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Development of a Measurement System for the Figure of Merit in the High-Temperature Region

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New equipment has been developed for evaluating the figure of merit, ZT, on the basis of the Harman method in the temperature range between room temperature and 650 K. In this temperature range, the sample holder in the vacuum chamber has a different construction as compared with the sample holder constructed for the temperature range below room temperature. Several issues that need to be considered, such as compensation for the thermal radiation effect, suppression of heat leakage from the lead wires, and the setup method for the lead wires on the sample, are examined in the considered temperature region. Evaluations of ZT are successfully made for typical thermoelectric materials, $(Bi,Sb)_2Te_3$ and $CeFe_3CoSb_{12}$. We then demonstrate that the influence of thermal radiation between the high- and low-temperature edges of the sample induced by the Peltier effect on the estimated value of ZT is negligible at around 600 K. Furthermore, the change in the thermoelectric properties due to repetition of the thermal cycle is studied, and a typical hysteresis behavior is observed in the considered thermoelectric materials. It is revealed that heating the sample to a high temperature causes a change in its thermoelectric properties, which one must take into account for practical applications of thermoelectric materials.

Key words: Thermoelectric material, Harman method, figure of merit, high temperature

INTRODUCTION

It is well known that the nondimensional figure of merit, ZT, can be determined by the Harman method[1] through voltage measurements and by using the equation $ZT = V_{dc}/V_{ac} - 1$, where "dc" and "ac" indicate direct and alternating current, respectively, and T is the absolute temperature. It has been reported[2] that other thermoelectric properties related to ZT can also be evaluated by improving this method. A differential chromel–alumel thermocouple with 25 μm diameter is used in the measurement of the temperature difference, ΔT, which is induced between the voltage terminals by the Peltier effect in Ref. 2. The Seebeck coefficient, α, is evaluated by the formula $\alpha = (V_{dc} - V_{ac})/\Delta T$ through simultaneous measurements of V_{dc}, V_{ac}, and ΔT. The thermal conductivity can be estimated by the relationship $\kappa = \alpha^2/\rho Z$, where the resistivity, ρ, is determined by ac voltage measurements. Experimental details are described in Ref. 2. The Harman method is also useful[3,4] in the evaluation of thermoelectric properties in materials of mesoscopic size. Current equipment based on the Harman method can operate only in the temperature region below room temperature. For measurements above room temperature, the system needs to be completely redesigned, which includes changing the setup method for the heater and the setting conditions relating to the sample, such as those of the electrical contacts between the sample and the lead wires. While the accuracy of the evaluation of thermal conductivity would reduce with temperature increase above room temperature in the conventional

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