Abstract

Both, Organic Light Emitting Diodes (OLEDs) and Organic Solar Cells (OSCs) still contain untapped potential on their way to higher efficiencies. A large portion of the generated light (ca. 80%) in OLEDs is waveguided inside the active layer and lost to absorption or edge emission due to total internal reflection. In OSCs, the low charge carrier mobilities force the use of very thin active layers in letting the charges efficiently reach the respective electrodes. This leads to rather weak absorption of the incident light and therefore insufficient charge carrier generation especially for wavelengths featuring low extinction coefficients. Both problems could be addressed by the implementation of diffraction gratings with suitable grating periods Λ in the sub-micron regime. Interaction of waveguided OLED-modes with the grating will lead to enhanced outcoupling of light into the far-field according to BRAGG-equation and therefore account for enhanced external quantum efficiency (*EQE*). Interaction of incident light in an OSC with a grating on the other hand will result in coupling light into waveguided modes which should result in an enhanced absorption and charge-carrier generation.

Photoembossing (Chapter 4.1) allows direct, holographic structuring of the emissive layer resulting both in a surface and a volume grating without any additional wet development step. In addition, this chapter presents two other applications of such gratings in solution-processed organic semiconductors.

Chapter 4.2 deals with the obtained OLED-results. Polarization- and angle-dependent electroluminescence (EL) spectra of structured OLEDs clearly showed outcoupling of three different modes. The dispersion of the effective refractive index (n_{eff}) could be calculated for all of the modes using the BRAGG-equation. By comparing the results with powerbudget calculations of the OLEDs, all outcoupled modes could be clearly assigned. Since OLEDs in general are similar in their layer properties it can be assumed that this assignment is generally true. Thus, a method allowing the determination of the n_{eff}-dispersion of all waveguided modes in structurable OLEDs without any theoretical calculations was invented. Variation of the emissive layer thickness furthermore proved the simulated localization of the modes inside the device: A plasmonic mode being waveguided near the cathodic interface, and two other modes (TE_1 and TM_1) showing expansion into the active

layer. Larger grating periods Λ resulted in diffraction of higher orders up to $m = \pm 4$. Higher-order diffraction did not contribute to enhanced emission compared to first order coupling. The illumination-setup was extended for 2-dimensional structuring of the emissive layer in order to further enhance the outcoupling compared to 1-dimensional gratings where efficiency-enhancement of 7% could be reached. While the 2D-structuring was successful the impact on the outcoupling was rather limited. Moving the location of the grating from the cathode side of the OLED-stack to the anode by structuring a photoresist underneath showed – as expected – an increased effect on the TE_1-mode since this mode is guided closest to the anode. Nevertheless, the photoresist-structured system is not completely investigate, yet. Simulations are needed for complete interpretation of the experimental results.

The concept of mode-diffraction by grating-implementation was then transferred to OSCs (Chapter 4.3). Here, only devices fabricated on top of a photoresist grating were examined since photovoltaic materials allowing the use of photombossing do not exist yet. Polarization- and angle-dependent measurements of the short circuit current (I_{SC}) under monochromatic illumination again allowed the determination of the n_{eff}-dispersion of three different modes. With certain illumination-wavelengths and under certain angles, I_{SC}-enhancement of more than a factor of 3 could be observed, with respect to flat reference cells. Diffraction orders up to $m = \pm 3$ could be seen. By comparison of experimentally obtained n_{eff}-values with refractive indices of the neat materials, the assumption could be made that one of the modes is localized in the ITO-layer whereas the most strongly coupled mode might be a plasmonic mode. These results could be confirmed by measurements in structured small molecule-OSCs, which had been vacuum-processed. Knowledge about n_{eff} of all waveguided modes finally allowed the implementation of gratings which should show enhanced I_{SC} under incident illumination with sun-like light, compared to the respective flat reference cells according to the BRAGG-equation. That expectation could not be fulfilled yet. Probably this is due to poor electrical contacts and high sheet resistance of the hole-collecting MoO_3 electrode, which serves as ITO-substitute. Therefore, the development of an alternative structuring-technique for OSCs will be of great importance for future research in this field.