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Parameters of the Constant-Energy Surface and Features of Charge Carrier Scattering of Bi_2Te_3-Based Epitaxial Films

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Galvanomagnetic properties of epitaxial $Bi_{0.5}Sb_{1.5}Te_3$ films grown by the hot-wall technique were investigated in magnetic fields of H = 5 T to 14 T through the temperature interval of 10 K to 300 K. The results were analyzed in terms of a many-valley model of the energy spectrum and anisotropic charge carrier scattering. The degeneracy parameter β_d, and ratios of components of the reciprocal effective-mass tensor $\overleftrightarrow{\alpha}$ and relaxation time tensor $\overleftrightarrow{\tau}(\varepsilon)$ were estimated. Substantial anisotropy of charge carrier scattering was observed in the investigated temperature interval. Anisotropy of charge carrier scattering along bisector axes is enhanced, as compared with that of corresponding bulk samples. High charge carrier mobility and higher angular factor of the temperature dependence of mobility promote enhancement of the figure of merit Z of the films as compared with that of corresponding bulk solid solutions.

Key words: Thermoelectricity, bismuth-telluride-based films, transport properties, anisotropic scattering mechanism

INTRODUCTION

Due to selective phonon scattering on block and interface boundaries, thin epitaxial $Bi_{0.5}Sb_{1.5}Te_3$ films possess higher figure of merit Z than bulk solid solutions. The materials under study exhibit strongly anisotropic transport properties (except the Seebeck coefficient), which is related to specific features of their crystal structure (space group $R\bar{3}m$) and chemical bonding. Both anisotropy of the transport properties and anisotropy of charge carrier scattering were observed for these materials. The most comprehensive information on charge carrier scattering mechanisms and the anisotropy of the constant-energy surface in thermoelectric films can be obtained from studies of their galvanomagnetic properties in the framework of a many-valley model of the energy spectrum.

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MANY-VALLEY MODEL

The constant-energy surfaces of the valence and conduction bands of thermoelectrics based on bismuth and antimony chalcogenides are reasonably well described by a six-valley model of the energy spectrum with anisotropic scattering of charge carriers.[1–4] The relations between the experimental galvanomagnetic coefficients (GMC) and the parameters responsible for the shape of the constant-energy surface (u, v, w) and the degeneracy parameter β_d are defined in the framework of a many-valley energy spectrum model.[5]

The degeneracy parameter β_d, determined to a large extent by the scattering mechanism of charge carriers, can be presented as

$$\beta_d = \frac{I_1^2}{I_0 I_2}, \quad (1)$$

where I_n (n = 0, 1, 2) is determined as