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Interface Microstructure and Performance of Sb Contacts in Bismuth Telluride-Based Thermoelectric Elements

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A thermoelectric joint composed of p-type $Bi_{0.5}Sb_{1.5}Te_3$ (BiSbTe) material and an antimony (Sb) interlayer was fabricated by spark plasma sintering. The reliability of the thermoelectric joints was investigated using electron probe microanalysis for samples with different accelerated isothermal aging time. After aging for 30 days at 300°C in vacuum, the thickness of the diffusion layer at the BiSbTe/Sb interface was about 30 μm, and Sb_2Te_3 was identified to be the major interfacial compound by element analysis. The contact resistivity was 3×10^{-6} ohm cm^2 before aging and increased to 8.5×10^{-6} ohm cm^2 after aging for 30 days at 300°C, an increase associated with the thickness of the interfacial compound. This contact resistivity is very small compared with that of samples with solder alloys as the interlayer. In addition, we have also investigated the interface behavior of Sb layers integrated with n-type $Bi_2Se_{0.3}Te_{2.7}$ (BiSeTe) material, and obtained similar results as for the p-type semiconductor. The present study suggests that Sb may be useful as a new interlayer material for bismuth telluride-based power generation devices.

Key words: Thermoelectric, interlayer, antimony, contact resistivity

INTRODUCTION

The thermoelectric (TE) conversion technique can convert heat into electricity and vice versa based on the Seebeck effect and Peltier effect. Because they are silent in operation and have long lifetime, high reliability, and no moving parts, TE devices have been explored for applications in electronics cooling and waste heat recovery and as a special power source.[1–3] Besides the temperature difference between the cold side and hot side, the conversion efficiency of a typical thermoelectric couple made of p-type and n-type elements (Fig. 1) is quantified by the figure of merit, ZT, given by Ref. 4 as

$$ZT = \frac{(\alpha_p - \alpha_n)^2 T}{\kappa R},$$

where α_p and α_n are the Seebeck coefficients of the p-type and n-type TE materials, respectively, R is the effective electrical resistance of the couple, and κ is the effective thermal conductance of the couple. R can be expressed as: $R = R_m + R_c$, where R_m is the electrical resistance of the TE materials and R_c is the contact resistance contribution from the metal electrode/interlayer and interlayer/TE material interfaces. The electrode and interlayer resistances are neglected. Research into TE technology has primarily focused on performance improvement in materials by doping, alloying, and nanostructuring.[5–7] It must be pointed out that, in addition to the ZT of the TE material, the interfacial contact quality is also an important factor for enhancing the efficiency and reliability of a TE module. Moreover, for bulk TE applications, the effect of the interfacial contact resistance becomes more significant for shorter element lengths, since R_c makes a greater contribution when R_m is reduced.

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