Abstract

In this work, different organic semiconducting devices – in particular organic bulk-heterojunction (BHJ) solar cells – are analyzed and manipulated by the focused electron beam of a scanning electron microscope (SEM).

In the first part, the morphologies of two different BHJ solar cells are examined. The active layer of the first devices consist of the electron donating polymer poly(3-hexylthiophene) (P3HT) and the fullerene derivative 1-(3-methoxycarbonyl)-propyl-1-phenyl[6,6]C_{61} (PCBM) as electron acceptor. This system is a well-studied model system in the organic photovoltaic community. SEM analysis of the blend morphologies is possible via selective staining of PCBM with osmium tetroxide leading to higher contrast between P3HT and PCBM. Correlation between the domain sizes delivered by statistical analysis of the SEM images and the short-circuit current density of the solar cells is successfully done for different compositions of the active layer, different post deposition treatments, and different solvent mixtures during spin coating. The whole procedure is transferred to the second BHJ system consisting of a merocyanine and PCBM. Additionally, the penetration of a solid organic hole conductor into mesoporous titanium dioxide is determined by X-ray analysis in SEM. Layers with a thickness of up to 1300 nm show a complete filling with a small gradient throughout the layer. These findings facilitate measurements of the optical properties of such a layer stack.

In the second part of this thesis, formation of diffraction gratings in organic media is done by the application of electron beam lithography. First, a classical approach is used for the generation of such gratings in a cross-linkable polymer showing optical gain to facilitate lasing. Moreover, a new process for creation of one-dimensional (1D) and two-dimensional (2D) surface relief gratings in P3HT:PCBM blends is developed by combining electron beam lithography, the negative tone electron beam resist behaviour of P3HT, and hot embossing ("Electron Beam Embossing", short EBE). The optimum process parameters, the process mechanism and the properties of the required gratings are empirically determined.

Finally, EBE is used for the creation of surface relief gratings directly in BHJ solar cells as light trapping structures. Due to technical difficulties, the efficiencies as well as the short-circuit current densities of patterned single solar cells are reduced compared to

the flat references. At last, implementation in tandem cells – two active layers in series – leads to higher short-circuit current densities in the BHJ cells after patterning.