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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.

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Universities: UCF/FSEC

Progress Summary

There has been one primary approach taken in our laboratory in order to improve the efficiency of the n-type PbTe and p-type TAGS: create controlled shape and size nanostructured materials. By using the bulk materials n-type PbTe and p-type TAGS in a nanostructured form, it could be possible to modify thermoelectric properties in ways that are not possible with bulk materials, which can lead to an improvement in ZT.

Reports of enhanced ZT on thin film structures and nanowires have demonstrated the principle of nanostructuring to improve ZT, although questions remain regarding the accuracy of the ZT reported due to experimental difficulties in measuring the properties accurately.(1) Our preliminary theoretical calculation of the phonon and electron transport in PbTe and TAGS superlattices indicated that the primary benefit from nanostructures, a reduced lattice thermal conductivity, require an atomically high density of interfaces and good geometry. Because of these requirements the fabrication process could be laborious and complicated. In order to improve the figure of merit ZT it is required that, the nanostructures should have a size smaller than the phonon mean free path but greater than the electron or hole mean free path, phonons are more strongly scattered by the interfaces than are electrons or holes, resulting in a net increase of the efficiency.

Out first challenge is to create a material with nanoscale structures throughout using inexpensive, fast bulk procedure. Once the bulk material has been fabricated, the next challenge is to optimize the fabrication conditions so that the efficiency is improved. In our case it is difficult because the effects of the fabrication conditions on the nanostructures formed and the material's thermoelectric properties are not always clear. Finally we have to fabricate a thermodynamically stable material which can retain its nanoscale structures while being used in a practical device. If the nanostructures dissolve during the course of operation the thermoelectric properties will return to those of the bulk material, removing any increase in efficiency that the nanostructured material was supposed to give.

For this work we are using the inkjet printing technique to fabricate the bulk materials of nanostructure. This method is a simple method in theory, but is rather involved in many areas.

Some of the main things that need to be controlled during the printing process are drop volume, drop shape and formation, printing distance and its impact on print quality, evaporation kinetics of the droplet, surface energy of the substrate and surface tension of the droplet, penetration or spreading parameters and film thickness. Furthermore, ink rheology varies and one must be able to print liquids ranging from low to relatively high viscosity, hot melts, phase-changing inks, etc. However, viscosity range is rather limited. The phase separation kinetics can be controlled by the drop size and substrate temperature which affects the annealing time. Upper limit for viscosity is dictated by the printer: in this research printer used have upper limit for viscosity of 15 cP and the surface tension 30 ~ 32dynes/cm. Despite these difficulties, several inks processes have been developed which we hope will successfully create stable nanocomposites with improved properties over those of their bulk counterparts.

1. R. Venkatasubramanian, E. Siivola, T. Colpitts and B. O'Quinn, *Nature*, 2001, **413**, 597