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Physics and Biophysics

Properties and Applications of Thermoelectric Materials

The Search for New Materials for Thermoelectric Devices

Edited by
Veljko Zlatic
Alex C. Hewson

Springer

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Properties and Applications of Thermoelectric Materials

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Preface

The NATO sponsored Advanced Research Workshop on "Properties and Applications of Thermoelectric Materials" took place on the Croatian island of Hvar over the period 20-26 September, 2008. This subject has attracted renewed interest as concerns with the efficient use of energy resources, and the minimization of environmental damage, have become important current issues. There has been the recognition that thermoelectric devices could play a role in generating electricity from waste heat, enabling cooling via refrigerators with no moving parts, and many other more specialized applications. The main problem in realizing this ambition is the rather low efficiency of such devices for general applications. The workshop addressed that problem by reviewing the latest experimental and theoretical work in this field and by exploring various strategies that might increase the efficiency of thermoelectric devices.

A measure of the potential of a particular material for an efficient thermoelectric device is the figure of merit ZT. This dimensionless ratio depends on the electronic conductivity, the total thermal conductivity and the thermopower (Seebeck coefficient) of the material. For practical applications in a given temperature range a figure of merit should exceed a value of 1, and the search, therefore, is to find or fabricate materials that satisfy this criterion. The difficulty that arises is the conflicting effects of the different factors. The high electrical conductivity of good metals enhances ZT, but this coexists with poor thermopower and high electric thermal conductivity which reduces ZT, so these materials are not suitable. Materials with a high thermopower and low thermal conductivity, on the other hand, tend to have a poor electrical conductivity, so some compromise has to be found between these conflicting factors in optimizing ZT. One existing class of materials which are metallic, but also have a high thermopower, are the compounds and alloys which have strong electron correlation. These materials predominantly contain rare earth or actinide ions, and the enhanced thermopower arises from narrow asymmetric renormalized bands near the Fermi level, resulting from the hybridization of the 4f or 5f states with the conduction electrons. The thermoelectric anomalies due to the proximity of the chemical potential to the Mott–Hubbard gap have also attracted a lot of attention recently. Typical examples are provided by high temperature superconductors and other oxides. The thermoelectric properties of these classes of materials were the main focus of the workshop.

The papers in this volume cover the broad range of approaches, from the experimental work of fabricating, and characterising, the properties of new compounds to enhance ZT, through to theoretical work on renormalized band structure calculations and model Hamiltonians to obtain a deeper understanding of the thermoelectric properties of these materials. The effects of disorder, the proximity to metal-insulator transitions, the properties of layered composite materials, and the introduction of voids or cages into the structure to reduce the lattice thermal conductivity are all explored. Other ways of enhancing ZT by exploiting glassy materials or using the thermoelectric properties of metal-excitonic insulator interfaces are also covered. Several papers dealing with the general physical properties of strongly correlated materials are included as well.

We hope the papers presented here give a guide to the current activity in the field, and convey the fact that real progress is being made. Much work still requires to be done – this is more of an interim report – but we hope it will encourage and stimulate further developments in the field, to bring forward the day when the general production of high efficiency thermoelectric devices can be realized.

Zagreb, London
March 2009

Veljko Zlatić
Alex Hewson

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