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Research Article

Properties of Nanostructure Bismuth Telluride Thin Films Using Thermal Evaporation

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Bismuth telluride has high thermoelectric performance at room temperature; in present work, various nanostructure thin films of bismuth telluride were fabricated on silicon substrates at room temperature using thermal evaporation method. Tellurium (Te) and bismuth (Bi) were deposited on silicon substrate in different ratio of thickness. These films were annealed at 50°C and 100°C. After heat treatment, the thin films attained the semiconductor nature. Samples were studied by X-ray diffraction (XRD) and scanning electron microscopy (SEM) to show granular growth.

1. Introduction

Bismuth telluride (Bi_2Te_3) is a semiconductor with an indirect bulk energy band gap of 0.165 eV. It is layered semiconductor material having trigonal structure with high melting point (585°C) and a density of 7.7 g/cm^3; also it is the heaviest stable binary compound [1]. These interesting properties grabbed the researchers' attention for its wide range application in the field of thermoelectric material [2]. Since last decades, efforts are in progress to enhance the properties of these materials using different approaches and one of the fruitful approaches is to synthesize it in nanoscale [3]. Till today, many methods have been discussed to prepare nanostructure bismuth telluride with various sizes and shapes such as microwave assisted method, mechanical alloying, ball milling, hot pressing, spark plasma sintering, and wet chemical method [4].

It is an attractive thermoelectric material with the highest figure of merit ($ZT = 0.68$) at room temperature in its bulk. Nanostructuring layered super lattice structure of Bi_2Te_3 produces a device within which there is good electrical conductivity but perpendicular to which thermal conductivity is poor. Bismuth telluride compounds are usually obtained with directional solidification from melt or powder metallurgy processes [5]. Materials produced with these methods have lower efficiency than single crystalline ones due to the random orientation of crystal grains, but their mechanical properties are superior and the sensitivity to structural defects and impurities is lower due to high optimal carrier concentration. The required carrier concentration is obtained by choosing a nonstoichiometric composition, which is achieved by introducing excess bismuth or tellurium atoms to primary melt or by dopant impurities. Some possible dopants are halogens and group IV and V atoms. Due to the small band gap (0.16 eV), Bi_2Te_3 is partially degenerate and the corresponding Fermi level should be close to the conduction band minimum at room temperature. The size of the band gap means that Bi_2Te_3 has high intrinsic carrier concentration. Bi_2Te_3 is a narrow band gap semiconductor [2].

In this paper, we have synthesized the compound thin film by depositing the elemental layers and thermal annealing. Typical measurement of different samples having different thickness shows similar behaviour of resistivity measurement. However, the data corresponding to the thickness of 500 nm are presented here.

2. Experimental Details

Tellurium (Te) was purchased from Koch-Light Laboratories Ltd., Colnbrook, Berkshire, England. Bismuth (Bi) was purchased from Sigma-Aldrich laboratories. Thin film of Te