THE MICROSTRUCTURE AND STRAIN CHARACTERISTICS OF GaSb-FeGa$_{1.3}$ DOPED WITH Co ATOMS

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Исследованы микроструктура и тензоэффект эвтектики GaSb-FeGa$_{1.3}$, легированной 0,1 ат% Co. Показано, что при легировании атомы Co локализуются в металлических включениях, длина которых уменьшается ~2 раза. Тензометрические характеристики тензорезисторов на основе GaSb-FeGa$_{1.3}$<Co> становятся более термостабильными по сравнению с нелегированной эвтектикой.

The microstructure and tensoresistive effect of GaSb-FeGa$_{1.3}$ eutectic doping with 0.1at% Co impurity atoms have been investigated. It is established that the Co impurity atoms located only in the metallic inclusions, the length of which is reduced ~2 times. The tensometric characteristics of gauges, GaSb-FeGa$_{1.3}$<Co> eutectics based, become more thermostability in comparison with undoped eutectics.

1. INTRODUCTION

The semiconductor strain gauges due to their high sensitivity in comparison with strain gauges of metallic wires and foils vide used as a tensometric sensor for determining of mechanical deformations [1-5]. The main disadvantage of semiconductor strain gauges is a high temperature coefficient of strain sensitivity and brittleness that creates certain difficulties at their use. Therefore, the investigation of potential semiconductor materials to be used as mechanical sensors with thermostable parameters is essential. Our early study of strain characteristics of eutectic compositions based on GaSb eutectics [6] showed that the strain sensitivity is reduced in comparison with the matrix element, but its strain parameters become thermostable due to iron atoms which form the deep impurity levels in the band gap of the GaSb matrix.

The present work we devoted to studies of the influence of Co impurity atoms (0.1 at.%) on microstructure and strain characteristics of GaSb-FeGa$_{1.3}$ eutectics.

2. EXPERIMENTAL

The GaSb-FeGa$_{1.3}$ eutectic composition doping with Co impurities were prepared by using the vertical Bridgman method as described in detail in [7, 8]. To avoid of ampoule vibration able to disturbance of crystallization it was motionless and movement of crystallization front was carried out by lifting of the furnace. The "solid – liquid" interphase was planar and placed perpendicularly to the transport direction on all ingot section. The furnace lifting rate is taken as the rate of crystal-melt interface and was set about 1 mm/min.

Employing this technique, the structure with needle-shaped metallic phase oriented in a specific direction and uniformly distributed within the GaSb matrix was obtained. Scanning electron microscopy (SEM) was employed to characterize the microstructure of the alloys. A energy dispersive X-ray spectroscopy (EDX) model EDAX^{TM} was used to obtain qualitative information on the elemental composition of the samples. The accelerating voltage during EDX analysis was 30 kV.

To determine the tensoresistive effect of gauges, the rectangular beams were sectioned from the grown crystals to obtain the sensitive elements [6]. After the mechanical and chemical treatment of the surfaces, tin contacts were applied on the gauges for electrical measurements. The points of the contacts should be located from the ends of the gauge at the minimum of 1mm.

The produced gauges were attached on bending beams using a VL-931 glue. The thickness of the glue layer was 15±5μm. The glue layer was cured at room temperature and then polymerized at elevated temperatures for 6 hours. The characterization of strain gauges was carried out using the compensation method in the range of 200-400 K and deformation up to 2x10^{-3} [9]. The measurements were done at directions when current (I) was perpendicular to the needles (x) and the needles are parallel to the plane (P) of the gauge substrate (I⊥x||P), owing to the strain gauges exhibit the greatest strain sensitivity coefficient (S). The relative deformation for bending beams is determined as $\varepsilon = \frac{hd}{L^2}$, where d is thickness of the beam, h is displacement of the beam on bending, L is the working length of the beam [9].

3. RESULTS AND DISCUSSION

In figure 1 is presented a SEM backscattering detector image of GaSb-$FeGa_{1.3}$ (a) and GaSb-FeGa<Co> (b) eutectics showing cross section of the sample along lateral direction of the needle-shaped metallic phase using a Philips^{TM} FEG SEM.

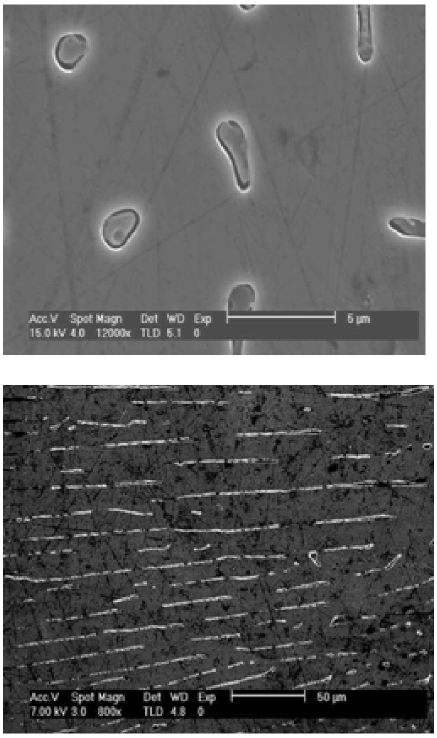

Fig 1a. SEM micrographs of the GaSb-$FeGa_{1.3}$ (lateral and longitudinal direction).

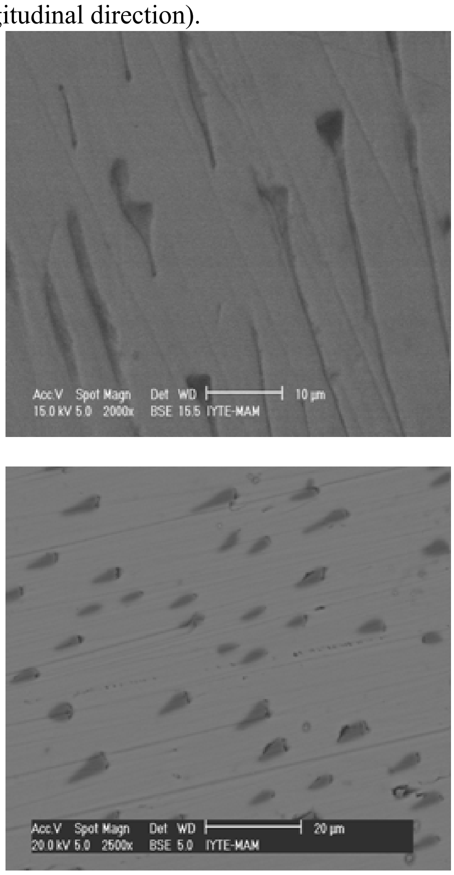

Fig 1b. SEM micrographs of the GaSb-$FeGa_{1.3}$<Co> (lateral and longitudinal direction)

Based on SEM examinations, the oriented needles were found to have about 1÷1.5 μm diameter, 20÷150 μm length for GaSb-$FeGa_{1.3}$ and 1.5÷2 μm diameter, 20÷50 μm length for GaSb-$FeGa_{1.3}$<Co>. The X-ray spectra and the elemental compositions obtained from the needle and matrix phases are illustrated in Fig.2 with the SEM images showing the location of the investigations. Consequently, the inclusions length in the GaSb-$FeGa_{1.3}$<Co> decreases about two times in comparison with GaSb-$FeGa_1$ eutectics. The EDX analysis has disclosed that the Co atoms located only in the metallic inclusions.

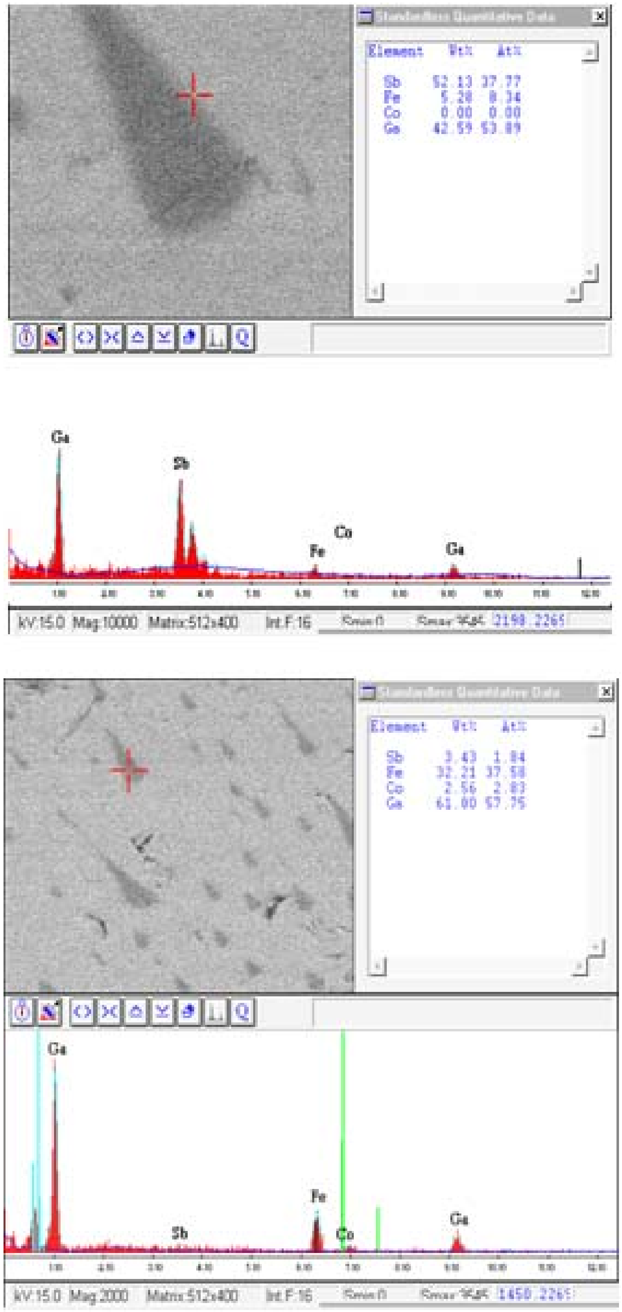

Fig2. EDX analysis of GaSb-$FeGa_{1,3}$<Co> in matrix and in inclusions.

Figure 3 shows measured values of the relative change in resistance (ΔR/R) for GaSb-$FeGa_{1.3}$<Co> composites as a function of strain (ε) for various temperatures.

One of the critical parameters of the strain gauge is the limit at which the linearity of strain characteristics is conserved. This limit value was found to be about $\pm 12.10^{-4}$ for GaSb-FeGa$_{1.3}$<Co>. As it is shown in the figures, there is a linear dependence of ΔR/R on both tension and compression types of strains within the considered strain range due to the flexural bending of the substrate. The linearity does not deviate with the variation of temperature**.**

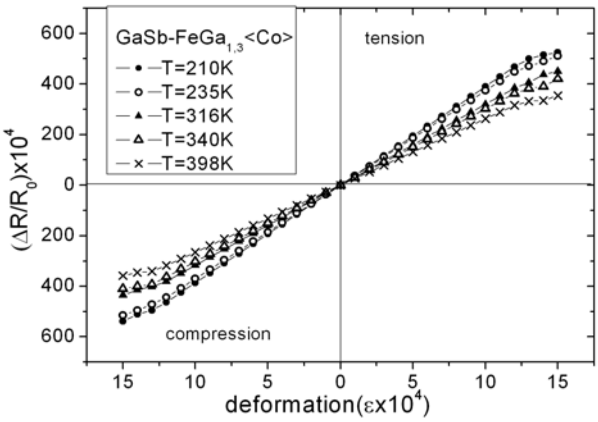

Fig 3. The relative change of resistance versus strain at different temperatures for GaSb-FeGa$_{1.3}$<Co>.

The dependence of *S* on temperature for GaSb-FeGa$_{1.3}$<Co> with data for GaSb and GaSb-FeGa$_{1.3}$ eutectics taking from work [6] is presented in Fig. 4 for loading under tensional and compressive strains resulted from the bending of the substrate. The strain and temperature characteristics of the gauges show no hysteresis phenomenon. The strain sensitivity (S) and temperature coefficient of strain sensitivity (α) were determined from the experimental data as:

$$S = \frac{\Delta R / R}{\varepsilon}; \; \alpha = \frac{\Delta S / S_0}{\Delta T} \cdot 100 \left[\% \text{ degree}^{-1}\right],$$

where $\Delta S = S_T - S_0$ and $\Delta T = T_T - T_0$; S_T and S_0 are coefficients of strain sensitivity at the fixed temperature and at room temperature, respectively. Average values of S at room temperature and α for GaSb-FeGa$_{1.3}$<Co> were calculated as 35±5 and 0.17 %/degree, respectively. The temperature coefficient of sensitivity of the GaSb-FeGa$_{1.3}$<Co> gauge decreases down to 15% compared with the GaSb-FeGa$_{1.3}$ one.

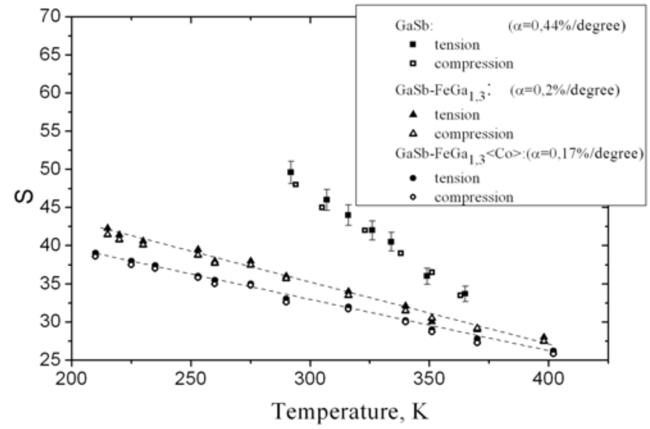

Fig. 4. The strain sensitivity coefficient of resistance versus temperature for GaSb matrix, GaSb-FeGa$_{1.3}$ and GaSb-FeGa$_{1.3}$<Co>. The dates for GaSb-FeGa$_{1.3}$ and GaSb is taken from work [6].

SUMMARY

The EDX analysis has revealed that the Co impurity atoms are located only in the metallic inclusions. The inclusions length in the GaSb-FeGa$_{1.3}$<Co> decreases about two times in comparison with GaSb-FeGa$_1$ eutectics. The gauges on the base of the GaSb-FeGa$_{1.3}$<Co> have revealed the better thermostable strain characteristics than the undoped eutectics.

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Received:10.02.2007