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Thermoelectric Properties of Si-Ge Nanostructured Thermoelectric Materials Synthesized by Mechanical Alloying

A.I. Voronin[1], A.A. Usenko[1], A.V. Korotitsky[1], D.U. Karpenkov[2], O.N. Soklakova[3], V.V. Khovaylo[1]

[1] *National University of Science and Technology "MISIS", 4, Leninskiy Ave., 119049 Moscow, Russia*
[2] *Tver State University, 33, Zhelyabova st., 170100 Tver, Russia*
[3] *Belgorod State National Research University, 85, Pobedy St., 308015 Belgorod, Russia*

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Silicon-germanium alloys is one of the best thermoelectric materials in power generation devices operating in 600-1000 C range in heat conversion into electricity directly. The enhancement of efficiency comes mainly from a significant reduction in the thermal conductivity caused by the enhanced phonon scattering off the increased density of nanograin boundaries.

Keywords: Thermoelectric materials, Silicon, Germanium, Nanostructured, Mechanical alloying.

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1. INTRODUCTION

Today there is a great need for high-temperature and medium-temperature thermoelectric materials. This gap may well take a silicon germanium, which lends itself well to modification by nanostructuring. Bulk nanocrystalline thermoelectrics are the most promising materials for commercial applications. This is due to two reasons: 1) the relative cheapness of their production as compared to the creation of nanostructures in the form of quantum wells, quantum wires, and quantum dots and other methods which are far from commercialization, 2) experimental and theoretical results that demonstrate the possibility of increasing the thermoelectric figure of merit in bulk nanocrystalline materials by 20 percent or more as compared to the crystalline material [1]. This method is recognized as the easiest and most efficient at the time. A lot of published papers show the significant increase of thermoelectric figure of merit, but don't tell a word about the methods and modes of its receipt [2]. This work presents studies of the structure of powders based on Si-Ge received with different parameters of mechanical alloying that allow one to get nano crystaline solid solution, as well as the alternative method for nanostructured material from the pre-alloyed samples, thus reducing the time of mechanosynthesis in the mill, and reduces contamination of the material [3]. It is shown in the present work that under optimum conditions of milling it is possible to get the nanoparticles with an average size of about 100 nm. Thermal properties were measured by a laser flash analysis method, Seebeck coefficient was measured by a static dc method and electric resistance was measured by a four-terminal method.

2. EXPERIMENT

The nanoparticles were prepared via techniques that include high energy ball milling under argon atmosphere of the pure elements. The nanostructure of the materials is confirmed by powder X-ray diffraction and transmission electron microscopy. Fig. 1 illustrates the appearance of the material after milling. The average particle size is 100 – 200 nm.

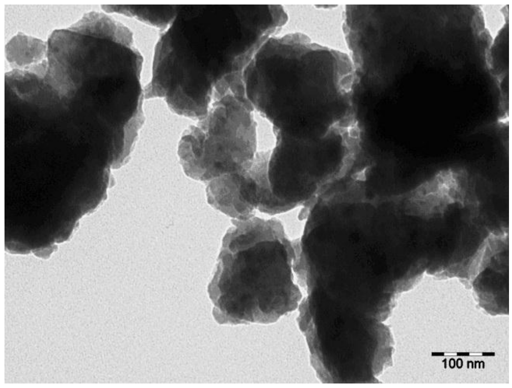

Fig. 1 – TEM Microphotograph of Si-Ge nanopowder after milling

Nanoparticles were compacted in thermal and mechanical testing systems Gleeble® 3800. Samples had the form of cylinders. Diameter of the samples was 12.7 mm. After the compacting process Seebeck coefficient and thermal properties of the samples were measured. Fig. 2 illustrates the dependence of the Seebeck coefficient on temperature. The data indicate that the compacting of nanoparticles leads to a significant increase in the thermoelectric characteristics of the material.

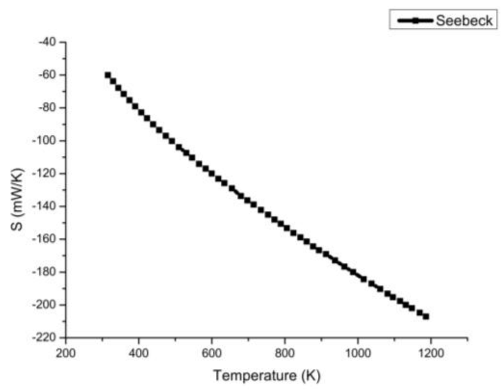

Fig. 2 – Seebeck coefficient of Si-Ge

Thermal properties were measured by LFA 457. The thermal diffusivity reached the minimum value 0.812 mm²/sec at 700°C.

3. CONCLUSIONS

Enhanced thermoelectric properties have been achieved in nanostructured dense bulk SiGe alloy. Application of system Gleeble® 3800 allowed us to receive samples of bulk nanostructured thermoelectric material, which allowed achieving a good thermoelectric parameters. The thermal conductivity reduction is mainly due to an enhanced phonon scattering at the increased boundaries of the nanograins.

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