Preface to Special Topic: Thermoelectric Materials

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<td><a href="http://dx.doi.org/10.1063/1.4966252">http://dx.doi.org/10.1063/1.4966252</a></td>
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<tr>
<td>Publisher</td>
<td>American Institute of Physics (AIP)</td>
</tr>
<tr>
<td>Version</td>
<td>Final published version</td>
</tr>
<tr>
<td>Accessed</td>
<td>Thu Dec 06 08:30:13 EST 2018</td>
</tr>
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<td>Citable Link</td>
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Mona Zebarjadi and Gang Chen

Citation: APL Materials 4, 104401 (2016); doi: 10.1063/1.4966252
View online: http://dx.doi.org/10.1063/1.4966252
View Table of Contents: http://aip.scitation.org/toc/apm/4/10
Published by the American Institute of Physics

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Preface to Special Topic: Thermoelectric Materials

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(Received 12 October 2016; accepted 14 October 2016; published online 27 October 2016)

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, $ZT = \frac{\sigma S^2 T}{\kappa}$, where $\sigma$ is the electrical conductivity,
$S$ the Seebeck coefficient, $T$ the temperature and $\kappa$ 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 $\Delta T$). 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 tech-
niques 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.