

INFLUENCE OF Ag UPON EFFICIENCY OF RADIATION DEFECT FORMATION IN SILICON p^+ -n-STRUCTURES

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It is well known that the degradation of characteristics of silicon devices under radiation influence is mainly due to introduction into lattice of material various radiation defect complexes [1-3]. These radiation defect complexes form different recombination centers that significantly influence upon currency characteristics and device's speed.

In order to decrease concentration of recombination centers the semiconductor materials are to be supplied with additional properties such as radiation and thermal hardness using different technological methods. One of the most efficient methods managing material properties is doping of silicon with chemical impurities that introduce deep levels into silicon band gap [4-6]. Therefore, studies of radiation defect formation in silicon and silicon structures with deep levels are of particular interest.

In this work the results of studies of the influence of Ag impurities upon radiation defect (RD) formation in silicon p^+ -n-structures irradiated by accelerated 4 MeV-electrons with fluences of 10^{14} - 10^{16} cm⁻².

Monocrystalline n-type silicon samples with resistivities from 0.3 to 20 Ohm-cm were used in the experiments. Ag impurities were introduced into p^+ -n-structures in the temperature range of 1000-1250°C during 3-5 hrs with rapid and slow cooling of samples afterwards. Parameters of Ag-centers and radiation defects were monitored by DLTS measurements according to the technique described in Refs. [7,8] in the temperature range of 80-400 K in constant voltage regime. Recombination properties of centers were studied by measuring life-time of minority carriers by stationary photoconductivity method and through transient characteristics of diodes [9,10].

Fig. 1 presents DLTS spectra of p^+ -n-structures fabricated from n-Si<Ag> with different post-diffusion cooling regimes. As seen from figure, Ag introduces into silicon band gap two donor type levels E_c -0.37 and E_c -0.53 eV. It was found that the post-diffusion cooling regime strongly influences upon concentration of these levels. In the case of cooling with rate of 10 degree/s it was observed the increasing of above concentrations 10÷20 times with respect to the case of cooling with rate of 0.1 degree/s (Fig. 1, curves 1 and 2).

Measurements of life-time of minority charge carriers (τ_p) have shown that τ_p has value of $(2\div5)\cdot 10^{-6}$ s in the case of slow cooling, while it decreases till $(1\div3)\cdot 10^{-7}$ s in the case of fast

cooling (Fig. 2). These results show that Ag impurities are able to get electrical non-active states in the slow cooling regime. Note that the concentration of Ag noticeably influences on recombination processes. 1.2 times increase of Ag concentration as compared with that of P leads to substantial decrease of the life-time of minority charge carriers (Fig. 2). After electron irradiation with fluences of $5 \cdot 10^{15} \text{ cm}^{-2}$ the value of τ_p remains practically unchanged regardless of cooling regimes, while in the p^+ -n-structures without Ag impurities τ_p decreases till $(5+8) \cdot 10^{-8} \text{ s}$. These results indicate a strong influence of Ag impurities upon radiation defect formation.

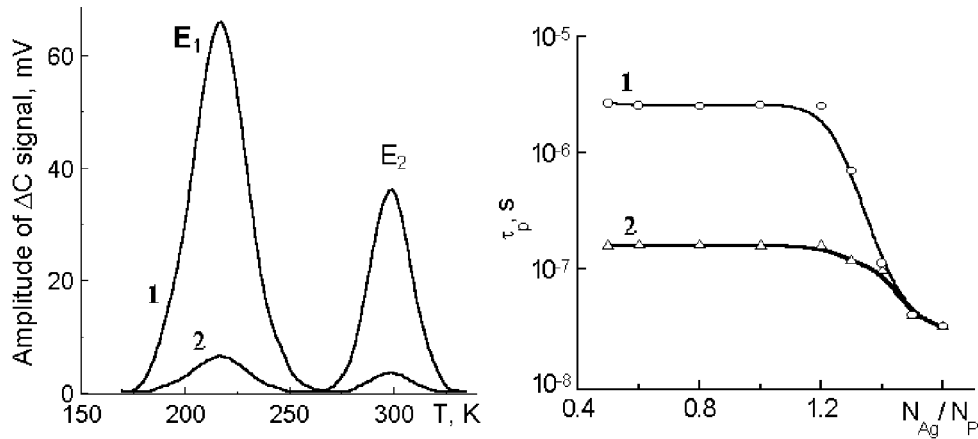


Fig. 1. DLTS spectra of p^+ -n-structures from n-Si<Ag> with rapid (1) and slow (2) cooling. $E_1 = E_c - 0.37 \text{ eV}$, $E_2 = E_c - 0.53 \text{ eV}$.

Fig. 2. Dependence of life-time of minority charge carriers on the ratio of total concentrations of Ag and P in the n-Si<Ag> with rapid (1) and slow (2) cooling.

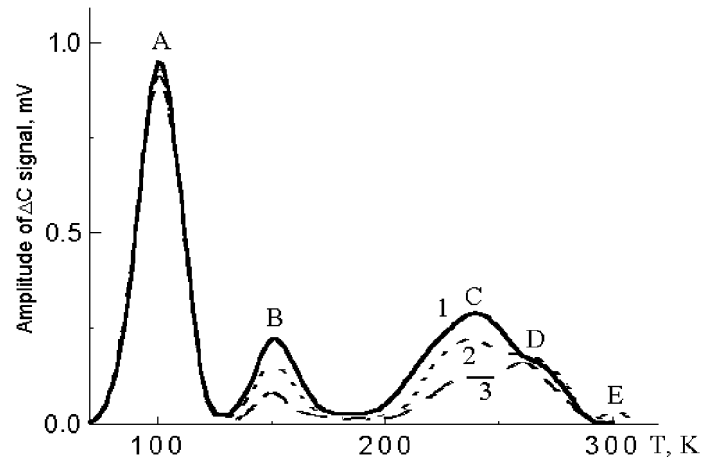


Fig. 3. DLTS spectra of p^+ -n-structures from n-Si (1) and n-Si<Ag> with rapid (2) and slow (3) cooling. Irradiation fluence is 10^{15} cm^{-2} . $E_c - E_i$, eV : A – 0.17; B – 0.23; C – 0.39; D – 0.44; E – 0.53.

In Fig. 3 the DLTS spectra are presented for the silicon p^+-n -structures with and without Ag impurities. As seen from figure, the main radiation defects created in the control and doped samples are A- and E- centers with levels of $E_c-0.17$ and $E_c-0.44$ eV, respectively, as well as divacancy with levels of $E_c-0.23$ and $E_c-0.39$ eV concentration of which increases with the increase of electron fluence (Fig. 4). Concentrations of A- and E- centers in the control and doped samples are practically the same (Fig. 4, *a*), while efficiency of introduction of divacancy in $\text{Si}<\text{Ag}>$ with rapid and slow cooling is 1.2 ± 1.5 and 2 ± 2.5 times, respectively, lower than that in the control samples (Fig. 4, *b* and *c*). Thus, the doped samples with slow cooling degrade less than those with rapid cooling.

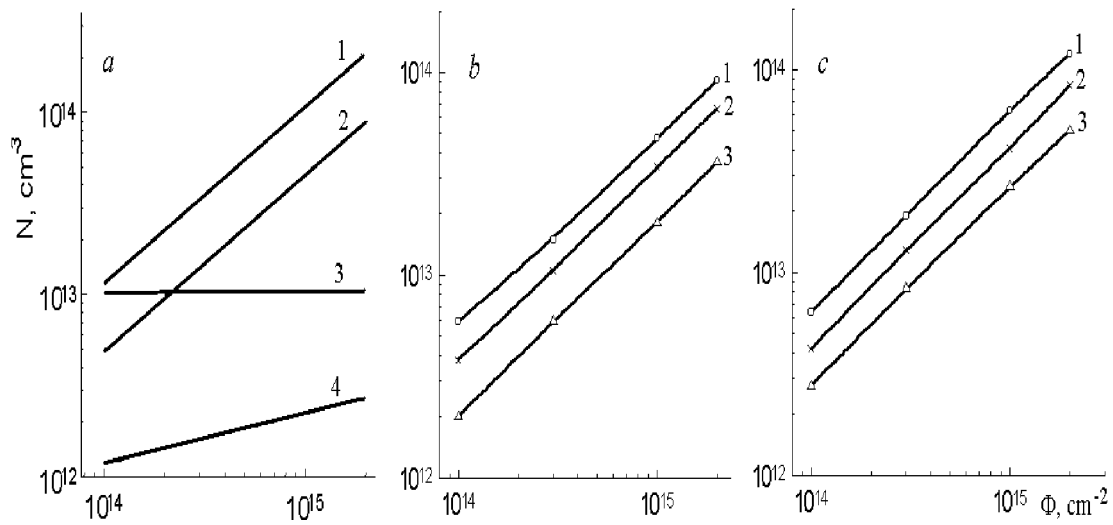


Fig. 4. *a)* Dependence of concentration of radiation defects (1 – $E_c-0.17$ eV, 2 – $E_c-0.44$ eV) and Ag-center with level $E_c-0.53$ eV on electron fluence: 3 – rapid cooling; 4 – slow cooling. *b)* Dependence of concentration of divacancy level $E_c-0.23$ eV on electron fluence in n-Si (1) and n-Si<Ag> with rapid (2) and slow (3) cooling. *c)* Dependence of concentration of divacancy level $E_c-0.39$ eV on electron fluence in n-Si (1) and n-Si<Ag> with rapid (2) and slow (3) cooling.

The observed change of divacancies concentration in doped structures depending on the content of Ag and cooling regimes is explained by efficient interaction of electrically non-active Ag atoms with divacancies created by irradiation with followed transition of Ag atoms to electrically active states.

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