# ADVANCES IN THERMOELECTRIC MATERIALS II

*This special issue of the Journal of Materials Research contains articles that were accepted in response to an invitation for manuscripts.*

## Introduction

**Guest Editors:**

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Thermoelectric (TE) materials were first discovered almost two hundred years ago by Thomas Seebeck. Interest was rekindled in these materials in the 1940s and 50s when A. F. Ioffe proposed the use of semiconductor thermoelements for TE devices. Subsequently, devices were developed for both TE cooling and power generation for many important applications. However, progress in the development of high performance materials stalled until recently. When the world's energy demands began to be directed at the need for renewable sources, and electronics were becoming more compact, the need for small scale solid state cooling and power generation greatly increased. The recovery and utilization of waste heat was realized as important in many applications, *e.g.* in current automotive exhaust systems. Consequently, TE materials research experienced a dramatic rebirth and is quite vibrant today, as evidenced by the breadth of articles herein. This rebirth was stimulated by two new directions of research: (i) the advent of "low dimensional materials" such as 2D structures, layered compounds and nanostructures and (ii) the use of a "designer materials approach" in order to tune the materials properties owing to their crystal structure and crystal formula, *e.g.* filled skutterudites and clathrates. Each of these directions have proven to be fruitful and in each case resulted in materials with a dimensionless thermoelectric figure of merit, ZT, on the order of 1.5 to 2. The ZT ($= \alpha^2\sigma T/\kappa$) is defined by the subsequent materials properties; $\alpha$ is the thermopower or Seebeck Coefficient, $\sigma$ is the electrical conductivity, $\kappa$ is the thermal conductivity, and T is the absolute temperature in Kelvin.

This is the second Focus Issue of *Journal of Materials Research* on Thermoelectrics; the first was published in August of 2011. Much of the importance of thermoelectric materials research that was discussed then is just as relevant today, especially in the area of world abundant and cost effective materials, including many new materials such as silicides. In this Focus Issue, *Advances in Thermoelectric Materials II*, we have captured a portion of the broad spectrum of research in thermoelectric materials that has gained prominence since that earlier benchmark. Many new advances in nanomaterials and nanocomposites have become evident. The use of Spark Plasma Sintering or (Electric Field Assisted Sintering) has played a very important role in the synthesis of fine powdered and highly densified bulk materials and/or nanocomposites. We hope the readers will find this volume to be a significant collection of papers representing the rapid advancement in the field of thermoelectric materials.

Finally, we are very grateful to both the authors and reviewers of the many high-quality manuscripts submitted to this *JMR* Focus Issue on *Advances in Thermoelectric Materials II*.

ON THE COVER:

The cover of this Focus Issue shows a generic diagram of two thermoelectric couples made of n-type and p-type thermoelectric materials. The couple on the left is driven by a battery or source (Cooling or Refrigeration Mode) and the couple on the right uses heat or thermal energy to drive a current through a load (Power Generation Mode, PGM). Red and blue colors represent the hot side and cold side respectively. The PGM is equivalent to a common thermocouple (a DV results in a DT). The charge carriers; electrons (black dots) and holes (open circles) carry both the heat and the charge transport through the materials.

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