Development and experimental validation of a predictive electrical model of organic light-emitting diodes

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OLEDs are large-area light sources with potentially unique applications, e.g. as very thin light-emitting foils with every desired color. The light-emitting layer is only approximately 100 nm thick, and consists of a large number of organic semiconductor sub-layers, each with a different function. The physics which describes the opto-electronic processes is radically different from that in inorganic LEDs, due to the presence of strong disorder. Three-dimensional Monte-Carlo simulations show that the current density is therefore filamentary.

In the first part of the talk, it is shown that such 3D calculations can now be used to obtain the 3D current density and recombination profile, without the need to develop for each layer and each charge carrier one-dimensional expressions for the mobility function [1]. Although such calculations are computer-time-intensive, they provide information about the 3D spatial distribution of the charge-carrier density and the exciton density, and at a 3D-level about the charge-exciton and exciton-exciton quenching processes which determine the efficiency and lifetime at high current densities. Whereas this is still work-in-progress, it is shown how such studies can already now be used to evaluate the sensitivity of the OLED properties to materials parameters and OLED stack design changes.

In the second part of the talk, it is discussed how the results of 3D calculations can be accurately “translated” to one-dimensional mobility models. The following situations concerning transport and recombination in white multilayer OLEDs are considered:

- A novel view on the effects of Gaussian disorder on the mobility [2].
- Accuracy and limitations of parameter extraction methods [3].
- Transport of in an electric field at interfaces and in the presence of trap states [4].
- Modelling of time-dependent transport, as in the case of impedance or dark-injection experiments, including a realistic description of the process of charge-carrier relaxation [5].
- Modelling of transport in systems with very thin layers, and with emissive dyes.
- Modelling of charge-carrier recombination in disordered systems [6].
- Experimental validation using emission profile reconstruction [7].

In an outlook, several open issues, where a 3D-to-1D translation has yet to be realized, are discussed.

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