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INVESTIGATION OF THE WIDTH OF THE FORBIDDEN ZONEHEAVILY DOPED SEMICONDUCTORS

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Abstract
The work examines changeswidth of the forbidden zoneheavily doped semiconductors. The introduction of impurities into the crystal lattice at low concentrations does not change the width forbidden zones semiconductor and does not affect the energy spectrum of electrons. Only discrete levels appear in the forbidden zone. When the concentration of impurities becomes large enough, the energy spectrum and the width of the BG of the crystal change.

Keywords Semiconductor, doping, impurity, band gap, impurity concentration, energy bands.

INTRODUCTION

In heavily doped semiconductors, the interaction of charge carriers with impurity atoms plays a special role. The absorption of light with a frequency lower than the threshold is naturally associated with the presence of a tail of the density of states (DS) in the forbidden zone. The total concentration of levels on the tails varies from substance to substance and from sample to sample and is often quite large, up to 1019-1020 cm-3.

Values of the light absorption coefficient at $h\omega < Eg$ depends on the doping level. Here, mainly the deepest levels on the hosts of the density of states of the PS value can participate $\alpha(\omega)$ at $\omega < Eg / h$ may be small. The values of the absorption coefficient observed experimentally are the result of some averaging over the coordinates of the impurity atoms (the set of these coordinates is referred to as the impurity concentration). Due to random distribution, the impurity concentration in different parts of the sample is different. When performing a measurement, averaging is performed over the configurations [1,2].

With weak doping, an electron interacts with one impurity atom. The interaction energy is the same for all electrons. With strong doping, the potential energy of an electron depends on the positions of several impurities at once. The energies of the carriers become random quantities. With a further increase in the impurity concentration, the overlap of the wave functions of electrons localized on different impurity atoms becomes noticeable and the impurity level is smeared into a zone. This effect is referred to as quantum level broadening. [3]. These broadenings of discrete levels lead to a

decrease in the widthforbidden zones(33).

METHODS

In progress [4] a mathematical model of the spectrum of the density of surface states was constructed by expanding it into a series in $GN(E_0,E_i,T)$ functions. Where $GN(E_0,E_i,T)$ is the derivative with respect to energy of the probability of ionization of electrons from an energy level. With the help of which, the temperature dependence of discrete energy levels in the forbidden zone of silicon was analyzed. The function $GN(E_0,E_i,T)$ determines the presence of an energy level.The model has been improved [5, 6] for the analysis of the spectrum of the PS in a wide energy range. Let us consider this model for this problem. Let us decompose the spectrum of the density of energy states, $Ns(E_0,T)$ By $GN(E_0,E_i,T)$ according to the model in the form:

$$N_s(E)=N_{sn}(E)+N_{ss}(E)+N_{sp}(E) \quad (1)$$

$N_{sn}(E,T)$ for salary: $N_{sn}(E,T)=\sum_{i=1}^{n}N_{n0}\sqrt{E_i-E_c}GN(E_i,E,T)\Delta E$ at $E>E_c$ (2)

$N_{sp}(E,T)$: for VZ: $N_{sp}(E,T)=\sum_{i=1}^{n}N_{p0}\sqrt{E_p-E_i}GN(E_i,E,T)\Delta E$ at $E<E_v$ (3)

$N_{ss}(E,T)$ for the forbidden zone:

$$N_{ss}(E,T)=\sum_{i=1}^{n}N_{ssi}(E_i)GN(E_i,E,T) \quad \text{at} \quad E_c>E>E_v \quad (4)$$

$$\text{Where } GN(E_0,E_i,T)=\frac{1}{kT}\exp\left(\frac{1}{kT}(E_i-E_0)-\exp\left(\frac{1}{kT}(E_i-E_0)\right)\right) \quad (5)$$

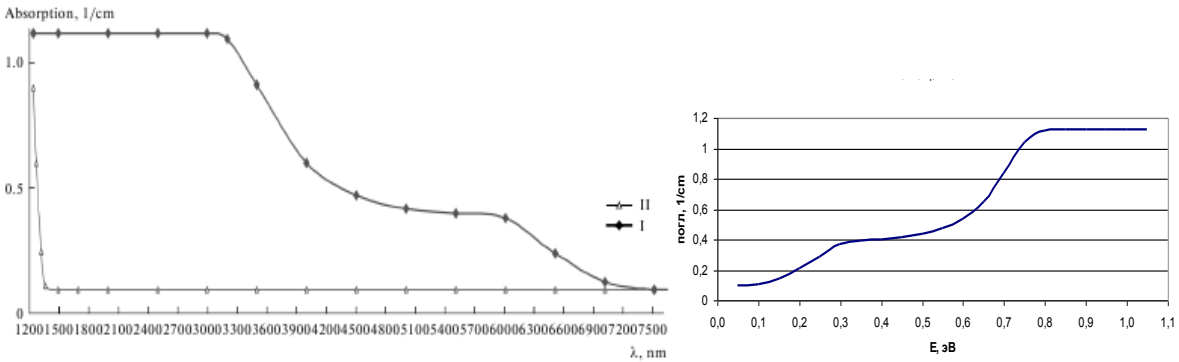
E1-can run across the entire valence, forbidden band (BG) and conduction band (CB). Ns_i -the concentration of energy states corresponding to energy E_i, E_0 - energy of states, T-temperature. k - Boltzmann constant.

Experiment

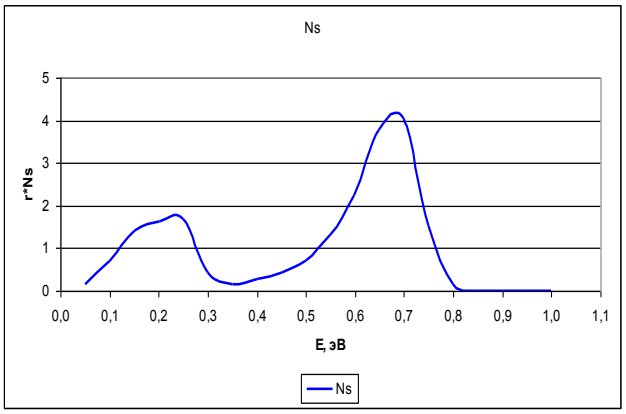
In progress [7] absorption of monochromatic light is observed at frequencies below the threshold. Heavy doping of silicon decreased the red boundary for photon energy from 1.2 eV to 0.6 eV. Consequently, doping with impurities at deep levels expands the band gap and the valence band. This enhances the absorption of light below the red boundary. The increase in absorption in the frequency range below the red boundary indicates a decrease in the width of the band gap. However, the absorption coefficient in the range of 0.6 eV-0.9 eV is approximately α~1-10 cm-1 and is 3-4 orders

of magnitude smaller than in the region of intrinsic absorption of pure silicon. As can be seen from Fig. 5.2, $\alpha(h\nu > Eg)/\alpha(h\nu < Eg) \approx 10^4$ If we assume that the absorption coefficients are proportional to the PS (combined PS), then the PS in the former forbidden zone is 104 orders of magnitude lower than the PS of the ZP and VZ (1022-1020).

In the new zone in the range of values Eg<0.9 Ns=1018-1019 (0.4<Eg<0.9 eV). This value of the PS gives the absorption coefficients α~1-10 cm-2. Thus, with the help of doping it is possible to control the width of the BG and the absorption coefficient. In Fig. 1.a. the PS value is determined from measurements of the absorption coefficient [7]. In Fig. 1.b. a variant of the dependence on energy in eV is shown. The graph marks the total number of level concentrations. Using the derivative of the number of level concentrations by energy from the graphical relationship, a graph of the energy PSs is obtained in Fig. 1.c. Using the above model (1), we will construct the PS spectrum for doped silicon taking into account the experimental conditions, T=300 K, Eg=1.21 eV. It is evident from the figure that a high concentration of impurities gives a sufficiently large number of levels determined by clusters formed by impurity levels. The levels in the forbidden zone are created by a random distribution of impurities. The absorption coefficient α is proportional to the total number of states. Perhaps, the formation of clusters is more suitable for explaining the absorption coefficient of heavily doped semiconductors with deep levels. Figure 2.b shows the integral PS (total number of states) calculated by the model. It is worth noting that the graph of the total number of states obtained using the model in Figure 2.b and the experimental graph of the total number of states in Figure 1.b are comparable.



a) b)



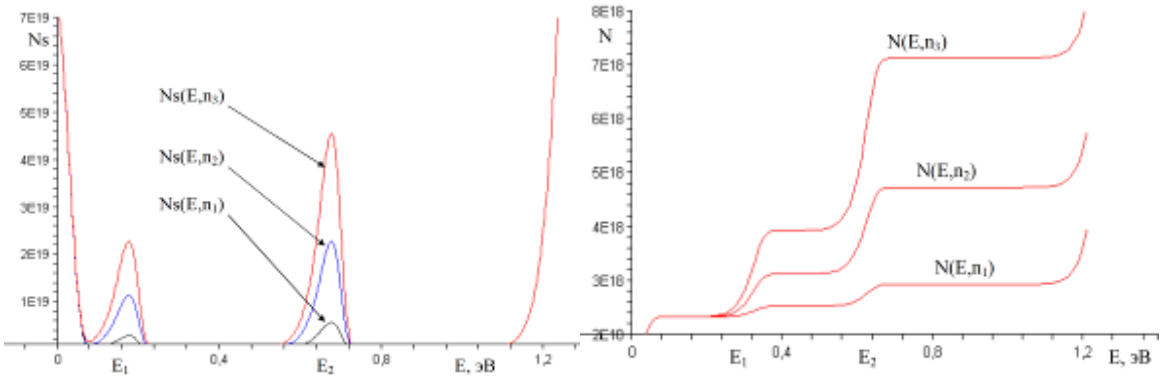
V)

a) relative to the wavelength,

b) relative to the wave energy in eV.

c) PS obtained by calculating the derivative with respect to energy from the graph

Fig. 1. Graph of light absorption of doped silicon from work [7].



a) b)

a) PS obtained according to the model. n1< n2< n3 is the degree of alloying.

b) the total number of states calculated according to the model. n1< n2< n3 is the degree of doping.

Rice.2. Graph obtained from the model.

DISCUSSION

At a sufficiently large concentration of impurities, discrete levels form an impurity zone. As the temperature increases, the oscillations of the crystal lattice increase

This leads to new configurations of the arrangement of atoms in the crystal lattice with various deviations. Changes in the configuration of atoms in the lattice lead to changes in the energy states of electrons.

CONCLUSION

Changes in energy states occur randomly, proportionally to the appearance of the corresponding configuration of impurity atoms and the lattice. This leads to different values of energy levels. Each configuration of atoms has its own energy of impurity states and its own edge of the band gap and edges of the band gap. Taking this circumstance into account, it can be concluded that absorption in the range of 0.5-0.9 eV for silicon is due to impurity states in the band gap. Impurity

states can greatly reduce the width of the band gap of a semiconductor.

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