University of Central Florida

Research to Improve Photovoltaic (PV) Cell Efficiency by Hybrid Combination of PV and Thermoelectric Cell Elements

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Description: Photovoltaic/thermoelectric (PV/TE) cell integration is a promising technology to improved performance and increase the cell life of PV cells. The TE element can be used to cool and heat the PV element, which increases the PV efficiency for applications in real-world conditions. Conversely, the TE materials can be optimized to convert heat dissipated by the PV element into useful electric energy, particularly in locations where the PV cell experiences large temperature gradients, i.e. use the thermoelectric module for cooling, heating and energy generation depending on the ambient weather conditions. Thus, the goal of this research effort is to research and develop nanoscale design of efficient thermoelectric material through a fundamental understanding of the materials properties and to design and build a photovoltaic thermoelectric (PV/TE) hybrid system.

Budget: $167,820
Universities: UCF/FSEC

Executive Summary

Photovoltaic/thermoelectric (PV/TE) hybrid cell integration is a technology that can improve performance and increase the longevity of PV cells. The TE element can be used to cool and heat the PV element, which can increase the PV efficiency. Conversely, the TE materials can be optimized to convert heat dissipated by the PV element into useful electric energy, particularly in locations where the PV cell experiences large temperature gradients. Thus, the overall goal of this research effort was to research and develop nanoscale and efficient thermoelectric materials through a fundamental understanding of the materials properties and to then design and build a photovoltaic thermoelectric (PV/TE) hybrid system. The specific activities conducted by this effort were to:

1. Develop a fundamental theoretical understanding of the electronic and thermal properties and their relationship with the efficiency of TE materials,
2. Develop and improve processing techniques for synthesis of TE nanomaterials,
3. Develop a method to fabricate nanostructures from bulk form to thin film structures,
4. Study the electronic properties of the thin film layers deposited by ink-jet printing and spraying, and
5. Design and fabricate photovoltaic and thermoelectric devices.

The work developed specific system configurations where size and shape of the nanostructures that constitute the bulk materials are carefully controlled during solution processing. This research leads to advance the understanding of process, structure, and properties of TE composites, devices and hybrid devices. The research also expanded the knowledge on the synthesis and characterization of nanostructures as well as the understanding of how nano-scale entities interact in a multi-scale system. The development of structure and property models, characterization techniques for the physical behavior of TE nanomaterials and composites, and understanding of synthesis and structure relationships ultimately provided the tools for engineering the efficiency of TE devices.

The specific tasks that were accomplished are:

1. Development of inks and improvement of the solution processing techniques for the deposition of TE leg elements -- The fabrication process used was innovative in the sense that TE materials were deposited under atmospheric conditions, with the flexibility of adjusting geometry, materials composition or batch scalability. Using the atmospheric solution processing technique, the cost of the hybrid device was reduced and the losses at the interfaces were eliminated increasing the net efficiency of the PV cell.

2. Study the optical, electronic, thermal and mechanical properties of the PV/TE device in relationship with the size and shape of materials and fabrication techniques -- The development of structure/property models and characterization techniques for the physical behavior of the TE materials and composites, along with understanding of synthesis/structure relationships, will ultimately provide a tool for engineering the efficiency of TE/PV devices.

3. Design and fabricate PV/TE device and prototype using the optimized materials and technique -- The n-type Bi_2Te_3, p-type Sb_2Te_3 compounds, and the working electrodes – ITO, Graphene, and SWCNT-MWCNT were deposited from solutions by printing and spraying at different temperatures at constant rate. A standard three-electrode configuration for the TE element: metalized oxidized silicon substrate, Pt counter electrode and a saturated calomel electrode (SCE) reference was used. The final PV/TE device consisted of a conventional crystalline Si cell and thermoelectric micro-module with n (Bi_2Te_3) and p ($SbTe_3$) - type leg elements connected in series electrically and in parallel thermally, using an atmospheric solution processing techniques.

4. Build a test facility where laboratory-developed PV and TE devices and prototypes may be tested, demonstrated and verified -- A PV and TE scientific laboratory was built at FSEC. This lab has a comprehensive suite of tools for testing the efficiency and longevity of the PV and TE materials and devices and is devoted to developing the fundamental science and engineering base required to improve PV and TE device performance and processing technologies. The Lab also supplies the facilities to train chemists, physicists and engineers in photovoltaic and thermoelectric testing.

Five major areas of core competency underpin the Lab activities. These are:

1. Materials discovery, design, synthesis and processing,
2. Analytical instrumentation/device design/fabrication,
3. Integration of modeling, fundamental science, engineering and economic expertise for energy issues,
4. Condensed matter theory (including photonic band gap and other novel materials), and
5. Materials characterization.

This Project has been completed. The Final report is found here.