Thermoelectric Energy Conversion: Materials, Devices, and Systems

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Thermoelectric Energy Conversion: Materials, Devices, and Systems

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This paper will present a discussion of challenges, progresses, and opportunities in thermoelectric energy conversion technology. We will start with an introduction to thermoelectric technology, followed by discussing advances in thermoelectric materials, devices, and systems. Thermoelectric energy conversion exploits the Seebeck effect to convert thermal energy into electricity, or the Peltier effect for heat pumping applications. Thermoelectric devices are scalable, capable of generating power from nano Watts to mega Watts. One key issue is to improve materials thermoelectric figure-of-merit that is linearly proportional to the Seebeck coefficient, the square of the electrical conductivity, and inversely proportional to the thermal conductivity. Improving the figure-of-merit requires good understanding of electron and phonon transport as their properties are often contradictory in trends. Over the past decade, excellent progresses have been made in the understanding of electron and phonon transport in thermoelectric materials, and in improving existing and identify new materials, especially by exploring nanoscale size effects. Taking materials to real world applications, however, faces more challenges in terms of materials stability, device fabrication, thermal management and system design. Progresses and lessons learnt from our effort in fabricating thermoelectric devices will be discussed. We have demonstrated device thermal-to-electrical energy conversion efficiency ~10% and solar-thermoelectric generator efficiency at 4.6% without optical concentration of sunlight (Figure 1) and ~8-9% efficiency with optical concentration. Great opportunities exist in advancing materials as well as in using existing materials for energy efficiency improvements and renewable energy utilization, as well as mobile applications.

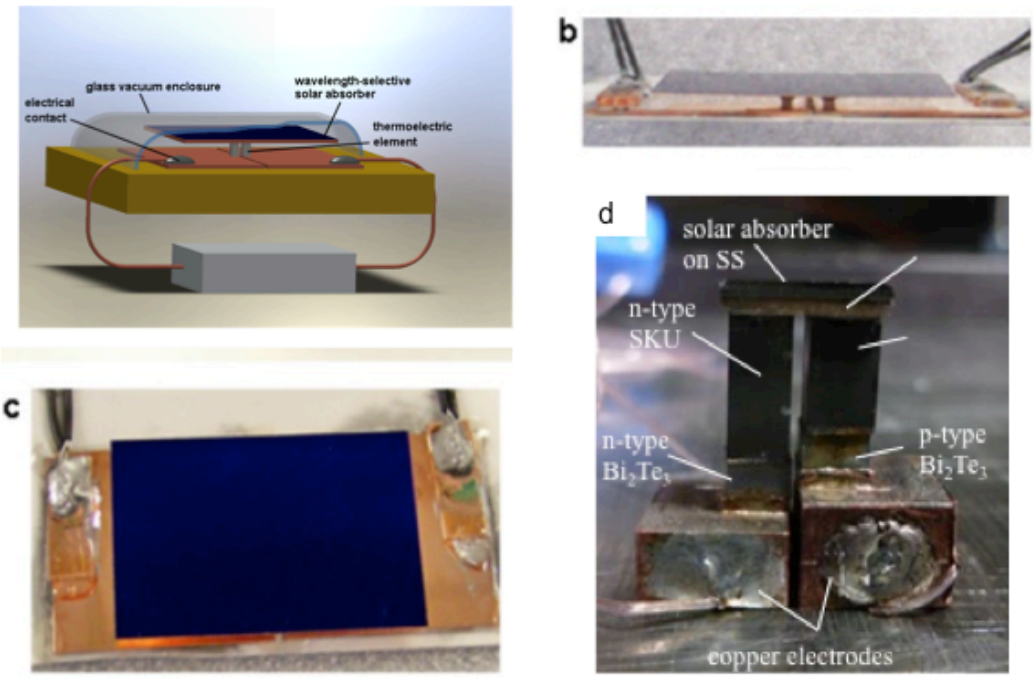

Figure 1 Solar thermoelectric generators (STEG) (a) a flat-panel STEG consisting of an absorber and a pair of thermoelectric legs enclosed in a vacuum chamber, (b) and (c) are cross-sectional and top views of a device, and (d) a segmented thermoelectric generator with optical concentration.