Synthetic Metals 197 (2014) 210–216

Contents lists available at ScienceDirect

Synthetic Metals

journal homepage: www.elsevier.com/locate/synmet

Improvement of P3HT–ICBA solar cell photovoltaic characteristics due to the incorporation of the maleic anhydride additive: P3HT morphology study of P3HT–ICBA and P3HT–ICBA–MA films by means of X-band LESR

A. Konkin[a,*], U. Ritter[a], P. Scharff[a], M. Schrödner[b], S. Sensfuss[b], A. Aganov[c], V. Klochkov[c], G. Ecke[a]

[a] Institute for Micro and Nanotechnologies, Ilmenau University of Technology, Gustav-Kirchhoff-Str. 7, D-98693 Ilmenau, Germany
[b] Thuringian Institute for Textile and Plastics Research, Breitscheidstr. 97, D-07407 Rudolstadt, Germany
[c] Institute of Physics, Kazan Federal University, Kremlyovskaya St. 18, Kazan, Russia

ARTICLE INFO

Article history:
Received 3 March 2014
Received in revised form 9 July 2014
Accepted 11 September 2014
Available online 6 October 2014

Keywords:
LESR
Organic solar cells
ICBA
P3HT
Maleic anhydride

ABSTRACT

A light-induced electron spin resonance (LESR) X-band study of poly(3-hexylthiophene)/indene-C_{60} bisadduct P3HT/ICBA flexible solid films containing the additive maleic anhydride (MA) is presented. An increase of P3HT crystalline domain orientation in P3HT:ICBA:MA in comparison with P3HT:ICBA films was confirmed by the angular LESR spectra dependence of P3HT positive polarons. It was assumed that the average increase of power conversion efficiency in P3HT:ICBA:MA solar cells films, relative to P3HT:ICBA, is connected with the more effective crystalline P3HT phase orientation due to the MA sublimation from the composites blends during annealing. The relative average increase of power conversion efficiency of SC films containing MA in comparison to pure P3HT:ICBA blends is estimated to be a factor of (1.15) higher, while the concentrations of functional composites (polymer/fullerene) in blends made with MA decrease by up to 25–30%.

1. Introduction

The perceptible correlation between the molecular chain orientation and electrical performance of most poly(3-alkylthiophene) family polymer thin-films [1,2] is the basis for the intensive morphology study of LED, FET and bulk heterojunction (BHJ) solar cell (SC) devices. The molecular packing of this perspective type of conjugated polymer has already been successfully studied experimentally by various physical methods (some references are listed in [3]). Among the other experimental methods applied for this topic, ESR should be held apart from the others due to the registration of only the molecular structure of the bulk, including the mobile photoinduced charge (polaron) pathway. For instance, in contrast to polymer transistors, in organic SC devices the transverse (perpendicular to the film plane) charge transport between the polymer chains (the transverse mobility) should be directly related to the orientation of the crystalline P3HT domains and therefore this information is very important. The correlation of molecular packing with the electrical and photo-electrical performance of P3HT based devices was studied in SCs and FETs and selected references are presented below. Representing some additional interest in the area of semiconducting polymers is the disorder of specific low-dimensional systems (one-dimensional chains and two-dimensional lamellae). For example, the transverse charge mobility in thin films can be 2–3 orders of magnitude less than in-plane [1] and therefore the morphology study in device films is one of the main goals of the stated experiments. The sensitivity of charge mobility to the nano/microscopic structures of the film–surface interface was reported in [2], where only a small fraction of crystallite misorientation decreases the charge mobility by a factor of 10. Moreover, recently performed investigations demonstrate the particular benefit for special processing additives in donor–acceptor polymer–fullerene blends, i.e. P3HT, low-bandgap PCPDTBT polymers and $PC_{61}BM$, $PC_{71}BM$ fullerenes as donors and acceptors, respectively, which can improve the polymer morphology and therefore the voltaic and photovoltaic performance of devices presented in literature [3–8].

The efficient BHJ SC devices, composed of PCPDTBT/$PC_{71}BM$ with the processing additive diiodooctane, had an average power-conversion efficiency (η) of 5.1%, contrary to 3.4% without the

* Corresponding author. Tel.: +49 3677 693437; fax: +49 3677 693499.
E-mail address: alexander.konkin@tu-ilmenau.de (A. Konkin).

http://dx.doi.org/10.1016/j.synthmet.2014.09.012
0379-6779/