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Microcavity Device Structures and Lanthanide Complexes for Narrow Bandwidth Organic Light Emitting Diodes

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1. Introduction

Display technology using organic light emitting diode (OLED) structures is currently under intense research due to the opportunity of fabricating flat panels with low costs and large scales [1]. Moreover, highly efficient electroluminescent organic materials for the whole visible spectrum with halfwidths of about 100 nm are easily accessible [2]. However, full color applications require more saturated colors and the FWHM of the spectra at the primary colors should not exceed about 60 nm. Therefore, either materials or device structure capable of this important demand have to be found.

2. OLED Device Concepts

At first, fluorescent lanthanide complexes of europium and terbium are incoorporated into a commonly used OLED structure (Fig. 1 (a) and (b)). This materials show luminescence spectra with FWHMs of around 10 nm in the red and green spectral region, respectively [3]. The second concept is a resonant cavity device, depicted in Fig. 1 (c). In this case, a conventional Alq_3 OLED is sandwiched between a dielectric Bragg mirror ($\lambda/4$ SiO_2/TiO_2 stack) and the Mg/Ag cathode as a metal reflector. The organic layer thickness is in the order of the emission wavelength. Thus, Fabry Perot microcavity effects, e.g. spectral narrowing, become effective [4].

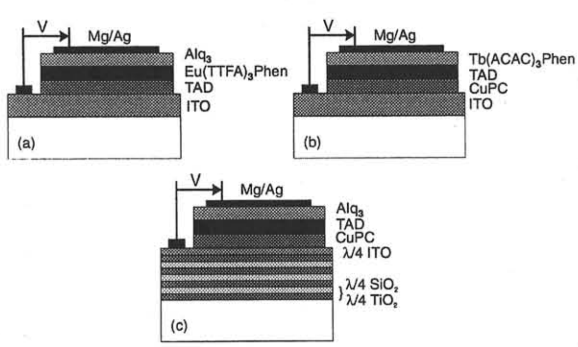

Fig. 1: Device structures: (a,b) lanthanide complex based and (c) microcavity OLED.

All devices are fabricated using organic molecular beam deposition [5] as a UHV thin film processing technique at base pressures of about 10^{-9} Torr. The low mass molecular materials for the functional organic layers featuring emission ($Eu(TTFA)_3Phen$, $Tb(ACAC)_3Phen$, Alq_3), hole (CuPC, TAD), and electron (Alq_3) transporting properties, are summarized in Fig. 2. The need of TAZ is described later.

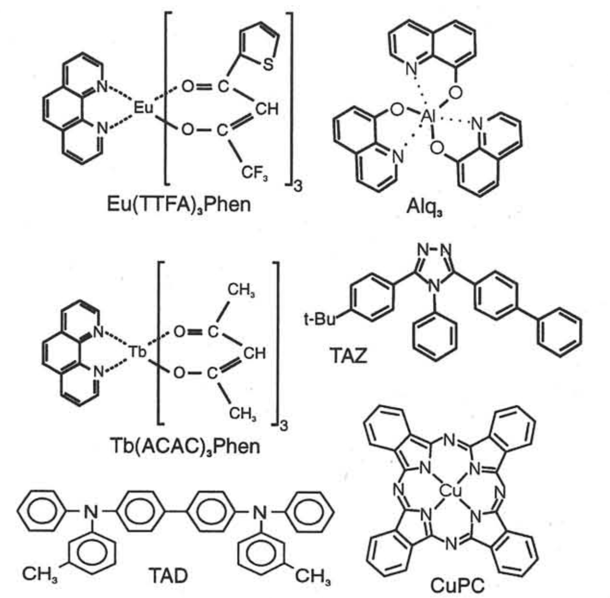

Fig. 2: Molecular structures of the organic materials.

3. Electroluminescence Characteristics

The electroluminescence spectra of the lanthanide complex based and the Alq_3 microcavity OLEDs are shown in Fig. 3 (a) and (b), respectively. Narrow red (613 nm) and green (543 nm) emission lines are obtained for the $Eu(TTFA)_3Phen$ and the $Tb(ACAC)_3Phen$ OLEDs. The color perception of the resonant device is blue (472 nm) due to the spectral narrowing from 100 nm to 22 nm in comparison to the originally broad electroluminescence spectrum of a non-cavity Alq_3 OLED also fabricated. In addition, the emission measured normal to the substrate surface is enhanced by a factor of about 4 at the resonance wavelength.

4. Optimization of Multilayer Microcavities

Further optimization of the microcavity OLEDs can be expected because the multilayer design is critical to fully benefit from the advantages described previously. Due to the standing wave of the optical field in the cavity, the position of the active layer, e.g. Alq_3, plays an important role for the emission characteristics. Therefore the standing waves for the emission wavelength maximum of Alq_3 (520 nm) and the excitation wavelength (UV argon laser at 363 nm) have been calculated (Fig. 4).

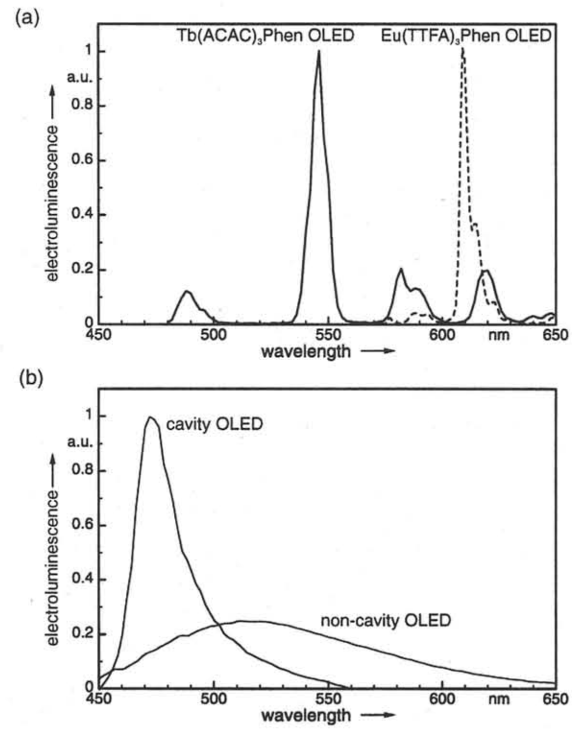

Fig. 3: Electroluminescence spectra: (a) red and green emitting OLED and (b) blue emitting microcavity OLED.

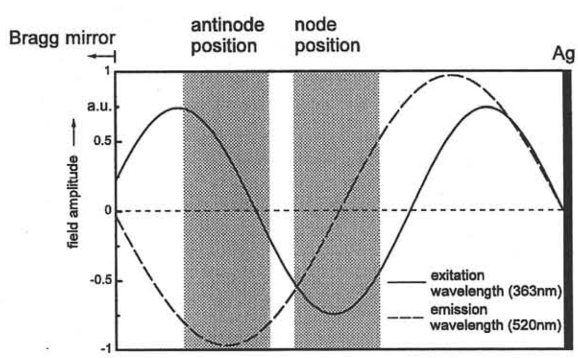

Fig. 4: Cavity standing wave for device optimization.

To investigate the influence of the overlap of the active layer with the antinode or the node position, reference and microcavity photoluminescence samples with the same effective resonator thicknesses have simultaneously been fabricated. Fig. 5 (a) and (b) displays the multilayer device sequencies and the corresponding emission spectra. TAZ thin films are used for they show no absorbance or fluorescence at the excitation and emission wavelengths and can therefore serve as optically neutral spacer layers. Placing the Alq_3 at the node (Fig. 5 (a)), strong suppression of the emission can be observed. On the other hand strong enhancement due to an efficient coupling between the emissive dipoles and the optical mode can be achieved if the antinode position is chosen (Fig. 5 (b)).

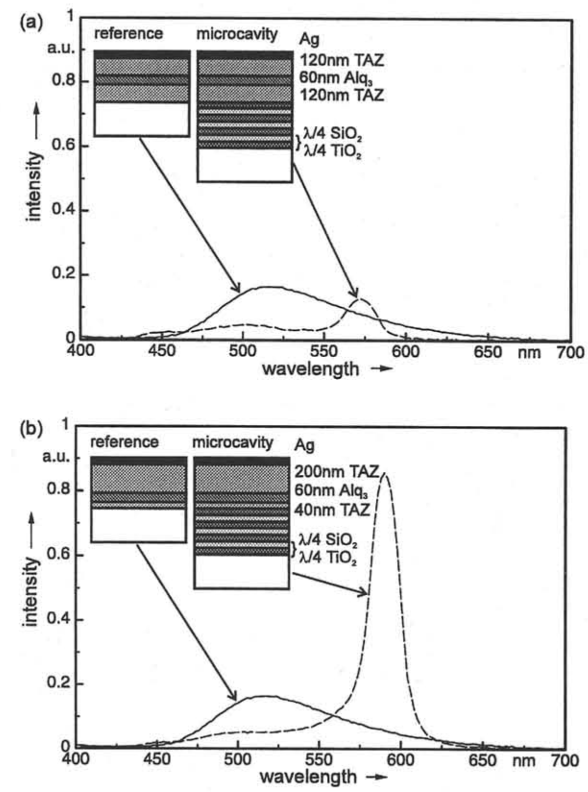

Fig. 5: Multilayer structures and emission spectra of reference and microcavity devices: Alq_3 layer placed at (a) the node and (b) the antinode of the cavity standing wave.

5. Conclusions

Organic electroluminescent devices with narrow emission bandwidths of about 10 to 22 nm in the red, green, and blue spectral region have been demonstrated following the device concepts of europium and terbium complex based and microcavity Alq_3 OLEDs, respectively. The color purities are sufficient for full color display applications. Photoluminescence experiments on resonant cavity Alq_3 structures carried out for further efficiency improvement of multilayer devices have shown that the emission can be drastically enhanced.

Acknowledgements

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References

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