Production and Analysis of Conjugate Polymer/ZnO Solar Cells

Michael White, Chemistry Major, Saint Michael's College
NNIN REU Site: NanoTech User Facility, University of Washington

NNIN REU Principal Investigator: Daniel Gamelin, Department of Chemistry, University of Washington
NNIN REU Mentor: William Liu, Department of Chemistry, University of Washington
Contact: mwhite3@smcvt.edu, gamelin@chem.washington.edu

Abstract:

The goal of this research is to fabricate a low cost and efficient solid state solar cell by coupling zinc oxide (ZnO) nanorods with a conjugated polymer of regio-regular poly(3-hexylthiopene) (P3HT). ZnO structures were grown onto FTO/nc-ZnO substrates through either hydrothermal solution phase or by electrodeposition and resulted in different morphologies depending on the growth parameters.

Introduction:

Conventional solar cells provide cheap and clean energy that can help reduce the world's dependence on oil. Currently, silicon solar cells have the highest solar energy conversion efficiency of around 24%, however, the efficiency is offset by the high cost of production [1]. Dye-synthesized solar cells have been explored as possible substitutions for conventional silicon cells [2], but they suffer from possible dye agglomeration [3] or electrolyte leakage. To overcome the limitations of dye-sensitized solar cells, conjugate polymers coupled to semiconductors to form 'solid state' cells are actively being explored [4].

In these solid-state heterojunction conjugated polymer/inorganic semiconductor solar cells, photoexcitation of the conjugated polymers leads to generation of a bound electron-hole pair or exciton. The exciton can be separated into free charge carriers by transferring the electron to the inorganic semiconductor. One semiconductor often used is ZnO because it is environmentally friendly, stable indefinitely, and can be synthesized easily and inexpensively into different shapes and sizes using various methods [5]. The use of ZnO nanorods anchored to the transparent conducting substrate will not only provide a direct path for electrical transport to the back contact, but also increase the polymer/ZnO interfacial area, both parameters that should improve overall cell performance.

Fabrication:

A layer of colloidal nanocrystalline ZnO (*nc*-ZnO) was spin-coated onto a cleaned fluorine doped tin oxide (FTO)-covered glass substrate and annealed at 400°C for 30 minutes. ZnO nanorods were grown on the FTO/*nc*-ZnO layer using two different adapted methods.

The first method was by a solution phase hydrothermal process [5]. The FTO/*nc*-ZnO substrate was submerged in an equimolar 25 mM aqueous solution of $Zn(NO_3)_2$ and hexamethylene tetraamine and heated at 90°C for several hours.

The second method was by electrodeposition under galvanostatic control [6] in an O_2 saturated 25 mM $ZnCl_2$ and 25 mM KCl aqueous solution at 65°C using a current range of 0.4-0.8 mA.

After either synthesis method, the FTO/*nc*-ZnO/ZnO(nanorods) substrates were thoroughly rinsed with distilled water and annealed at 400°C for 30 minutes. P3HT was spin-coated onto the FTO/*nc*-ZnO/ZnO(nanorods) and heated for 1 hour at 100°C. Subsequently, PEDOT:PSS was spin-coated on top of the P3HT layer.

Finally, a gold layer was deposited onto the PEDOT:PSS by thermal evaporation in vacuum to form an ohmic contact. Illumination of the cell was performed using a (200 W) mercury xenon lamp coupled to a monochromator. Film morphology was examined by scanning electron microscopy (SEM) (FEI Sirion XL30). Electronic absorption spectra were collected using a Cary 5E spectrophotometer (Varian).

Results:

The absorption spectrum, Figure 1, of the ZnO grown by the solution phase hydrothermal method shows the

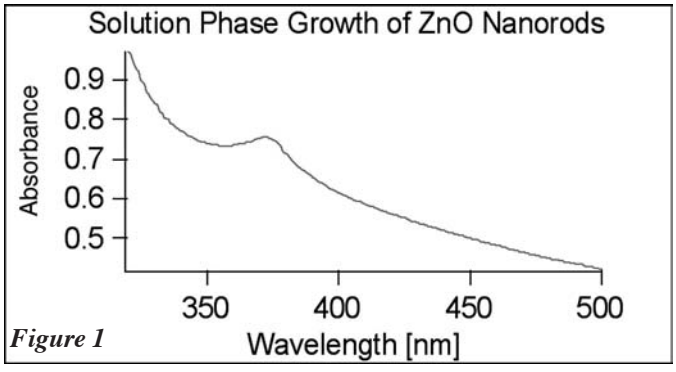

Figure 1

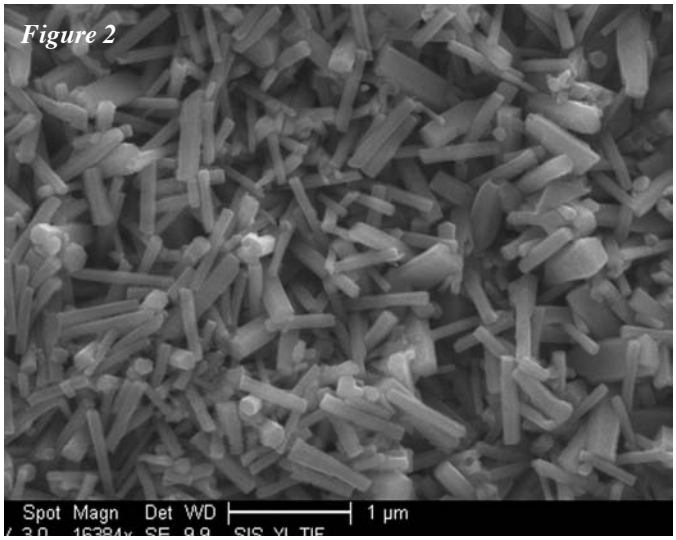

Figure 2

ZnO band gap transition at 375 nm (3.3 eV), which is in agreement with bulk ZnO [7]. The absorption spectrum shows a broad tail due to light scattering from the opaque ZnO film. The SEM, Figure 2, of the same film shows that the ZnO grown are in the shape of rods; however, the rods do not show well-oriented growth or attachment to the FTO/*nc*-ZnO substrate and therefore may not provide a good electrical pathway for the photogenerated electron to travel to the FTO back contact. The SEM of the electrodeposited ZnO layer, Figure 3, does not show any rod structures but rather a porous film network. Although ZnO rods are absent, this type of morphology does provide a greater surface-area-to-volume than a flat solid film and may offer the same advantages as the rods. Unfortunately, under illumination all the solar cells that were built exhibited a short-circuit behavior and so no cell efficiency data could be collected.

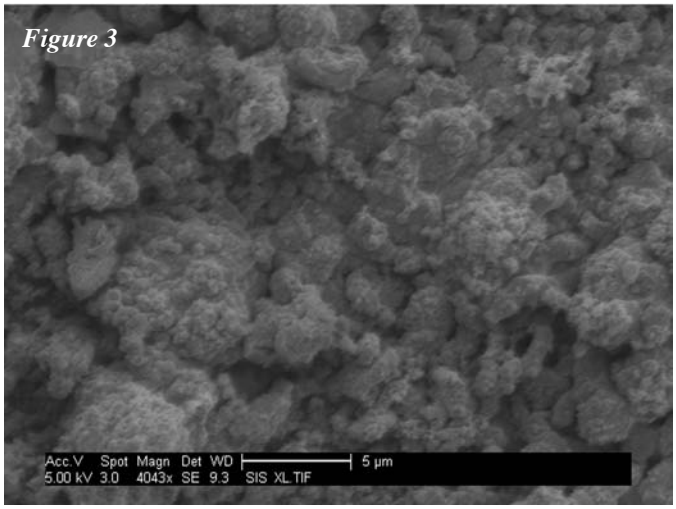

Figure 3

Summary and Future Work:

ZnO was grown onto FTO/*nc*-ZnO substrates through either hydrothermal solution phase or by electrodeposition, resulting in different morphologies. Preliminary results for the fully assembled solar cell indicated a possible short in the cell. A possible source of this short could be the P3HT penetrating the ZnO layer and contacting the FTO. Further investigation is needed to identify and correct the short circuit. Once properly functioning cells have been fabricated, the influence on cell efficiency from different film morphology can be determined.

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