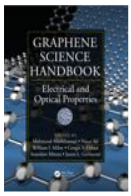

Graphene Science Handbook

Previous Chapter Next Chapter Table of Contents Add to Bookshelf Email Download Citations.

Chapter 18. Thermoelectric Effects in Graphene

N. S. Sankeshwar,S. S. Kubakaddi andB. G. Mulimani

Citation Information
Graphene Science Handbook
Electrical and Optical Properties
Edited by Mahmood Aliofkhazraei, Nasar Ali, William I. Milne, Cengiz S. Ozkan, Stanislaw Mitura and Juana L. Gervasoni
CRC Press 2016
Pages 273–292
Print ISBN: 978-1-4665-9131-8
eBook ISBN: 978-1-4665-9132-5
https://doi.org/10.1201/b19642-20

18 Thermoelectric Effects in Graphene

N. S. Sankeshwar, S. S. Kubakaddi, and B. G. Mulimani

CONTENTS

ABSTRACT

Graphene, owing to its unique electronic properties, has become one of the active areas of condensed matter research with promising applications in future efficient thermoelectric (TE) and energy storage devices. The present work reviews the status of thermoelectric power (TEP) of graphene systems, including single-layer, bilayer, and nanoribbons. The theory of TEP, based on the Boltzmann transport formalism in 2D systems, is given. An analysis of the experimental data, in terms of the diffusion and the phonon-drag contributions to TEP, with regard to the various scattering mechanisms operative in graphene systems, is presented. The outlook on TEP for better understanding of the TE properties of graphene is discussed.

18.1 INTRODUCTION

A useful measure of the potential of a material for thermoelectric (TE) applications is its TE figure of merit, $Z = S^2\sigma/\kappa$, where S is the thermoelectric power (TEP) (also called Seebeck coefficient), σ the electrical conductivity, and κ the thermal conductivity of the material. Materials, therefore, that have an enhanced power factor ($S^2\sigma$) and reduced κ, are suitable candidates for efficient TE devices [1,2]. A desirable combination of the quantities, S, σ, and κ, are generally possessed by semiconducting materials [1–3]. Bi_2Te_3 is found to have a high room temperature value of $ZT \sim 1$. Search is on for nanostructured materials for use in smaller and more efficient TE devices, necessary for cleaner, more efficient cooling, and power generation [1,2,4,5]. In recent years, graphene, which exhibits unique properties such as high thermal conductivity and high electron mobility, has generated renewed interest in the search [6–9]. Although there is no well-defined theoretical limit to ZT, even a modest increase in value of ZT would provide opportunities for applications [10]. Recent studies indicate that ZT could be enhanced nearly fourfold by optimizing the potential of graphene systems [11].

The TEP of a material is an important and interesting transport property for study because of its sensitivity to the composition and structure of a system and to the external fields. It has been able to shed much light on the interaction of electrons with phonons, impurities, and other defects, be it metals [12], bulk semiconductors [3], or conventional 2D semiconductor systems [13–15]. It is also known to provide information complementary to that of resistivity (or conductivity), which alone is inadequate, say, in distinguishing different scattering mechanisms operative in a system [12,16]. An optimization of the Seebeck coefficient for any material, therefore, involves understanding and appropriately modifying its electronic properties and provides a challenge for theoreticians and experimentalists alike to search for ways to increase the value of TE figure of merit. Graphene, a monolayer of graphite with the carbon atoms arranged in a honeycomb crystal lattice, exhibits interesting TE effects. For instance, compared to elemental semiconductors, it has higher TEP and can be made to change sign by varying the gate bias [17–19].