TENSOMETRIC PROPERTIES OF VOLUMETRIC CRYSTALS OF GERMANIUM-SILICON SOLID SOLUTIONS

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In the present work the tensometric properties of monocrystal of Ge-Si solid solution of p-type with Si content 5-10 at.% have been studied. From the studied crystals the strain gauge sensors have been made. To do this, the section was cut out from a sample perpendicular or parallel to the crystal (111) axis, and then crystal was cut on plate of 200 mcm thickness. The samples after polishing had a thickness 30-40 mcm and a length 2 mm.

The semiconducting materials hold a special place among the substances, possessing the tensor effect. The investigations [1-3] established that the resistance semiconducting tensometers have a variety of advantages in comparison with the wire ones.

The most widely used semiconducting materials in strain gauge sensors and transformers are germanium and silicon offering the significant tensor effect [4-6]. The successful use of tensoresistors in different fields of science and engineering specifies the necessity for the further study of the tensometric properties not only of germanium and silicon but also of the germanium-silicon solid solutions. As to the solid solutions of the germanium-silicon system, their tensometric properties have been studied [2-3]. Here the monocrystals Ge – Si have been studied. From the works [2-3] it follows that the systematical investigation of Ge – Si solid solutions has not been carried out. Evidently, for elucidation of all the advantages of Ge – Si solid solutions the further research in this direction is necessary.

In the present work the tensometric properties of monocrystal of Ge – Si solid solution of p – type with Si content 5-10 at.% have been studied.

From the studied crystals the strain – gauge sensors have been made. To do this, the section was cut out from a sample perpendicular or parallel to the crystal (111) axis, and then crystal was cut on plate of 2 mcm thickness. The samples after polishing had thickness 30-40 mcm and length 2 mm.

Since the semiconducting crystals limiting deformation increases with decrease of their diameter [3-5] as well as the surface areas are slightly damaged in cutting, the samples are etching in hydrofluoric acid. As a contact material there has been used the golden microwire prekept in antimony vapours. The contact quality was checked by their volt-ampere characteristics.

The unit described in [3] was used in investigation. For determination of the tensosensitivity coefficient the tensoresistor was fastened to an elastic cell which was given the known value of deformation. In this case the dependence between deformation and deflection was used. This dependence for the clean bend is determined by formula:

$$\varepsilon = \frac{Mh}{2EJ} = \frac{h}{2\rho} = \frac{4hy}{l^2 + 4y^2}$$

where l is a distance between supports, y is a value of deflection, M is a bending moment, h is a thickness of elastic cell (beam), E is a module of elasticity, J is a inertia moment, ρ is a radius of curvature

Dependence of resistance change on deformation (ε) is presented on the Fig.1.

The samples are different in base that has led to the lack of coincidence of their graduation characteristic though they have been cut out from the same Ge – Si solid solution. In the case, when the axis of Ge – Si solid solution tensoresistor is parallel to the plane (111), the tensosensitivity coefficient is equal to 0 unlike the tensoresistors orientated in the direction (111) when tensosensitivity coefficient is large and the graduation curves are characterized by the linear dependence.

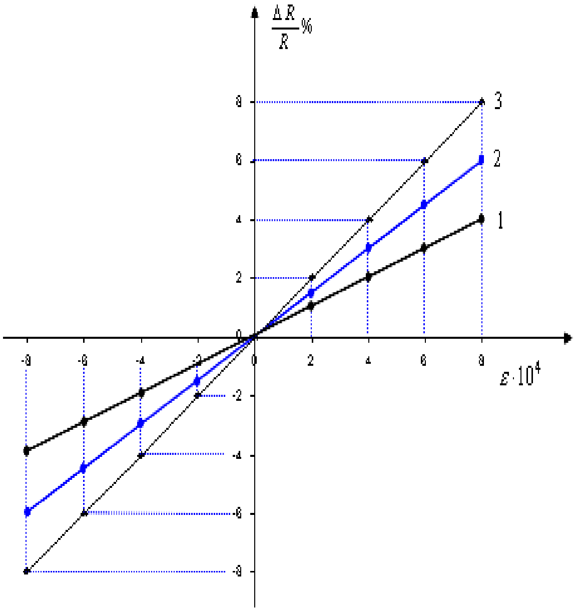

Fig.1. Dependence of $Ge_{1-x}Si_x$ crystals resistance change ($\frac{\Delta R}{R}$) on deformation at x values: 1-0; 2-0.05; 3-0.10

For the investigation of the mechanical properties of the studied Ge – Si solid solutions tensoresistors the method of tensile strain was used.

The deformation and tension of the elastic region was calculated by formula:

$$\varepsilon = \frac{\delta}{l^2/3r} \quad \sigma = \frac{F}{\pi r^3/2l}$$

where ε is a relative strain, σ is a tension, r is a radius, l is a length of a sample, δ is an arrow of flight.

Thus, the tensometers made from Ge – Si solid solution have the high tensosensitivity coefficient, the dependence of the resistance change on strain change in the strain region under investigation is linear one, hysteresis is absent, the influence of different physical factors on the tensometers operation is minimum; therefore the marked samples may be recommended as tensoresistors.

The nature of strength change depending upon Si content in Ge. The presented plots show that in these dependences two representative regions are observed: strong softening and little change of the mechanical parameters. With Si content up to 10 at. % the mechanical strength of $Ge_{1-x}Si_x$ crystals increases as compared with higher Si content and this agrees well with the results of works [1]. It is seen that with the most sharp changes and going into the saturation of microdefect values at different doses the foregoing statement is well confirmed, i.e. at $10^{15} \div 10^{16}$el/ñm^2 doses the annihilation of defects plays a leading part and at 10^{17}el/cm^2 the annihilation process and microdefect are saturated. It should be taken into account that in $Ge_{1-x}Si_x$ crystals under study the local heterogeneities with linear sizes ~2 and ~12mcm connected with dislocations [7] are available. It is established that $Ge_{1-x}Si_x$ crystals strength increases with increase of irradiation dose up to 10^{16} el/ñm^2 and at the large (~10^{17} el/ñm^2) doses it decreases. As it is shown above the nature of $Ge_{1-x}Si_x$ crystals strength change, is well explained by interaction of point defects created by the irradiation with the structural defects and dislocations.

Obtained in experiments the whole complex of data on the study of the accelerated electrons flow action on mechanical properties on $Ge_{1-x}Si_x$ base is possible to be explained assuming that under the accelerated electron flow action the simplest disturbances of the crystal lattice, arising at irradiation and being the defects of "vacancy" type lattice take place.

From these considerations for the explanation of the radiation effects in $Ge_{1-x}Si_x$ crystals there has been proposed a model based on the ideas of the structural heterogeneities of the solid solutions consisting of the regions enriched either by silicon or germanium. The interface between these regions serves as the efficient drain for interpoint atoms forming as a result of irradiation. Their intense absorption and enrichment of volume with free vacancies determine the features of the radiation processes in $Ge_{1-x}Si_x$ crystals and in devices on their basis.

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