Enhanced Control of OLED Deposition Processes by OVPD®

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Keywords: Organic Vapor Phase Deposition, Equipment, OLED Manufacturing, OVPD

Abstract

The enhanced control of OLED deposition processes by Organic Vapor Phase Deposition (OVPD®) is discussed. OVPD® opens a wide space of process control parameters. It allows the accurate and individual control of deposition layer properties like morphology and precise mixing of multi component layers (co-deposition) in comparison to conventional deposition manufacturing processes like e. g. VTE (vacuum thermal evaporation).

1. Objectives and Background

The objective was to clarify the controllability of the deposition process for a wide range of deposition rates. For the manufacturing process it is a basic economic requirement of low manufacturing costs to achieve low tact times. This is resulting in the need to achieve high deposition rates in order to keep the deposition time short. In previous publication we have published deposition rates as high as 30 Å/s [1]. We investigated the morphology of single layers of organic material in dependence of OVPD® process parameters like deposition temperature and deposition rates. Further we investigated OLED device performance in dependency on doping concentration. As we found a particular high sensitivity of the EL-Spectra on the doping level the device reproducibility was investigated with an optimized co-deposition mixing ratio.

2. Results

We deposited α-NPD single layers on Si-wafers using an AIXTRON Gen1 OVPD® tool. For the investigation of the morphology of the organic films we analysed the surface roughness characterised by AFM (Atomic Force Microscope) and X-Ray Reflectometry. Single layers of α-NPD have been deposited at different deposition rates ranging from 2-18 Å/s and two different substrate temperatures. The controlled substrate temperature is an unique feature of the AIXTRON OVPD® process in comparison to conventional manufacturing methods as described elsewhere [2-7].

Figure 1 shows AFM images of two series of samples with different deposition rates at two different substrate temperatures. The first series using substrate temperature T_1 shows the transition from a smooth surface to rougher surface with increasing deposition rate. The second series using substrate temperature T_2 shows the opposite behavior. The film is rough at low deposition rates and gets smoother with higher rates. In conclusion this investigation shows that it is possible by OVPD® to adjust the process parameters to achieve certain desired morphologies in a wide range of deposition rates. In other words OVPD® offers a broad process parameter space to control and optimize the morphology of films as it might be advantageous for organic solar cells to have certain interfaces with rough transitions as demonstrated by

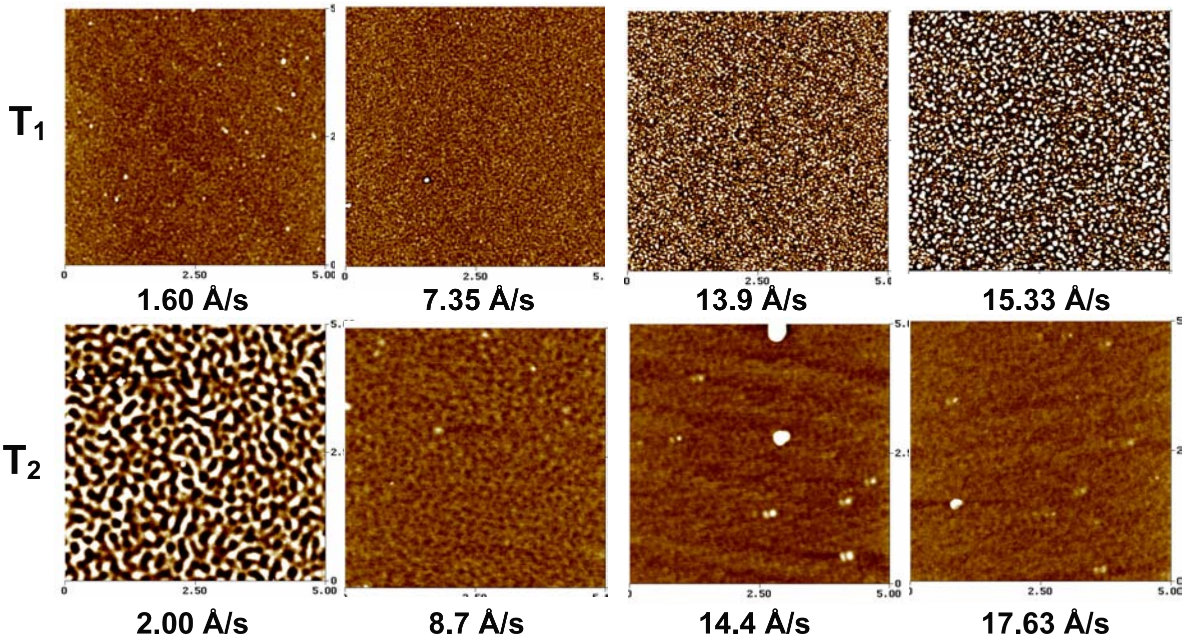

Figure 1: AFM Analysis of a-NPD single layers on Si-wafers

S. R. Forrest [6] or for smooth films for OLED devices.

For the purpose to investigate the precision of the co-deposition of a multi component film we have chosen an OLED device structure with an emission layer (EML) consisting of one host and two dopants, a green dopant (GD) and a red dopant (RD). The concentration of the red dopant was varied within a range of 0.1-0.8 % and the device characterized by electroluminescence (EL) measurements.

Figure 2 shows EL-Spectra of OLED devices. The EL-spectra is characterized by two dominant peaks: The first peak at 520 nm corresponds to the emission of the green dopant, the second peak corresponds to the emission of the red dopant. The spectra were normalized to the maximum emission peak of the red dopant.

As shown in Figure 3 the relative peak intensity GD:RD is sensitive to the doping concentration of the red dopant and decreases with increasing doping concentration.

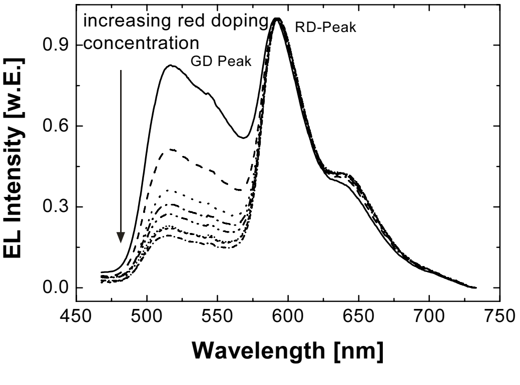

Figure 2: EL of OLED with varied doping concentration

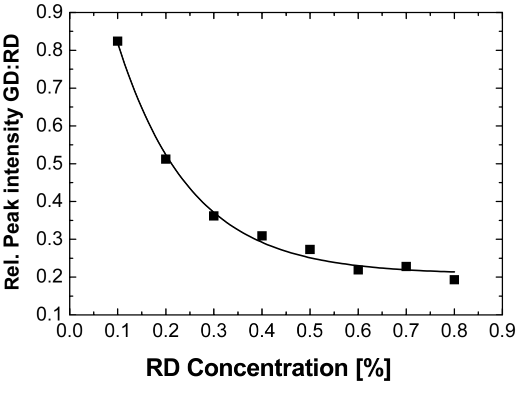

Figure 3: Dependency of relative peak intensity to doping concentration

For the investigation of the run-to-run reproducibility and controllability of the doping concentration we have chosen a fixed doping concentration of the red dopant, which showed a high sensitivity to changes of doping concentration in the previous investigation described above. The device has been manufactured eight times with the same and constant OVPD® process conditions. Figure 4 shows nearly 8 identical EL spectra indicating a very good reproducibility. We have used the calibration curves from Figure 2 and Figure 3 to back calculate the doping level obtained in the device from the respective EL spectra. As shown in Figure 5 an average doping level of 0.26 % has been achieved with a reproducibility of better than 0.38 % std. dev.

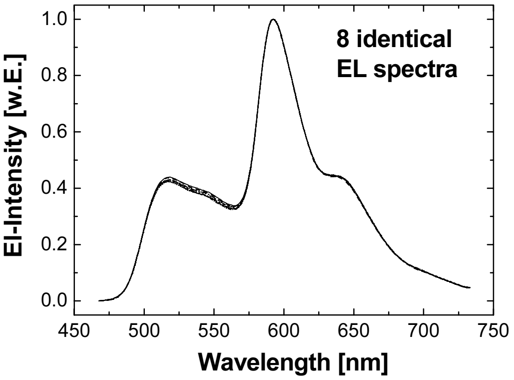

Figure 4: Reproducibility of EL-Spectra of 8 OLED devices

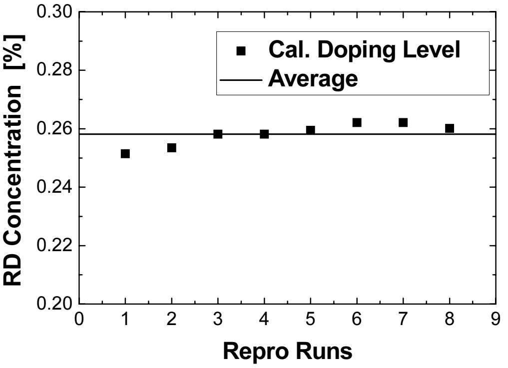

Figure 5: Reproducibility of doping level

3. Impact

OVPD® is a novel technique for the deposition of small molecular organic materials that overcomes many of the limitations of VTE. Its superiority with respect to precise, stable and reproducible control of the deposition processes could, and excellent uniformity across large areas together with high deposition rates and material utilisation efficiency when combined with Close Coupled Showerhead technology has been demonstrated [8-13]. OLEDs deposited by OVPD® show similar or better performance compared to similar devices made by VTE. Scalability, increased yield and throughput in OVPD® are important factors towards making OLED products commercially competitive to LCD. Reduced organic material consumption and reduced maintenance requirements contribute further to the reduction in manufacturing cost, which makes OVPD® the technology of choice for the next generation manufacturing of OLED displays and for the manufacturing of next generation organic devices. Here we could demonstrate important features of the OVPD® technology, which are control of morphology over a wide range of deposition rates and excellent reproducibility of the doping control.

4. Acknowledgements

The author gratefully acknowledges the valuable discussions with M. Gersdorff at AIXTRON AG, Germany.

Further we thank our collaborators at Philips-Aachen, Germany, Braunschweig University and RWTH-Aachen University.

Part of this work was financially supported by the Federal Ministry of Education and Research in Germany (BMBF, contract no. 13N8650).

OVPD® is a registered trademark. OVPD® technology has been exclusively licensed to AIXTRON from Universal Display Corporation (UDC), Ewing, N.J. USA for equipment manufacture. OVPD® technology is based on an invention by Professor Stephen R. Forrest et al. at Princeton University, USA, which was exclusively licensed to UDC. AIXTRON and

UDC have jointly developed and qualified OVPD® pre-production equipment.

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