Journal of Optoelectronic and Biomedical Materials Vol. 14, No. 4, October-December 2022, p. 187-190

Physical-chemical properties of InSb+Mg_3Sb_2 eutectic systems: synthesis, characterization, and applications

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InSb+Mg_3Sb_2 systems are synthesized by the vertical Bridgman–Stockbarger method. InSb and Mg_3Sb_2, a form of lamellar eutectic. XRD analysis and microstructural study of InSb+Mg_3Sb_2 composites show that Mg_3Sb_2 lamellar are uniformly distributed in the InSb matrices. The initial and final melting temperatures for InSb+Mg_3Sb_2 eutectic alloys are 770K and 772K, respectively.

(Received July 31, 2022; Accepted October 18, 2022)

Keywords: XRD, SEM and EDX analysis, Eutectic alloy, Lamellar, Raman spectra

1. Introduction

Remarkable achievements have been in the development of high-performance thermoelectric (TE) materials in recent years. Although challenges still exist in further enhancing ZT and developing highly efficient thermoelectric devices for commercial applications, which require multidisciplinary and intense effort, the TE field will have a future [1-3].

Thermoelectric materials provide a clean and reliable way of generating electricity from waste heat. The deployment of thermoelectric materials for deriving an enhanced figure of merit (ZT) for power generation in inexpensive is important.

The Mg_3Sb_2-based Zintl compound is a promising candidate for a high-performance thermoelectric material with the advantage of the component elements being low cost, non-toxic and earth-abundant. Since the ZT of the Mg_3Sb_2 compound is very low and degrades above 900 K the pure phase is not a good candidate for thermoelectric applications. Further investigation of the InSb+Mg_3Sb_2 eutectic composite along with the correlation of microstructure to thermoelectric properties might be worthwhile for the optimization of this system [4-9]. Here, we investigate a Zintl compound of Mg3Sb2 and InSb+Mg3Sb2 eutectic composites' physical-chemical properties and applications.

2. Experimental

InSb+Mg3Sb2 eutectic composites were prepared by using the vertical Bridgman method. InSb and Mg3Sb, form a lamellar eutectic. The eutectic concentration is 2.2 percent by weight Mg3Sb2. The rate of the crystallization front was about 1.2 mm/min. XRD intensity data were collected on an Advance-D8 diffractometer using CuKα radiation. Scanning Electron Microscope (SEM), equipped "With Oxford EDS" и "And HKL EBSD", were used to characterize the morphology of the specimens and to obtain qualitative information on the elemental composition of the samples, respectively.

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https://doi.org/10.15251/JOBM.2022.144.187

3. Results and discussion

Diffraction patterns of the $InSb+Mg_3Sb_2$ eutectic composite are shown in Fig. 1. The most intense peaks corresponding to the (111), (220), (311), (400), (311), (422) və (511) Muller index are identical to the InSb matrix, while the weak peaks found at 2θ = 34.08º, 47.12º, and 57º coincide with the lamellar Mg_3Sb_2 line.

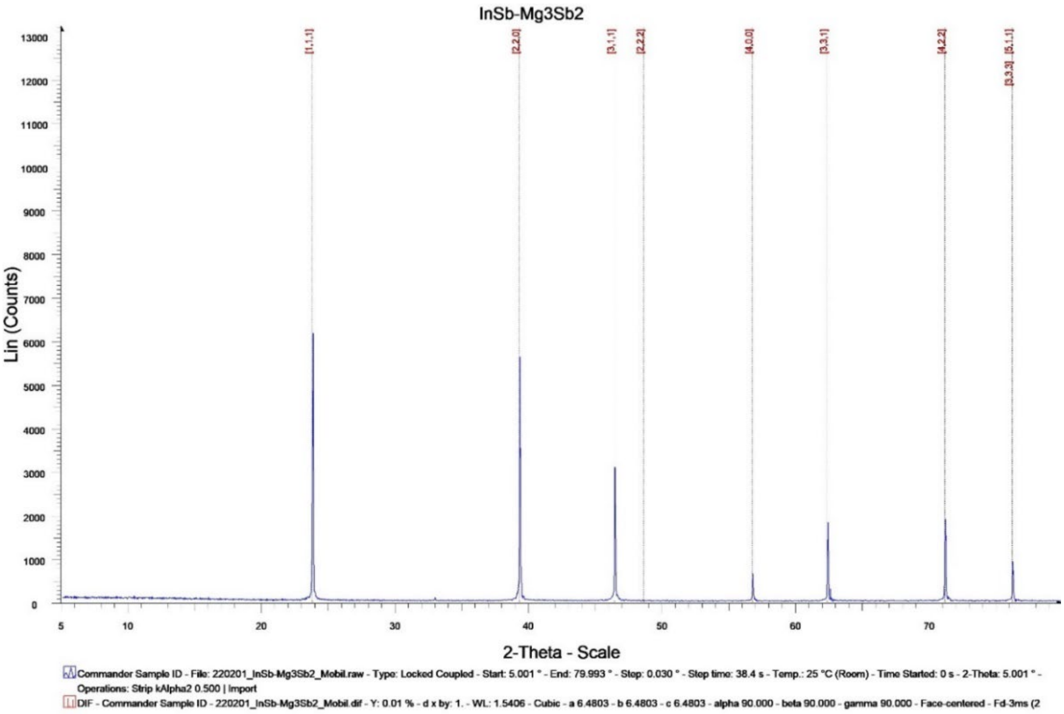

Fig. 1. X-ray spectrum of $InSb+Mg_3Sb_2$ eutectic composite.

Based on SEM examinations (Fig.2), the Mg_3Sb_2 lamellar inclusions with a length of 20÷50 µm and a density of ~$6,4x10^4$ mm^{-2} are uniformly and parallel distributed in the InSb matrix. It was found that the $InSb+Mg_3Sb_2$ eutectics contains In = 47.83wt%, Mg = 1.12 wt%, and Sb = 51.05 wt%.The data correspond to the stoichiometric composition of the matrix and inclusions.

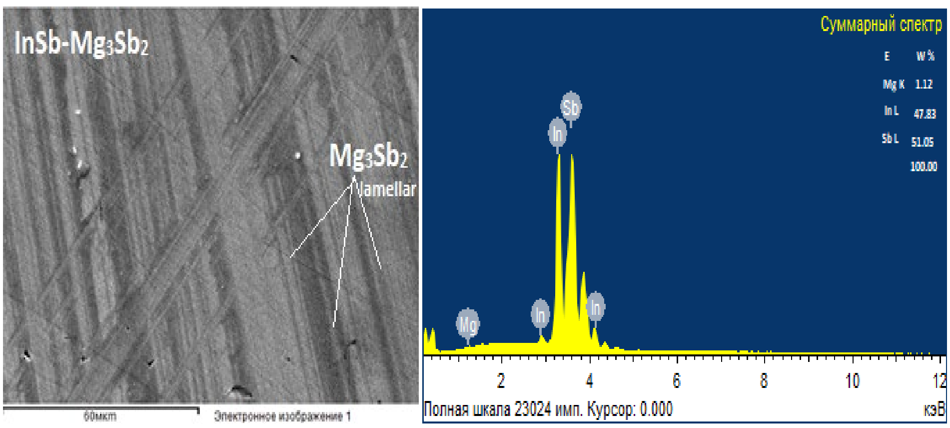

Fig. 2. X-ray spectra of $InSb+Mg_3Sb_2$ eutectic composite obtained with SEM–EDX from the lamellar and matrix phases along the lateral directions of the specimens.

In this paper, we analyzed InSb+Mg_3Sb_2 systems using Raman spectroscopy (Fig.3). These samples consist of two phases which are a consequence of eutectic reactions.

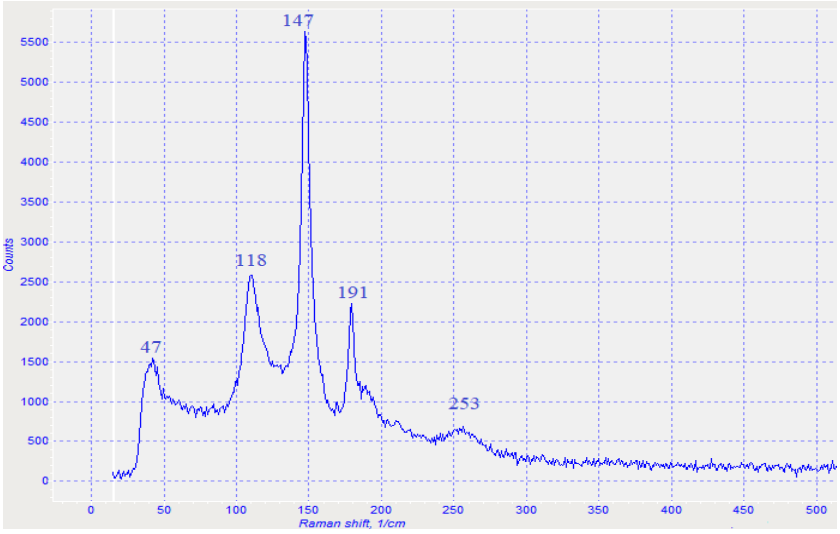

Fig. 3. Raman spectrum of the InSb+Mg_3Sb_2 bulk sample at 300 K.

Analysis of microscopic areas of larger samples and identification of coexisting phases were carried out by micro-Raman spectroscopy. By analyzing the Raman spectra, phases have been identified. Raman spectra of InSb+Mg_3Sb_2 eutectic composites were experimentally obtained for the first time. The Raman analysis is an important tool to study atomic interactions in semiconductors and the dynamics of the crystal lattice [10]. Raman analysis were investigated to confirm the existenceof two-phase and inter-phase zones in the InSb+Mg_3Sb_2 lamellar eutectic composites at room temperature. Fig.7 shows the Raman lines at about 47cm^{-1}, 118 cm^{-1}, 191cm^{-1} are the mode LO InSb+Mg_3Sb_2 eutectic composite, and 118 cm^{-1}, 253 cm^{-1} for Mg_3Sb_2 compound.

DSC studies for InSb+Mg_3Sb_2 eutectic composite have been made in the 0÷600^{0}C temperature range.

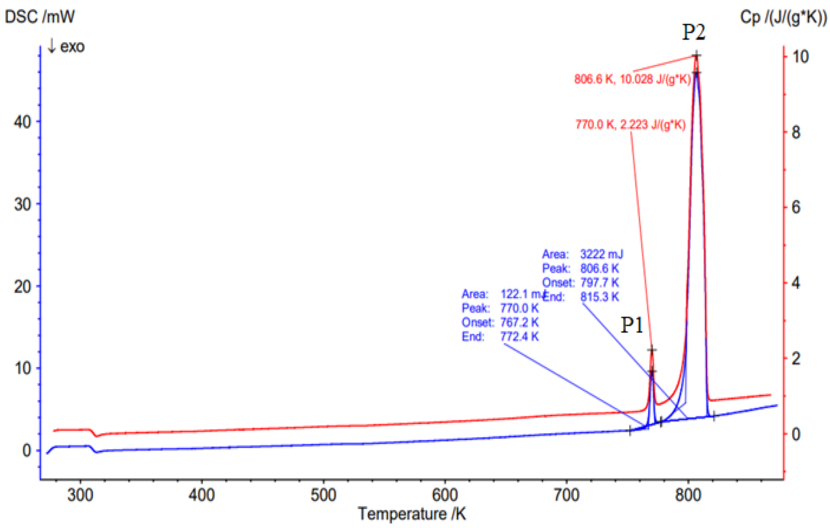

Fig. 4. DSC curves of the InSb-Mg_3Sb_2 eutectic composite.

To study the phase change at high temperature, differential thermal analysis (DSC) was employed to monitor the exo or endothermic behavior of the sample during the scanning, and the result was shown in Figure. 4. As can be seen, there are two endothermic peaks in the DSC curve: P1 at about 772,4K and P2 at about 806K. According to the DSC phase diagram in Figure. 4, the peak P2 corresponds well with the melting temperature of InSb [11]., while the peak P1 is just the melting point of the InSb-Mg_3Sb_2 eutectic; the enthalpy of melting is 122, 1 mJ/g.

4. Conclusions

The electron microscopy (SEM) and XRD studies of InSb-Mg_3Sb_2 eutectic have confirmed that the systems consist of a semiconductor matrix (InSb) and oriented (Mg_3Sb_2) lamellar inclusions. The initial and final melting temperatures for this eutectic composite are 770K and 772K, respectively. It has been found that the peaks detected in the Raman spectra correspond to the InSb+Mg_3Sb_2 alloys and Mg_3Sb_2 bond.

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