Inorganic Thermoelectric Materials

Book

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Preface

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Preface

Thermoelectric devices offer a unique capability in their ability to convert thermal energy directly into electrical power. At the heart of any device is an array of *n*- and *p*-type semiconductors. The efficiency of the device is determined primarily by the performance of these materials. The performance is commonly embodied in a figure-of-merit (*ZT*), expressed in terms of the transport properties of the material. The growing demand for energy, coupled with recognition of the impact of greenhouse gas emissions arising from combustion of finite reserves of fossil fuels has led to renewed interest in energy harvesting using thermoelectric devices in a wide range of applications.

High materials performance is a requirement common to all applications. However, high figures of merit typically occur over a relatively limited range of temperatures, necessitating the development of a portfolio of materials, each optimised to the temperature range of a particular application. This has led to a tremendous expansion in the range of materials under investigation for thermoelectric energy recovery. Advances in understanding have led to the formulation of design principles that target improvements in the electrical properties or reductions in the thermal conductivity to increase *ZT*. Figures of merit in excess of unity are routinely achieved in the mid- to high-temperature regions and may exceed two in favourable cases.

This book describes recent developments in important families of inorganic thermoelectric materials. It begins (Chapter 1) with an overview of materials synthesis, the key first step in the investigation of thermoelectric materials, together with an outline of property measurement techniques and consolidation methods. The conversion of a typically polycrystalline powder into a monolith suitable for the measurement of properties and ultimately, the fabrication of devices, is a key step that can have a significant impact of performance. Chapter 2 describes the underlying solid-state concepts behind the electrical and thermal transport properties that govern thermoelectric performance and the computational methods increasingly used to support and guide experimental investigations. The synergy between experimental and computational studies is of growing importance in advancing understanding of the properties of thermoelectric materials and in guiding the search for new materials.

The remaining chapters cover key classes of thermoelectric materials. Chapter 3 describes the advantages and performance enhancements achieved through the fabrication of composites. The increased interface scattering arising from incorporation of a second phase, often nanocrystalline, into a pristine thermoelectric material, can have a beneficial impact on thermal conductivity, while interaction between the nanoparticulate material and parent matrix also affects charge transport. Chapter 4 describes recent advances in chalcogenides for thermoelectric applications, focusing on efforts to alleviate environmental concerns associated with lead, through the exploration of phases derived from lighter congeners. This approach has resulted in lead-free materials with figures of merit of two or more. The book concludes with a discussion of intermetallic phases (Chapter 5), including skutterudites, in which weakly-bound species reduce thermal conduction through localised vibrational modes, and Heusler and half-Heusler systems, which show a surprising complexity in their phase behaviour. Such materials are already finding their way into prototype devices.

While formidable challenges remain in translating materials performance into high-efficiency devices, there now exists a significantly expanded range of materials that provides coverage over the wide spectrum of potential application temperatures. This is indeed an exciting era for thermoelectric materials.