) and conventional fluorescence, widely recognizes as the fourth generation of OLED emitting technology. Consisting of simple and pure organic aromatics, TADF molecules naturally possess a small singlet-triplet energy gap (ΔE_{ST}) and rapid reverse intersystem crossing (RISC). These features activate the upconversion of triplet excitons while allowing the energy to be effectively utilized as the singlet excitons. By taking this advantage, TADF successfully solves a longstanding hurdle in pure organics that only one-fourth of the excitons can be harnessed, which endows TADF to achieve a nearly 100% exciton utilization efficiency, equivalent to phosphorescence. The rapid RISC of TADF molecules enables the high energy generated to fully sensitize typical fluorescent dopants. Compared to TADF molecules, the typical fluorescence dopants usually exhibit narrow emission bandwidth, drastically improving the low color purity caused by wide charge transfer (CT) emission of TADF and phosphorescence. The very narrow full-width half maximum (FWHM) smaller than 25 nm in the primary RGB colors enables HF to cover a wide color space to realize BT.2020. The wide color gamut of BT.2020 will render next-generation OLED products deliver an even more vivid color experience to their consumers. Therefore, HF is the ultimate solution for OLED emitting technology, providing high efficiency and pure color without using rare metals such as iridium and platinum.

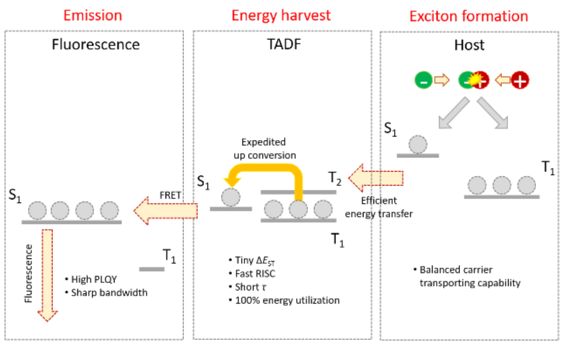

Fig. 1 Mechanism of Hyperfluorescence™

2 Development

Kyulux has been focusing on the development of HF technology and its materials since 2015. Throughout these years, Kyulux has accumulated considerable discoveries and knowledge in HF. What technically supports Kyulux's steady research and development growth is our original Materials Informatics System, Kyumatic. It is an all-round interface that integrates our in-house computation library, machine learning, mass molecular generation, device simulations and experimental data management. With this coherent cornerstone system, Kyumatic enables not only the material development expedition close to hundred folds, but also the curation of proper materials combination in the emission layer. In Kyulux, scientists leverage Kyumatic's intelligence to develop promising TADF materials in pursuit of excellent HF performance. The obtained experimental information, such as materials properties and device results, will be ingested by machine learning to further enhance the prediction accuracy of the next new design loop.

3 Progress

Apart from DCI-P3, a modern color standard adopted by state-of-the-art OLED displays, the narrow emission HF technology can further expand the color gamut to another more spacious coverage of CIE 1931 color space called BT.2020. As the most promising cutting-edge technology, HF continuously progresses and advances ever highly efficient performance for the next-generation OLED display.

Regarding green HF, recently our top emission performance has achieved BT.2020's color requirement with an FWHM < 17 nm. The sharp green HF emission at the CIE coordinates of (0.17, 0.78) successfully demonstrated the HF's advantage in color purity. In addition to the color achievement, the current efficiency and LT95 (device lifetime to 95% of the initial luminance) have achieved 224 cd/A and 59,000 hours at 1,000 nits, respectively. Moreover, a record-high LT95 performance of 74,000 hours at an initial luminance of 1,000 nits is attainable via device optimization, which met the industrial targets for mobile applications. We believe these thrilling achievements would allow us to expedite the commercialization and enter the next phase with our customers by the end of this year.

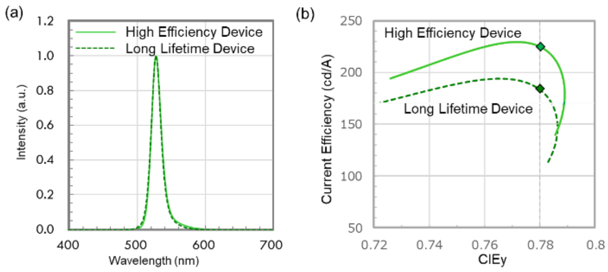

Fig. 2 (a) The EL emission spectrum and (b) the current efficiency simulation against CIEy of the efficiency-oriented and lifetime-oriented green HF devices

Table 1. The simulated EL performances of top-emission green HF devices towards BT.2020

	CIE(x,y)	FWHM (nm)	η_c[1] (cd/A)	LT95[2] (h)
High Efficiency Device	(0.17,0.78)	17	224	59,000
Long Lifetime Device	(0.17,0.78)	17	183	74,000

[1]η_c: Current efficiency at 1,000 nits. [2]Measured at 1,000 nits.

In addition to green, the blue HF progress is also smoothly proceeding. We have been striving for blue HF development to respond to the strong market desire for a highly efficient and robust deep-blue HF system. A series of approaches have been implemented via combining developing robust blue TADF and dopant as well as the proper combination with the adjacent materials have been implemented. As a result, the efficiency and lifetime of blue HF have reached significant breakthroughs. Our blue HF attained a LT95 of 480 hours at an initial luminance of 1,000 nits in a bottom-emission device. When emitting at CIE coordinates of (0.11, 0.09), its blue index (BI) can be as high as 225 cd/A/y, according to our top-emission simulation. Concerning deep-blue HF, we achieved a very small CIEy of 0.07 with an ultra-narrow emission bandwidth of 14 nm. The simulated result indicates its BI can be as high as 273 cd/A/y. We also evaluated this deep-blue materials set in its bottom-emission device structure, where a preliminary LT95 of 270 hours was obtained. Still, the materials design and device engineering for even higher deep-blue performance are ongoing. We aim to realize a robust lifetime of > 750 hours with a CIEy < 0.05 at 1,000 nits by the end of 2022. Kyulux will present its latest achievements at the conference.

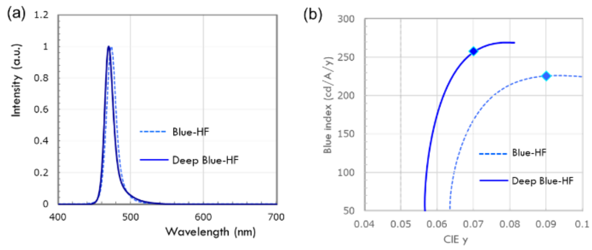

Fig. 3 (a) The EL emission spectrum and (b) the current efficiency simulation against CIEy of the efficiency-oriented and lifetime-oriented blue HF devices

Table 2. The simulated EL performances of top-emission blue HF devices

	CIE(x,y)	FWHM (nm)	BI[1] (cd/A/y)	LT95[2] (h)
Blue HF	(0.11,0.09)	16	225	480
Deep-blue HF	(0.12,0.07)	14	273	270

[1]BI: Blue index (current efficiency over CIEy) at 1,000 nits. [2]Measured at 1,000 nits at the respective bottom-emission devices.

4 Conclusion

Hyperfluorescence™, combining TADF and fluorescence technologies, potentially realizes 100% exciton utilization efficiency with a robust lifetime performance under an even vivid color gamut of BT.2020 for three primary colors, red, green, and blue. Kyulux recently has drastically boosted the green and blue HF performance for BT.2020 via incorporating our self-development Materials Informatic System, Kyumatic. Our green HF system has successfully attained the color coordinates of BT.2020 with an unprecedented efficiency performance of 224 cd/A at 1,000 nits. Its LT95 can be extended to 74,000 hours after the device optimization. Furthermore, our blue performance also reached many breakthroughs in terms of prolonged LT95 as well as a high-efficiency performance for deep-blue HF emission. The successful materials and device design strategies will enable Kyulux to reach its 2022 development goal by the end of the year.