doi: 10.1017/S1431927609098109
Microsc Microanal 15(Suppl 2), 2009

Nanocrystalline Solar Cell Materials Characterization

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With today's escalating energy crisis there is an increasing demand for renewable resources like solar power. An alternative to the silicon solar cell, that is cheap to make and requires less exotic materials (e.g. raspberry juice and TiO_2 nanoparticles), has been reported in the literature[1,2]. We have constructed nanocrystalline solar cells[3], as pictured in Fig. 1, as part of a NSF STEP undergraduate science academy project and begun to study the materials that are required for construction in an attempt to improve efficiency of the device.

The nanocrystalline solar cell being studied produces current after incoming photons knock electrons off the photo-sensitive dye molecules, which in this study was raspberry juice. This generates a slight electron flow onto the tin oxide coated glass, which is the electrode that carries the electric current produced by the device. Current is boosted by increasing the surface area where light interacts with the photosensitive dye. This increase in surface area was achieved by applying a thin coating of titanium dioxide nanoparticles to the tin oxide surface. We investigated the TiO_2 particle size and electrode surfaces to determine if improvements in construction methods or materials could be made to gain device performance.

Characterization of tin oxide coated glass, TiO_2, and conductive carbon layer used in the solar cell was performed by scanning electron microscopy (SEM) and atomic force microscopy (AFM). This initial analysis was used to establish a better understanding of RMS roughness of the electrode surfaces and TiO_2 nanoparticle size distribution. A Veeco Dimension NanomanV AFM, operated in tapping mode, was used to acquire several micro-scale scan areas of the solar cell electrode surfaces. As shown in the 3D rendering of the AFM height image of Figure 2, the tin oxide electrode surface was found to have an average RMS roughness of ~61nm before a conductive carbon coating was applied. To document the TiO_2 nanoparticle size distribution and morphology a Hitachi S4000 field emission SEM (FESEM), operated at 20kV, was employed to acquire secondary electron (SE) micrographs of the TiO_2 powder. Figures 3A and 3B show a low and high magnification micrograph of representative TiO_2 nanoparticles morphologies. The micrographs revealed the nanoparticles were agglomerated into larger micron sized particles which may contribute to a reduction in the solar cell performance.

The materials characterization data was used to determine which materials in the construction of the nanocrystalline solar cell needed to be modified to produce a more efficient device. From the data acquired to date we have chosen to experiment further with different conductive carbon deposition techniques (e.g. evaporation) and to further process the TiO_2 powder for a finer final particle size.

References
[1] B. O'Regan and M. Grätzel, Nature, 253 (1991) 737.
[2] M. Grätzel, Prog. Photovolt. Res. Appl., 8 (2000) 171.
[3] http://mrsec.wisc.edu/Edetc/nanolab/TiO2/index.html

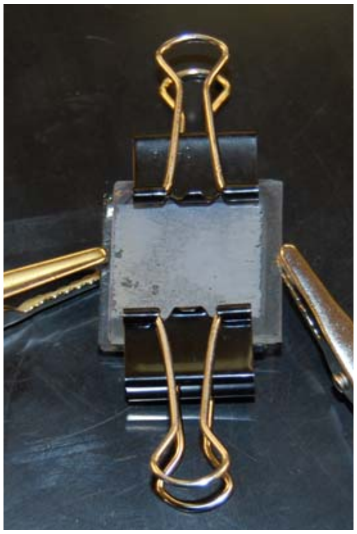

Fig. 1. As constructed nanocrystalline solar cell attached to leads for testing.

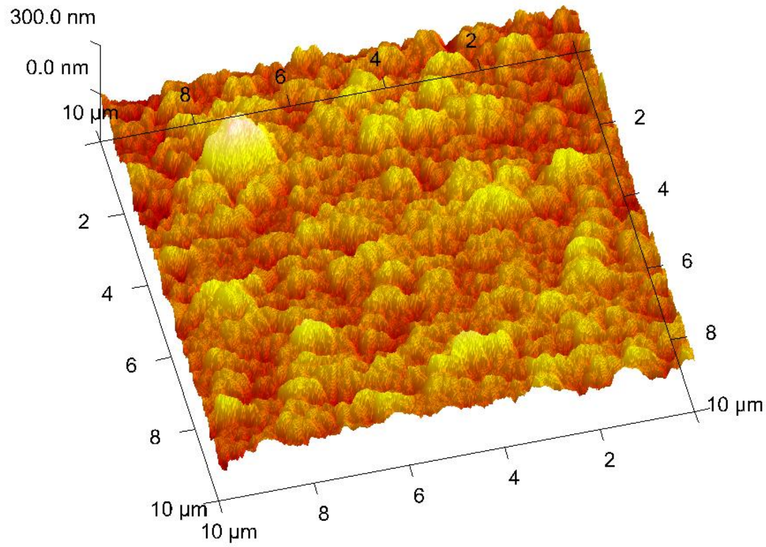

Fig. 2. 3D rendering of AFM height data acquired from a tin oxide electrode surface.

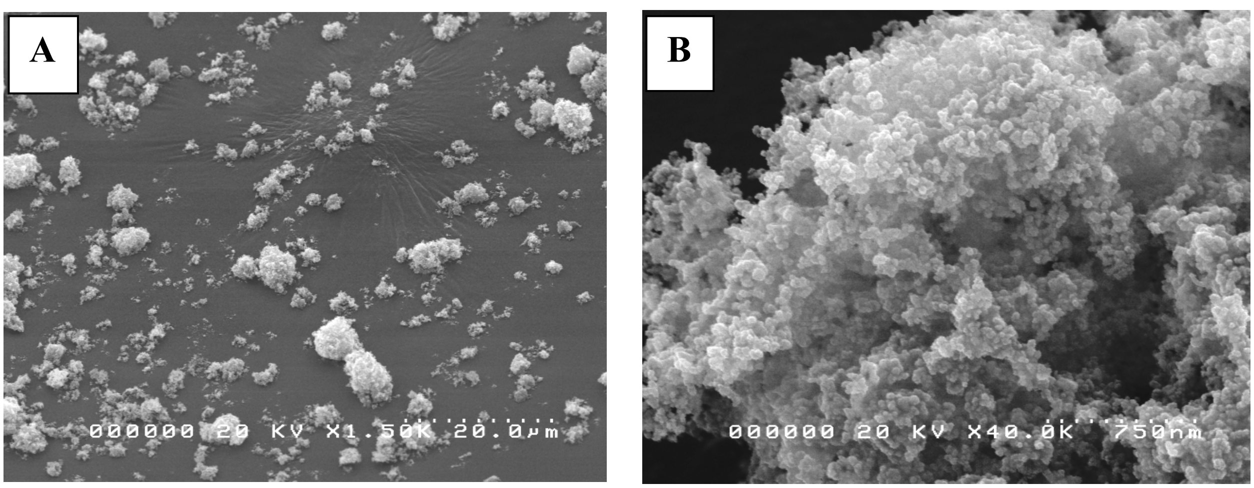

Fig. 3. A. The lower magnification micrograph of the TiO_2 nanoparticles shows a large distribution of micron scale agglomerates. B. At higher magnifications individual TiO2 nanoparticles were observed in the larger agglomerates. To improve output of the nanocrystalline solar cell further processing of the TiO_2 powder will be needed to reduce particle sizes.

https://doi.org/10.1017/S1431927609098109