Characterization of $Mg_2Sn_{1-x}Ge_x$ Thin Films for Thermoelectric Applications

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Magnesium-based (Mg_2X, X= Si, Sn and Ge) materials are intermetallic compounds that have been studied for decades as potential high ZT thermoelectric materials[1]. Most of the articles focus on the improvement of thermoelectric property on bulk materials at middle temperatures. However, a few studies have been reported at the room temperature range. In the case of this temperature range, various heat sources such as body heat can be utilized to provide the required electricity, and as the temperature differences are small, and relatively large areas are required, thermoelectric thin films can be a good target. In this work, we utilized molecular beam epitaxy (MBE) to fabricate high quality thermoelectric thin film to achieve high power factor at room temperature.

$Mg_2Sn_{1-x}Ge_x$ films were deposited on sapphire (0001) substrates (Shinkosha) using a MBE system (Eiko, EV-500) under vacuum conditions of 10^{-6} - 10^{-7} Pa [2]. Elemental magnesium (>99.95%), tin (>99.999%) and germanium (>99.999%) metals were evaporated using conventional Knudsen cells at 389 °C for Mg, 1120-1180 °C for Sn and 1050-1105 °C for Ge. Two series of depositions were made where the substrate was heated to a temperature of 400°C. After 30-minutes depositions, films of 200-400 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.

In the first series (Mg_2Sn series), the deposition speed and the Mg/Sn supply rate, the appropriate conditions were searched. The optimized growth condition was achieved for a low rate/temperature on the Sn cell (Sn= 1120 °C, Fig. 1a). In the second series ($Mg_2Sn_{1-x}Ge_x$ series), the partial substitution between Sn to Ge was studied, Fig. 1.b. A peak shift was obtained, suggesting a substitution between the Sn and Ge in Sn site, Fig. 1.c.

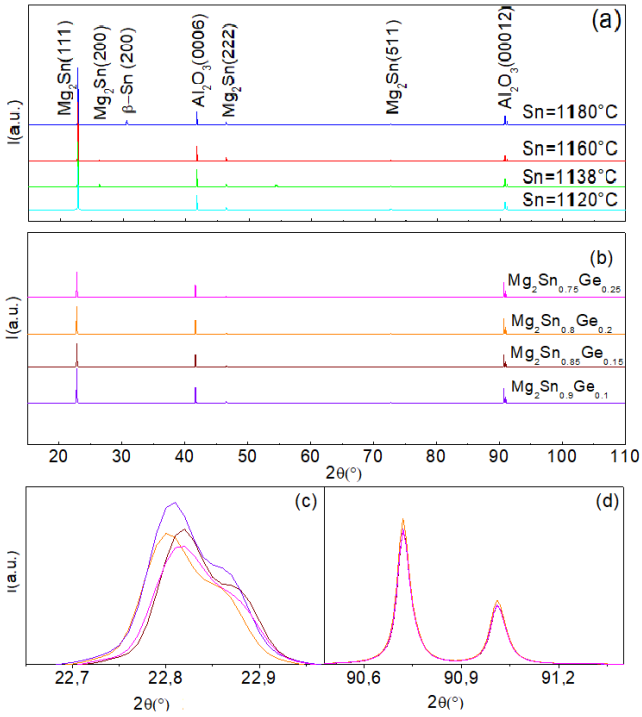

Fig.1 -θ-2θ XRD of epitaxial $Mg_2Sn_{1-x}Ge_x$ film

The thermoelectric properties of both series also were studied. In the Mg_2Sn series, all the samples present a semiconductor behavior, however in $Mg_2Sn_{1-x}Ge_x$ series exhibit a reduction in the resistivity with the increase of Ge content. Also, the Seebeck coefficient exhibits a large difference between both series. In $Mg_2Sn_{1-x}Ge_x$, all the samples are p-type, however in Mg_2Sn series, the n-type is dominant. In the $Mg_2Sn_{1-x}Ge_x$ case, a relatively high power factor reaching 1mW/m.K^2 was obtained at room temperature.

Here, we show the study of thin film synthesis of $Mg_2Sn_{1-x}Ge_x$. Our results suggest that the partial substitution of Ge for Sn not only effectively improves the Seebeck coefficient but also reduces resistivity. Additional study will present to clarify the origin of this behavior.

References

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2)Aizawa, T. et al, Journal of Vacuum Science & Technology A, 2019,37(6), 061513