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: $161,200
Universities: UCF/FSEC

Progress Summary

Photovoltaic/Optical/ Thermoelectric Device- Unconventional architectures for low cost solar device with high efficiency due to the light capture and conversion

FSEC researchers have fabricated high efficiency and low cost unconventional cylindrical architecture solar devices for terrestrial applications by combining the solar cell design with a novel optical design and a thermoelectric element. . This approach allows multiple benefits including: decreasing the amount of active semiconducting materials to less than 5%, increasing the light absorption and conversion, improved performance with non-ideal (lower cost) materials, increased flexibility of the material choices and increase the overall efficiency. The concept has been demonstrated using organic materials and a similar platform as used for high performance inorganic solar cells. The process uses inexpensive fabrication technologies which could define a new direction in the PV large-scale fabrication of this PV/optical/TE device.

The realization of a high efficiency/low cost solar hybrid device which is easily manufactured is one of the defining problems of photovoltaics. Our innovation is to design an integrated optical/PV/TE cell hybrid system allowing efficiency improvements while decreasing the costs, and hence expand the applications for solar energy. It utilizes a design approach which focuses first on performance, enabling the use of old or new photovoltaic materials. The flexibility of these architectures allows a wide portal to accommodate new breakthrough concepts because the device accepts light at wide angles from a large fraction of the sky and it is therefore able to capture most of the diffuse light, which makes up ~10% of the incident power in the solar spectrum, in the most populated regions of the world.

Unconventional architectures: Photovoltaic/Optical Device

The PV/Optical cell consists of four layers deposited on a very thin glass or polymer fiber: a transparent anode shell, a positively charged/doped shell; a negatively charged/doped shell and a transparent cathode shell. [1] (fig.1) The light is incident on the fiber and cell and it is transmitted down the fiber and reflected multiple times from its interior surface, until passing through the active layers and absorbed or passed through the transparent electrodes, thus allowing for multiple passes through active layers of the incident or adjacent cells. Two metal layers separated by a dielectric material are used to collect the photo-generated charges. They constitute the device back side of the

PV/optical hybrid device. The electrode shells of each cell are of different length, with the outer and shorter electrode shell connected to the upper metal layer, and the longer inner electrode shell passing through the dielectric layer and connecting to the lower metal layer. One of the metal layers is connected to the positively charged transport electrode and the second metal is connected to the negatively charged transport electron.

The PV device consists of many cylindrical cells imbedded into a polymeric matrix with nanoparticles which scatter the light back into the cells.[2] (fig.2)The key optical elements which enhance the light capture are: light trapped by the glass/polymer fiber, light transmitted through the transparent electrodes (ITO and graphene), light absorbed and scattered by the nanoparticles imbedded into the polymeric matrix and, light reflected back into the device by the metallic substrate

The key electrical elements which enhance the light conversion are: photo-excited electrons and holes traveling very short distances before being collected by the electrodes, which could decrease the electronic recombination caused by impurities, high anti-reflection, high surface energy which could increase EQE. [3]

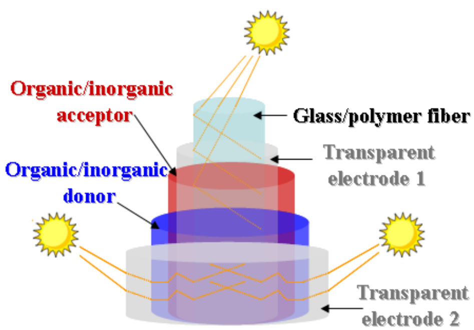

Figure 1. PV cell

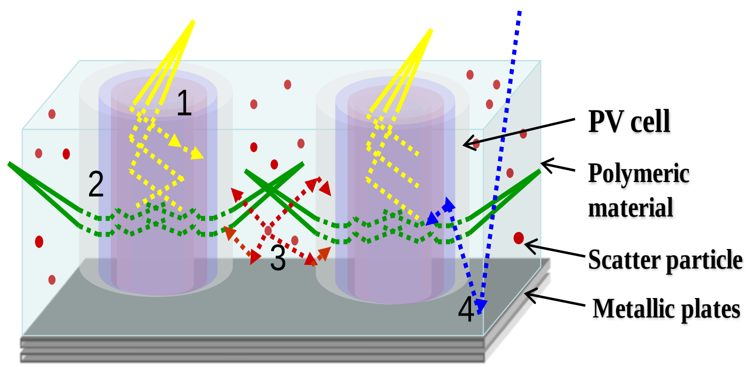

Figure 2. Schematic of the PV/optical device

Transparent electrodes fabrication:

The ITO electrode was deposited using a sputtering machine for thin-film followed by a cure process. The film thickness, optical transparency and electrical conductivity were modified by the deposition time. Graphene oxide (GO) was obtained from exfoliation of graphite through oxidation. A stable 1 mg/mL GO aqueous dispersion was obtained by adding GO into DI water followed by 1 h sonication. In order to achieve a highly uniform deposition, we employed a motor controlled two-dimension spraying system. The prepared GO coatings were reduced by hydrazine vapor and followed by annealing under Ar atmosphere at 400 ^{o}C for 30 min. This room-temperature solution process is completely compatible with polymeric substrates and does not require a sophisticated transfer process.

Donor-acceptor fabrication (PEDOT-PSS, P3HT/PCBM):

For standard devices a layer of 0.45 μm filtered PEDOT:PSS was sprayed in a temperature controlled environment onto ITO coated glass fibers which were then annealed at a temperature of 125 °C for 1 minute. A layer of 0.45 μm filtered 1:0.8 P3HT:PCBM was then sprayed forming the active layer of the devices and following that the devices were solvent annealed for 5 minutes. Studies of the thickness and thermal annealing were performed in order to optimize the power conversion efficiency.[4]

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