High Power Factor in $Mg_2Sn_{1-x}Ga_x$ Epitaxial Thin Films

[1]Univ. Tsukuba,[2]NIMS, °(D)M. S. L. Lima[1,2], T. Aizawa[2], Isao Ohkubo[2],
T. Sakurai[1] and T. Mori[1,2]
E-mail: s1930101@s.tsukuba.ac.jp

The IoT (Internet of Things) is a reality and requires developing a new generation of devices.[1] They should be small, portable, room temperature efficient, and environmentally friendly.[2] Therefore, thermoelectric (TE) thin films are a promising alternative to power generation because of their capacity to convert waste heat into electricity by the Seebeck effect. We recently grew $Mg_2Sn_{1-x}Ge_x$ epitaxial thin film by molecular beam epitaxy (MBE). The optimal power factor value obtained was $0.27\cdot10^{-3}$ $W\cdot m^{-1}\cdot K^{-1}$.[3] In this work, we study the influence of incorporation of Ga in Mg_2Sn epitaxial thin films on their thermoelectric properties.

$Mg_2Sn_{1-x}Ga_x$ ($0 < x < 0.1$) films were deposited on sapphire (0001) substrates (Shinkosha) using an MBE system (Eiko, EV-500) under vacuum conditions of 10^{-6} - 10^{-7} Pa. [4] Elemental magnesium (>99.95%), tin (>99.999%) and gallium (99.9%) were evaporated using conventional Knudsen cells at 400-470 °C for Mg, 1110-1120 °C for Sn and 750-850 °C for Ga. A series of depositions were made where the substrate was heated to a temperature of 400°C. After 30-minutes depositions, films of 200-250 nm thickness were obtained. Afterward, the crystal phases were analyzed by ex-situ X-ray diffraction (XRD) using a powder diffractometer (Rigaku SmartLab 3). The film thicknesses were measured using a Dektak 6M surface profiler system. The thermoelectric properties were measured by ZEM 3 under a He flow.

The structural properties were studies by XRD. In case of $0 < x < 0.03$ and $x > 0.07$, non-epitaxial phases were observed. However, for $0.03 < x < 0.05$, the epitaxial thin films were obtained, Fig. 1.

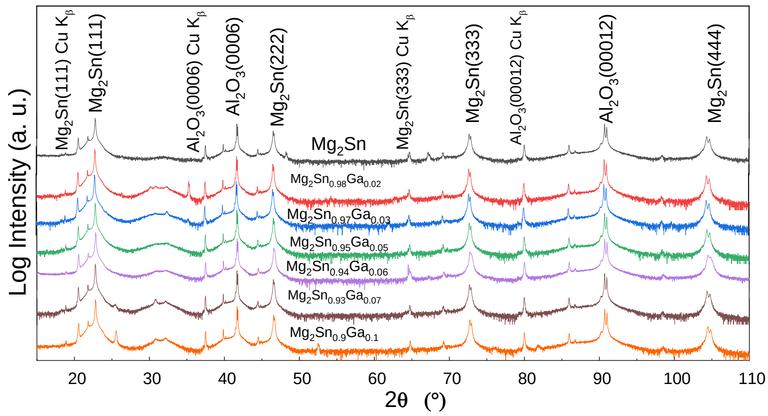

Fig.1 -θ-2θ XRD of epitaxial $Mg_2Sn_{1-x}Ga_x$ thin film

The thermoelectric properties of the series also were studied. The resistivity shows a systematic reduction from a semiconductor to metallic behavior with the Ga doping. Also, the Seebeck coefficient exhibits an improvement for the p-type behavior. In the case of x=0, a transition from p-type at room temperature to n-type at high temperatures was observed. In the case of $Mg_2Sn_{1-x}Ga_x$ samples, the p-type behavior was observed for all temperature range studied. The optimal power factor value obtained was $1.2\cdot10^{-3}$ $W\cdot m^{-1}\cdot K^{-1}$ at room temperature for $Mg_2Sn_{0.95}Ga_{0.05}$.

Here, we reported the study of thin film synthesis of $Mg_2Sn_{1-x}Ga_x$. Our results suggest, the partial substitution of Ga probably promotes two effects: a hole doping for the Sn site substitution and a formation of vacancies for the Mg site. The combination of both effects improves the thermoelectric properties of $Mg_2Sn_{1-x}Ga_x$ epitaxial thin films.

References

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