THE EFFECTS OF LIGHT SCATTERING ON OLED EFFICIENCY

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Introduction

OLED outcoupling efficiency is limited by several factors, one major fact or the limitation caused by internal reflection of light with the interface between organic layers including the anode and glass substrate. We approach this problem by adding a finely exotically material to the OLED setup, which strongly scatters light. We expect the scattering to lower total internal reflection and increase outcoupling efficiency. We compare the out coupling efficiency of the control OLEDs and the OLEDs with the scattering layer.

• OLEDs can reach 15-20 times more efficiency than incandescent lighting systems.
• Of all the energy consumed in the United States (U.S.), approximately 25% is consumed by lighting.
• Lifetime efficiency in OLEDs brings high economic and ecological benefits.
• Tang and Van Slyke invented the first OLED in 1987 at Kodak labs.

THE PIN OLED STRUCTURE

Pin OLEDs architectures have the most promising efficiency. The pin OLED consists of at least five organic layers between a transparent indium tin oxide (ITO) anode and an aluminum cathode. From bottom to top these layers are a p-doped hole injection layer (HTL), an electron blocking layer (EBL), an emission layer (EML), a hole blocking layer (HBL), and an n-doped electron transport layer (ETL). Electrons are injected through the Al cathode and holes are injected into the ITO anode. These electrons and holes are driven through their respective transport layers until they drift and recombine. The EBL is designed specifically to stop electrons from passing into the ETL, while the HBL is designed to stop holes from passing the EML into the ETL. If either case was to occur, there would be a disproportional amount of recombination outside of the EML thereby lowering the efficiency of an OLED. In the emission layer, excitons are formed by the recombination of electrons and holes. Light is finally produced by the radiative decay of excitons.

THE THERMAL EVAPORATION PROCESS

1. We use a thermal evaporation process performed in an ultra-high vacuum (UHV) environment at a base pressure of 10^-7 mbar.
2. The organic molecules are placed into crucibles at the bottom of the chamber, heated by Cu coil.
3. The thickness of the HBL and EBL is set at 10nm. The thicknesses are kept between 0.3-0.4 Å/s save the HTL.
4. The ETL, along with the scattering layer (12H-2Bz) benzophenazine is varied at differing thicknesses: 40, 60, 80 and 100nm for the ETL and 0, 20, 60 and 100nm for the 12H-B.

Methods

\[ \eta = \frac{P_{ext}}{P_{in}} \]

where \( P_{ext} \) is the output power, \( P_{in} \) is the input power. The current density is calculated using the formula:

\[ J = \frac{I}{A} \]

where \( I \) is the current and \( A \) is the area of the OLED.

Extraction efficiency is calculated by integrating the spectral radiant flux over the range of wavelengths.

\[ \Phi_r(W) = \int \Phi_r(\lambda)d\lambda = \sum \Phi_r(\lambda)d\lambda \]

where \( \Phi_r \) is a function of \( f \), the wavelength. \( 16f \) is given by \( \Phi_f \) and \( \Phi_r \) is given by: \( \Phi_{f}(lm) = \int \Phi_{f}d\lambda \)

In the emission layer, excitons are formed by the recombination of electrons and holes. Light is finally produced by the radiative decay of excitons.

Results

The observed trends indicate a slight increase in efficiency for an additional thickness of 80nm. When considering the addition of the scattering layer, we see a significant increase in luminance as function of anode voltage. The same can be said for current density. Conversely, there is an increase in EQE and luminous efficiency as a function of luminance. When considering the addition of the scattering layer, we see a significant increase in EQE and luminous efficiency as a function of luminance.

Conclusion

When considering the addition of the scattering layer, we see a significant decrease in luminescence as function of anode voltage. The same can be said for current density. Conversely, there is an increase in EQE and luminous efficiency as a function of luminance. The observed increase is seen for EQE and luminous efficiency as a function of current density. This agrees with the slight increase observed when the 20nm scattering layer is added for a total ETL thickness of 80nm.

External Quantum Efficiency

The external quantum efficiency (EQE) is one of the most important figures of merit for OLEDs; it is defined as the ratio of photons outcoupled from the device to the electrons generated within the device. The best OLEDs have an EQE of about 25%. The most severe factor that limits the EQE is the outcoupling efficiency \( \xi \), which is the ratio of emitted photons to the total number of photons generated inside the OLED cavity. Although almost all charge carriers injected into the OLED form an exciton, which decays and emits a photon, most of these photons are trapped inside the OLED. Therefore, most OLED research currently focuses on clarifying the reasons for the low outcoupling efficiency and on developing new approaches to increase it.

References


