Synthesize of amorphous $Si_{1-x}Ge_x$ containing nano-sized crystalline particles by means of mechanical alloying for thermoelectric application

M.Omprakash[1], S. Nishino[1], M. Adachi[2], T. Takeuchi[1]

Toyota Technological Institute[1], Sumitomo Electric Industries ltd.[2]

omprakashmuthusamy@gmail.com

The $Si_{1-x}Ge_x$ alloy semiconductor is a good material for thermo-electrical power generators at high temperature. In order to improve the efficiency of thermoelectric $Si_{1-x}Ge_x$, we tried, in this study, to synthesize the amorphous bulk samples involving nano-sized crystalline particles. The preparation of thin film amorphous $Si_{1-x}Ge_x$ by means of MBE and RF sputtering technique has already been reported [1-2]. Instead of using these sophisticated methods for making thin films, we employed the simple mechanical alloying process for preparing amorphous samples containing nano-sized $Si_{1-x}Ge_x$ crystalline particles.

The mother ingots of $Si_{1-x}Ge_x$ ($0.1 \leq x \leq 0.3$) were prepared by means of arc melting, and the obtained ingots were crushed into fine powders using a mortar and a pestle. The obtained $Si_{1-x}Ge_x$ powders were sealed in a stainless steel container together with stainless steel balls (ϕ 10 mm) under the pressurized Ar atmosphere. The weight ratio of sample to the ball was fixed at 1 : 20 in the all sample preparations. The alloying was conducted in a planetary ball mill (Fritsch P7) rotating at 400 rpm for long durations up to 171 hours. The structure, morphology, composition, crystallinity, and thermal stability of synthesized powders were investigated by means of powder x-ray diffraction (XRD), transmission electron microscope (TEM), scanning electron microscope (SEM), energy dispersive x-ray spectrometry (EDX), and differential thermal analysis coupled with thermogravimetric analysis (DTA-TG).

Figure 1 shows the XRD patterns of $Si_{0.8}Ge_{0.2}$ at different milling time. It revealed that XRD peaks became broadening due to impact of ball that leads to both the decrease of grain size and the formation of amorphous phase. The particles size at 24, 72, and 171 hours ball milling were 35, 8, and 4 nm, respectively. The presence of amorphous phase became obvious especially in the 171 h sample.

Figure 2 shows TEM image of 171 h sample. It clearly shows that formation of amorphous and nano-sized crystalline particles. The particles size was well matched with XRD data. In future work, we add the heavy element with amorphous $Si_{1-x}Ge_x$ and investigate their thermoelectric property.

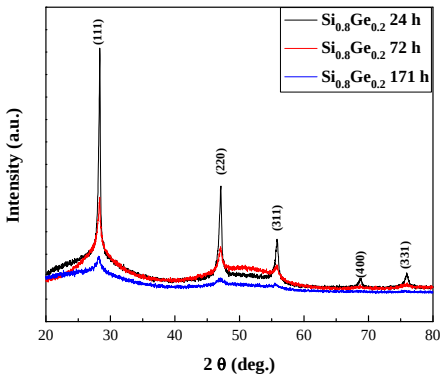

Fig. 1. XRD pattern of ball-milled $Si_{0.8}Ge_{0.2}$

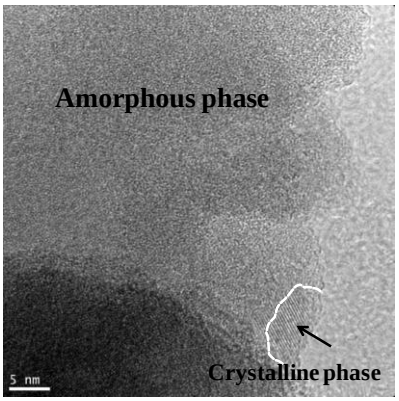

Fig. 2. TEM image of 171 h ball-milled $Si_{0.8}Ge_{0.2}$

References

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