Coating and drying of SMOLEDs

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Research on electronic devices based on organic materials, like organic light-emitting diodes (OLEDs), has gained much attention due to the potential for cheap and ultrathin illumination sources with high viewing angle and color range. Charges are induced from the electrodes into an organic semiconducting layer and recombine to form an exciton. The relaxation from the excited to the ground state results in the emission of light [1]. In multilayer devices it is possible to improve the carrier injection efficiency from the electrodes into the light-emitting layer (EML), ensuring the emission color purity, but increasing cost and complexity. The structure may include specific layers for hole or electron injection (HIL/EIL), transport (HTL/ETL) and blocking (HBL/EBL) [2]. Figure 1 gives an overview about the basic working principle.

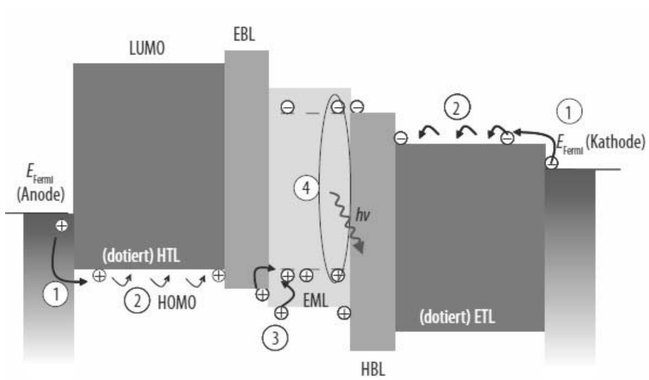

Fig. 1: Potential schematic of the device structure [2]

As OLED material, low and high molecular weight compounds can be used. Currently small molecule based OLEDs show the best performance for applications in the lighting market. SMOLEDs are commonly fabricated via vacuum deposition processes, which include an additional purification and allow the multi-layer preparation without serious problems [3]. Unfortunately, the sublimation technique is relatively expensive and limited to vaporizable

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materials. Alternatively, solution processes allow continuous, low cost and large-scale production with less material usage, but there are still challenges to face, like the solubility and coatability of the materials and the formation of homogeneous thin films.

In the project "Print-OLED" within the BMBF cluster of excellence "forum organic electronics in the metropolitan region Rhine-Neckar" the preparation of solution processed SM-OLEDs is investigated. The goal of the project is a highly efficient monochrome multilayer OLED. Topic of the presented investigations are the deposition method and the drying of the hole injection layer during the solution process.

Different materials with different solvents or solvent mixtures are investigated, regarding the solubility and coatability. Primarily, the hole-injection-layer is coated from solution on glass substrates with a transparent conducting layer (ITO or ZnO) and different deposition methods for thin, homogeneous and structured films are evaluated. A simple method with low material usage is knife coating, but for this self metered method a calibration for each material system is necessary. Slot die coating produces very homogeneous layers and the film thickness can be adjusted by pre metering the coating fluid without calibration. By employing a syringe pump and optimizing the die cavity a slot die with less than 2 ml holdup was developed (figure 2). Material data like viscosity and surface tensions were determined to obtain the coating process parameters.

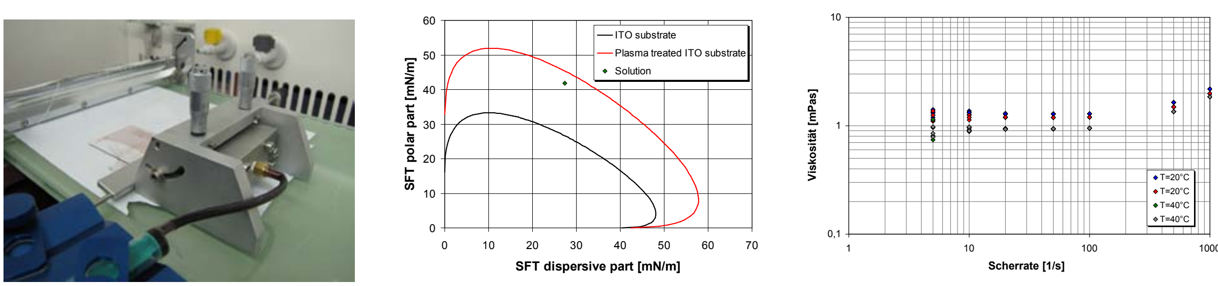

Figure 2: Coating parameters. Left: Experimental setup for slot die coating, Middle: Wetting envelopes of ITO, Surface tension of solution, Right: Viscosity of solution

Special attention will be drawn to the drying process of the casted solutions, since this is an important step during the production. The exact knowledge of the drying process is not only required for the construction of dryers in an economical production, first results also denote a strong influence on the formation of the film (homogeneous material spreading, dewetting, surface structure, alignment of the molecules). The use of solvent mixtures with more and less volatile solvents permit to control the drying kinetic and hence the film formation of the hole injection layer. Figure 3 gives an overview about the influence of the drying kinetics. The used small molecule solved in Dioxane tends to dewetting phenomena after film deposition (left). If a mixture with a more volatile solvent is applied a homogeneous film can be generated by fast drying (middle). Slow drying results in a primarily homogenous film at the edge, segregating to single droplets in the middle (right).

Figure 1: Hole injection layer (small molecule) prepared by dropcasting and dried under different conditions. Left: Solved in Dioxane, Middle: Solvent mixture, fast drying, Right: Solvent mixture, slow drying.

To characterize the drying behavior, the thin film will be dried on a temperature controlled plate within a drying channel, where defined drying conditions can be adjusted. To analyze the drying process, the experimental results have to be compared to model calculations. Therefore, the mass transport in the gas phase, the sorption equilibrium at the phase boundary and the mass transport within the film [4] have to be taken into account.

In the next step, the missing layers and the electrodes will be applied via vacuum deposition and hence the consequent influence of the solution processed layers on the electronic properties and electroluminescence of the device can be tested.

Acknowledgement

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References

[1] Nuyken O., Jungermann S., Wiederhirn V., Bacher E., Meerholz K., Modern Trends in Organic Light-Emitting Devices (OLEDs), Chemical Monthly 137, 811-824, 2006

[2] Klein M., Heuser K., Lichthimmel und Lichttapeten, Organische Leuchtdioden ermöglichen völlig neuartige Beleuchtungsanwendungen, Physik Journal 7, Nr. 5, 2008

[3] Köhnen A., Riegel N., Kremer J., Lademann H., Müller D., Meerholz K., The Simple Way to Solution-Processed Multilayer OLEDs – Layered Block-Copolymer Networks by Livinf Cationic Polymerisation, Adv. Mat., 21, 879-884, 2009

[4] Schabel W., Scharfer P., Müller M., Ludwig I., Kind M., Messung und Simulation von Konzentrationsprofilen bei der Trocknung binärer Polymerlösungen, Chemie Ingenieur Technik 75 (9), 1336-1344, 2003