Nanostructured composites: Potential materials for Organic Light Emitting Diodes and Organic Solar Cells

Nguyen Nang Dinh, Dinh Van Chau, Do Ngoc Chung, Nguyen Phuong Hoai Nam,
University of Engineering Physics and Technology
Vietnam National University Hanoi
144 – Xuan Thuy Road, Cau-Giay Dist. Hanoi, Vietnam
dinhnn@vnu.edu.vn

Tran Quang Trung
College of Natural Science, Vietnam National University, Ho Chi Minh
No. 227 Nguyen Van Cu Road, District 5, Ho Chi Minh City, Vietnam

It is known that adding metallic, semiconducting, and dielectric nanocrystals into polymer matrices enables enhance the efficiency and service duration of the devices. The inorganic additives usually have nanoparticle and nanorod form. Inorganic nanoparticles can substantially influence the mechanical, electrical, and optical (including nonlinear optical as well as photoluminescent, electroluminescent, and photoconductive) properties of the polymer in which they are embedded. The influence of the nanocrystalline oxides on the properties of conducting polymers has been investigated by many groups [1-3]. A very rich publication has been issued regarding the nanostructured composites and nano hybrid layers or heterojunctions which can be applied for different practical purposes. This paper presents recently achieved results on nanocomposites used for optoelectronic devices such as organic light emitting diodes (OLED) and organic solar cells (OSC).

By embedding TiO_2 nanoparticles in PEDOT (see Fig. 1) the enhancement of both the contact of hole transport layer (HTL) with ITO and the working function of PEDOT films. Incorporation of metal (Ni, Cu) and metal-oxide (NiO) nanoparticles in PEDOT used for both OLEDs and solar cells has also been studied, for example in [4]. The composites with the TiO_2 nanoparticles in MEH-PPV (abbreviated MPT) have been studied as photoactive material. It is shown that MEH-PPV luminescence quenching is strongly dependent on the nature of nanostructral particles embedded in polymers. Fluorescence quenching is much higher with rod titanium dioxide. In principle, rod particles can be expected to exhibit higher photoactivity with respect to spherical particles. In fact, when compared with the dot-like shape, rod-like geometry is advantageous for a more efficient packing of the inorganic units, owing to both a higher contact area and more intensive Van der Waals forces. Actually, the higher quenching of the polymer fluorescence observed in presence of titania nanoparticles proves that transfer of the photogenerated electrons to TiO_2 is more efficient for rods. Characterization of the nanocomposite films showed that the current-voltage (I-V) characteristics of the OLEDs made from nanocomposite layers were significantly enhanced in comparison with the standard polymers (Fig. 2). The OLEDs made from these layers exhibited a large photonic efficiency.

For MPT composites with a 25 wt% of nc-TiO_2, both the homogeneity and the porosity in the distribution of nc-TiO_2 particles in the polymer (Fig. 3) exhibited a suitable material for OSCs. A solid-state photovoltaic device using a surface-adsorbed dye complex for light absorption and electron injection to the TiO_2 layer is called eta-solar cell, in which an extremely thin absorber (eta) is sandwiched between two wide-band gap semiconductors, one n-type and the other p-type. In our experiments, instead of the polymer layer, the MPT layer was deposited by spin coating onto the thin TiO_2/ITO electrode. To prepare an OSC with the structure of ITO/TiO_2/MPT/Al, a thin aluminum electrode was successively evaporated onto the MPT layer.

Figure 4 shows the current-voltage characteristics of an OSC using the nanocomposite with 25 wt% of nc-TiO_2, the dark current is given in a dashed line. The light gray rectangle illustrates the fill factor (FF) that is equal to 0.34. The fact that FF is considerably large proves that the nanostructured composite is a good matrix where TiO_2 particles are tightly surrounded. This is because during the spinning process in the spin coating technique, the nanoparticles can adhere by strong electrostatic forces to the polymer and between themselves, and capillary forces can then draw the MEH–PPV solution around the nanoparticles into cavities without opening up pinholes through the device. Although the thickness of the MPT layer is small (300 nm), the photoenergy conversion efficiency (PEC) of the multilayer OSC with the structure of Al/MPT/TiO_2/ITO was found to be of 0.15%. This value is still not large, but can be comparable to the PEC of the polymer/nanocomposite solar cell that was obtained after an annealing treatment under the Dc- voltage of 4V [5].

Acknowledgement

This work has been supported by the National Foundation for Science & Technology Development (NAFOSTED) of Vietnam from 2010 – 2011 (Project Code: 103.02.88.09).

References

1. K. Kawata, V. M. Burlakov, M. J. Carey, H. E. Assender, G. A. D. Briggs, A. Ruseckas, I. D. W. Samuel, *Sol. Energy Mater. Sol. Cells* 87 (2005) 715.
2. S. A. Choulis, M. K. Mathai, V-E. Choong, *Appl. Phys. Lett*. 88 (2006) 213503.
3. N. N. Dinh, L. H. Chi, T. T. C. Thuy, D. V. Thanh, T. P. Nguyen, *J. Korean Phys. Soc*. 53 (2008) 802.
4. C. C. Oey, A. B. Djurixic , C. Y. Kwong, C. H. Cheung, W. K. Chan , J. M. Nunzi, P. C. Chui, *Thin Solid Films* 492 (2005) 253.
5. K. Pandey, J. -M. Nunzi, H. Wang, C. C. Oey, A. B. Djurisic, M. H. Xie, Y. H. Leung, K. K. Y. Man, W.K. Chan, *Organic Electronics* 8 (2007) 396.

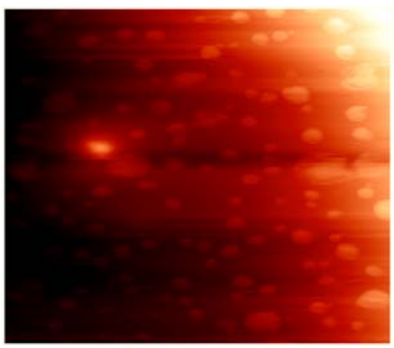

Fig.1. AFM of a PEDOT+nc-TiO_2 composite film.

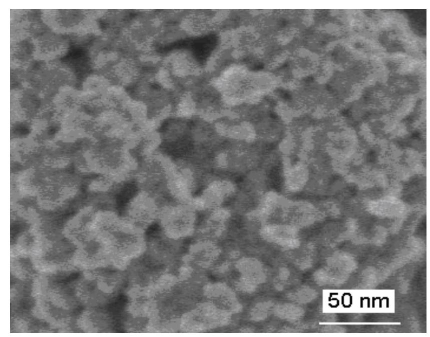

Fig. 3. FE-SEM photograph of a MEH-PPV+nc-TiO_2 film with 25 wt% of nc-TiO_2.

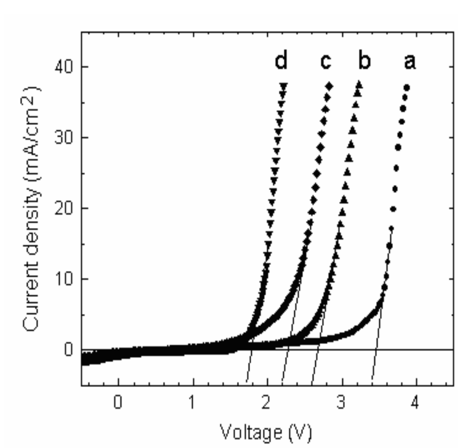

Fig. 2. I-V characteristics of OLED with different laminated structure. (a) – Single MEH-PPV; (b) – with HTL layer, (c) – with HTL and EL composite layers, and (d) – With super thin LiF.

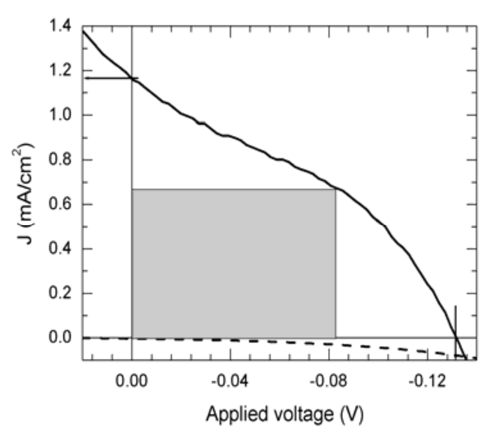

Fig. 4. I-V characteristics of a OSC: Thickness the TiO_2 layer is of 30 nm, the MPT composite film – 300 nm and the Al electrode – 100 nm. Pin = 50 mW/cm^2, Voc = 1.15 V, Jsc = 0.125 mA/cm^2, FF = 0.34, PEC = 0.15.