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Thermoelectric Materials 2000— The Next Generation Materials for Small-Scale Refrigeration and Power Generation Applications

Symposium held April 24–27, 2000, San Francisco, California, U.S.A.

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PREFACE

Symposium Z, "Thermoelectric Materials 2000—The Next Generation Materials for Small-Scale Refrigeration and Power Generation Applications," held April 24–27 at the 2000 MRS Spring Meeting in San Francisco, California, was the fourth in a series of MRS symposia which are specifically related to research in new thermoelectric materials [see MRS Symposium Proceedings Vol. 234 (1991), Vol. 478 (1997) and Vol. 545 (1999).] At this Meeting there were over 60 contributed oral presentations, 11 invited talks and 22 poster presentations. Some of the highlights of this Meeting were results presented by Ted Harmon of MIT Lincoln Labs on quantum dot nanostructures of PbTe materials. These materials appear to exhibit a substantial improvement over their bulk counterparts with a $ZT \approx 2$. The Kanatzidis group at Michigan State University presented an update on the $CsBi_4Te_6$ material since their announcement in *Science* Vol. 287, pp.1024-7 (2000). In addition, George Nolas of Marlow Industries and Brian Sales of Oak Ridge National Laboratory presented results on a Yb partially filled skutterudite with $ZT > 1$ at 300 °C. There were also many interesting results in the clathrates, skutterudites, quasicrystals and novel chalcogenide materials systems as well as in III-V compounds for thermionic refrigeration. As in past symposia, both bulk and thin film thermoelectric materials research was well represented. Thermoelectric materials are used in a wide variety of applications related to small-scale solid state refrigeration or power generation.

Over the past thirty years, alloys based on the Bi_2Te_3 compounds (refrigeration) and $Si_{1-x}Ge_x$ compounds (power generation) have been extensively studied and optimized for their use as thermoelectric materials. Thermoelectric cooling is an environmentally "friendly" method of small-scale cooling in specific applications such as cooling computer chips, small beverage coolers, cooling laser diodes and infrared detectors. Another very important application of thermoelectric materials is in power generation for deep space probes such as in the Voyager and Cassini missions. Despite the extensive investigation of these traditional thermoelectric materials, there is still substantial room for improvement, and thus, entirely new classes of compounds will have to be investigated. Therefore, the focus of this symposium centers around the development of the next generation materials for small-scale refrigeration and power generation applications.

The essence of a good thermoelectric is given by the determination of the material's dimensionless figure of merit, $ZT = (\alpha^2\sigma / \lambda)T$, where α is the Seebeck coefficient, σ is the electrical conductivity, and λ is the total thermal conductivity. The thermal conductivity consists of two parts, the electronic and the lattice thermal conductivity. Many of the papers presented in this proceedings revolve around either maximizing the numerator of ZT called the power factor, $PF = \alpha^2\sigma T$, or by minimizing the lattice thermal conductivity. As previously described by Glen Slack, a promising thermoelectric material should possess the thermal properties of a glass and the electronic properties of a crystal, i.e. a phonon-glass and electron-crystal (PGEC). This theme is quite prevalent in the many papers presented in this volume. The best thermoelectric materials have a value of $ZT \approx 1$, which has been an upper limit for more than 30 years, yet no theoretical or thermodynamic reason exists for why it cannot be larger. We believe that the future advances in thermoelectric applications will come through research in new materials, and that is why we have focused the symposium on research in new materials, instead of further optimization of established materials. There are currently many new methods of materials synthesis and much more rapid characterization of thermoelectric materials than were available 20 to 30 years ago. Many new researchers and new ideas are appearing in this field, which gives us much 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 new thermoelectric materials at this time.

At the end of the symposium, there was a special session where program managers Wendy Fuller-Mora (NSF), Valarie Browning (DARPA), Jack Rowe (ARO), and Jerry Smith (DOE) discussed potential opportunities for thermoelectric research. This was followed by a short question and answer period. One distinction at this symposium was the large number of graduate student presentations, numbering over twenty. The symposium organizers were able to give three graduate student presentation awards and a poster award. The student awards for best papers and presentations were: Ganesh Ramachandran, Arizona State University (who also won one of the general MRS best paper awards), Marc Ulrich, Auburn University, and Melissa Lane, Northwestern University. The best student poster award went to Nishant Ghelani of Michigan State University. These awards were enabled by the support of High-Z Corporation, Marlow Industries, MMR Technologies and MRS. The organizers appreciate and acknowledge the support of these sponsors. Much of the research and the results which are presented in this volume were supported by DARPA, the Office of Naval Research and the Army Research Office. Their financial support is greatly appreciated and acknowledged. We also acknowledge the assistance of Marian Littleton and Lori McGowan of Clemson University in all phases of assistance concerning the symposium organization and subsequent proceedings. Their diligence and hard work both before and after the symposium allowed for the timely progress of the manuscripts and proceedings in preparation for publication of this volume.

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September 2000

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