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Thin Solid Films for OLED-s and Optoelectronic Applications

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OPTIMIZATION OF LAYER THICKNESSES IN OLEDs WITH INTERMEDIATE LAYER FOR ENHANCED OUTCOUPLING EFFICIENCY

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1. Introduction

Due to total internal reflection or partial reflection at the interfaces, a lot of light generated in the organic light emitting devices is trapped inside the device, and absorbed in the electrodes or emitted at the edges of the substrate. Only the light in a cone with half angle equal to the critical angle \( \theta_{\text{cr}} = \sin^{-1} 1/n \) (where \( n \) is the emitters’ refractive index) can avoid total internal reflection. In order to outcouple the light trapped inside the device we need to change the angular distribution of the emitted light. The angular distribution of the emitted light is influenced by the interference effects in the optical microcavity [1]. By optimizing the thicknesses of the layers or by adding intermediate layers we can tune the optical microcavity in order to gain more light out of the device.

2. The model of a dipole antenna

We use the model of dipole antennas for the emitters in thin-film microcavities [1]. The theory of the model uses the equivalence between the power emitted by the dipole antenna and the probability for the emission of a photon by a dipole transition. With the formulas provided by the theory [1,2] we can calculate the total power emitted by the dipole antennas depending on their location in the microcavity. We assume that the emitting layer is nonabsorbing. All other layers in the microcavity can be either transparent or absorbing. The model takes into account the wide-angle interference, the multiple-beam interference and the effect of the absorbing media. The OLED is a thin-film structure with layers that have thicknesses of the order of one wavelength and lateral dimensions that are much larger. Thus the structure can be approximated as one-dimensional.

3. The outcoupling efficiency

The theory [2] provides formulas to calculate the net power flux in each plane of the one-dimensional OLED structure. In this way we can calculate the power flux in the glass substrate or in air. The outcoupling efficiency for glass/air is calculated as the ratio between the power flux in the glass/air and the total generated power.

4. Optimization

For the optimization we will use a standard OLED stack with an intermediate layer between ITO and the glass substrate Al/Alq3/a-NPD/ITO/intermediate layer/glass. The thickness of the intermediate layer and the thickness of Alq3 will be optimized for the outcoupling efficiency for glass and air, and the influence of the intermediate layers’ refractive index will be investigated.

REFERENCES

Optimization of layer thicknesses in OLEDs with intermediate layer for enhanced outcoupling efficiency

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1. Introduction

Problem: total internal reflection
Solution: microcavity redirects light
Aim: increase outcoupling

2. The model of a dipole antenna

The theory of the model uses the equivalence between the power emitted by the dipole antenna and the probability for the emission of a photon by a dipole transition [1,2].

1D structure
Power density:
(dependence on $\lambda$, n, d, $\kappa$)

Multiple-beam interference:

Wide-angle interference:

$d$ - dipole antenna

$K \sim \frac{(1 \pm a_1)(1 \pm a_2)}{1 - a}$

$\mathbf{a} = r_e \exp(2ikz_e)$

Power density for a random oriented dipole antenna:

$K_{RND} = \frac{1}{3} K_\perp + \frac{2}{3} K_\parallel$

The total emitted power:

$F = \int_0^\infty K(\kappa) d\kappa$

The outcoupling efficiency:

Into glass: $\eta_{glass} = \frac{I_{glass}}{F}$
Into air: $\eta_{air} = \frac{I_{air}}{F}$

3. Optimization

The thicknesses of Alq3 and the intermediate layer (IL) were optimized for enhanced outcoupling efficiency.

4. Simulation results

The influence of the refractive index of IL is investigated:

5. Conclusions

The intermediate layer always gives enhancement for the outcoupling efficiency into air ($\eta_{air}$). It is better that into index of refraction is much higher than the one of glass or the one of the organic layers.

In the case of outcoupling efficiency into glass ($\eta_{glass}$), the intermediate layer gives in enhancement only if his refractive index $n_{IL}$ is higher than the refractive index of glass.

References