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**Research Article**

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# Deformation Effect in Compensated Silicon

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**Abstract** The effect of uniaxial compression along the [111] direction on electrophysical parameters of Si alloyed with Ni has been studied as a function of the conductivity type and compensation degree.

The results have thus shown that in all the specimens we investigated resistance decreased with the applied pressure. The studies on the Hall effect indicate that for n - Si<Ni > samples the density of current carriers increases and mobility decreases. Thus, for p — Si < Ni > samples the effect of tensor resistance strengthes, mobility increases, and density increases insignificantly with the compensation degree. Variations of this sort are connected with the shear deformation which is manifested at Ni impurity levels and, in turn, with variations in energy gap between deep levels and allowed zones due to uniaxial compression.

**Keywords** Deformation Effect, Compensated Silicon, Hall effect, uniaxial compression

## 1. Introduction

By its electro physical properties, silicon is known [1,2] to be attributed to the class of anisotropic semiconductor materials. Si conduction band has six equivalent minimal which are located along the [100] crystalline axis. The valence band apex degenerates at K= 0, i.e. apexes of energy branches are coincident for heavy and light holes at the above point. When suffering anisotropic, i.e. uniaxial deformation, a crystalline lattice structure is disturbed and relative mixing of equivalent valleys is observed for the conduction band along with the band splitting of heavy and light holes. This effect results in Si resistance variations, i.e. the tensor resistance onsets. In silicon with shallow impurity levels, the strain sensitivity is induced by the variations in the carrier mobility only. Thus, although deformation leads to the mixing of impurity levels, the carriers density remains constant since shallow impurity levels are fully ionized up to liquid helium temperature. In many cases deep impurity levels are not always fully ionized in silicon in the range of the room temperature and higher. In this connection, when subjected to uniaxial deformation (apart from the mobility variations) the carrier densities vary as well. Moreover, in many of case the above changes play a decisive role in tensor resistance manifestation [3].

## 2. Experiment

In the present paper, reported are the experimental results we obtained for tensor Hall-effect, which was investigated in compensated *Si* < *Ni*> samples subjected to uniaxial elastic deformation, depending on their conduction type and compensation degree. The experimental setup and technique have been described elsewhere (4).

In Figure 1, shown are the resistivities plotted versus uniaxial pressure, X, along the [111] crystallographic axis, for *n* - *Si*, n-and *p*- *Si* < *Ni* > samples {*I* || *X* || [111]} under the room temperature. The figure shows that for the initial *n* - *Si* samples resistivity varies insignificantly (see curve 1) and for the remainder of the samples it decreases with increase in applied uniaxial pressure. Thus, in *n* - *Si* < *Ni* > samples, the tensor resistance effect strengthens with the increase in degree of their compensation (or resistivity) see curves 2 and 3 for $\rho \sim 10^3 \Omega \cdot cm$ and $10^5 \Omega \cdot cm$, respectively).

Vice versa, in p - Si < Ni > samples tensor properties are reduced when their compensation degree increases (see curves 4,5 for $\rho \sim 10^3$ and $\rho \sim 10^5 \Omega \cdot cm$ respectively).

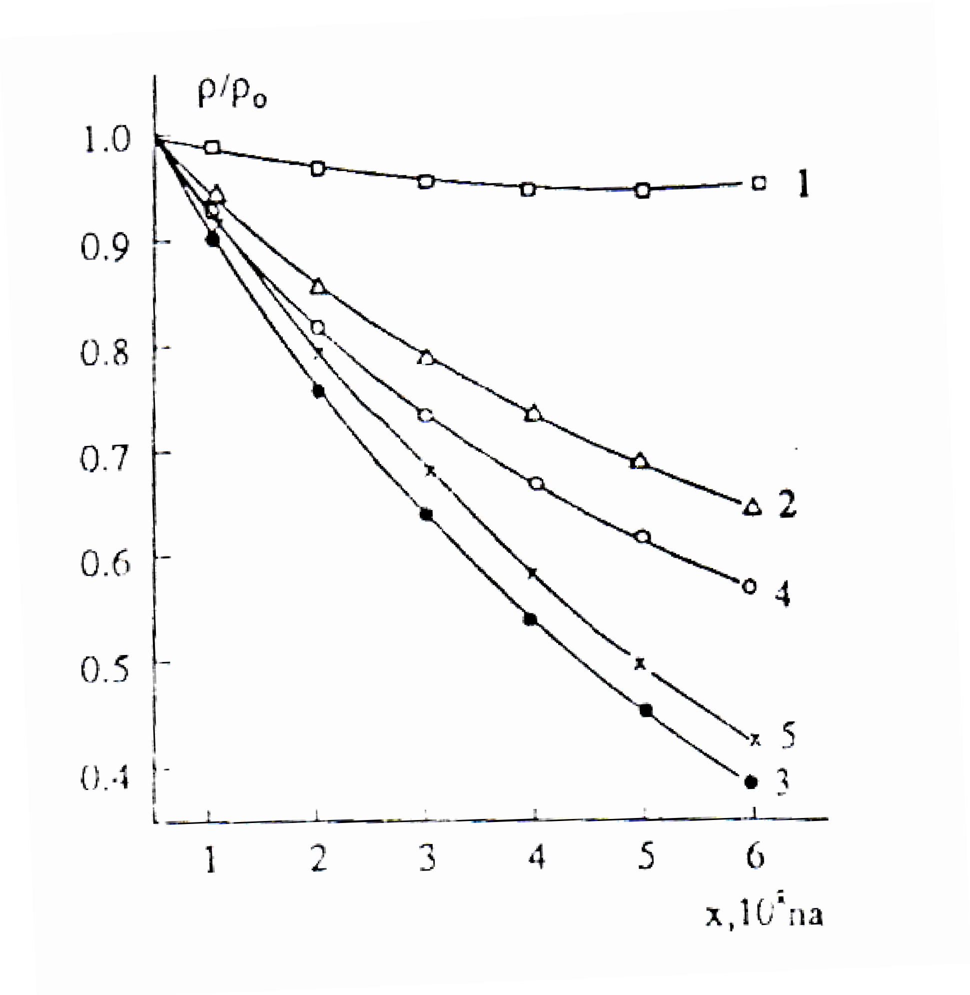


*Figure 1: Releative values of resistivity, $\frac{\rho}{\rho_0}$, depending on X plotted for n-Si (1), n-Si < Ni > (2,3), and p-Si < Ni> samples (4,5) under uniaxial elastic deformation (UED) for X||I||[111] and T=300K*

In order to elucidate the mechanism of the observable tensor resistance in *n*-and *p-Si<Ni>* sample the carriers density and mobility which were dependent on the applied uniaxial pressure, X, have been investigated by means of the Hall effect. When measuring the Hall coefficients the results obtained have thus shown that (see Figure 2) in *n - Si < Ni >* samples the values for electron density increased with pressure and, vice versa, their mobility decreased, moreover, higher the degree of samples compensation, larger were the relative variations in n and $\mu$ (see curves 1,2 and 1',2' respectively), As seen from the figure, variations in the Hall electron mobility amount to 15-20%, and their density increased by 70-90%.

The results for similar measurements in *p-Si < Ni >* samples are plotted in Figure 3 versus their compensation degree under uniaxial pressure. As shown in Figure for the above samples, y the values of the hole mobility increase with pressure, X, (see curves 1',2', in Figure 3) and these mobility variations are strengthened with the compensation degree. In *p — Si < Ni >* samples, the values of hole density increase insignificantly (see Figure 3 curves 1,2).

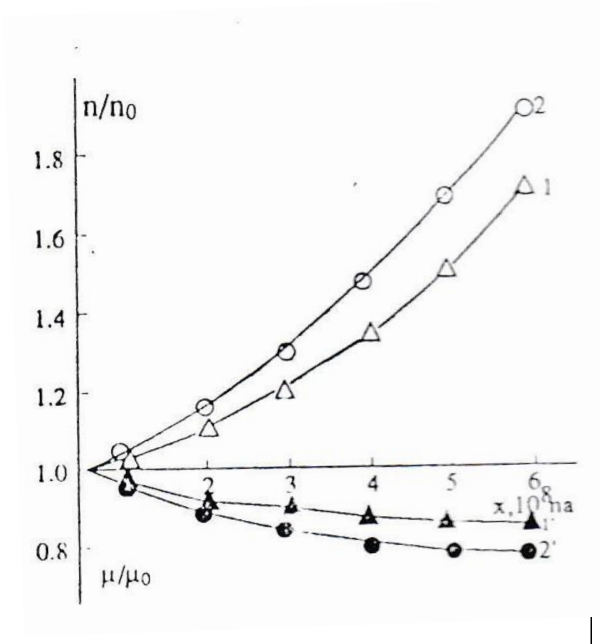


*Figure 2. Relative values of the hole density,* $\frac{n}{n_0} = f(P),(1,2),$ *and mobility,* $\frac{\mu}{\mu_0} = f(X),(1',2')$ *depending on X plotted for n-Si<Ni> samples under UED with {X || I ||[111]} and T=300K*

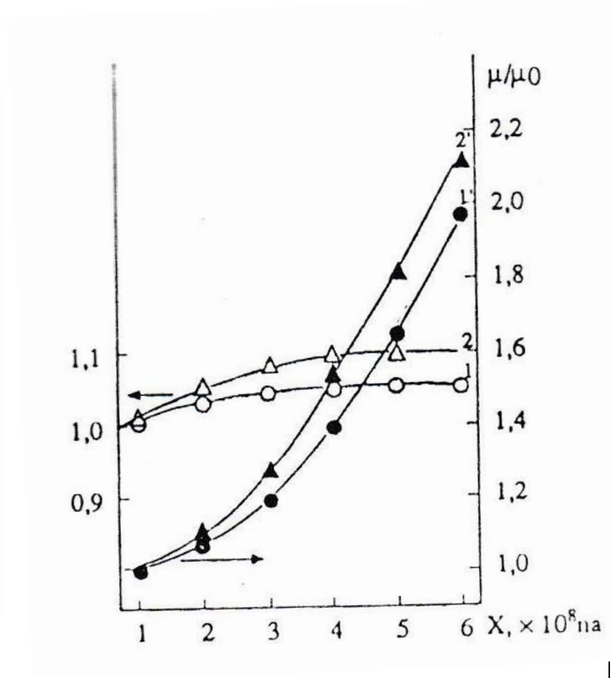


*Figure 3. Relative values of the hole density,* $\frac{P}{P_0} = f(X),(1,2),$ *and mobility* $\frac{\mu}{\mu_0} = f(X),(1',2')$ *depending on X plotted for p-Si <Ni> samples under UED with {||X|| I[111]} and T=300K*

**3. Discussion**

From the results thus obtained one can see that in *p — Si < Ni >* samples, on the contrary to *n — Si < Ni >*, tensor resistance is induced largely by variations in hole mobility. It is known [5.6] from the theory of the strain sensitivity that in *n — Si < Ni >* samples, as is the case for isotropic deformation, the relative valley mixing of the conduction band is lacking. Therefore, in *n-Si < Ni>* samples subjected to uniaxial pressure the observable insignificant (5-8%) decrease in electron mobility, with these variations being strengthened due to the compensation degree increase, are associated with the manifestation of shear deformation and deformational strengthening of electron scattering into Ni impurity precipitates and into the other uncontrollable impurity formation, since in such a case deformation is anisotropic unlike the results which follow from the physical mechanism of tensor resistance being discussed for the case of uniform hydrostatic pressure (UHP) [7]. In *p- Si < Ni >* samples under uniaxial deformation, in contrast to the isotropic one, degeneracy is known [1,2] to be relieved at K=0, i.e. bands of light and heavy holes are splitted leading to variations in the hole mobility. So, in *p-Si < Ni >* samples under uniaxial pressure such a significant increase in the hole mobility may be attribute to band splitting and, in fact, this is in agreement with the conclusions draw from the tensor sensitivity theory. Variations in density of current carriers for the above samples under uniaxial pressure are likely associated with those in energy gap between Ni deep level and the allowed bands. Note that for not highly compensated samples variations in the hole density is connected with those in the capture cross-sections of current carriers, i.e. electrons and holes within the impurity centres, as conductivity of the above samples is close to the intrinsic one.

## 4. Conclusions

The investigations have thus shown that in all the specimens investigated resistance decreased with applied pressure. Variations of this sort are connected with the shear deformation which is manifested at *Ni* impurity levels and, in turn with variations in energy gap between deep levels and allowed zones due to uniaxial compression.

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