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Structural and Thermoelectric Properties of $Bi_{1-x}Sb_x$ Nanoalloys Prepared by Mechanical Alloying

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$Bi_{1-x}Sb_x$ nanoparticles were prepared by mechanical alloying and compacted using different techniques. The influence of the composition as well as the pressing conditions on the thermoelectric performance was investigated. A strong dependence of the thermoelectric properties on the composition was found, which deviates from the behavior of single crystals. The results indicate a significant change in the band structure of the material induced by the reduced size. The influence of the pressing conditions on the thermoelectric properties also showed composition dependence. The results show that the compacting method has to be chosen carefully.

Key words: Bi-Sb alloys, mechanical alloying, pressing conditions

INTRODUCTION

Bi-Sb alloys are the most suitable thermoelectric materials for applications below 200 K.[1,2] Both elements are semimetals with the rhombohedral crystal structure $R\bar{3}m$. They form a complete series of solid solutions without a miscibility gap,[3] which makes them perfect candidates for composition-dependent investigations of thermoelectric properties. A significant body of work deals with the thermoelectric and structural properties of $Bi_{1-x}Sb_x$ single crystals[4–6] or nanostructures such as nanowires[7–9] and thin films.[10,11] Also, many efforts have been made to produce microcrystalline alloys and investigate their properties.[12–14] However, so far, only a few results have been published regarding $Bi_{1-x}Sb_x$ nanoparticles.[15,16] For single crystals it is known that the thermoelectric properties show very strong dependence on composition that is caused by changes in the band structure with increasing antimony content. In the composition range between $x = 0.07$[17] and $x = 0.22$[18] the alloys are semiconducting, while they are semimetallic for all other compositions. For systematic investigation of the thermoelectric properties of nanoparticles, we produced $Bi_{1-x}Sb_x$ nanoparticles in the whole composition range by mechanical alloying and carried out composition-dependent as well as compaction dependent measurements.

EXPERIMENTAL PROCEDURES

Bi and Sb powders (≥99.5%) were mixed in the desired ratio, put into a steel beaker, and sealed under argon atmosphere. The powder mixture was ball-milled for 20 h at speed of 450 rpm and ball-to-powder ratio of 7.5 with four steel balls of 10 mm diameter. After the milling process, the product was annealed for 17 h at 250°C under inert atmosphere and afterwards pressed into pellets, which were again annealed for 17 h at 200°C.

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