Thermoelectric properties of compositionally homogeneous p and n-type SiGe bulk crystals

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1. Introduction

$Si_{1-x}Ge_x$ is a promising material for thermoelectric application at high temperature. The performance of thermoelectric device is determined by the dimensionless figure of merit (ZT). In order to improve the efficiency of thermoelectric device, the compositionally homogeneous $Si_{1-x}Ge_x$ and optimized doping concentration are required. In the present study compositionally homogeneous Ga and Sb-doped (1 x 10^{19} cm^{-3}) $Si_{1-x}Ge_x$ bulk crystals were grown by vertical temperature gradient freezing method (VGF) under mild temperature gradient (0.57 ºC/mm) and the thermoelectric properties were investigated.

2. Experimental procedure

The cylindrically shaped samples were arranged as a sandwich structure Si(feed)/Ga and Sb doped Ge/Si(seed) and covered by BN crucible. It was inserted into the quartz ampoule. The ampoule was evacuated upto 10^{-4} Pa and sealed. The sandwich sample was placed vertically inside the furnace under mild temperature gradient position (0.57 ºC/mm). The furnace temperature was kept constant for 300 h and then cooled at a rate of 6 ºC/h. After the experiment, the sample was removed from the ampoule and sample surface was polished. The Si composition distribution was measured by EPMA. The grown sample was cut with dimensions (10 X 3 X 2 mm^3) for Seebeck coefficient and electrical resistivity measurements with respect to temperature.

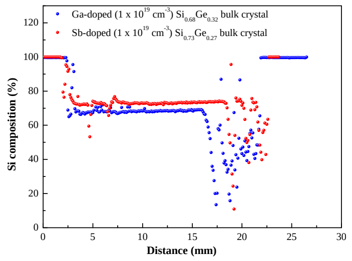

Fig. 1 Si composition distribution of Ga-doped (1 x 10^{19} cm^{-3})

3. Results and discussion

Ga and Sb-doped (1 x 10^{19} cm^{-3}) $Si_{1-x}Ge_x$ bulk crystals were grown from seed towards feed and the corresponding Si composition of both samples were $Si_{0.68}Ge_{0.32}$ and $Si_{0.73}Ge_{0.27}$, respectively as shown in Fig. 1. Resistivity of both samples was increased up to 918 K, which indicated the metallic behavior [1]. The Seebeck coefficients of Ga-doped $Si_{0.68}Ge_{0.32}$ and Sb-doped $Si_{0.73}Ge_{0.27}$ were positive and negative, which showed the p and n-type nature of the material, respectively. The maximum values of the Seebeck coefficient for Ga-doped and Sb-doped samples were 459 µV/K at 892 K and 481 µV/K at 827 K, respectively. The Seebeck coefficient was decreased due to carrier-carrier and carrier-phonon scattering at high temperature [2]. The Seebeck coefficient at room temperature for Ga-doped (1 x 10^{19} cm^{-3}) $Si_{0.68}Ge_{0.32}$ (371µV/K) and Sb-doped (1 x 10^{19} cm^{-3}) $Si_{0.73}Ge_{0.27}$ (-427 µV/K) were higher than a reported value for Ga-doped $Si_{0.81}Ge_{0.19}$ (274 µV/K) and P-doped (5 x 10^{19} cm^{-3}) $Si_{0.8}Ge_{0.2}$ (-211 µV/K) [3]. It is possibly due to doping concentration and composition of the crystal.

References

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