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High-Temperature Measurement of Seebeck Coefficient and Electrical Conductivity

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We have developed a system for simultaneous measurement of the electrical conductivity and Seebeck coefficient for thermoelectric samples in the temperature region of 300 K to 1000 K. The system features flexibility in sample dimensions and easy sample exchange. To verify the accuracy of the setup we have referenced our system against the NIST standard reference material 3451 and other setups and can show good agreement. The developed system has been used in the search for a possible high-temperature Seebeck standard material. $FeSi_2$ emerges as a possible candidate, as this material combines properties typical of thermoelectric materials with large-scale fabrication, good spatial homogeneity, and thermal stability up to 1000 K.

Key words: Thermoelectrics, measurement technique, measurement of Seebeck coefficient, Seebeck coefficient reference material

INTRODUCTION

Thermoelectricity deals with direct conversion of heat into electrical energy and can therefore make a valuable contribution to the solution of the energy crisis of the 21st century. Thermoelectric generators can utilize waste heat from various sources such as combustion engines to generate electrical power and thus increase the energy efficiency of such devices. This form of energy recuperation has various implemented and potential applications in the fields of space flight, traffic, and aviation.[1,2]

The efficiency of such waste heat to electrical energy conversion is governed by the thermoelectric figure of merit ZT, which is given by basic material properties as

$$ZT = \frac{\sigma S^2}{k} T. \quad (1)$$

A good thermoelectric material thus has high electrical conductivity σ, large Seebeck coefficient S, and low thermal conductivity k; T is the absolute temperature. The identification and especially the optimization of thermoelectric materials require repeated measurement of σ, S, and k, as these three quantities are strongly interdependent and optimization of ZT cannot be achieved by simple optimization of the individual quantities.[2] This is particularly true for the Seebeck coefficient and the electrical conductivity, which are coupled via the charge carrier concentration of the material: a high charge carrier concentration usually increases σ and decreases S. For better understanding of measurement results and to reduce the measurement time and sample count, it is highly advantageous to employ a system that can measure σ and S simultaneously. This is particularly interesting for materials that are unstable under heat treatment, as sequential measurements on the same sample would give misleading results in this case. Although there are some commercially available systems for measurement of σ and S, we decided to set up a custom-designed system. These are more flexible in measurement routines and measurement data analysis; furthermore, we wanted an apparatus that is applicable up to 1000 K.

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