Abstract

This work focuses on the enhancement of α-sexithiophene / buckminsterfullerene (α-6T / C_{60}) inverted bilayer organic solar cell efficiency by the introduction of crystalline nanostructures in the electron donor layer. In order to utilize the charge carrier mobility anisotropy in crystalline α-6T structures in solar cells, the orientation of the individual molecules should favor charge transport perpendicular to the substrate plane. Such orientation is realized from α-6T molecules lying on the substrate, which additionally infers the preferred orientation of the transition dipole for maximal light absorption.

In this work, an organic molecular beam deposition (OMBD) system was used for studies on growth of α-6T crystalline formations directly on C_{60} thin-films. For that, a dedicated, 3-source (α-6T, C_{60}, bathocuproine (BCP)), high vacuum OMBD system has been designed and assembled. The source temperatures and a shutter were controlled by the supervisory control and data acquisition (SCADA) system, which has been implemented in LabVIEW environment. The temperatures, process pressure, and deposition rate were stored for future analysis.

By variation of the substrate temperature during deposition, different structures has been obtained ranging from a rough film, through individual clusters, a dense mesh of elongated islands, fiber like- and dendritic structures, polygonial mono-crystallites, to long curly fibers. The molecular packing in those formations has been investigated with usage of epifluorescence polarimetry and X-ray diffractometry (XRD).

Layer thicknesses of inverted α-6T / C_{60} bilayer organic solar cells fabricated at room temperature were optimized to obtain the model device for the performance enhancement studies. By variation of the substrate temperature during deposition of α-6T, the structures identified in the preceding study were introduced into solar cell devices. Using power conversion efficiency as a figure of merit, a 100% performance enhancement has been reported for devices fabricated within 10°C substrate temperature window. The enhancement was due to peaks in short circuit current density and fill factor, which were obtained when fiber-like structures consisting of lying α-6T molecules were present. Such molecular packing agrees with a favorable molecular orientation for maximal charge carrier mobility in solar cell applications.

A solar cell characterization station has been designed and build including a solution for reliable connection of an examined device to the measurement equipment. The measurement of the illumination beam profile has revealed a strong nonuniformity which led to the integration of a translational stage, which assures 1 sun illumination during device characterization. The characterization process was controlled by SCADA system implemented in LabVIEW.