Thermoelectric Materials 2001—
Research and Applications
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This Symposium G, "Thermoelectric Materials 2001—Research and Applications," held November 26–29 at the 2001 MRS Fall Meeting in Boston, Massachusetts, was the fifth in a series of thermoelectric materials research symposia specifically related to research in new thermoelectric materials [see MRS Proceedings Vol. 234 (1991), Vol. 478 (1997), Vol. 545 (1999) and Vol. 626 (2001)]. In this symposium there were 88 contributing presentations, including 9 invited talks and 33 poster presentations. Based on results presented at this symposium it is apparent that there is acceleration in the pace of innovation in thermoelectrics research, as well as materials and device improvements. Some of the highlights of this meeting were results on superlattices by Rama Venkatasubramanian of the Research Triangle Institute who showed a $ZT = 2.4$ at room temperature in p-type Bi$_2$Te$_3$/Sb$_2$Te$_3$ superlattice thermoelectrics. This represents a greater than two-fold improvement in $ZT$ as compared to the best materials presently in use. For n-type superlattices, $ZT = 1.2$ at room temperature were achieved. In addition, preliminary results on p-n couple devices from these superlattices indicate fast-acting spot cooling in addition to improved performance. This work recently appeared in Nature Vol. 413, 597-602 (2001). David Singh of the Naval Research Laboratory presented theoretical insights for improvements in compounds with the skutterudite crystal structure, a material system that continues to grow in interest. He showed how fully filled skutterudites should have higher mobilities due to the reduction of disorder from vacancies. Millic Dreselhaus of the Massachusetts Institute of Technology (MIT) presented band structure and transport properties of Bi$_{1-x}$Sb$_x$ nanowires. By varying the Sb concentration and the wire diameter, $ZT$ can be optimized in these nanowires. Peter Hagelstein (MIT) and Yan Kucherov of Eneco Inc. presented work showing the development of an improved device for waste heat power generation. This work was announced prior to the conference and reported in the Technology section of the November 27, 2001 New York Times.

There were also a large number of graduate student presentations. This continues to be a focus of our symposium, emphasizing the strong interest from our future scientists in this field of materials research. The symposium organizers were able to give two graduate student presentation awards and a poster award. These students were Nathan Lowhorn of Clemson University, John Ireland of Northwestern University, and Oded Rabin of Massachusetts Institute of Technology.

Thermoelectric cooling is a particularly advantageous method of small-scale refrigeration for specific applications such as cooling of electrical components, for example laser diodes and infrared detectors. Another very important application is that of power generation from waste heat. Despite the extensive investigation of traditional thermoelectric materials (alloys based on Bi$_2$Te$_3$ for refrigeration and Si$_{1-x}$Ge$_x$ for power generation) there is still substantial room for improvement, and thus, entirely new classes of compounds will have to be investigated. This symposium focused on these new materials as well as developments in device engineering.

The essence of a good thermoelectric is given by the determination of the material's figure of merit, $Z = S^2\sigma/\kappa$, where $S$ is the Seebeck coefficient, $\sigma$ the electrical conductivity and $\kappa$ the thermal conductivity. Many papers presented in these proceedings revolve around either maximizing the numerator of $Z$, called the power factor, or by minimizing $\kappa$. The theme of a phonon-glass electron-crystal (PGEC), first proposed by Glen Slack, is very prevalent in the many papers presented in this volume. In the PGEC model the ideal thermoelectric material would possess the thermal properties of a glass and the electronic properties of a crystal. The best thermoelectric materials presently in use have a maximum value of $ZT = 1$, the upper limit for more than 30 years, however from some of the papers in this volume this "upper limit" may now begin to be irrelevant. There are currently many new methods of materials synthesis and much more rapid characterization of thermoelectric materials than were
available 15 or 20 years ago. Many new researchers and new ideas are appearing in this field, which gives us great anticipation about future advances. It is the hope of the organizers of this symposium that these proceedings will provide a benchmark for the current state in the field of thermoelectric materials research and development.

This symposium was enabled by the support of Advanced Research Systems, General Motors Corp., Marlow Industries, MMR Technologies, Quantum Design, Springer-Verlag and the MRS. The organizers appreciate and acknowledge the support of their sponsors.

George S. Nolas
David C. Johnson
David G. Mandrus

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MATERIALS RESEARCH SOCIETY SYMPOSIUM PROCEEDINGS


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