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Effect of nano particle sizes on the third-order optical non-linearities and nanostructure of copolymer P3HT:PCBM thin film for organic photovoltaics

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ABSTRACT

Organic solar cells are based on (3-hexylthiophene):[6,6]-phenyl C61-butyric acid with methyl ester Bulk Heterojunction. An inverted structure has been fabricated using nano-anatase crystalline titanium dioxide, as the electron transport layer, which was prepared on either the Indium Tin Oxide coated glass (ITO—glass), or Silicon wafer, as well as on glass substrates by the sol–gel method, at different spin speed, using the spin-coating system. The effect of thickness on the surface morphology and on the optical properties of TiO_2 layer, was investigated using the Atomic Force Microscopy (AFM), X-ray diffraction, and UV–visible spectrophotometer. The samples were examined to feature currents and voltages, in the darkness and light extraction efficiency of the solar cell. The highest open-circuit voltage, V_{oc}, and power conversion efficiency were 0.66% and 0.39%, fabricated with 90 nm, respectively. The non-linear optical properties of nano-anatase TiO_2 sol–gel, were investigated at different particle sizes, using the *z*-scan technique.

1. Introduction

With a steady improvement in energy conversion efficiency over the past decades, Organic Photovoltaics (OPV) has evolved into a promising technology for renewable energy, and this is made possible by the first report of planar donor–acceptor heterojunction. Organic Bulk Heterojunction (BHJ-OPV) Photovoltaics, are solar cells that employ the use of organic materials, using either polymers (macromolecules) or small molecules, to absorb light and produce free electrons [1,2]. The most promising BHJ-OPV devices to date, consist of conjugated polymers, such as poly(3-hexylthiophene) (P3HT), blended with soluble fullerene derivatives, such as (6,6-phenyl C61 butyric acid methyl ester) (PCBM). A basic requirement for efficient photovoltaic devices is the ability of the free charge carriers, produced upon photoexcitation of the photoactive material, to be transported to the other electrode without recombining with oppositely charged carriers. Photovoltaic devices, composed of conjugated polymers as the only active material, have extremely low electron mobility, and thus, limited performance. Recent developments have shown that the use of inter-penetrating electron donor–acceptor heterojunctions, such as polymer: fullerene, polymer: polymer and polymer: nanocrystal can result in highly efficient photovoltaic conversions [3,4].

Polymeric solar cells have attracted a lot of attention, due to the advantages of light weight, flexibility, and low cost, with the possibility of fabricating large area device by cheaper liquid based process. However, the power conversion of organic solar cells is limited as a result of the low dissociation probability of excitons and the inefficient hopping carrier transport [5,6]. The optoelectronic features of organic semiconductors are substantially different, with respect to the inorganic ones. Organic semiconductors have low charge carrier mobility, relatively strong light absorption coefficients, and shorter exciton diffusion length, in the range of 3–15 nm. However, the exciton binding energy usually exceeds those of inorganic semiconductors. Therefore, a stronger electric field is required to dissociate them into free charge carriers. The material can be formulated as nano films, using a variety of techniques, such as Spry Pyrolysis (SP) [7–9], Chemical Vapor Deposition (CVD) [10–12]: and the sol–gel method [13–19]. Titania has three main crystal phases (antatase, rutile and brookite). Among these phases, anatase phase, which is a meta-stable phase, is chemically and optically active and suitable for photocatalyst [20–22].

The sol–gel method has advantages, due to low temperature processing,easy coating of large area, and being suitable for the

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