PWDAS-38

THERMAL AND ELECTRICAL CHARACTERIZATION OF LARGE AREA OLEDS

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1. Introduction

Research until now has mainly been motivated by glassbased organic electroluminescence (OLED – Organic Light Emitting Diode) displays [1], where the aspects of increased contrast, high viewing angle and response speed are critical. With the increasing luminance and efficiency of OLEDs intelligent lighting applications are becoming increasingly relevant. In our EU FP7 research project called Fast2Light [2] the overall objective is to develop a novel, cost-effective, high-throughput, roll to-roll, large area deposition process for fabricating light-emitting polymer-OLED foils for intelligent lighting applications.

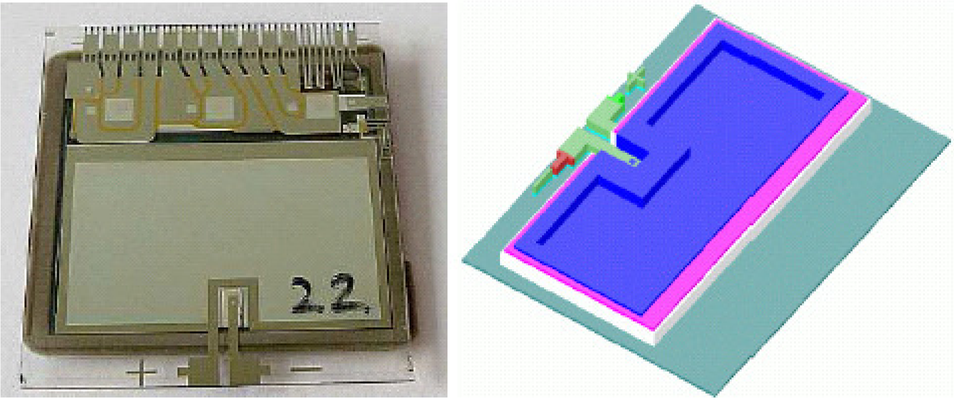

Figure 1: Photograph and 3D simulation model of the investigated OLED device.

To ensure uniform luminance over the large surface of the targeted lighting device (60 cm × 60 cm) the voltage distribution must be (very close to) uniform. Due to the poor conductance of the anode material this goal can only be achieved by using a grid of some material of high conductance (shunting grid). Copper or silver are possible solutions from technological point of view, the latter makes the production cost higher. Whichever metal is used the grid wires are not transparent to light so they decrease the luminance of the device (out-coupling efficiency). In order to work out thermal and electro-thermal characterization strategy for the Fast2Light project, for the actual initial simulations and measurements we used a proprietary OLED device (see Figure 1) provided by a project partner. The device was realized on glass substrate. The size of the large device was approximately 3.3x2.1cm$_2$.

2. Simulation needs

The poor electrical conductance of the anode layer and the large area of the targeted lighting device (60 cm × 60 cm) raise the need for electrical simulation, to predict the voltage drop over the large surface. The electrical simulations aim at finding the optimal grid geometry that can ensure the uniform voltage but does not reduce luminance by more than a few percent. For the electrical simulation of large area OLEDs conventional lumped electrical circuit models are not appropriate; a distributed approach must be applied. In its physical nature, the electrical simulation problem resembles thermal simulation. The electrical potential distribution can be studied using a thermal simulation tool utilizing the electrica – thermal analogy. 1W dissipation corresponds to 1A electrical current. In this case, 1K/W thermal resistance represents 1 Ω of electrical resistance and the simulated temperature corresponds to the potential distribution, consequently, 1K temperature difference corresponds to 1V of potential drop. Thermal simulation is also a must in OLEDs mainly because heat-sensitive organic materials are applied. Thermal simulations aim at examining the temperature distribution over the surface and inside the layer structure to ensure the correct functioning of the device by avoiding e.g. hot spot formation, thus avoiding local overheating which may result in dark dots.

3. Simulation and measurement of OLEDs

The SUNRED algorithm has been developed for thermal field simulation [3], [4] at the Department of Electron Devices (DED) of BME, and later it has been completed by an electrostatic extension [5]. Electro-thermal simulation required a major revision of our algorithm: while thermal and electro-static problems can be described by scalar fields, electro-thermal problems require the computation of two dimensional vector fields. The description of the successive node reduction method can be found in our earlier publications such as [3] and [10]. Considering the 2D/2.5D nature of OLED devices, using the in-house implementation of the SUNRED algorithm was an ideal choice, also because this algorithm yield very precise results for heat-flux / electrical current density distributions which are also of major concern. Thermal and electrical measurements: Usual electrical characteristics of OLEDs () can be measured with conventional laboratory equipment. At our laboratory such measurements can We carried out measurement of I-V characteristics in temperature controlled environment, the device under test was attached to a thermostated cold-plate (Figure 2).

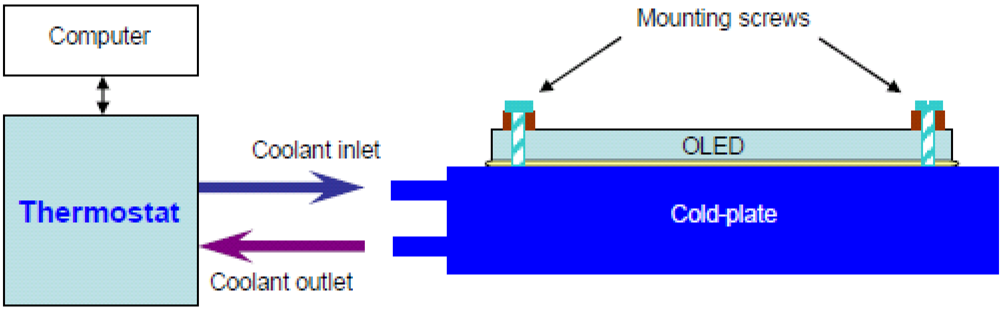

Figure 2: Measurement setup for measuring the I-V characteristics of OLEDs

For a comprehensive characterization of OLEDs the light emission should also be measured as function of operating current and temperature. The overall energy efficiency (emitted optical power related to supplied electrical power, ie. P_{opt}/P_{el}) can be calculated this way, which is inevitable for validating the simulation model and for predicting the surface temperature distribution. These measurements were done using the TERALED equipment of Mentor Graphics MicReD [7] (see Figure 3).

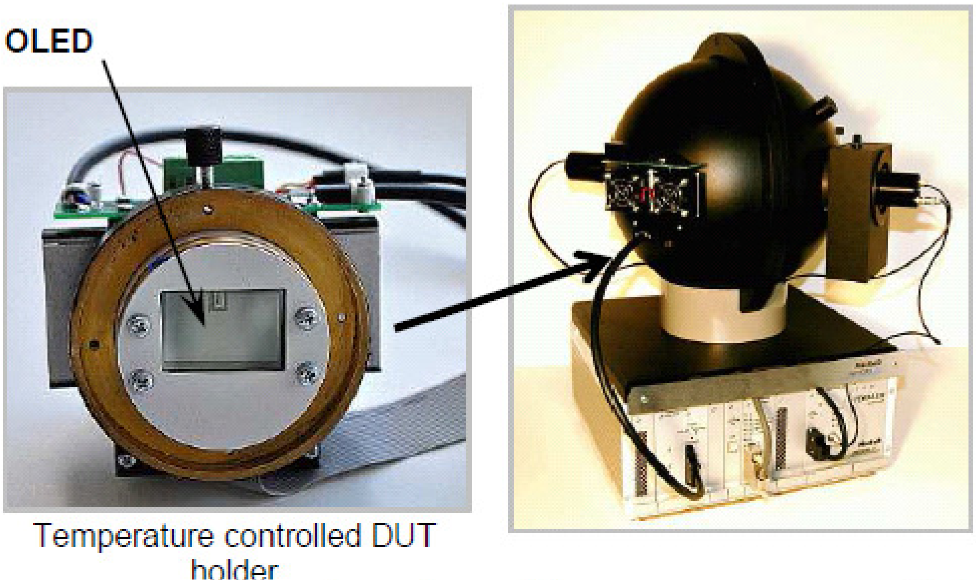

Figure 3: Integrating sphere with a temperature controlled DUT holder and the OLED device attached to it.

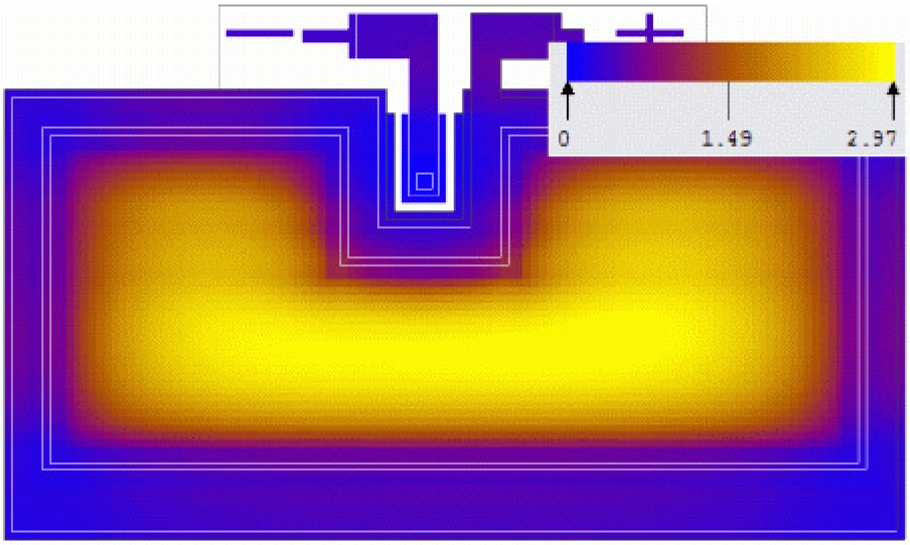

Figure 4: Temperature map of the active layer

4. Results

All simulation results presented here were generated with the newly developed electro-thermal capable SUNRED program. The thermal result, the distribution of the temperature rise with respect to the ambient temperature is shown in Figure 4. As it can be seen the maximum temperature rise is 3°C. To decide whether this temperature variation is important or not from the point of view of light emission, luminous flux measurements must be completed at different ambient temperatures with fine temperature steps. This way, based on the measured temperature sensitivity of the luminous flux, the simulated temperature distribution can also be correlated to the luminance distribution of the device. The electrical result, the potential distribution in the active layer is shown in Figure 5. The potential in the cross-section AA (marked in Figure 5) is shown in Figure 6.

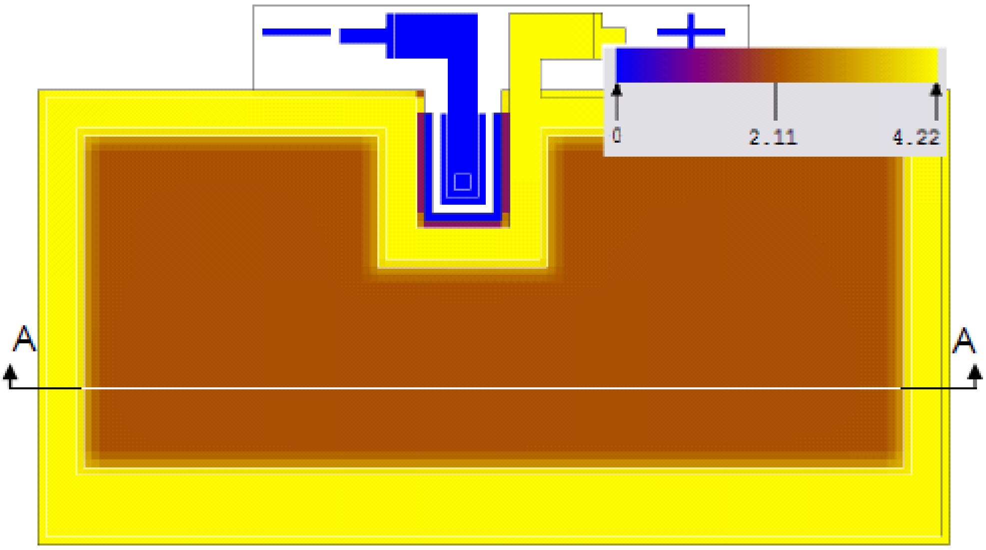

Figure 5: Potential distribution in the active layer.

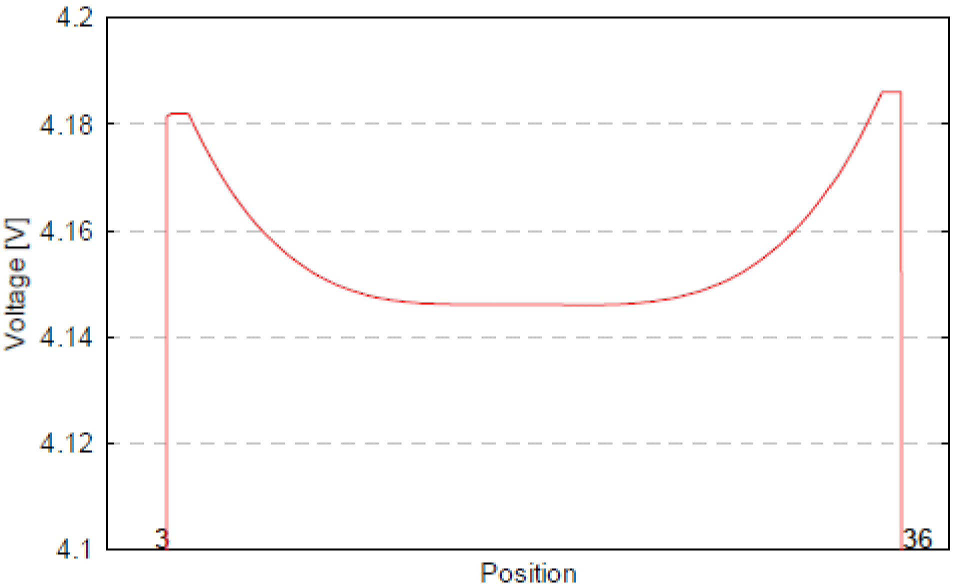

Figure 6: Potential along the cross-section line AA. structure.

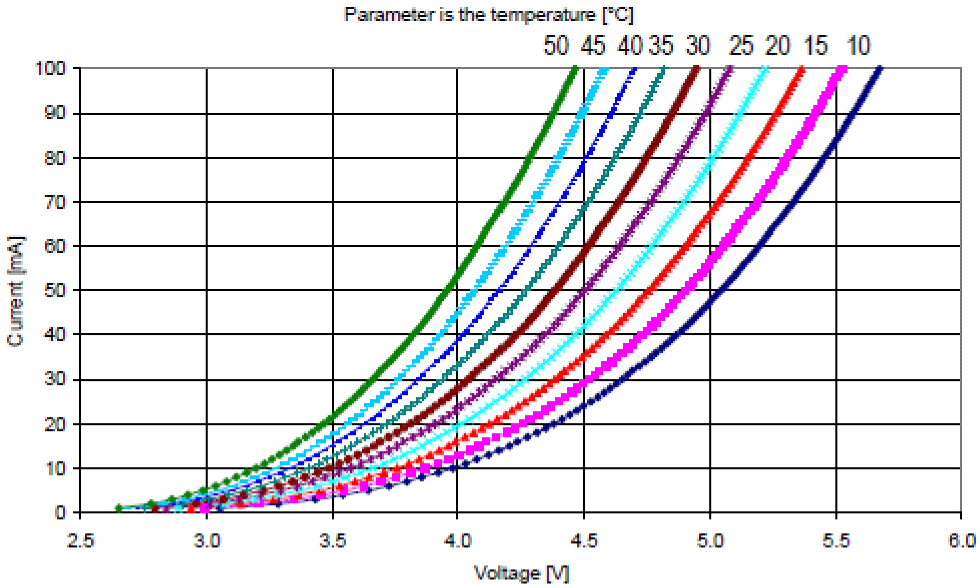

Figure 7: Measured current-voltage characteristics.

Current–voltage characteristics were measured at 10 different temperature values between 5°C and 50°C. The measured I–V curves are presented in Figure 7. Based on these measurement results we already started creating temperature dependent lumped SPICE-like model aimed at circuit level simulation. Further measurement results are shown in Figures 8-10.

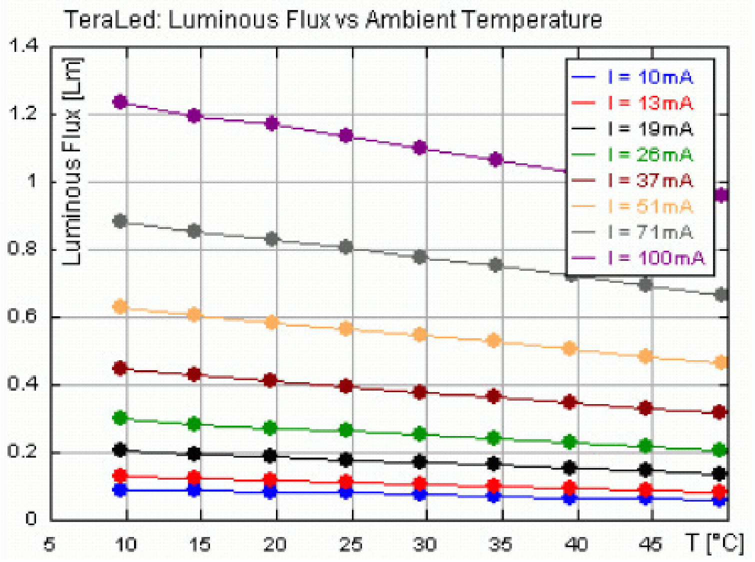

Figure 8: Measured luminous flux of the OLED sample as function of operating current and temperature.

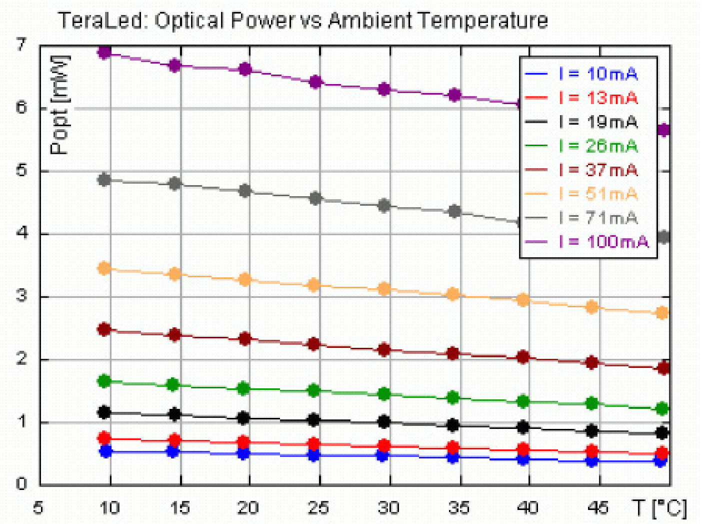

Figure 9: Measured radiometric flux (emitted optical power) of the OLED sample as function of operating current and temperature.

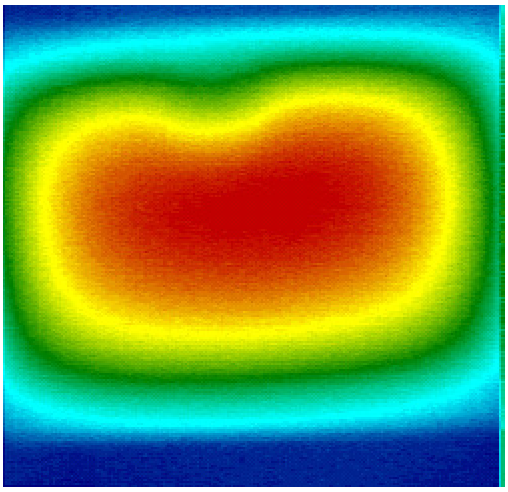

Figure 10: IR image of the OLED sample to be used for validation of the thermal simulation model

5. Conclusions

Preliminary simulation study based on the layer structure of an existing OLED was carried out, aiming at development of simulation methodology for large area, foil based OLEDs to be developed in the Fast2Light project. Inspired by the needs of OLED simulations the SUNRED code was modified to handle electro-thermal problems [8]. A validation technique of the OLED simulation models was outlined, including the following:

- measurement of I-V characteristics of OLEDs in a temperature controlled environment; identification of the temperature sensitivity of the forward voltage as a temperature sensitive parameter (TSP);
- measurement of the temperature sensitivity of the light output
- measurement of the energy conversion efficiency (providing input for correction IR measurement results)
- IR measurements to validate thermal simulation models.

Acknowledgments

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