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Effect of Initial Bulk Material Composition on Thermoelectric Properties of Bi_2Te_3 Thin Films

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V_2VI_3 compounds and solid solutions based on them are known to be the best low-temperature thermoelectric (TE) materials. The predicted possibility of enhancement of the TE figure of merit in two-dimensional (2D) structures has stimulated studies of the properties of these materials in the thin-film state. The goal of the present work is to study the dependences of the Seebeck coefficient S, electrical conductivity σ, Hall coefficient R_H, charge carrier mobility μ_H, and TE power factor $P = S^2\sigma$ of Bi_2Te_3 thin films on the composition of the initial bulk material used for preparing them. Thin films with thickness d = 200 nm to 250 nm were grown by thermal evaporation in vacuum of stoichiometric Bi_2Te_3 crystals (60.0 at.% Te) and of crystals with 62.8 at.% Te onto glass substrates at temperatures T_S of 320 K to 500 K. It was established that the conductivity type of the initial material is reproduced in films fairly well. For both materials, an increase in T_S leads to an increase in the thin-film structural perfection, better correspondence between the film composition and that of the initial material, and increase in S, R_H, μ_H, σ, and P. The room-temperature maximum values of P for the films grown from crystals with 60.0 at.% and 62.8 at.% Te are $P = 7.5 \times 10^{-4}$ W/K^2 m and 35×10^{-4} W/K^2 m, respectively. Thus, by using Bi_2Te_3 crystals with different stoichiometry as initial materials, one can control the conductivity type and TE parameters of the films, applying a simple and low-cost method of thermal evaporation from a single source.

Key words: Bi_2Te_3 thin films, bulk material, stoichiometry, substrate temperature, thermoelectric properties

INTRODUCTION

Bi_2Te_3 semiconductor compound and Bi_2Te_3-based solid solutions are among the best low-temperature thermoelectric (TE) materials, being widely applied in TE devices of different types.[1,2] Broad prospects for practical applications of low-dimensional structures stimulate study of bismuth telluride in the thin-film state.

Bi_2Te_3 films can be obtained by different methods, such as molecular-beam epitaxy, magnetron sputtering, hot-wall epitaxy, liquid-phase epitaxy, laser evaporation, thermal evaporation from a single or from two sources, electrochemical deposition, and others.[3–9] Improvements in the technology of Bi_2Te_3 film preparation for TE applications are aimed at enhancing the dimensionless TE figure of merit $ZT = S^2\sigma T/\lambda$ (S is the Seebeck coefficient, σ is the electrical conductivity, λ is the thermal conductivity, and T is the absolute temperature) and TE power factor $P = S^2\sigma$, which determine the efficiency of TE materials.

One of the simplest low-cost methods for thin-film preparation is thermal evaporation in vacuum from a single source. However, the main deficiency of this method is limited control over the deposition process.

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