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Research Article

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Strain Effects in Silicon Doped with Gold at Pulse Hydrostatic Pressure

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Abstract This study examines the mechanisms of relaxation effects of silicon doped with gold at pulse hydrostatic pressure. It is shown that the pulse pressure in the samples the process of redistribution of the primary spatial heterogeneity of impurities was occurred. Thus, the electron-hole relaxation after stress was appeared in new potential relief.

Keywords Strain Effects, Silicon, Gold, Pulse Hydrostatic Pressure

1. Introduction

The impact of external factors (temperature, pressure, light, electric and magnetic fields) changes not only to the electronic structure of defects in the crystal lattice, but also significantly alters the conditions of interaction of defects and carriers. Therefore, impurity atoms with deep levels under these conditions are not fixed in the lattice state, as it usually occurs in an uncompensated semiconductor, and to constantly readjust with changing external factors [1-4]. The influence of high pressure is one of the effective processes of identification, especially, pulse pressure.

It is known [5] that in semiconductors with deep levels under pulsed pressure changes $\frac{\partial P}{\partial t} = 2 \cdot 10^{8} \frac{Па}{сек}$ at temperature of the sample increased up to 7-10^{0}Cthat lead to a noticeable change in the concentration of charge carriers in expanded zoneswhich, in addition to the sample temperature change also stimulates the emergence and relaxation effects.

2. Experimental Procedure

To investigate the effects of contact tenzo-electricalSi samples were prepared, with varying degrees of compensation and conductivity type. Samples Si:Au compensated gold have been obtained on the basis of single-crystal silicon brandSDP (Silicon Doped with Phosphorus) and SDP (Silicon Doped with Boron) with resistivity ρ ~ 20-80 Om·sm, Grown by Zhohralski method and the floating zone melting. For studies were made crystal size and 6x3x3 mm^{3}, with the directions of the crystallographic axes [100], [110], [111] along the edges of a large, crystallographic directions were determined by X-ray analysis.

After Si single crystal cutting, the samples were grinded with diamond micropowders M-14 and M-4 by providing specific flatness lapping opposite edges up to (2-3) micron. In order to remove the surface layer is impaired and degreased, the samples were chemically etched in a solution of HF: HNO_3 = 3: 5.

The process of gold doping of silicon single crystals carried out diffusing layer deposited on a silicon surface by vacuum deposition on the installation VUP-5. The diffusion furnace was carried out in a horizontal-type SOUL-4 in the temperature range of T = 900÷1200^{0}C for two hours. The temperature in the furnace was controlled by thermocouple platinum –Platinum-Radii and maintained to within ± 3°C. As used Au diffusing high purity (99.999%). After diffusion annealing, to remove the surface layer on each side of the samples ground off layers

50-60 microns using lapping, under the conditions preserve flatness of opposite faces, and then re-samples were subjected to chemical treatment.

The electrical parameters of the samples (conductivity, concentration and mobility of charge carriers) were determined on the installation measurements of the Hall effect.

The sample was placed between the poles of the permanent magnet with the magnetic field H = 3000 Oersted the magnetic field direction is changed by turning the magnet 180^0.

Resistivity measurement sample was calculated according to the formula:

$$\rho = \frac{u}{I}\frac{db}{l},$$

where I - current through the sample, u -voltage between the potential contacts, b - width, d - thickness, l - length of the sample.

The Hall coefficient is calculated as follows:

$$R_x = \frac{U \cdot d}{J \cdot B}10^8 \left[\frac{sm^3}{Kl}\right]$$

where the U - Hall Electrical driving forces, B - magnetic induction.

The Hall mobility was calculated by the formula:

$$\mu = \frac{R_x}{\rho}\left[\frac{sm^2}{V \cdot s}\right]$$

Electric parameters of investigated samples are resulted in table 1.

Table 1

№	Samples	Type Conductivity	Specific resistance ρ, Om·sm	the concentration of charge carriers sm^{-3}	charge carrier mobility $sm^2/V.s$
1	Si :Au	n	$1.5{\cdot}10^2$	$3.96{\cdot}10^{13}$	1219
2	Si :Au	p	$2.1{\cdot}10^2$	$3.15{\cdot}10^{14}$	500
3	Si :Au	n	$2.88{\cdot}10^5$	$1.78{\cdot}10^{10}$	1214
4	Si :Au	n	$4.7{\cdot}10^4$	$1.15{\cdot}10^{10}$	1205
5	Si :Au	n	$2.98{\cdot}10^5$	$1.96{\cdot}10^{10}$	1091
6	Si :Au	p	$5.8{\cdot}10^4$	$4.39{\cdot}10^{11}$	254
7	Si :Au	p	$1.2{\cdot}10^5$	$1.82{\cdot}10^{11}$	343
8	Si :Au	n	$3.2{\cdot}10^5$	$1.67{\cdot}10^{10}$	1208
9	Si :Au	n	$1.95{\cdot}10^5$	$2.7{\cdot}10^{10}$	1220
10	Si :Au	n	$2.2{\cdot}10^3$	$2.66{\cdot}10^{12}$	1073

To control the temperature in the measurement samples was attached to the alloyed copper thermocouple. To protect the electrical contacts of the samples were coated with epoxy resin. Prepared in this way the samples were mounted on the holder and placed in a chamber in which a high hydrostatic pressure created. Also, a heater has been installed on the holder for changing the temperature of the sample.

To investigate strain properties of compensated samples under uniform hydrostatic compression installation hydrostatic pressure is used as described in [6].

3. Results and discussion

Figure 1 shows the kinetics of the current flowing through the samples of n- and p-type Si:Au under the influence of pulse pressure and a change in temperature by a heater.

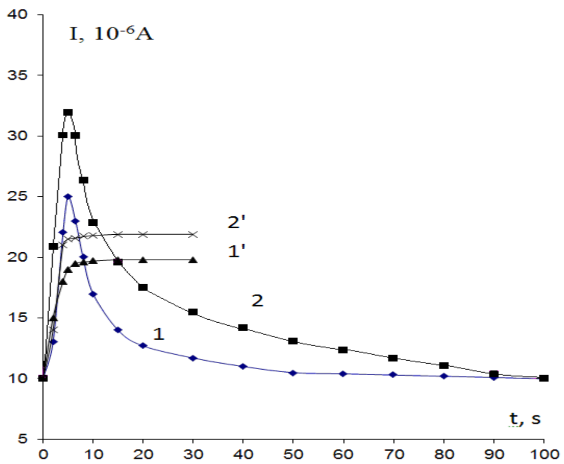

Figure 1: Kinetics of dependences of a current in samples n-type Si:Au (1,1$^{'}$) with specific resistance 1,1·10^{5}Om·sm and p-type Si:Au (2,2$^{'}$) with specific resistance 1,3·10^{5}Om·sm

Samples n- or p-type Si:Au or with increasing of port - hydrostatic pressure current is increased within 5-6 seconds, reached a maximum value and then decreases. The process of static strainconductivity Si:Au samples is not observed (Figure 1) at pulse hydrostatic pressure. When the pressure is changed to $5 \cdot 10^{8}$ Pa at a rate of temperature of the sample is changed to 10^{0}C.

When the sample temperature is changed by a heater at 100°C. Current varies by almost 40-45% compared to the initial value. This suggests that the hydrostatic pressure pulse of magnitude of 40-45% of the observed effects are due to the temperature, and the rest through relaxation processes. From the Fig. 1 it shown that as the specific resistance of the sample is larger, so the percentage of relaxation effects is greater.

The measurement results show that the kinetics of changes in conductivity in the samples n- or p-type Si:Au when exposed to hydrostatic pressure pulse has the characteristic features associated with the relaxation current changes, and in the control samples under the same conditions, a substantial change in conductivity is observed.

From the analysis of the results it can be concluded that the relaxation effects are more pronounced in n-type samples than in the p-type samples. At the same time changing the charge carrier mobility, in spite of the quantitative differences of mobility, obeys to the general laws.

Figure 2 shows the dependence of the relaxation effects on the resistivity of n or p-type Si:Ausamples. The figure shows that in the n-type Si:Au samples values of relaxation effects to overcompensation greater than after the change in conductivity type. This suggests that the compensated n-type samples, the relaxation effects are more pronounced than in the p-type samples. This is possible due to the fact that due to the relatively high mobility of the electrons easier to relax than a hole under the influence of pulse pressure.

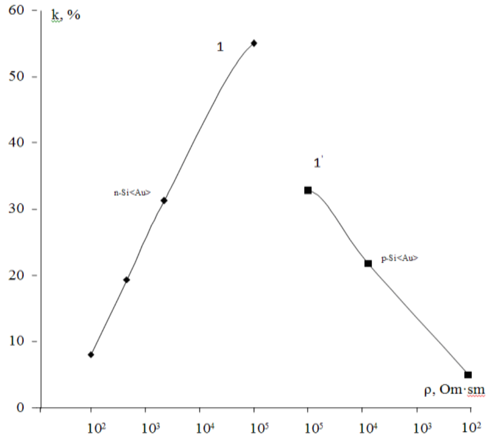

Figure 2: Dependence of a share relaxation effects from specific resistance in samples n-typeSi:Au (1) andp-type Si:Au (1$^{'}$).

Thus, the pulse strain conductivity connected not only with the temperature, but also with relaxation effects. Current varies mainly due to the temperature, and with increasing pressure amplitude value share relaxation effects increases at lower pressures. With the increase in the degree of compensation n-type Si:Au share relaxation effects increases, reaches its maximum value when, and then when you change the type of conductivity with increasing concentration of deep impurities, the percentage of relaxation effects reduced. This is probably due to the mobility of charge carriers as in n-type electron mobility samples of more than 1200 cm /v·s carrier mobility, and pulsed pressure more additional electron relaxes to the conduction band, compared to less mobile holes in the valence zone.

In [7] the change in the current flowing through the silicon samples with deep impurity levels were considered, and it had been shown that the effects occur due not only to a change in temperature, but associated with relaxation effects.

It is known [8] that in compensated silicon samples changing the mobility of the charge carriers, the static pressure insignificantly. In this case, compensated samples of silicon n-type charge carrier mobility increases, and p-type samples is reduced.

In this regard, we have conducted a study tensor Hall effect in Si samples doped with gold.

It is known that when a pressure pulse is applied, the sample temperature is changed, thus, increasing the temperature may vary the carrier mobility.

The redistribution of carriers between the level shift in the deformed semiconductor shift of the energy level of impurity centers, which are the recombination centers and lead to a change in carrier mobility [9].

It is known that the hydrostatic pressure at the pulsed sample temperature changes. It can be assumed that the change in the mobility of charge carriers at the pulse hydrostatic pressure due to the temperature change, stimulated by a pulsed pressure. But, as can be seen from Figure 3, when the temperature increase to 10^0C by a heater mobility is only slightly reduced.

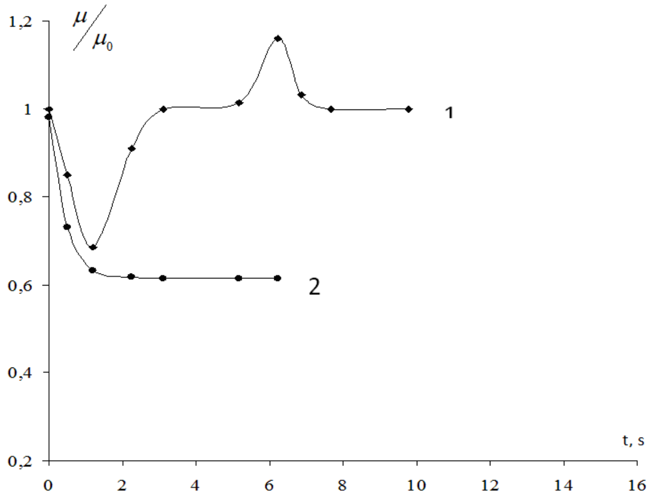

Figure 3: Mobility kinetics of carriers of a charge in samples n-type Si:Au with specific resistance 10^5Om·sm at pulse hydrostatic pressure and change temperatures

This suggests that the momentum hydrostatic pressure increasing of mobility of charge carriers in the n-type Si:Au samples is connected with the relaxation effects and increasing the temperature of the sample at a pressure reduces the growth of mobility of the charge carriers by relaxation effect.

4. Conclusion

Thus, when the pulse pressure is a redistribution of the samples are primary spatial in homogeneities of impurities so that the electron-hole relaxation after stress relief will already take place in the new potential relief. Moreover, for both types of conductivities of the carrier mobility decreases, and in both cases this reduction only occurs due to changes in temperature.

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