Seminar

COMPLEX THERMOELECTRIC MATERIALS

G. Jeffrey Snyder
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Time: 10:30 am, August.15, 2014 (Friday)
时间：2014年8月15日（周五）上午 10:30
Venue: Conference Room A (607), No. 5 Science Building
地点：理科五号楼607会议室

Abstract

The widespread use of thermoelectric generators has been limited by the low material efficiency of the thermoelectric material. A number of strategies for *Complex Thermoelectric Materials* [1] with higher Thermoelectric figure of merit, zT, are being actively studied at Caltech. Complex electronic band structures provide mechanisms to achieve high zT in thermoelectric materials through *band structure engineering*. High zT is obtained p-type PbTe and PbSe which contains both light and heavy valence bands that can be engineered by alloying to achieve high valley degeneracy which leads to an extraordinary peak zT of nearly 2 at 750K [2].

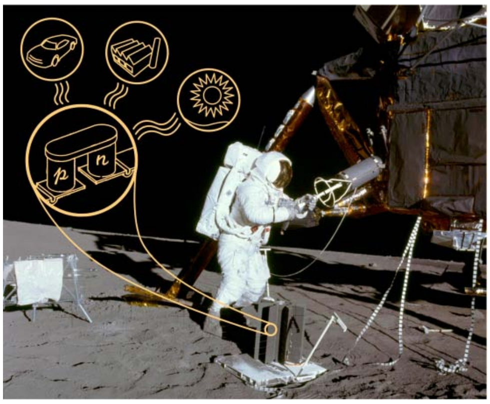

Figure: A thermoelectric generator directly converts heat into electricity with no moving parts. The long term reliability of these systems has encouraged NASA to use thermoelectric generators in many space probes since the 1960s (up to 35 years unattended). Today, thermoelectrics are being considered for terrestrial applications such as automotive and industrial waste heat recovery as well as solar-electricity generation.

Complex crystal structures that enable relatively low thermal conductivity have lead to several new classes of thermoelectric materials. Ca_3AlSb_3, $Ca_5Al_2Sb_6$ and $Yb_{14}AlSb_{11}$ are complex Zintl compounds containing differently connected $AlSb_4$ tetrahedra that obtain zT near 1 at high temperatures. Fast diffusing or ‘liquid-like’ elements in the complex materials Zn_4Sb_3 [3] and Cu_2Se [4] provide additional mechanisms to scatter and otherwise inhibit phonon heat conductivity. The principles of Zintl chemistry facilitates the search for new complex materials and the tuning of known thermoelectric materials with earth abundant, non-toxic elements [5]

Finally, the incorporation of nanometer sized particles reduces thermal conductivity from long mean-free-path phonons. This principle has been successfully demonstrated in PbTe with large nanoscale precipitates (>100nm) that can be independently doped with La (n-type) or Na (p-type). The synthesis of nanoscale composites can be controlled with the aid of equilibrium phase diagrams (experimental or theoretically determined) to produce microstructure of varying composition and length scale [6].

[1] G. J. Snyder, E. S. Toberer. “Complex thermoelectric materials” *Nature Materials* **7**, p 105 - 114 (2008)

[2] Y. Z. Pei, G. J. Snyder, et al. "Convergence of Electronic Bands for High Performance Bulk Thermoelectrics"*Nature* **473**, p 66 (2011); *Advanced Materials* **23**, 5674 (2011)

[3] H. Liu, X. Shi, G. J. Snyder, et al. “Liquid-like Copper Ion Thermoelectric Materials” *Nature Materials*, **11**, 422 (2012); *APL Materials*, **1**, 052107 (2013)

[4] G. J. Snyder, et al., "Disordered Zinc in Zn_4Sb_3 with Phonon Glass, Electron Crystal Thermoelectric Properties" *Nature Materials*, **Vol 3**, p. 458 (2004); *J. Mater. Chem.*, **20**, 9877 (2010)

[5] E. S. Toberer. A. F. May, G. J. Snyder, “Zintl Chemistry for Designing High Efficiency Thermoelectric Materials” *Chemistry of Materials* **22**, p 624 (2010)

[6] D.L. Medlin and G.J. Snyder "Interfaces in Bulk Thermoelectric Materials" *Current Opinion in Colloid & Interface Science* **14,** 226 (2009); *Energy and Environmental Science* **4**, 3640 (2011)

About the Speaker

G. Jeffrey Snyder obtained his B.S. degree in physics, chemistry and mathematics at Cornell University (1991) focusing on solid state chemistry which he continued during a two year stay at the Max Planck Institut FKF (Festkörperrperforschung) in Stuttgart, Germany. He received his Ph.D. in applied physics from Stanford University (1997) where he studied magnetic and magneto-electrical transport properties of metallic perovskites as a Hertz Fellow. He was a Senior Member of the Technical Staff in the thermoelectrics group at NASA’s Jet Propulsion Laboratory for 9 years (1997-2006) where he focused on thermoelectric materials and devices. He is currently a Faculty Associate in materials science at the California Institute of Technology (Caltech). His interests include the discovery of new Zintl phase thermoelectric materials and nanostructured thermoelectric composites using bulk processing, band structure engineering and thermoelectric performance optimization. Dr. Snyder has published over 200 articles, book chapters and patents. He serves as treasurer of the international thermoelectric society.

Dr. Snyder is one of the world’s most prominent scientists in the rapidly growing field of thermoelectrics. His 2008 review article in *Nature Materials*, is used internationally to instruct many new students, and introduce the essentials of thermoelectricity to a multi-disciplinary audience. It is the most cited article in thermoelectrics in 2013.