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Plasmonics in organic light-emitting diodes

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After development of phosphorescence materials, the internal quantum efficiency of organic light emitting diodes (OLEDs) reaches close to unity. However, the external quantum efficiency is still as low as ~20%. This is caused by the use of metallic cathodes. In contrast to inorganic LEDs metal is almost unavoidable material for cathodes due to its conductivity and work function and the metal cathode must completely cover whole device area. Additionally, the distance between the metal cathode and the emitting layer is ~100 nm. Thus, most of the energy of excitons is transferred to surface plasmons and other guided modes. Figure 1 shows modes to which exciton energy dissipates and the fraction of the energy dissipation to each mode. As can be seen, only 14% of energy is extracted into free space, whereas more than half of energy dissipates to surface plasmons, which just turn into heat. Thus, it is important to extract energy from the surface plasmons as photons for improving the efficiency. Appropriate plasmonic structures improve the light extraction efficiency. The introduction of 2-D periodic surface corrugation and aperiodic surface corrugation improves the light extraction efficiency of OLEDs for monochromatic light and that for white light, respectively.

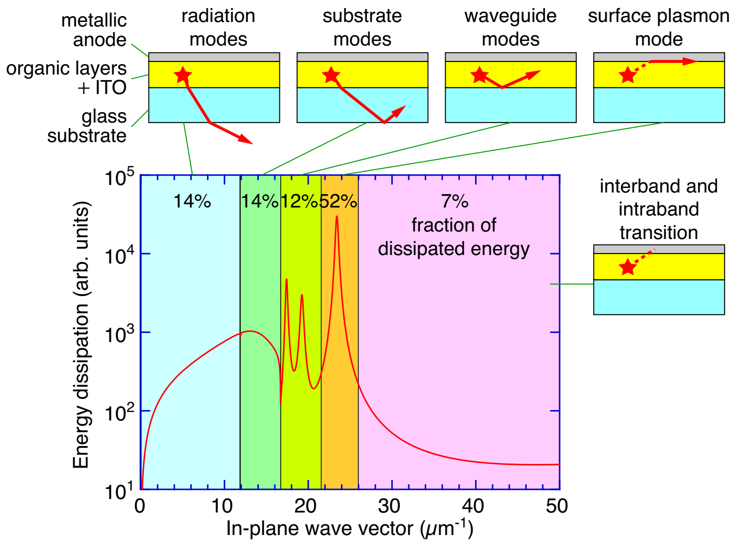

Figure 1: Energy dissipation of excitons in an OLED as a function of in-plane wave vector. The assumed layer structure is air / Ag(50 nm) / Alq_3(50 nm) / NPB(50 nm) / ITO(150 nm) / SiO_2, where the values in the parentheses are the layer thicknesses. Emission at 550-nm wavelength was assumed to originate in the Alq_3 layer, 5 nm from the Alq_3-NPB interface. The fraction of energy dissipation to each mode in the OLED is also shown.

Another function of plasmonic structures is used for top-emitting OLEDs, which are desired for displays because of easier fabrication of active matrix driving circuits on the substrates. Plasmonic structures enable us to extract light emission through metallic cathodes with high efficiency. Here I present three kinds of plasmonic structures for top-emitting OLEDs.

Although the direction of the energy flow is opposite with each other, the structure of organic thin-film solar cells is quite similar to that of OLEDs. Thus, similar concepts can be adopted for organic thin-film solar cells. I will also present plasmonics in such solar cells.