Simulated Organic Light-emitting Diode Optimization

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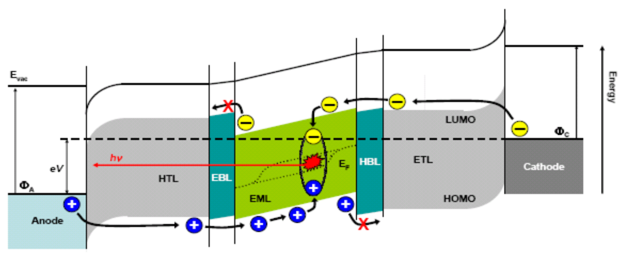
Introduction

The optical properties for an organic light-emitting diode (OLED) are modeled by the transfer matrix algorithm. Using the commercially available software package SimOLED, we adjusted the dimensions of the organic layers of the OLED to achieve the optimal optic properties for a red OLED. We also studied the underlying model the program uses for its calculations, and how it can be used to determine the emission of the OLED at different wavelengths and viewing angles.

The advantages of using an OLED include high energy efficiency, vibrant color, high contrast, low cost, and the ability to be placed on flexible substrate. The major disadvantage is the low optical efficiency. The goal of this sort of optical simulation is to optimize the outcoupling efficiency, which is usually around 28-29%

Organic Light-emitting Diode



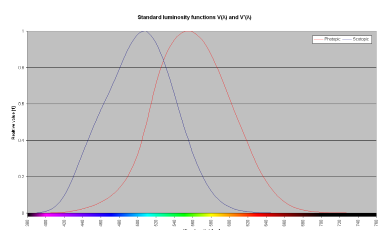
[1] Meerheim, PhD Thesis 2009

An organic light-emitting diode (OLED) is made up of at least 5 organic layers

- The hole-transport layer
- The hole-blocking layer
- The emission layer
- The electron-transport layer
- The emission layer

In order to optimize the optical properties of the OLED, we adjusted the width of the organic layers to achieve resonance for red light. The OLED acts as a resonance cavity, and the light acts as a standing wave, with the node positioned on the emitter.

Optical Properties

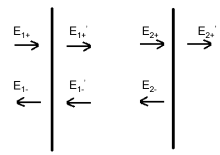


http://www.giangrandi.ch/optics/eye/eye.shtml

This graph (red curve) shows the relative sensitivity of the human eye with respect to differing wavelengths, with the peak around 555nm (in the green region).

Radiance: radiant power per solid angle per projected area of a light source
Photon Flux: the number of photons per second per unit area
Luminous Flux: radiant power with respect to the sensitivity of the human eye to light
Luminous Intensity: luminous flux per solid angle
Luminance: luminous intensity per unit projected area, or "brightness"

Transfer Matrix Algorithm



$$\begin{bmatrix}E_{1+}\\E_{1-}\end{bmatrix}=\frac{1}{\tau_1}\begin{bmatrix}1&\rho_1\\\rho_1&1\end{bmatrix}\begin{bmatrix}E'_{1+}\\E'_{1-}\end{bmatrix}$$
$$=\frac{1}{\tau_1}\begin{bmatrix}1&\rho_1\\\rho_1&1\end{bmatrix}\begin{bmatrix}\exp(ikl)&0\\0&\exp(-ikl)\end{bmatrix}\begin{bmatrix}E_{2+}\\E_{2-}\end{bmatrix}$$
$$=\frac{1}{\tau_1}\begin{bmatrix}1&\rho_1\\\rho_1&1\end{bmatrix}\begin{bmatrix}\exp(ikl)&0\\0&\exp(-ikl)\end{bmatrix}\frac{1}{\tau_2}\begin{bmatrix}1&\rho_2\\\rho_2&1\end{bmatrix}\begin{bmatrix}E'_{2+}\\0\end{bmatrix}$$

The transfer matrix algorithm gives the change in electric field as light propagates through a medium (propagation matrix) and passes through an interface(matching matrix).

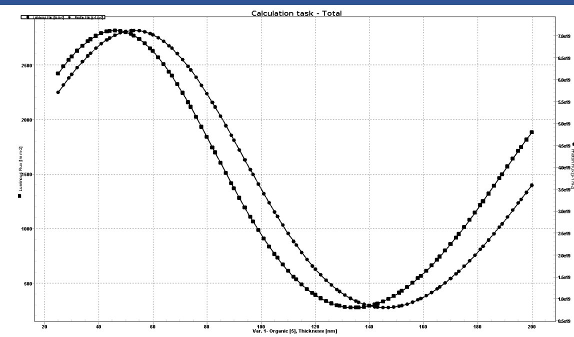
SimOLED

The SimOLED program uses the transfer matrix algorithm to calculate the optical properties of light as it travels through an OLED. We input the materials that made up each layer of this particular OLED. We then adjusted the width of the electron-transport layer to achieve resonance and maximize the efficiency of the OLED.

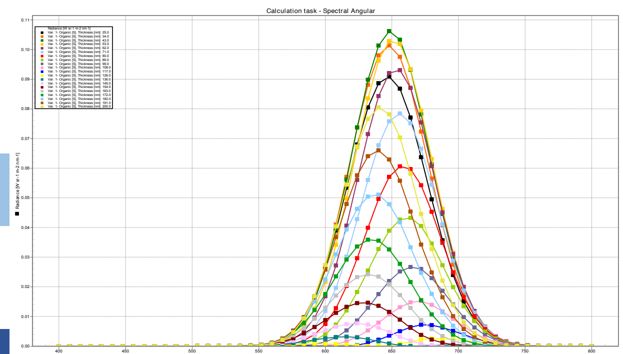
Future Direction

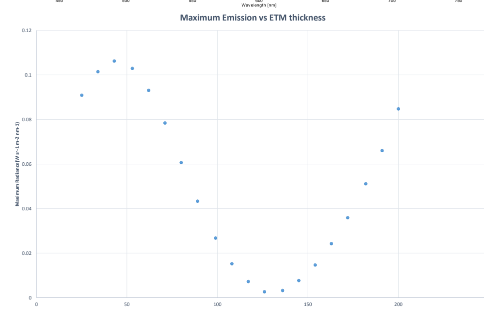
Future application of this sort of research includes improving the optical efficiency of OLEDs. They are highly energy efficient, but only have an optical efficiency of around 28-29%. Another application would be constructing these OLEDs on flexible substrates for a wide variety of purposes.

Results

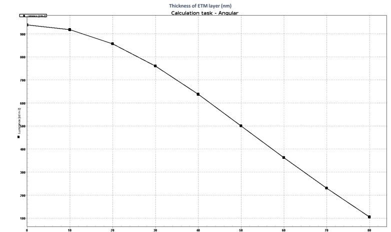


This graph shows the luminous and photon fluxes as the thickness of the ETM layer is adjusted. The shift between these two fluxes is due to the change in wavelength (color) of the light as the cavity changes its resonance state. It shows a maximum emission at 50nm and a minimum at 140nm. This is due to the interference as the OLED is closer or further from its resonance state. When the ETM layer is at 50 nm, the light constructively interferes as a standing wave, with the node on the emitter. When the ETM layer is at 140nm, the light destructively interferes and very little light is emitted.





These graphs show how the radiance and wavelength of the emitted light varies as the thickness of the ETM layer changes. This shows a peak radiance for the wavelength of red light, about 650nm. This graph also shows a loss of radiance and a deviation of the peak radiance for thicknesses that differ from the resonance state.



This graph shows how luminance drops as the viewing angle increases. This is because the OLED is a *Lambertian* emitter, that is, it obeys Lambert's emission law. The observed radiance, or luminance, is the same from any angle since the apparent size (solid angle) of the surface corresponds to the decreased emission.