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Wet Chemical Synthesis and Characterization of Nanomaterials for Solar Cell Applications

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Abstract

During long term space missions, it is necessary to have a reliable source of energy. Solar cells are an easy and reliable way to convert energy from the sun to electrical energy. NASA has used solar cells manufactured on Earth as an energy source for many of its missions. In order to develop technologies that will enable high efficiency solar cells, we are synthesizing nanostructured materials. A range of nanostructured materials, such as titanium dioxide nanowires, nickel nanoparticles, copper nanoparticles, and silver nanoparticles/nanowires, are synthesized. In this work, we are reporting on the synthesis of these nanomaterials and the electron microscopic characterizations. Nanomaterials were synthesized using well-known protocols, such as the polyol process for silver nanowires and the hydrothermal method to produce titanium dioxide nanowires. The nanomaterials were characterized using Scanning Electron Microscopy (SEM) at NASA Ames and X-ray Photoelectron Spectroscopy (XPS) from the Stanford Synchrotron Radiation Lightsource at SLAC National Accelerator Laboratory. This study will bring understanding on the chemical structure and morphology of these nanomaterials that will potentially be used for high efficiency solar cells.

Material Synthesis

Each material was synthesized using a well-known protocol. All chemicals were purchased from Aldrich and used as provided unless otherwise noted.

Material	Synthesis	Procedure
TiO_2 NWs	Hydrothermal method[2]	Titanium Dioxide mixed with 100mL Potassium Hydroxide (10M) for 30min. Placed in autoclave at 200˚ C for 24h. Filtered with methanol, water, and hydrochloric acid then stored in water.
Ag NWs	Polyol method[2]	Polyvinylpyrrolidone (PVP) in Ethylene Glycol (EG) at 160˚ C for 1h mixed with Silver nitrate in EG using titration method. The nanowires were then washed in acetone and centrifuged to remove EG and PVP. Then suspended in methanol.[4]
Cu NPs	Solution Reduction Method[1]	Copper (II) nitrate trihydrate added to acetonitrile and water in a 3 neck round flask and stirred. PVP was added then mixed under Argon gas for 25 min. Sodium borohydride (NaBH4) in 5mL of water added all at once.
Ni NPs	Solution Reduction Method[1]	Same as above but substituted nickel nitrate for copper nitrate.

SEM Characterization

The following images were taken with the Hitachi S4800 Scanning Electron Microscope (SEM). All materials were drop casted on silicon. Figure 1 shows titanium nanowires with the expected nanostructure. The silver nanowires did not come out as expected. The synthesis called for a capping agent (PVP) to facilitate growth. However, the capping agent removes the desired conductivity. Figure 2 shows images of the silver nanowires before and after cleaning in an attempt to remove the capping agent. The images show a reduction of particles and does not give the desired properties. It may be necessary to find another cleaning procedure. The nickel and copper nanoparticles came out as expected.

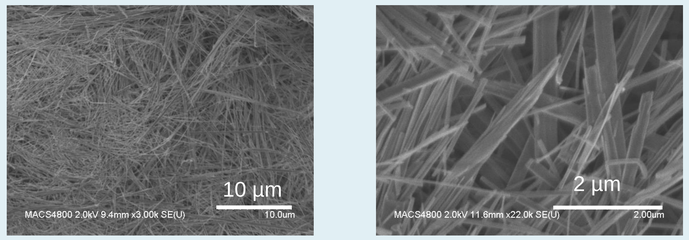

Figure 1. Titanium Dioxide Nanowires at different magnifications. Images show a good distribution of the nanowires.

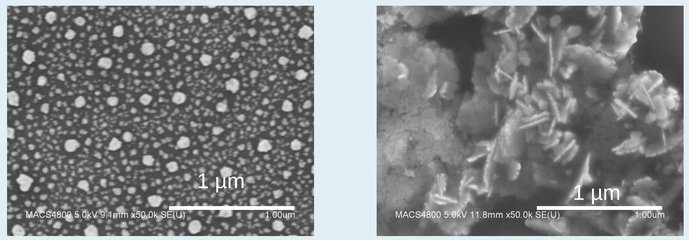

Figure 2. Silver Nanowires before (left) and after (right) washing with acetone.. The figure on the right shows the formation of nanowires with large quantities of capping agent contaminants. Further optimization work is under progress.

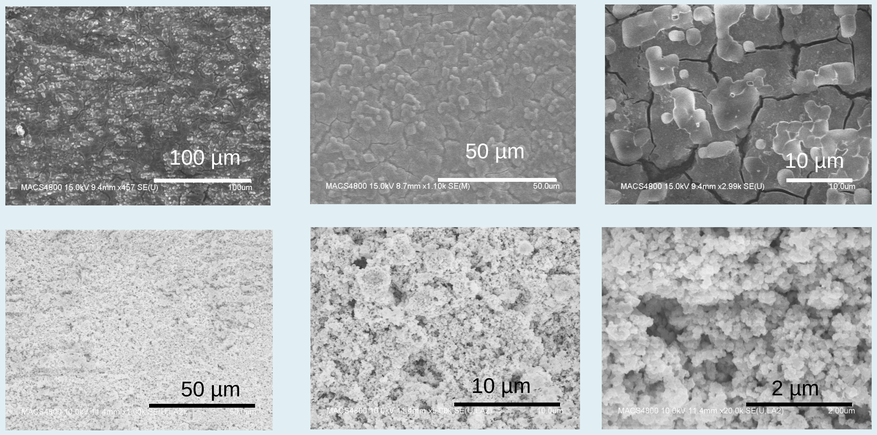

Figure 3. Nickel (top) and Copper (bottom) Nanoparticles at different magnifications.

X-Ray Characterization

At beamline 8-2 in SLAC National Acceleratory Laboratory, X-ray absorption measurement of copper L edge and oxygen K edge were measured using soft x-rays to study the electronic structure of these materials. Samples previously synthesized by the same protocols were analyzed. Total electron yield, Auger electron yield, and fluorescence yield were measured.

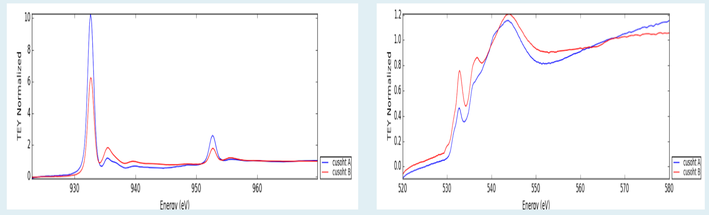

Figure 4. XAS (left) Cu L edge spectra and (right) O K edge spectra of copper nanoparticles heat treated after synthesis to reduce the copper oxide. Red and blue denote two different samples from the same badge confirming that the copper K edge spectra are similar. Each spectrum is an average of 3 scans.

Future Work

In the future, the materials will be used in the following ways:

- A different cleaning method will be used to remove the capping agent from the silver nanowires, and optimization will be performed.
- The materials will be deposited on different substrates to be tested as solar cells. Substrates include silicon, treated glass, and flexible plastic.
- The applicability of the materials for solar cells will be studied.

Conclusions

In this work, nanomaterials were synthesized using wet chemical methods. They were characterized using electron microscopy to analyze the morphology. It has been observed that the titanium dioxide nanowires and copper nanoparticles synthesis are optimized to obtain tailored nanostructures. However, further optimization work is required for silver nanowire synthesis. The X ray absorption spectroscopy shows the oxidation state of copper nanoparticles, which confirms the formation of oxides.

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