2-5-3. Organic EL

Overview

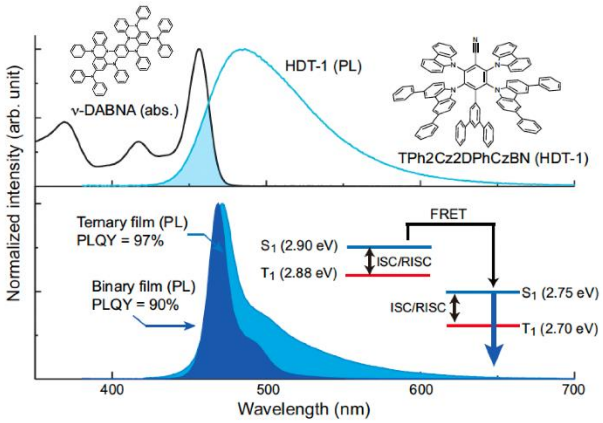
OLEDs (Organic Light Emitting Diodes) are being put to practical use as advanced displays because of their basic performance, such as high efficiency, high resolution, and low power consumption, as well as their ability to be made into thin-film, flexible displays. In particular, thermally activated delayed fluorescence (TADF) is the central axis of material development. Currently, TADF molecules are dispersed in the emission layer host as an assistant dopant (AD), and excitons generated by the AD are transferred to the terminal emitter (TE) by Förster-type energy transfer (FRET) to achieve the possibility of blue light emission with high efficiency, high durability, and narrow spectral bandwidth has been dramatically opened up by the FRET.

Current Status and Frontiers

Although research and development to realize blue OLEDs with high efficiency, narrow emission bandwidth, and high stability have been ongoing for more than 30 years, many problems remain in both efficiency and durability. As a result, blue OLEDs in practical use are still heavily based on blue fluorescent molecules that emit from the excited singlet (S_1) state (fluorescence). One of the reasons for the short operating lifetime of pure blue OLEDs utilizing triplet excitons (T_1), which in principle exhibit 100% internal quantum efficiency, is due to the formation of triplet excitons, which have a "long excitation lifetime" compared to singlet excitons. Triplet excitons form hot exciton states with high energy levels (> 2T) due to collisions between two triplets or with polaron (charged molecule) states, and the excitons in these high-energy states sufficiently exceed the binding energy of the molecules to decompose the emitting molecules.[1] Furthermore, to effectively confine the high triplet energy of blue luminescent molecules within the emission layer, a host material with a higher triplet energy is required. Further, to satisfy both high singlet and triplet excited-state energies, it is often challenging to ensure electrochemical stability, as this is limited to relatively simple molecular skeletons. Therefore, to achieve stable blue OLEDs, emitting materials with short triplet lifetimes and OLED device structures that can reduce triplet exciton density must be designed to maintain high electrochemical stability. Recently, to realize ideal pure blue OLEDs, it has been shown that the design of blue-emitting molecules that function as terminal emitters (TEs) and devices that use TADF molecules as assist dopants (ADs) to sensitize pure blue have excellent performance.[2]

In general, many TADF molecules exhibit broad PL spectra arising from their CT states, which are inappropriate for display applications. Figure (top) shows the emission spectrum of HDT-1, a typical TADF material. Although the emission peak wavelength is 476 nm, HDT-1 emits sky blue. This emission color purity problem can be solved by co-depositing narrow emission fluorescent molecules (TE) with TADF emission molecules (TADF-AD) in the host matrix.[3] An OLED composed of host:TADF-AD:TE is called a

hyperfluorescence (HF)-OLED. Here, ν-DABNA, etc., which has TADF characteristics and pure blue emission characteristics with a narrow full width at half maximum (FWHM) of the emission spectrum, is used as TE. ν-DABNA shows shorter wavelength emission than HDT-1, but the ν-DABNA absorption spectrum overlaps with the HDT-1 emission spectrum. and thus a Förster-type energy transfer (FRET) from S_1 of HDT-1 to S_1 of ν-DABNA occurs. Figure (bottom) shows the PL properties of a thin film of 20 wt% HDT-1 and 0.5 wt% ν-DABNA uniformly dispersed in an mCBP host by three-source codeposition. The composite film shows blue emission, mainly derived from ν-DABNA, with a high quantum efficiency Φ_{PL} = 97%. The transient PL waveform of this thin film is almost consistent with the profile of the 20 wt%-HDT-1:mCBP bimolecular mixture film, indicating that the singlet exciton generated by HDT-1 undergoes intramolecular interterm crossing and reverse intersystem crossing processes (ISC and RISC) before finally being transferred to the S_1level of ν-DABNA The HF-OLEDs quickly convert triplet excitons generated in the emitting layer to singlet excitons, which are then emitted as fluorescence by the TE molecules, Although it is challenging to design a single molecule to perform all the various functions, it is a valuable solution to improve device performance by combining multiple molecules, and we have been studying the energy transfer process in molecular assemblies and the optimum Further improvement of device properties can be expected by clarifying and optimizing the energy transfer process in molecular assemblies.[4]



References

1. N. C. Giebink, S. R. Forrest, *Phys. Rev. B*, **77**, 235215 (2008).
2. H. Nakanotani, T. Higuchi, T. Furukawa, K. Masui, K. Morimoto, M. Numata, H. Tanaka, Y. Sagara, T. Yasuda, C. Adachi, *Nature Commun.*, **5**, 4016 (2014).
3. C. Y. Chan, M. Tanaka, Y.-T. Lee, Y. W. Wong, H. Nakanotani, T. Hatakeyama, C. Adachi, *Nature Photonics*, **15**, 203–207 (2021).
4. Y.-T. Lee, C.-Y. Chan, N. Matsuno, S. Uemura, S. Oda, M. Kondo, R. W. Weerasinghe, Y. Hu, G. N. I. Lestanto, Y. Tsuchiya, Y. Li, T. Hatakeyama, C. Adachi, *Nature Commun.*, **15**, 3174 (2024).

Future Perspectives and Directions

Issues to be solved or realized by the end of the decade: The development of stable phosphorescent and TADF blue light-emitting molecules has not yet been achieved. In fluorescent molecules, high durability has been achieved through the use of complex polycyclic aromatic skeletons, such as anthracene and pyrene. In the future, the development of phosphorescent and TADF stable blue emitting molecules is a key technology for OLEDs, especially the improvement of photochemical stability of the excited triplet state is essential. (Author: Chihaya Adachi)