THERMOSTABLE STRAIN TRANSDUCERS

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ABSTRACT

The strain gauge resistors of $(2InSb)_{1-x}$ $(In_2GeTe)_x$ were fabricated using melt quenching method and their strain gauge characteristics have been investigated. It has been established that such strain transducers of $(2InSb)_{1-x}(In_2GeTe)_x$ exhibits thermostable characteristics.

Keywords: resistors, transducers, semiconductor, crystallographic, compound.

I. INTRODUCTION

The strain gauges of semiconductor materials have high sensitivity, the smaller sizes, less hysteresis, high electric resistance in comparison with strain gauges of metallic wires and foils (on 1-2 order) [1-5]. In their use, it is possible to receive the high signal, and executive mechanism without the preliminary signal amplification. The main disadvantage of semiconductor strain gauges is a high temperature coefficient of strain sensitivity and brittleness that creates certain difficulties at their use in wide temperatures and deformation intervals. Therefore, the investigation of potential semiconductor materials to be used as mechanical sensors with thermostable parameters is essential.

Strain gauges of InSb have high sensitivity coefficient at temperatures below 210K [6]. Thin film of InSb also have high sensitivity coefficient and they have been applied for manufacturing microphones [7]. Aliyev and et al. have shown that eutectic composites based on A^3B^5 have thermostable characteristics [8, 9].

It was shown that the strain characteristics of $(2InSb)_{1-x}$ $(In_2GeTe)_x$ strain gauges exhibits special features. In the In-Sb-Ge-Te system, Ge atoms owing to the variable valence occupy places in both anionic and cationic sublattices in consequence they turned out to be in crystallographic nonequilibrium positions. The change of the heterogeneity degree with the composition of In_2GeTe in $(InSb)_{2(1-x)}$-$(In2GeTe)_x$ solid solutions, and also the change in the anion valence is expected effect on optical, electrical and thermal properties. [10, 11, 12].

In literature there is only one work by Woolley`s and Williams [13] about the receptions, Hall coefficient and the optical energy gap measurements for In-Sb-Ge-Te system. Electrical and optical properties of $(InSb)_{2(1-x)}$-$(In2GeTe)_x$ solutions have been studied in our previous work [10, 12] and it has been shown that the quasi-local level of the donor behavior is formed by 0,21-0,19 eV above the bottom of the conductivity band. In this case, this level is displaced in the direction of the band gap with increasing temperature and the content of In_2GeTe component.

The charge carriers concentration in these alloys changes more than two times ($n=3\div7x10^{18}cm^{-3}$) with increasing the solid solution content [12]. Therefore, the apparent energy gap versus the content of alloys also changes more than two times due to the Burstein effect [14].

The thermal conductivity of $(2InSb)_{1-x}(In_2GeTe)_x$ and it's dependency to with In_2GeTe content and temperature also were investigated by our group [11]. The anomalous dip has been observed in the temperature dependence of thermal conductivity that was explained by resonance scattering of phonons on acoustic modes, resulting from impurity of various characters.

The present work is devoted to investigate the strain gauges properties of $(InSb)_{2(1-x)}$-$(In_2GeTe)_x$ depending on In_2GeTe content, strain and temperature .

II. EXPERIMENTAL RESULTS AND DISCUSSION

The semiconductor matrix element (InSb) with an electron concentration of $2x10^{16}$ cm^{-3} were obtained by alloying the related components in stoichiometric quantities, that were refined by the method of the horizontal recrystallization. $(InSb)_{2(1-x)}$-$(In_2GeTe)_x$ solid solutions with x≤0.2 have been obtained by the method of quick cooling of InSb and In_2GeTe hypothetic "ternary" compound and quenching from melt. The obtained samples were annealed for 14 days [13]. The electron concentration was varied within $n=3\div7.10^{18}cm^{-3}$ [12].

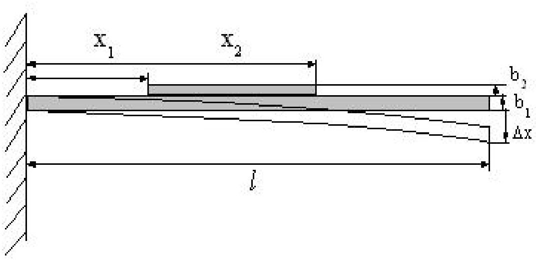

Fig.1. Schematic of the beam construction.

The thermogravimetry and X-ray diffraction investigations of $(2InSb)_{1-x}(In_2GeTe)_x$ have shown that the hypothetical "ternary compounds" of In_2GeTe dissolves up to x=0,1 in InSb and solid solutions forms. In these systems, the second metastable phase is observed at x≥0,12 and it passed to the stable state at 1125 K with dissipation of heat [12]. The initial (T_i), and final temperatures (T_f) of molten materials were determined. Also, heat (Q), entropy (ΔS) and activation energy (E) of melting were calculated from thermogravimetry measurements. Values of these parameters are given in Table 1.

Table 1. Termodynamical characteristics of $(2InSb)_{1-x}(In_2GeTe)_x$.

x	T_i, K	T_f, K	Q J/mol	ΔS J/molK	E, J/mol
0		809	19646	24,46	74069
0.01	778	798	17974	22,53	59732
0.1	763	792	14630	18,64	46816
0.12	782	803	14212	17,56	73150
0.2	783	803	13376	16,1	73150

A scanning electron microscope equipped with an energy dispersive X-ray spectroscopy was used to obtain qualitative information about the elemental composition of the samples, respectively. The accelerating voltage during EDX analysis was 30 kV. The results confirm that in $(2InSb)_{1-x}(In_2GeTe)_x$ system at x≤0,10 the continuous solid solution is formed and at x≥0,12 the second component accumulates as separate phases.

To determine the characteristics of the gauges, the rectangular beams with sizes of 7 x 0,08 x 0,2 mm^3 were sectioned from the grown crystals to obtain the sensitive elements. Specimens were prepared by polishing with traditional techniques and etching in "Wolski" etchant ($HCl+CH_3COOH+HNO_3$ – 7:8:1) following washing in alcohol.

After the mechanical and chemical treatment of the surfaces, tin contacts were applied on the gauges for electrical measurements. The contacts were ohmic, mechanically strong and reliable. It was found that the Ohm's law hold true for the prepared contacts up to 30 mA in the range of 80 K to 400 K. The produced gauges were attached on bending beams using a VL-931 glue.

The choice of this glue was caused by its good adhesion to metals and nonmetallic materials, at insignificant thickness the glutinous film possess high dielectric qualities, flexibility and durability. An operating temperature range of glue is 80-390K. The quality of glutinous connection is one of the determinative factors in semiconductivity strain-gauge techniques [15]. The main characteristics of strain gauges, such as strain sensitivity coefficient, linearity, creep, life service are in direct dependence on glutinous connection.

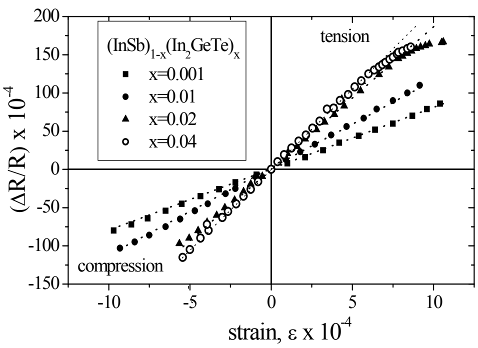

Fig. 2. Relative change of the resistance versus strain for $(2InSb)_{1-x}(In_2GeTe)_x$.

The thickness of the glue layer was 15±5μm. The volumetric pressure in the glue film plays an insignificant role. 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 [16].

To investigate the strain gauge characteristics versus temperature and strain, $(2InSb)_{1-x}(In_2GeTe)_x$ solid solutions was used mounting offered by us that described in this work [16]. A furnace and dewar flask was used for temperature dependence of strain characteristics. These devices allow determination characteristics of strain gauges in vacuum space at pressure of 0.133 Pa in the range of 80-500 K. Measurements carried out at tension and compression-type strain up to $\pm 6x10^{-4}$relate unit (r.u.) and in temperatures between of 240 and 360K.

Figure 2 shows measured values of relative change in resistance ($\Delta R/R$) as a function of strain (ε) for $(2InSb)_{1-x}(In_2GeTe)_x$ with x=0.001, 0.01, 0.02, 0.04

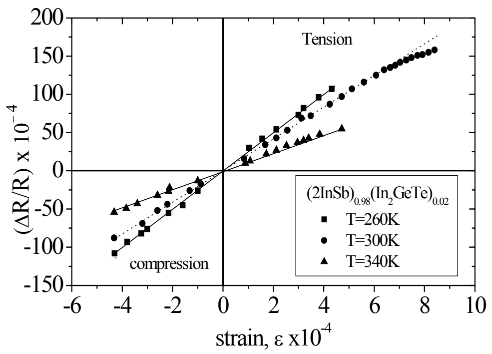

Fig. 3. Relative change of. the resistance versus strain in different temperature for $(2InSb)_{0,98}(In_2GeTe)_{0,02}$.

solid solutions. As seen from Fig. 2, the $\Delta R/R_0(\varepsilon)$ dependence is linear up to 6-8x10^{-4} strain and its inclination changes with In_2GeTe content.

The strain sensitivity coefficient (gauge factor) is determined as:

$$S = \frac{\Delta R \;/\; R_0}{\varepsilon} \;;\quad \varepsilon = \frac{3ac}{l^3}\Delta x \;;$$

$$c = \frac{b_1 + b_2}{2} \;;\qquad a = x_1 + \frac{(x_2 - x_1)}{2}$$

where, $\Delta R = R_\varepsilon - R_0$. Here R_0 and R_ε is electric resistance of a sample before and under deformation, ε is relative deformation, b_1 is thickness of a beam, b_2 is thickness of strain gauge, l is operative long of beam; Δx is displacement of free end bent beams; x_1 and x_2 are distances between strain gauge contacts and places of fastening of console beam (fig.1). The dependence of relative change in resistance ($\Delta R/R$) as a function of strain (ε) for various temperatures for $(2InSb)_{0,98}(In_2GeTe)_{0,02}$ gauge that are typical for all contents of solid solutions, is plotted in fig.3. As it is shown in the figures a linear dependence of $\Delta R/R$ on both tension and compression type strains does not change with temperature. However, the gauge factor decreases slightly with temperature for all strain gauges. The strain and temperature characteristics of gauges do not show any hysteresis phenomenon.

The temperature coefficients of strain sensitivity and resistance were determined from the experimental data based on below;

$$\alpha = \frac{\Delta S \;/\; S_0}{\Delta T} \cdot 100 \;\left(\%\ degree^{\ -1}\right),$$

$$\beta = \frac{\Delta R \;/\; R_0}{\Delta T} \cdot 100 \;\left(\%\ degree^{\ -1}\right)$$

$\Delta S = S_T - S_0$, $\Delta R = R_T - R_0$ и $\Delta T = T_T - T_0$,

where S_T and S_0 (R_T and R_0) are coefficients of strain sensitivity (resistance) at the fixed temperature and at room temperature, respectively. The basic characteristics of strain gauges of $(2InSb)_{1-x}(In_2GeTe)_x$ are given in the Table 2.

Table 2. The basic characteristics of strain transducers of $(2InSb)_{1-x}(In_2GeTe)_x$

x	R, Ohm	α, %/degree	S	β, %/degree
0,001	2,6	0,1	9	0,3
0,01	8,2	0,6	10	0,3
0,02	4,1	0,65	20	0,4
0,04	7,9	0,7	19	0,3

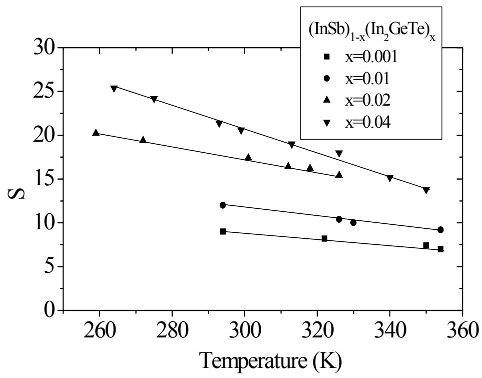

Fig. 4. Strain sensitivity coefficient (gauge factor) versus temperature for $(2InSb)_{1-x}(In_2GeTe)_x$.

As seen the gauge factor of $(2InSb)_{1-x}(In_2GeTe)_x$ solid solutions up to x=0,02 is increased about two times (Fig. 4) and apparently it is related to effect of various defects existing in solid solutions. The sharp reduction of thermal conductivity for $(2InSb)_{1-x}(In_2GeTe)_x$ solid solutions up to x=0,02 content is also connected with scattering phonons on defects [10] that confirm this assumption.

III.CONCLUSION

Thus, $(2InSb)_{1-x}(In_2GeTe)_x$ solid solutions can be offered as sensitive elements for strain transducers with thermo-stable characteristics.

REFERENCES

[1]. *Xing Lu and Yansheng Zhang,* J.Phys.D: Appl.Phys. 1996, **29**, 1428-1430.

[2] *Imam H.Kazi, Wild P.M., Moore T.N., Sayer M.* Thin Solidi Films, 2003, **433,** 337-343.

[3] *Ved Ram Sing.* Engineering application of superconductor strain gauge*. "*Res. And Ind." 1972, **17**, No1, 18-20.

[4] *Maryamova I., Druzhinin A., Lavitska E.N., Gortynska I., Yatzuk Y.* Sensor and Actuators 2000, **85***,* 153-157.

[5] *Middelhoek S., Bellekom A.A., Dauderstadt U., French P.J., Srin`t Hout, Kindt W., Riedijk F., Vellekoop M.J.* Meas. Sci. Technol. 1995, **6,** 1641-1658

[6] *Moldaver T.J., Troyskaya E.A.* Poluprovodnikovaya tenzometriya (Semiconductivity strain-gauge) book 1. NETI, Novosibirsk, 1969 (inRussian).

[7] Patent 48-6154 (Japan) Semi-conductor sensor of pressure "*Izobreteniya za rubejom*", 1973, No 9 (in Russian).

[8] *Aliyev M.I., Khalilova A.A, Arasly D.H, Rahimov R.N, Tanoglu M., Ozyuzer L.*, Appl. Phys. A, 2004, **79,** 2075-2078.

[9] *Aliyev M.I., Rahimov R.N., Khalilova A.A., Arasly D.H.* 2nd International Conference on Technical and Physical Problems in Power Engineering, Tebriz, 2004, 497-499.

[10] *Rahimov R.N.* Ukr.J. Phys., 2004, **49**, No2, 118-120.

[11]. *Rahimov R.N., Arasly D.H., Khalilova A.A.* Ukr.J.Phys. 2005, **50**, No 6, p598-601.

[12] *Rahimov R.N.* Azerbaijan National Academy of Sciences, Transactions, ser.Phys.Math.and Tech. Sci. 2004, **24**, No 5, 10-18 (in Azeri).

[13] *Woolley J.C., Williams E.W.* J.Electrochem.Soc., 1964, .**111**, No 2, 210-215.

[14] *Burstein E.* Phys. Rev. 1954, **93**, 632-633.

[15] *Onnen O.* Feinwerktechnik,1969,**73**, H2.

[16] *Aliyev M.I., Khalilova A.A., Arasly D.H., Rahimov R.N., Tanoglu M., Ozyuzer L.* Azerbaijan

National Academy of Sciences, Transactions, ser.Phys.Math.and Tech. Sci. 2003, **23**, No5, 93-96 (in Russian).