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Chapter

Introductory Chapter: Introduction to Advanced Thermoelectric Materials for Energy Harvesting Applications

Saim Memon

1. Introduction

Due to a cumulative trepidation of global carbon dioxide emissions and balancing the global electricity supply, an advancement into progressive technologies such as thermoelectrics has appeared to be promising [1]. With the fact that enormous amount of radiative heat from the sun, specifically in hot arid climate, and waste heat from electromechanical machines and devices can be harnessed. Over the past three decades, there has been an increasing significance of advancing the thermoelectric materials for energy harvesting applications [2] such as of passive cooling and utilizing the waste heat into useful electrical power, with Seebeck effect, from the automotive exhausts, combined heating and power devices, radiators [3], geothermal steam, electric vehicles and smart grids [4]. Thermoelectric generators have no mechanical moving parts but traditionally have lower efficiencies [5] and they are still in their development stage for the mass production scale for a wider industrial and domestic energy harvesting applications.

This book enlightens the design, implementation and thermoelectrical performance of existing and advanced thermoelectric materials for the vast number of energy harvesting applications. The authors lay the framework to emphasis from the quantum theory to the advanced development of the thermoelectric materials and bring attention to the questions of development, performance, evaluation and implementation of the advanced thermoelectric materials in the energy harvesting projects. To optimize the performance and apply thermoelectrics are of the paramount focus on this book. This book also discusses the methodologies and current state-of-the-art research in the field of thermoelectrics for energy conversion and management. The book establishes sustainable energy development goals of harnessing the waste heat energy from appliances, machines and devices and conversion to useful electrical power to a range of applications.

To appreciate the significance of advancing thermoelectric materials, here in particular the intention is to present the challenges that thermoelectric materials face today. However, thermoelectric material is a semiconducting material of two distinctive metals comprising p-type and n-type materials. These are accepted as the electron transport mechanism from the hot side to the cold side. Here, the Seebeck effect ascertains the characteristics of the materials, their series-parallel connections and of course thermally generated potential difference. So, the output-generated voltage with respect to the input (the temperature difference between two dissimilar metals) determines the efficiency and so far the maximum efficiency that traditionally reported was up to 5% with the use of Bismuth Telluride (Bi_2Te_3) composite. The limits of Bismuth Telluride (Bi_2Te_3)-based thermoelectric material and advancing it with the novel effects of doping the electron properties of Lead Telluride (PbTe) for the improvement of the thermoelectrical performances are discussed in this book. The recent methods for thermoelectric efficiency enhancement with (PbTe)1-x(BiTe)x alloys could be used to improve electronic optimization.

There is a need of improving the efficiency of thermoelectric materials. Balancing the properties of the thermoelectric materials such as lowering the thermal conductivity, which is linked to figure of merit, is important. In this book, the organic (polymer and nanocomposite based) thermoelectric materials are discussed. The significance of organic and inorganic materials, technologies for the fabrication and performance parameters of thermoelectrics are discussed along with carbon-based materials such as graphene and carbon nanotubes for cost-effective solutions and enhancement of conversion efficiency. It is also important to understand the quantum theory of the Seebeck coefficient for the advancement of thermoelectric superconducting material which is also discussed in this book. This material incorporates the main superconducting properties such as zero resistance and superconducting temperature higher than the liquid nitrogen temperature.

Passive cooling using thermoelectric modules is usually applicable to remote locations where electricity from the grid is not possible, while utilizing the geothermal heat is of great importance in the future, for example, powering the closed-circuit television cameras, LED lightings and mobile cellular devices, which is discussed in detail in this book. A recent development in electronic mobile devices, lighting systems, concentrated quartz-halogen heat and batteries have allowed thermoelectric modules to use its generated power to add up the system efficiency. Thermoelectric generators are bridging their implication to electric vehicles, solar thermal and photovoltaic technologies, in which the scope of harnessing waste heat energy to electrical power is demanding with vacuum insulation [5, 6], and advancing the performance of thermoelectric materials [7] is of vital importance.

The question is what the optimum performance of using Bismuth Telluride (Bi_2Te_3)-based thermoelectric generator would be if the experimental setup is designed specifically for this? In this book, the experimental and simulated thermoelectrical performance parameters, such as the VI characteristic curves at variable temperatures, are analysed. In this, the focus is on harvesting the maximum possible waste direct heat to electrical power with the Bismuth Telluride (Bi_2Te_3)-based thermoelectric generator and demonstrating the experimental test setup necessary to achieve optimal performance for the recovery of the waste heat.

In terms of specific energy harvesting applications in the modern day, thermoelectric cooling devices could be used to operate ultraviolet LED in its nominal conditions in order to improve its optical performance. To harness the waste heat from the vehicles has already been an industrial automotive focus, and this book explains how waste heat from the exhaust system can be used to harness into useful electrical power.

However, this book does not stipulate the complete coverage of all the important advanced thermoelectric materials but specifically enlightens the submitted contributions by the authors. This book, nevertheless, provides state-of-the-art advanced thermoelectric materials and a range of energy harvesting technologies that might be helpful to readers to enhance their knowledge and develop eagerness to details in the science and development of thermoelectrics. It is intended that this book will motivate scientists, researchers, engineers and students to investigate further into the modern applications and materials development in the area of thermoelectrics.

Author details

Saim Memon
Centre for Advanced Materials, Division of Electrical and Electronic Engineering, School of Engineering, London South Bank University, London, UK

*Address all correspondence to: s.memon@lsbu.ac.uk

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