Preface to Special Topic: Thermoelectric Materials

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Mona Zebarjadi and Gang Chen
Department of Electrical and Computer Engineering and Department of Materials Science, University of Virginia, Charlottesville, Virginia 22904, USA and Department of Mechanical Engineering, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139, USA

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Thermoelectric power generators are solid-state devices, which can directly convert heat into electricity. Their clean and environmentally friendly operation makes them attractive in applications such as power generation and heat pumping. Thermoelectric devices have been invented more than 70 years ago, however their commercial applications remained limited due to their low energy conversion efficiency. The main limiting factor in thermoelectric devices is the quality factor of the materials used. The efficiency of the thermoelectric energy conversion is an increasing function of the materials' nondimensional figure of merit, $ZT = \sigma S^2 T/\kappa$, where σ is the electrical conductivity, S the Seebeck coefficient, T the temperature and κ the thermal conductivity.

For a long time, the best-known thermoelectric materials were bismuth telluride-based alloys with a peak ZT around 1. An average ZT of one, is equivalent to conversion efficiency of about 10% when the hot side is at 600 K and the cold side is at 300 K, which is significantly lower than the Carnot limit (50% for the described ΔT). If we can increase the average ZT to two, it would be corresponding to 16% efficiency and 20% at larger temperatures (800 K). Enhancement in ZT while keeping the materials and device fabrication costs down can open up many applications for thermoelectric power generators and heat pumps.

In the last decade, thermoelectric society has witnessed rapid progress. ZT of many known good thermoelectric materials such as bismuth telluride, lead telluride, skutterudites, half-Heuslers have been enhanced and peak ZT values of about two have been reported. Many new members have been introduced to these families and many new compounds have been studied. At the same time, new strategies have been introduced and proven effective in enhancing thermoelectric figure of merit. As a society, we have improved the precision and the reliability of our characterization techniques and introduced new techniques enabling extraction of crucial information such as spectral dependence of carrier mean free path. New and exciting phenomena such as Spin-Seebeck effect has been observed and created a lot of excitements in the field both at the fundamental level (e.g. understanding the physics of magnon-electron coupling) and the device level.

In this special topic, we have invited many of the well-known scientists of the thermoelectric field to provide and update on their latest work. The issue highlights an introduction written by Professor Mahan on thermoelectric materials. We have covered a wide range of exciting topics including improvements in specific classes of materials such as oxides, synthetic minerals, bismuth telluride, half-Heuslers, copper sulfides, lead selenite, chalcogenides, etc., some of the strategies to improve thermoelectric figure of merit such as nanostructuring and phonon engineering and finally physics and the latest improvements in the Spin-Seebeck field.

