Application-Driven Development of Thermoelectric Materials: Beyond the Efficiency Myth

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ABSTRACT

With the advent of nanotechnology, thermoelectric materials have rapidly reached efficiencies that are high enough to make thermoelectric generators of interest well beyond their traditional application niches in space exploration. Microharvesters providing small yet crucial power to wireless sensor networks or larger systems aimed at recovering waste heat in cars or in industrial plants are in the actual line of fire of thermoelectric technology. Yet, the approach to the development of novel materials often seems not to have acknowledged this change of scenario. Integration of material research and module development is still unusual, with material scientists targeting high efficiency, possibly without paying the due attention to the final need of maximizing output power densities in the actual thermoelectric generator – and module designers having to adapt their layout to existing material characteristics.

Aim of this talk is to discuss the importance of a closer feedback between material and module design, showing how excellent thermoelectric materials may show unsuitable for practical applications while instead modules may take profit of relatively low-efficiency thermoelectrics. Three classes of systems will be analyzed. Firstly, advantages and limitations of nanowires in microharvesting will be considered. Their actual exploitability to power temperature sensors in industrial appliances will be discussed, showing how optimal nanowire sizing and layout critically depend on the power profile of the heat source. As a second scenario, body heat harvesting will be considered. Here it will be shown how the achievable electric power density paradoxically depends more on the mechanical properties of the material and on the eventual limits it imposes to the device layout than on its thermoelectric efficiency. The impact of non-conventional TEG layouts on attainable power densities will demonstrate the potential of new polymer-based nanocomposites, which may be foreseen to outclass higher efficiency inorganic materials in this application. Finally, use of thermoelectrics to replace or to increase the conversion rate of photovoltaic generators will serve to elucidate the role played by effective heat dissipation, and the part played by thermoelectric thermal conductivity in this framework.

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KEYWORDS

Thermoelectricity; Microharvesting; Nanowires; Nanocomposites; Heat