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 fairly exotic material to the OLED setup, which is strongly scattering 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.
• All of the energy consumed in the United States (U.S.), approximately 25% is consumed by lighting.
• OLED efficiency in OLEDs brings high economic and ecological benefits.
• Tang and Van Slyke invented the first OLED in 1987 at Kodak labs.

Methods

TEMPERATURE EVAPORATION PROCESS

• We use a thermal evaporation process performed in an ultra-high-vacuum (UHV) environment at a base pressure of $10^{-9}$ mbar.
• The organic molecules are placed into crucibles at the bottom of the chamber, heated by Cu coil.
• The thicknesses of the HBL and EBL is set at 10nm. The ITO is defined by integration of the photo voltages.
• We use a thermal evaporation process performed in an ultra-high vacuum(UHV) environment at a base pressure of $10^{-9}$ mbar.
• We later use an integrating sphere, allowing us to measure some characteristics directly.
• Since we cannot account for a continuous spectrum of flux, such as EQE, luminous flux($\Phi_{\text{lum}}$[lm]), luminous efficiency($\eta_{\text{lum}}$[lm/W]), and luminous intensity($\Phi_i$[lm/200W]), we use a thermal evaporation process performed in an ultra-high vacuum(UHV) environment at a base pressure of $10^{-9}$ mbar.
• We later use an integrating sphere, allowing us to measure some characteristics directly.
• The radiant flux $\Phi$ is defined by integration of the spectral radiation flux over the range of wavelengths.
• Since we cannot account for a continuous spectrum of wavelength, we use a function defined by:

$$\Phi_{\text{lum}}[W] = \int \Phi_{\text{lum}}(\lambda)d\lambda$$

where $\lambda$ is the wavelength, $\Phi_{\text{lum}}(\lambda)$ is the luminous flux of the source, and $\eta_{\text{lum}}$ is the luminous efficiency.

$$\eta_{\text{lum}}[W] = \Phi_{\text{lum}}[W] = \int \eta_{\text{lum}}(\lambda)d\lambda$$

where $\eta_{\text{lum}}$ is the area of the OLED. We can attain $\eta_{\text{lum}}$ by measuring the spectral response of the human eye. For our measurements, $\eta_{\text{lum}}$ is the intensity of light emitted from a surface per unit area given by:

$$\eta_{\text{lum}}[W] = \int \frac{\eta_{\text{lum}}(\lambda)d\lambda}{\Phi_{\text{lum}}(\lambda)}$$

where $\lambda$ is the wavelength, $\eta_{\text{lum}}(\lambda)$ is the luminous flux of the source, and $\Phi_{\text{lum}}(\lambda)$ is the luminous flux of the source.$\Phi_{\text{lum}}(\lambda)$ is varied at differing thicknesses: 40, 60, 80 and 100 nm for the ETL and 0, 20, 60 and 100nm for the 128-B.

• Evaporation rate is kept between 0.3-0.4 Å/s save the EML and cathode which were 1.0 Å/s.
• After processing the run we measure efficiency with a photodiode by stepping the voltage by 0.1V to 4.0V on a forward forward spectrum.
• The data obtained allows us to calculate relevant attributes such as EQE, luminous flux($\Phi_{\text{lum}}$[lm]), luminous efficiency($\eta_{\text{lum}}$[lm/W]), and luminous intensity($\Phi_i$[lm/200W]), we use a thermal evaporation process performed in an ultra-high vacuum(UHV) environment at a base pressure of $10^{-9}$ mbar.
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where $\lambda$ is the wavelength, and $\eta_{\text{lum}}(\lambda)$ and $\Phi_{\text{lum}}(\lambda)$ are defined by the Planck's constant $h$ and is the speed of light in a vacuum, and $q$ is the elementary charge.

Conclusion

When considering the addition of the scattering layer, we see a significant decrease 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. The same increase trend 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. The observed trends indicate a slight increase in efficiency for an additional scattering layer of 20nm. However, the increase is small (about 1-2% in EQE), which is most likely within the usual scattering of experimental data. Furthermore, thicker scattering layers (40nm and above) show severely degraded charge transport properties and almost no light emission. More experiments must be performed to clarify the influence of a thin scattering layer on the efficiency of OLEDs. Structural characterization of the scattering layers, e.g. by scanning electron microscopy, is essential. Furthermore, modelling by FTDT methods will clarify the influence of scattering on the OLED behavior in more detail.

References