Grid Optimization of Large-Area OLED Lighting Panel Electrode

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Introduction:
OLED (Organic Light Emitting Diodes) are light emitting panels made from organic material that emits light when electricity is applied. OLED are used today to make beautiful and efficient display and large lighting panels. An OLED light source is a thin film of material that emits light. OLED is now the only technology that can create real plat panels light source (Fluorescent and LEDs are all point light source). OLED s can be used to make flexible and transparent panels, and can also be made to be color-tunable. It has the advantages of energy saving (low operating voltage and current density), and it emits beautiful soft diffused light, which is the closest light source to natural light so far (with exception of the old incandescent lamps). Several company already offer OLED lighting panel, include Philips and LG. It was expected that the OLED market will emerge in force by 2016 to 2017. This project intend to reduce the energy loss in the operation of OLED lighting panel and improve the light uniformity by the geometry optimization of metal grid on OLED electrode by quantified models and experiment verifications.

Abstract:
One method to optimize the performance of OLED lighting panel is to add narrow metal mesh grid to transparent electrode. The uniformity and potential wastage can consequently be improved thanks to less transmission losses on metal. The luminance losses of different shapes of grids vary from each other and it is important to find an optimal shape Our aim is to demonstrate a calculation model and an optimization model on electrical properties of meshed OLED, simulate the voltage and luminance distribution to find an ideal mesh pattern and fabricated the real meshed OLED for experiment measurement. The stage of process can be shown in Fig.1.

Calculation Model:
The calculation model is constructed based on the Poisson equation of in electrostatic field. Top-bottom electrode mode in OLED lighting panel was adopted as shown in Fig.2. The I-V characteristic relationship of OLED material in our lab initialize the calculation of current density and potential distribution on lighting panel anode. L-V characteristic relationship of OLED material in our lab enable a regression from potential distribution towards luminance distribution.

\[ j_x(x,y) = -\sigma \text{grad} V_x(x,y) \]
\[ j_y(x,y) = -\sigma \text{grad} V_y(x,y) \]
\[ j_z(x,y) = \sigma (V_x(x,y) + \alpha(V_y(x,y) - V_0(x,y)) \]
\[ L(x,y) = k(V_y(x,y)) \times V_x(x,y) \]

Fig.2: square (left) and hexagonal (right), Parameter width (w) and height (h) are the same for this 2 shape. (b) Top overview of grid pattern: square (left) and hexagonal (right)

Fig.3: Cross-section of OLED device with metal cathode and transparent bottom electrode with metallic grid applied.
Optimization Model:

The optimization model constructed is based on the data analysis of free data simulated result from the calculation model. With calculated geometry factor $A$, minimum luminance loss under best apothem $h$ can be derived. With optimized $h$, the optimized relative luminance under different driving voltage can again be simulated as a feedback simulation towards the calculation model.

$$V_{drop,ITO} = A \cdot j \cdot \frac{R_b}{h^2}, \quad V_{drop,grid} = B \cdot j \cdot \frac{R_{eff_g}}{a^2},$$

$$V_{drop,grid} = 1 - \frac{2}{D(V)} \frac{h}{a} \cdot \frac{1}{A \cdot \frac{j}{V} \cdot \frac{R}{b} \cdot \frac{2}{Le} \cdot \frac{h}{a}}$$

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$$L_{avg,min}(V_e) \rightarrow \Delta V \rightarrow A \ (geometry \ factor) \rightarrow \Delta L \rightarrow h \ (optimized \ apothem)$$

$\Delta e^h (relative \ luminance)$

Fig.5 Process of modeling

Calculation:

It was found each shape has a unique geometry parameter that are independent from width, height and other physical condition of anode metal grid by calculation model. With this geometry parameter $A$, the optimized result of the height of metal grid and corresponding luminance and relative luminance can be simulated base on the optimization model. Comparing with the simulation of former calculation model. A certain degree of enhancement on relative luminance has been proved. The relative luminance on largest edge voltage is 73%.

Fig.6 Simulation image of (a) current distribution (b) voltage distribution on metal grid (c) voltage distribution on ITO electrode.

Simulations was done based on calculation model with free parameter $w_1=0.5mm$, $w_2=0.05mm$, $h=5mm$. The data of minimum and average voltage as well as luminance was taken from simulation in order to find the geometry parameter that will be used in optimization model.

Fig.7 optimized result of (a)grid height (b) relative luminance (c) un-optimized relative luminance.

Fig.8 Product and 3D model of OLED lighting panel fabricated in university nano-material fabrication facilities.

Fig.9 Experimental result of (a) Maximum luminance (b) Minimum luminance (c) Average luminance (d) Relative luminance of OLED panels with 4 different electrodes.

Conclusions:

A calculation model and a voltage model for the voltage distribution and luminance drops on a bare or grid patterned OLED lighting panel has been constructed. Simulations based on the calculation model was done in order to conduct the geometry optimization simulation based on optimization model. The best geometry hexagonal shape was found among 5 geometries. Simulation on optimization model shows a result of 73% relative luminance in largest boundary voltage. The experiment conducted in NFF has demonstrated 4 kinds of different anode grid device. The experimental data shows same profile with that of the simulations, which verified the feasibility of our calculation model.

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