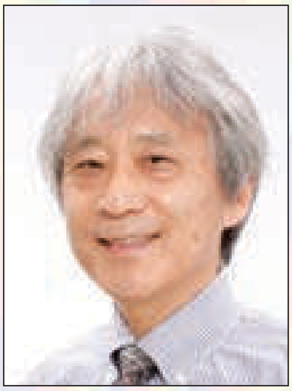
Session II: Functional Colorants - I

Introduction to device physics of OLEDs



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Prof. Hiroyoshi Naito received his B. S., M. S., and D. Eng. degrees from Osaka Prefecture University in 1979, 1981, and 1984. He joined the Department of Electronics in 1984 and had been a professor at the Department of Physics and Electronics since 2000. His current research interests include physics of organic devices, and optical and electrical characterization of organic semiconductors. He retired and was awarded the title of emeritus professor in 2022 at Osaka Prefecture University. He continues to teach and to do research at the Department of Applied Chemistry of Osaka Metropolitan University.

Prof.Naito is a fellow of the Imaging Society of Japan and the Japan Society of Applied Physics. He was awarded the Outstanding Achievement Award from Japan OLED forum, the Society Award from the Imaging Society of Japan, the Outstanding Achievement Award from Molecular Electronics and Bioelectronics Division of the Japan Society of Applied Physics, and the Slottow–Owaki Prize from The Society of Information Display.

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Abstract

Organic light-emitting diodes (OLEDs) have been extensively studied from the viewpoint of device physics, device design and material synthesis and have already been applied to flat panel displays (OLED TV) and flexible displays. In addition to these application, OLEDs are promising light sources for photodynamic therapy and low level light therapy.

Recent OLED structure is anode/hole transport layer (HTL)/emissive layer (EML)/electron transport (ETL)/cathode fabricated by means of vacuum evaporation. The efficiency has been improved using hole injection layer (HIL), electron injection layer (EIL), hole blocking layer (HBL) and electron blocking layer (EBL). HIL and EIL facilitate hole and electron injection from the anode and the cathode, respectively. HBL and EBL are formed between EML and ETL and between HTL and EML, respectively and are confined injected hole and electrons in EML. Injected holes and electrons are recombined in EML and 25% singlet and 75% triplet excitons are generated because of the spin statistics. Electroluminescence from OLEDs is observed as fluorescence of the radiative deactivation of the singlet excitons.

Essential improvement has been made by the development of new classes of emitters; the first generation is fluorescent emitters developed since 1980's, the second generation is phosphorescent emitter containing a rare metal such as Ir reported in 1998, the third generation is thermally-activated delayed fluorescent (TADF) emitters reported in 2012. The internal quantum efficiency of 100% was obtained in OLEDs with phosphorescent and TADF emitters (the efficiency is 25% in case of fluorescent emitters).

OLEDs with phosphorescent or TADF emitters do not always exhibit high external quantum efficiency without optimizing HTL, EML and ETL (the maximum external quantum efficiency is expected to be 20% because the optical outcoupling efficiency is about 20%). The information of opto-electronic properties (for instance, electronic transport, the energy level of HOMO and LUMO, refractive index) of HTL, EML and ETL is essential to fabricate high-efficiency OLEDs. Once such opto-electronic properties are known, the properties are used as inputs to a device simulator and hence the performance of OLEDs including the response speed to externally applied voltage modulation as well as the efficiency can be predicted. For example, when maximizing the efficiency of an OLED with a particular EML, the combination of HTL and ETL showing the highest efficiency can be predicted from a limited number of HTLs and ETLs. Of course, developing methods to measure these optoelectronic properties is important. The development of methods to assess electronic properties in organic semiconductors, which are insulating semiconductors, was particularly an important challenge.

Issues related to device physics, mentioned above, will be briefly reviewed