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Light-emission simulation of organic light-emitting diodes by using discrete ray-trace optical computation

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Abstract – Discrete ray-trace optical simulation have been used in order to reproduce the light- emission properties of organic light-emitting diodes in real situations. Distributions of discrete emitting points were spread over the whole organic active layer accordingly to the charge-carriers distributions calculated considering trap-limited space-charge current behavior under different conditions of applied voltage. Optical properties as rear electrode reflectance, internal absorption of the polymeric layer and the reflectance of the ITO/glass substrate were considered in the model and demonstrated to influence the angle dependence of the emitted light. Results obtained from the calculations can be used to improve device structures as well as to simulate the optical characteristics of RGB pixels.

Optical computation using discrete optical elements are generally used in several research and development areas, mainly in optical instruments design and optimization. Recently [1], a model using ray-trace simulation in a non-sequential configuration was used to simulate radiation effects on optical components in space have shown that such method is also suitable to simulate material properties of optical devices. In this work, the optical characteristics of organic light-emitting diodes (OLEDs) are simulated by considering discrete distributions of emitting points due electroluminescence in the active organic layer.

The density distribution of emitting points in the OLED active layer was estimated by using a trap-limited space charge current model considering transport of both type of charge carriers and bimolecular recombination as the source of the device electroluminescence [2]. In this model, the charge carrier mobility of both type of carriers was considered to be the same, however, electron transport in the bulk is severely dominated by traps, giving rise a considerably lower distribution of negative charge carriers which contribute to the light-emission from the organic layer. Figure 1 shows the charge carrier distributions of free electrons and holes, at an applied voltage of 10V, considering ohmic electrodes for both types of carriers, a carrier mobility of 5×10^{-7} $cm^2/V.s$, and an electron trap density of 10^{18} cm^{-3}. Discrete distributions of emitting regions were spread over the polymeric layer considering a 120nm thick active layer and uniform distribution in the plane perpendicular to the emission direction. Emitting area of the device was limited to a 200x200 μm region, simulating a large-area pixel. Optical properties of the device as internal transmittance, reflectance of ITO/glass substrate and of rear electrode were considered in the simulations. Fig. 2 shows the detector image of the simulated pixel at normal incidence. Dependence of the emission with the viewing angle and wavelength were obtained in different conditions and can be used to improve device performance in multiple pixel arrays.

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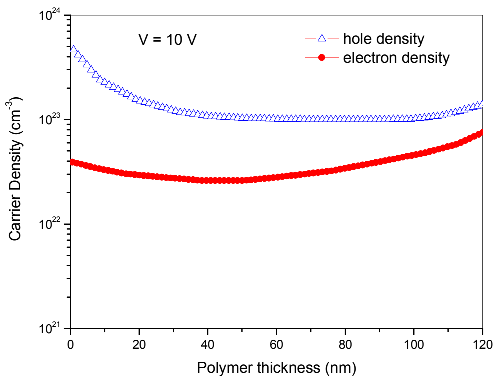

Figure 1: Carrier density distributions calculated for electrons and holes.

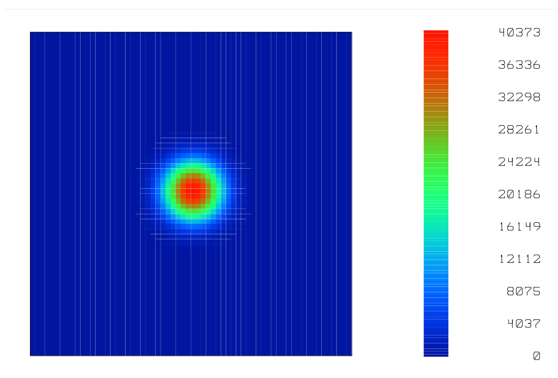

Figure 2: Detector image of the simulated pixel.

[1] L.F. Santos, L.C.N. Scaduto, E. G., Carvalho, M.A. Stefani, *Simp. Bras. Sens. Rem.* **13**, 6387-6394 (2007).
[2] P. W. M. Blom, M. J. M. de Jong, IEEE J. Sel. Top. Quant. Elec., 4, p. 105 (1998).