

Solid-State Dye-Sensitized Solar Cell Based on Semiconducting Nanomaterials

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Dye-sensitized solar cell (DSSC) has become an emerging competitor for commercial applications in solar energy harvesting since its invention¹. The energy conversion efficiency of DSSC can be greater than 10% while its cost is much lower than other photovoltaic technologies due to low material cost, simple fabrication and ease of scale-up for large area production. However, the prospect of using DSSC for long-term energy harvesting is uncertain mainly due to issues caused by the accompanied liquid redox electrolyte². With liquid component inside, performance stability and packaging become major issues to overcome. One way to solve this problem is to replace the liquid redox electrolyte by a solid-state p-type semiconductor, which leads to the solid-state dye-sensitized solar cells (SSDSSC)³. In this work, we present a SSDSSC device based on semiconducting nanomaterials (Fig. 1). The device consists of a thin film of ZnO nanoparticles that is loaded with light-absorbing dyes. A p-type semiconductor film is then deposited on top of the dye molecules to replenish lost electrons in dye molecules after light absorption and charge transfer. Both single-walled carbon nanotube (SWNT) and poly(3-hexylthiophene) (P3HT) are used as the p-type semiconducting films.

To fabricate the SSDSSC device, ZnO nanoparticles of 5 nm in diameter were first prepared from Zn(Ac)₂(H₂O)₂, KOH, and methanol⁴. Mesoporous ZnO thin film on SnO₂ electrode is then prepared from those nanoparticles. To load dye molecules onto ZnO nanoparticle surface, ZnO thin film was immersed in 0.5mM Ruthenium 535-bisTBA dye solution in ethanol for 6 hours. Figure 2 shows the XPS spectra of ZnO films with and without dye loading. The shifts of C 1s, N 1s, O 1s, and Zn 2p peaks indicate that chemical bonds are formed between ZnO and dye molecules. Following dye loading, P3HT solution or SWNT suspension was casted onto the device to form a p-type semiconductor film. Figure 3 shows the transmission spectra of the device after each film preparation step. The last step in the fabrication process was gold evaporation, which serves as the cathode for the solar cell device. Under illumination, open-circuit voltage and short-circuit current were measured in both devices. The performance of those devices will be reported in detail and the optimization of the device structures for better conversion efficiency will also be presented. This SSDSSC device has the potential to address the reliability and packaging issues of the conventional liquid electrolyte based DSSC while at the same time maintains solution processing characteristics for low-cost and large-scale production.

¹ Brian O'Regan and Michael Grätzel, *Nature*, 353 (1991) 737-740.

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³ Michael Grätzel, *Nature*, 395 (1998) 583-585.

⁴ D. Sun, M. Wong, L. Sun, Y. Li, N. Miyatake and H.-J. Sue, *J. Sol-Gel Sci. Tech.*, 43 (2007) 237-243.

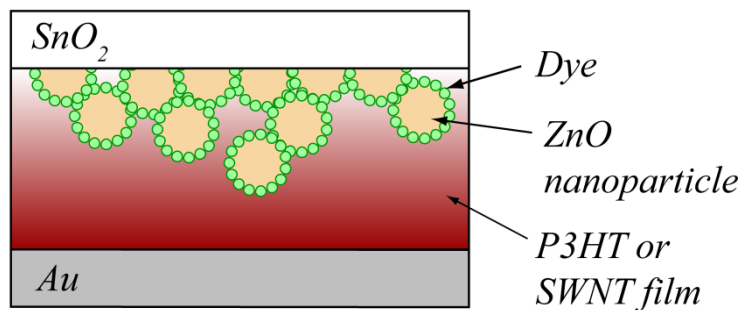


Figure 1. A schematic of a solid-state dye-sensitized solar cell based on semiconducting nanomaterials.

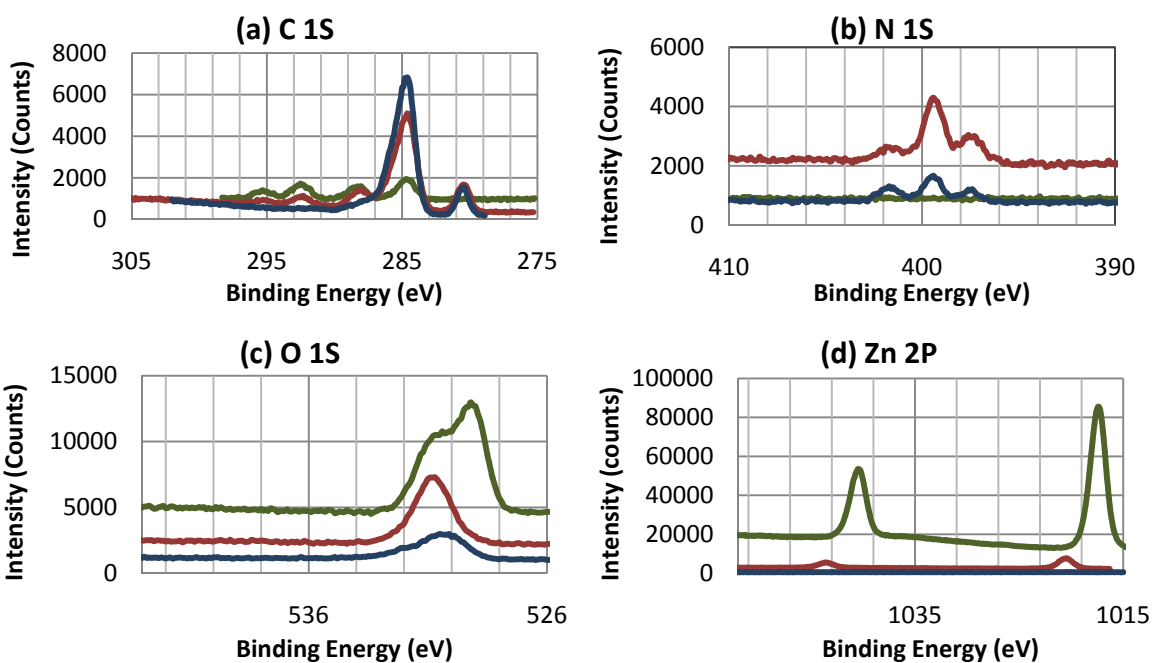


Figure 2. XPS spectra of ZnO nanoparticle film (green line), ZnO film with 6 hour dye loading (red line), and dye film (blue line), (a) C 1s peak; (b) N 1s peak; (c) O 1s peak; (d) Zn 2p peak.

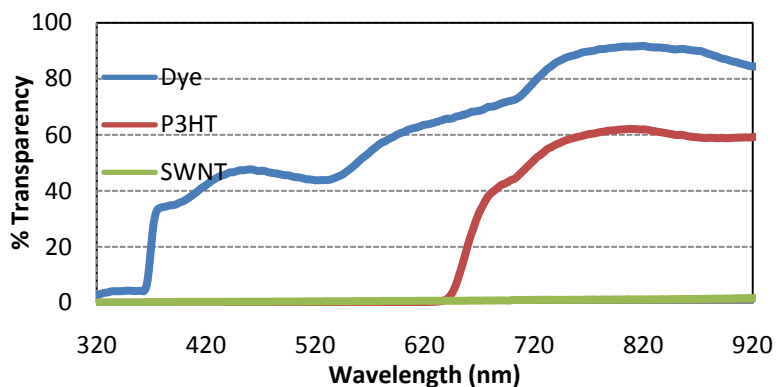


Figure 3. Transmission spectra of the SSDSSC device after each film preparation step.