Introduction

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Energy is a scarce resource.[1] Nevertheless, heat (thermal energy) can be found escaping unused almost everywhere you look. In the future, exploiting waste heat to produce reusable energy may contribute to the more efficient utilization of existing resources by using so-called energy harvesting or waste heat recovery approaches. Highly efficient, cost-effective thermoelectric (TE) generators are being proposed to convert waste heat in automobiles and large-scale industrial plants, such as furnaces and refuse incinerators, into reusable energy—with no moving parts. Thermoelectrics, as a recycler of "nomadic" energy supplies, will play an important role in complementing renewable energies and furthermore make a significant contribution to climate protection.

In particular, the automotive market could play a very key role in the advance of thermoelectrics: in the near future based on exhaust energy conversion and longer term for e-cars that have distributed climate control and Li-battery power. It is projected that TE materials for climate-controlled seats and zonal cooling applications may be large markets.[2]

Up until about 1990, thermoelectric applications mainly involved three classes of materials: V_2–VI_3-compounds (such as Bi_2Te_3 alloys); IV–VI-compounds (such as PbTe), and the IV–IV group alloys (e.g., Si_{1-x}-Ge_x).[3,4] Since recent methods from the field of nanotechnology have been used, the quality of materials—and by association efficiency of conversion—has improved significantly.[5] To compete in the automotive industry requires the cost-effective production of large tonnages of TE materials. Consequently, many R&D efforts are concentrated on alternative materials, which occur abundantly, in contrast to tellurium, and can be isolated at low cost and with high purity.

TE applications are also very attractive for room-temperature operation. Low temperature gradients, regardless of their source, are already sufficient for many TE-driven autonomous sensor networks. Future TE generators should obviate the need for disposable and rechargeable batteries, which have insufficient operating lifetimes for many types of electronic sensors. The energy generated with a TE material is sufficient not only for operating the sensor but also for powering wireless transmission of the measurement data. Such energy-autarkic sensor systems can be used in a variety of ways.

Furthermore, interesting mass markets are beginning to emerge in the field of consumer goods such as intelligent clothing, which makes use of thermoelectrically driven sensors on the body.

In summary, future tasks in thermoelectrics must encompass the entire value-added chain, from physical and chemical effects via technological implementation of components to the function within the system.

Taking into account the applications mentioned above, this focus issue reports on new theoretical ideas, materials and device concepts in the field with a focus on novel materials, various methods of materials processing and synthesis as well as the technologies and applications related to the evolution of novel direct thermal-to-electric energy conversion, and cooling utilizing thermoelectrics, thermionics, and thermophotovoltaics. Processing plays a central role in the performance of many materials. For example, spark plasma sintering has had an ever-increasing role in the development of TE materials as it enables densification of fine-grained bulk materials that are difficult to obtain by other densification methods. To rapidly advance the state of the art of high performance, TE materials require a multidisciplinary research approach (materials science, physics, chemistry, and engineering). Theoretical studies of transport properties, band structure and crystal chemistry of materials, thermodynamic analysis, and energy transfer in ballistic processes will also be very important. Experimental efforts will include new capabilities in solid-state synthesis, new bulk materials, thin films, superlattices, and nanostructured materials such as in situ nanostructures from melt spinning as discussed herein. New developments in material properties and device performance measurements are also included in this issue.

We would like to take this opportunity to thank all the authors and coauthors as well as the many reviewers for their outstanding contributions to this *JMR* Focus Issue on Thermoelectrics. While we know that we could not possibly capture all the exciting and wonderful work going on in the field of thermoelectrics, we do hope that we have at least captured a "snap shot" of these efforts in the more than 30 papers published in this issue. We also

DOI: 10.1557/jmr.2011.200

thank our home institutions for the time allowed to put this *JMR* Focus Issue together.

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