Effect of Semiconductor Nanocrystal Surface Exchange on Bulk Hetero-Junction Solar Cells Performance

Nguyen Tam Nguyen Truong[1], Umme Farva[1], X.D. Luo[1] and Chinho Park[1]*
[1]School of Display and Chemical Engineering, Yeungnam University,
[2]Jiung su Key Laboratory of ASIC Design, Nantong University, China
(chpark@ynu.ac.kr*)

Introduction

Bulk hetero-junction solar cells incorporating conjugated polymer and semiconductor nanocrystals may provide a lightweight, flexible, and cheaply produced alternative to convention for bulk hetero-junction solar cells. In this design, nanocrystals are employed as light absorbers and components of charge transport networks. Bulk hetero-junction solar cells fabricated from conjugated polymer and semiconductor nanocrystals have reached efficiency of 1.7 % [1]. The interaction of nanocrystals with the polymer is mainly controlled by organic ligands absorbed another surface of the nanocrystals that make them soluble [2]. However, due to their low charge carrier mobility, the nanocrystals dispersed in P_3HT conjugated polymer not well, the power conversion efficiency of devices are very low. Herein this purpose, nanocrystals TOPO-coated CdSe was exchange to pyridine-coated CdSe in order to promote the formation of percolation for charge transport.

Finally, we report our experiment result concern the effect of CdSe surfactant ligand exchange to solar cells performance.

Experimental

The CdSe nanocrystals were synthesized in laboratory by using the colloidal process developed by Peng et al [3]. In this synthesis, CdSe was coated by TOPO with particle size a range of 3 nm ~5 nm. Pyridine coated CdSe were exchanged by using liquid-liquid exchange process [4]. The optical properties of CdSe nanoparticles were characterized by photoluminescence (PL) spectroscopy. Poly (3-hexylthiophene-2,5-diyl) (P_3HT) was used the polymer matrix material, A binary solvent of chlorobenzene/pyridine mixture was combined with CdSe Q-dots and P_3HT polymer to form composite films, as described previously [5]. The active layer thin film was spin-coated on the patterned indium tin oxide (ITO)-coated glass which served as substrate for devices. The ITO substrate was cleaned by TCE (trichloroethylene), acetone and methanol for 10 min, respectively, with ultrasonification and dried by the nitrogen blow. The spin-coated composite thin film was vacuum-dried for 30 min at the drying temperature at 140 ^{o}C for chlorobenzene/pyridine binary solvent. The CdSe:P_3HT weight ratio was kept at 70:30 for all the experiments performed in this study. The power conversion efficiency were measured by using AM 1.5 solar simulation.

Results and Discussions

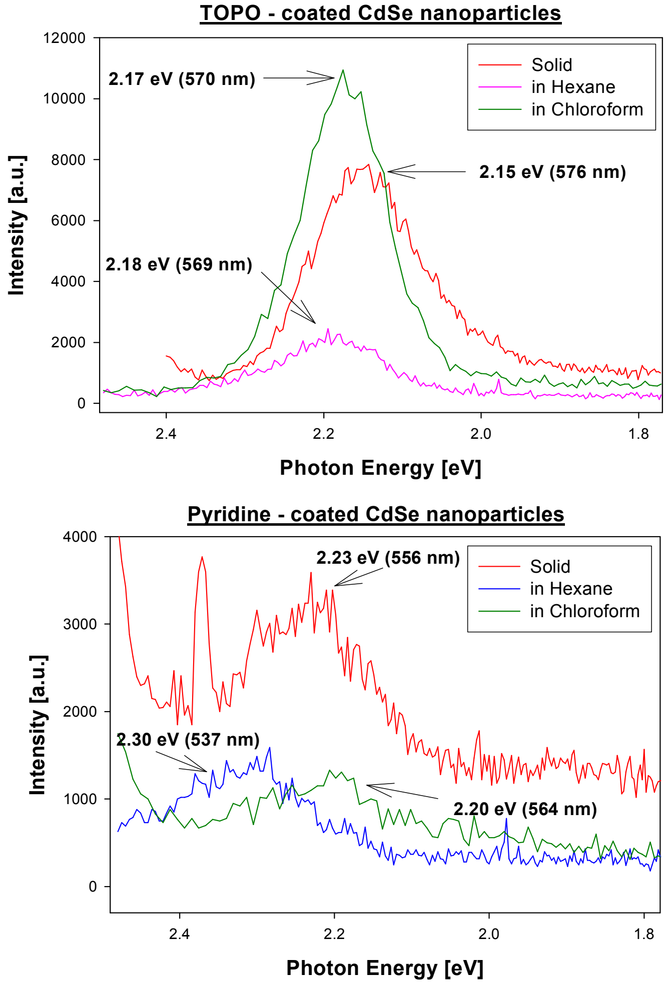

Figure 1. Photoluminescence spectra of CdSe nanocrystals capped with TOPO and pyridine

The TOPO-coated CdSe nanocrystals were received after synthesized in laboratory [3]. The TOPO acts as an electrical insulator and makes the nanocrystal insoluble in solvents as chloroform, and chlorobenzene. To improve these problems, a surface ligand exchange was performed on the surface of nanocrystals to replace the TOPO capping layer with the pyridine. The pyridine capping nanocrystals allowed these particles to be dissolved in solvents. Beside the enhancement of solubility, it was predicted that some properties of the nanoparticles improve on pyridine surfactant. The following exchange process found that a blue-shift occurs in the crystal' photoluminescence spectra. This phenomenon can be suggested as follow: before TOPO-capping CdSe is replaced by pyridine capping CdSe, an amount of Cd and Se was lost. It makes nanoparticles smaller and higher surface energy, and photoluminescence quenching.

The effect of surface exchange is the change in nanocrystals solubility and it's useful in spin-coating composite active layer. The active layer was spin-coated from binary solvent mixture of chlorobenzene and pyridine, but pyridine-coated CdSe allows a significantly lower amount of pyridine to be used in the mixture. The composite polymer P_3HT is poorly soluble in high polarity as pyridine, so if large of pyridine in solvent mixture result in polymer precipitation from solution. Solar cells fabrication was investigated to measure power conversion efficiency. The active layer deposited from a binary solvent mixture of chlorobenzene and pyridine was compared for TOPO-Coated CdSe and pyridine-coated CdSe. Controlling the morphology of active layer also was investigated and founding out an optimized condition for devices performance in previous woks [6]. Bulk hetero-junction solar cells were fabricated by using binary solvent mixture of Chlorobenzene/pyridine was compare for TOPO and pyridine surfactant.

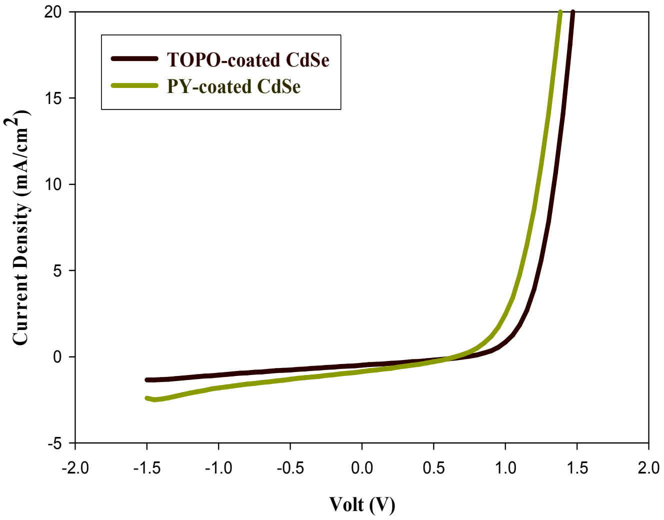

Figure 2. I-V curves of devices for TOPO-coated CdSe and pyridine-coated CdSe

Fig. 2 show I-V curve of devices in case of pyridine surfactant nanocrystal and TOPO surfactant nanocrystals. The results show that power conversion efficiency was reached 0.18 % for pyridine-coated CdSe and 0.11 % for case of TOPO-coated CdSe.

Conclusion

It was shown that nanocrystals surface exchange effect strongly on the properties of CdSe nanoparticles. Photoluminescence spectra have blue-shift occurring, so charge carries separation was improved. We have shown that the bulk hetero-junction solar cells made of nanocomposite of nanocrystals and composite polymer were fabricated; the power conversion efficiency in case of treated nanocrystals was improved much more.

Acknowledgement

This work was supported by grant No. RTI04-01-04 from the Regional Technology Innovation Program of the Korean Ministry of Commerce, Industry, and Energy (MOCIE), and the researchers involved in this work was supported by of the BK21 Program.

References

1. Huynh, W.U., J.J. Dittmer, A.P. Alivisatos, Science, **295**, 2425 (2002).
2. Huynh, W.U., J.J. Dittmer, A.P. Alivisatos, Adv. Funct. Mater.**13**, 73 (2003).
3. Z.A Peng, X. Peng, J.Am. Chem. Soc, **123**, 183(2001).
4. Sang-Hyung Choi, HongJu Song, Yung-Eun Sung, Chemistry, **179**, 135-141 (2006).
5. N. T. N Truong, Umme Farva, Chinho Park, Proceeding of *33rd IEEE Photovoltaic Specialists Conference (PVSC 33)*, pp. 585, 2008.
6. N. T. N Truong, Umme Farva, Chinho Park, Proceeding of *11th International Symposium and Advanced Display Materials and Devices (ADMD), 2007.*