# Hybrid Solar Cells Based on ZnO nanoparticles and nanorods

Tao-Hua Lee[1], Hung-Jue Sue[2,3] and Xing Cheng[1,3]
[1]Department of Electrical and Computer Engineering, Texas A&M University, College station, TX 77843
[2]Department of Mechanical Engineering, Texas A&M University, College station, TX 77843
[3]Polymer Technology Center, Texas A&M University, College station, TX 77843

Dye-sensitized solar cell (DSSC) has become an emerging competitor for commercial applications in solar energy harvesting since its invention[1]. However, the prospect of using DSSC for long-term energy harvesting is uncertain mainly due to issues caused by the accompanied liquid redox electrolyte[2]. Another major issue is that nanoparticle DSSC relies on a thick nanoparticle-based film to provide sufficient surface area for the adsorption of dye molecules. However, the configuration of the nanoparticle-based film limits device efficiency[3]. One way to solve both of these problems is to replace the liquid redox electrolyte by a solid-state p-type semiconductor and by optimizing the device geometry. In this work, we present a solid-state dye-sensitized solar cell (SSDSSC) device based on semiconducting nanomaterials (Figure 1). The device consists of an array of ZnO nanorods and a layer of absorbed ZnO nanoparticles, both of which are loaded with light-absorbing dyes. A poly(3-hexylthiophene) (P3HT) film is then deposited on top of the dye molecules to replenish lost electrons in dye molecules after light absorption and charge transfer.

To fabricate the ZnO nanorod-based SSDSSC, ZnO nanoparticles of 5 nm in diameter were first synthesized[4]. Mesoporous ZnO thin film on $SnO_2$ electrode was then prepared from these nanoparticles to serve as a seed layer for hydrothermal ZnO nanorod growth[5]. After nanorod growth, a thin layer of ZnO nanoparticles was drop-cast on the surface of the nanorods with varied thicknesses. The device was then immersed in 0.5mM Ruthenium 535-bisTBA dye solution in ethanol for 30 minutes. Following dye loading, P3HT solution was first cast onto the device and then spin-coated onto the device to form a p-type semiconductor film. Figure 2(a) shows the SEM image of the device after preparation step without the ZnO nanopaticle layer and figure 2(b) shows the image of the device with both nanorods and nanoparticles. Gold was then evaporated and served as the cathode for the solar cell device. Under illumination, open-circuit voltage and short-circuit current were measured and shown in Figure 3. The overall efficiencies of those devices containing additional ZnO nanoparticles were more than doubled than the device without nanoparticles. With a thin layer of ZnO nanopartcles on the nanorods that is thin enough to minimize negative impact on electron transport, there is more surface area for dye loading in the device. More results will be reported in detail and the optimization of the device structures for better conversion efficiency will be presented. This SSDSSC device has the potential to address the reliability and packaging issues of the conventional liquid electrolyte based DSSC and to increase the surface area for dye loading, while at the same time maintaining the solution processing characteristics for low-cost and large-scale production.

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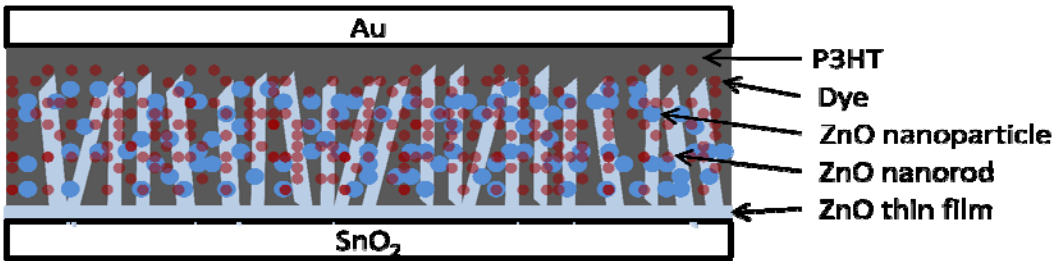


Figure 1. A schematic of a solid-state dye-sensitized solar cell based on ZnO nanoparticles and nanorods.

(a) (b)

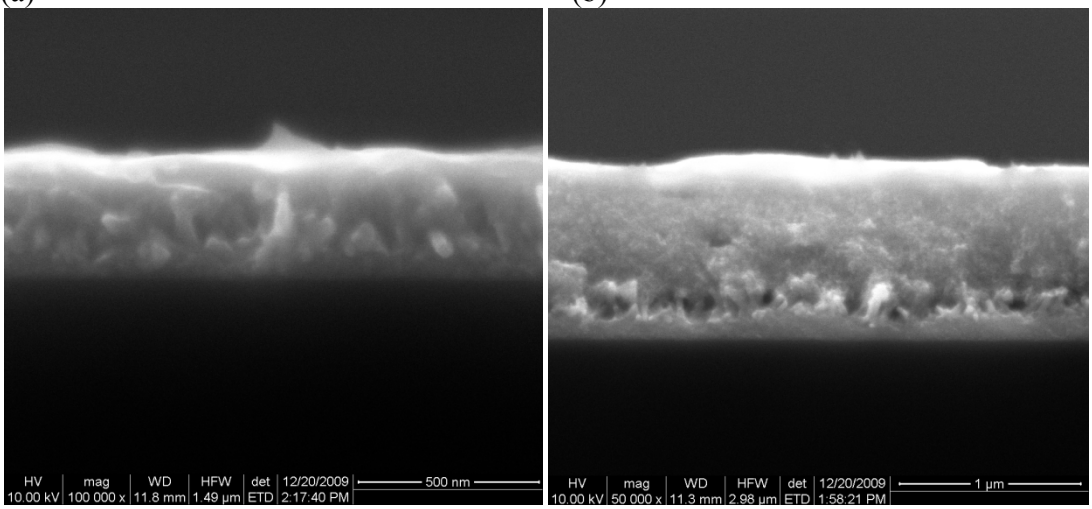


Figure 2. SEM images of the device (a) without ZnO nanoparticles; (b) with ZnO nanoparticles.

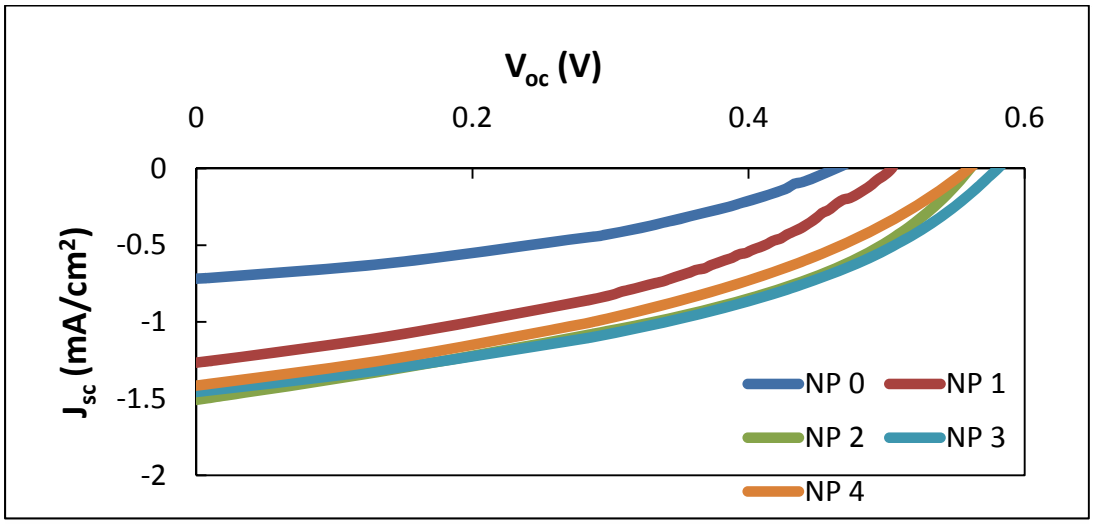


Figure 3. I-V curve for the devices without nanoparticles (NP 0) and with different thicknesses of nanoparticle layers (NP 1 to NP 4, the thickness of the nanoparticle layer in NP4 is the greatest).