Development of Highly Efficiency, Ultra-light Weight, Radiation-Resistant, High-Specific-Power CdTe Thin-Film Solar Cells using Quantum Dots

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Start Date = March 2005
Planned Completion = Dec 2006

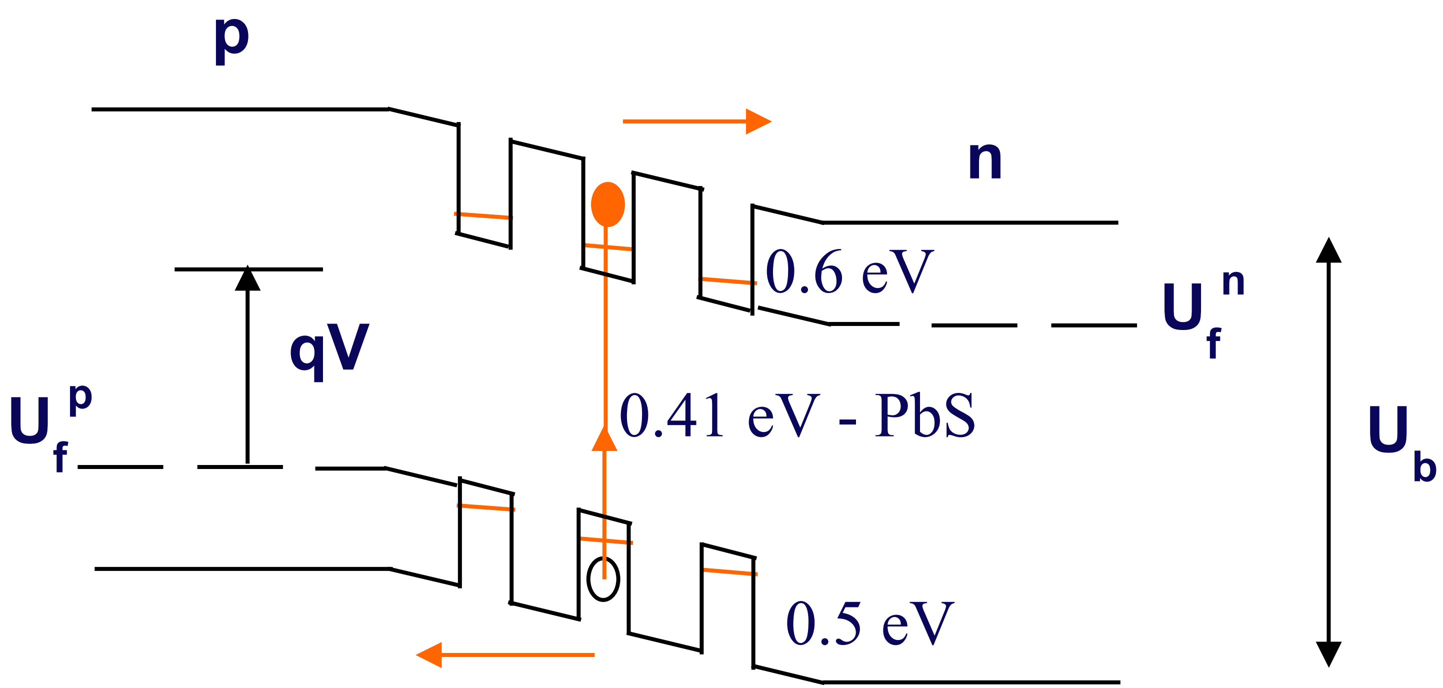
Research Goals and Objectives

- Develop highly efficient, radiation-resistant CdTe thin-film solar cells using an intermediate layer of quantum dots for space power applications.

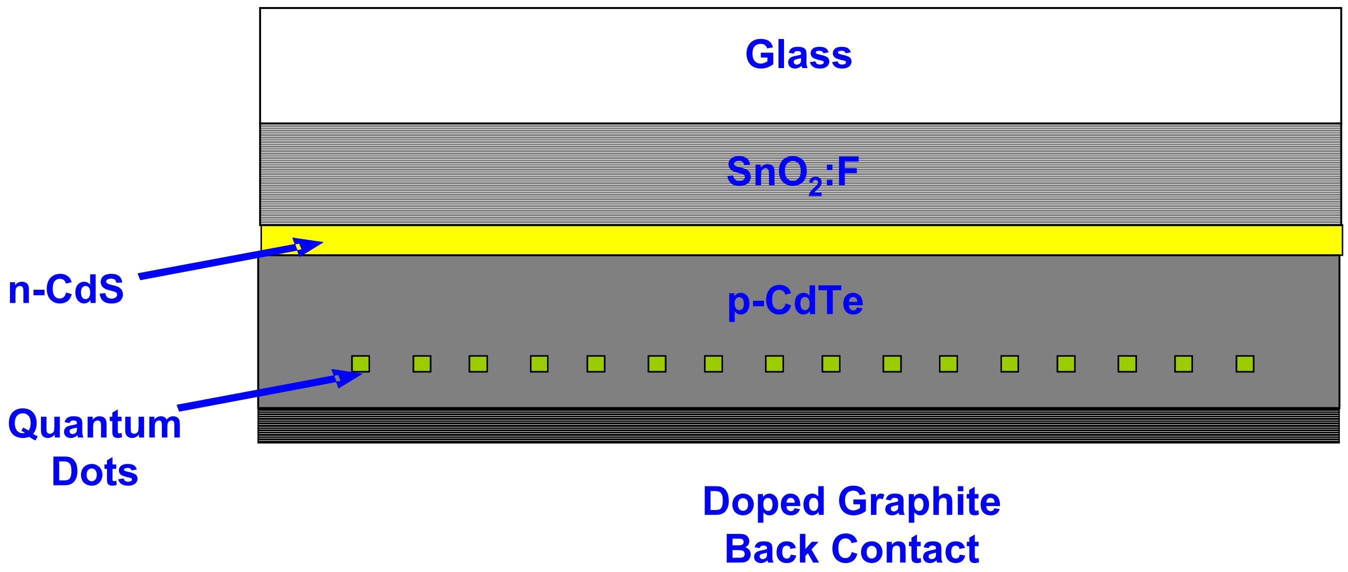
Relevance to Current State-of-the-Art

- The present best one sun, AM 1.5 efficiencies of solar cells are as follows: Si-24.5% , a-Si:H-13.1%, CIGS-19.5%, CdTe-16.5%, GaInP-34.7%.
- It would be possible to increase the efficiencies considerably by using the novel concept of quantum dots.
- The proposed project will develop quantum dots to engineer the semiconductor band gap and prepare a tandem of highly efficient ultra-light weight, radiation-resistant, high-specific-power solid state PV cells.

Energy Band vs. Distance for a p-i-n quantum solar cell

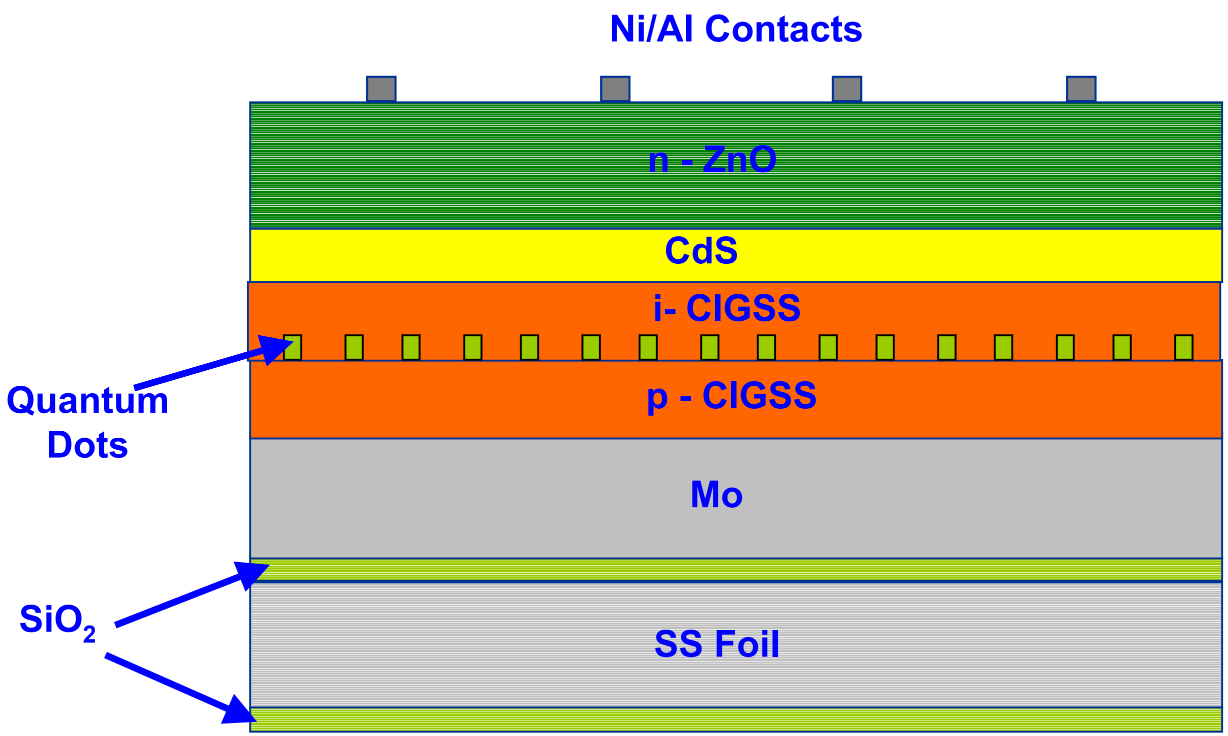


Quantum Dot Solar Cell Structure



CdTe solar cell is preferred for quantum dots solar cell because the space charge region extends through most of the CdTe thickness.

Quantum Dot Solar Cell Structure



Relevance to NASA

- Facilities at FSEC PV Materials Lab will give NASA an efficient and most economic way for fabrication of ultra-lightweight thin film solar cells for space power.
- Close space sublimation and RF sputtering setups will be added to complement the existing facilities.

Schedule and Deliverables

- **Schedule**
  - **Mar 2005 – Sep 2005**: Fabricated nanoporous alumina membrane. Carried out detailed literature survey on the quantum dot material for the solar cell. Carried out preliminary experiments to incorporate quantum a dot layer in a CdTe solar cell.
  - **Oct 2005 – Mar 2006**: To build setup for deposition of CdTe layer by close space sublimation and modify the existing set up for deposition of quantum dots by RF sputtering through nanoporous membrane.
  - **Apr 2006 – Dec 2006**: Continue the development of quantum dot CdTe solar cell and carry out detailed analyses of the fabricated cells.

Schedule and Deliverables

- **Deliverables**
  - Mar 2005 – Aug 2005: Report Submitted (Aug 31, 2005)
  - Sept 2005 – Mar 2006: Report (Mar 31, 2006)
  - Apr 2006 – Dec 2006: Final Report (Dec 30, 2006)

Anticipated Technology End Use

- Highly efficient thin film solar cells can be used in NASA’s future space missions.

Experimentation – Al Membrane Preparation

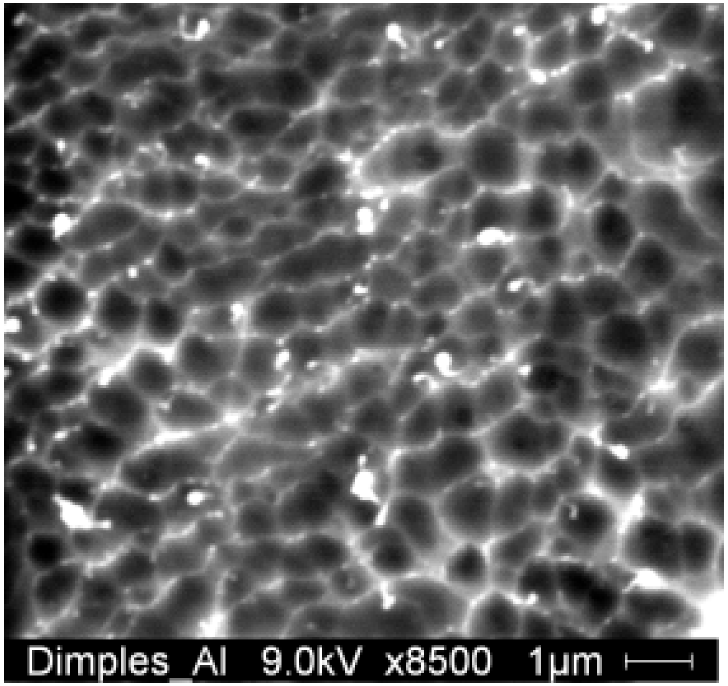
- Three step anodization process was followed for the preparation of alumina membrane.
  - **Step 1: Anodization** – Creates dimples (concave pattern) on the surface for the development of pores in the second anodization process.
  - **Step 2: Anodization** – Nanopores are created with a barrier layer.
  - **Step 3: Soaking** – This process extends the pores through out and also enlarge them.

Experimentation – Al Membrane Preparation

- Substrate: 0.02” thick (99.9 %) or 0.004” thick (99.99%) Aluminum.
- Anode:- Al, Cathode:- Pt (99.997%)
- Ultrasonic cleaning: DI water – Acetone – DI Water (each for 5-10 min)
- Coat with butyl methacrylate polymer and paraffin wax on one side.
- Anodic oxidation process
  - Electrolyte: 0.25 M Oxalic Acid
  - Temperature: 1- 3 ºC
  - Voltage: 60 V

Experimentation – Al Membrane Preparation

- First anodization – 8 hours
- Wet etch the first anodic alumina in a solution of chromic and phosphoric acid at 50-60 ºC.
- Dimples are created on the surface.
- Coat the foil again with polymer and wax.



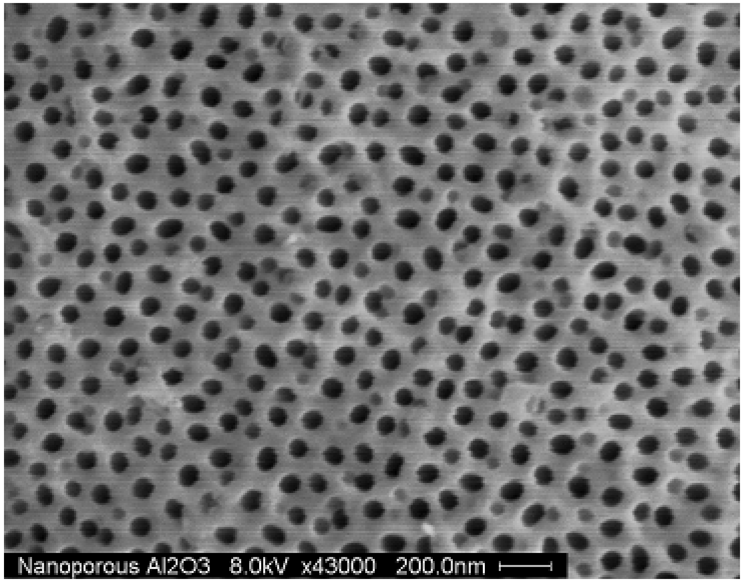
Experimentation – Al Membrane Preparation

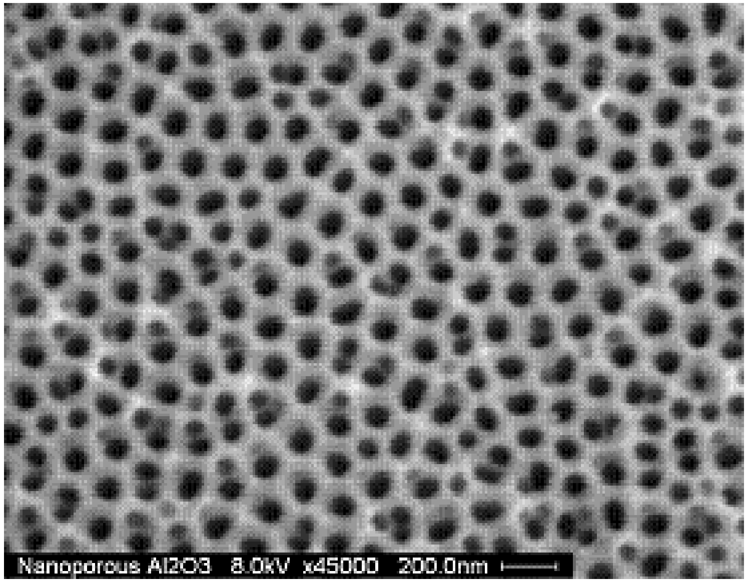
- Second anodization – 8 hours.
- Strip wax and polymer.
- Create windows with fresh wax.
- Etch aluminum – 0.15M cuprous chloride and 10% (v/v) hydrochloric acid.
- Place few drops of phosphoric acid on the front face.
- Pores extended completely creating the membrane.
- Pores also get enlarged.

Accomplishments and Results

- Detailed literature review of the fabrication of quantum dots CdTe solar cell has been carried out.
- Successfully fabricated the nanoporous alumina membrane having uniformly distributed 50-100 nm diameter nanopores using 0.02” (99.9%) and 0.004” (99.997%) thick aluminum foil.
- Carried out preliminary experiments to incorporate quantum a dot layer in a CdTe solar cell.

Accomplishments and Results





Nanoporous Alumina Membrane

Average Diameter: 50-100 nm

Future Plans

- Closed spaced sublimation (CSS) set up will be designed and fabricated.
- The existing RF magnetron sputtering will be modified to deposit PbS quantum dots through the nanoporous alumina membrane template.
- Deposit CdTe layer by CSS.
- Continue preparation of CdTe thin film solar cells with a layer of quantum dots.
- Deposit a CdTe buffer layer.

Future Plans

- Complete the quantum dot CdTe solar cell by application of doped graphite back contact.
- Study the material properties.
- Carry out detailed photovoltaic analysis such as I-V and QE analysis of the completed cell and compare with that of the parent cell.

Acknowledgement

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