Study Of The Influence Of Radiation Gamma And Thermal Annealing On The Dlts Spectra Of Diodes From Si (Cr)

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ABSTRACT

It was shown from capacitive measurements that the concentration of chromium levels decreases after irradiation of the samples with gamma quanta of the 60Co isotope, and the rate of formation of A centres in Si (Cr) is 8-10 times higher than in the control samples.

KEYWORDS

Irradiation, gamma quanta, 60Co isotope, Si (Cr) doped with chromium, radiation defects, rate of formation, charge exchange, complexes, activation of neutral atoms.

INTRODUCTION

The properties of chromium in silicon have been comparatively poorly studied [1, 2]. The authors of these works found the following deep levels (DE) associated with chromium. E_c - 0.22, E_c - 0.41, E_c - 0.55 eV, their parameters and concentration in Si (Cr) were determined.

This work aimed to study the effect of gamma irradiation and thermal annealing on DLTS spectra in chromium-doped silicon diodes.

Silicon alloying was carried out by the diffusion method at 1200 $^{\circ}$C for 3-30 hours.

To measure DLTS, n-Si crystals with an initial resistivity $\rho_{uc} \cong 5 \div 50$ Ohm.cm were used.

After diffusion of chromium, they did not change the type of conductivity and their resistance did not change significantly at 300K, and at 77K it increased to
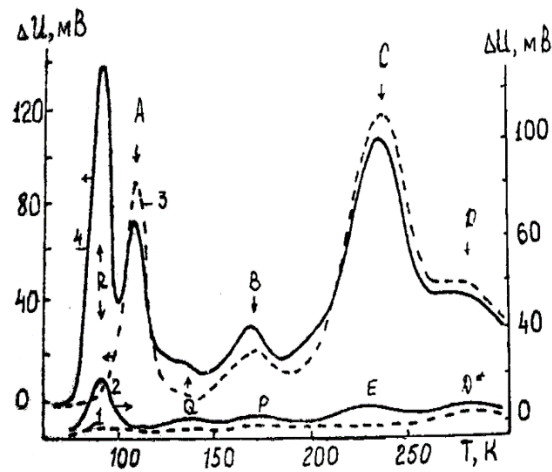
$\rho_{uc} \cong 10^3$ Ohm.cm.

DLTS measurements were carried out using Schottky barriers. The measurement results did not depend on the nature of the rectifying contact. The DLTS spectra were measured in the constant-capacitance mode in the temperature range 77-300K at $t_1 = (0,5 \div 50)$мс,

$t_2 = 3t$. The dimensions of the samples were 12x4x0.8 mm^2 [1,4].

MATERIALS AND METHODS

Irradiation of the samples with ^{60}Co gamma quanta was carried out at a temperature of 30 $^{\circ}$C in the dose range $\Phi = 2.10^{15} \div 5.10^{18}$ см$^{-2}$.

After each stage of irradiation, DLTS spectra were measured in n-Si (Cr) control samples. The concentration of HC in the control samples before irradiation did not exceed ~5.10^{11} см$^{-3}$ (Fig. 1, curve 1).

1, 2 - control sample; 3, 4 - n - Si (Cr); 1, 3 - before irradiation; 2, 4 - after irradiation; $\Phi = 5 \cdot 10^{17}$ см$^{-2}$; $t_2 = 3 \cdot t_1 = 6$ ms.

Figure: 1. DLTS spectra of Schottky barriers on n-Si.

In all these samples, the concentration of optically active oxygen was ~ 8.1017 cm^3. Measurements showed that in n-Si, before

gamma irradiation, four is associated with chromium are observed (see Fig. 1, curve 3).

$$E_1 (A)=E_c\text{-}0{,}21 \text{ эB}, \sigma_n(A) = 2.\,10^{-14}\,cm^2, N_t\,(A) = 4.\,10^{13} cm^{-3};$$

$$E_2 (B)=E_c\text{-}0{,}32 \text{ эB}, \sigma_n(B) = 5.\,10^{-15}\,cm^2, N_t\,(B) = 5.\,10^{12} cm^{-3};$$

$$E_3 (C)=E_c\text{-}0{,}43 \text{ эB}, \sigma_n(C) = 4.\,10^{-14}\,cm^2, N_t\,(C) = 4.\,10^{13} cm^{-3};$$

$$E_4 (D)=E_c\text{-}0{,}52 \text{ эB}, \sigma_n(D) = 1.\,10^{-14}\,cm^2, N_t\,(D) = 4.\,10^{12} cm^{-3};$$

The concentration of HC in the control samples before irradiation did not exceed ~ 5.10^{11} cm $^{-3}$ (Fig. 1, curve 2). After irradiation of control and chromium-doped samples from n-Si, levels R, Q, P, E and D* of radiation defects (RD) are formed (see Fig. 1, curves R, 4) [3]. As can be seen from Fig. 1, after gamma irradiation at a dose of $\Phi = 5.10^{17}$ cm^{-2}, the most noticeable change occurs with the concentration of A centres (E_a (R) = E_c - 0.17 eV).

Measurement of the dependence N_t = f(Φ) of radiation defects in n-Si (Cr) showed that changes in the concentration of N_t A centres in all studied samples in the range of irradiation doses ($2.10^{15} \div 5.\,10^{18}$) cm^{-2} have a linear character, as in Si (Zn) [3,5].

The rate of change of N (R) is in n-Si (Cr). $\vartheta_R = |\frac{\Delta N}{\Delta \Phi}| = 5.\,10^{-5}$cm^{-1}, whereas in control samples $\vartheta R = 5.10^{-6}$ cm^{-1}. This shows that the rate of A-center formation under the same conditions is 8-10 times lower in control samples, that is, n-Si (Cr) samples react more strongly to gamma irradiation. It is possible that chromium atoms prevent the direct annihilation of Fresnel pairs, the concentration of vacancies increases and, accordingly, the concentration of defects associated with the samples with vacancies increases.

In chromium-doped samples, in addition to the A centre, a Q level is also formed (Fig. 1, curve 4) which is attributed to divacancies with the parameters E_c –(0,23 $\pm$ 0,1) эB, $\sigma_{n=}10^{-15}$ cm^{-2}.

The concentrations of the remaining RDs (P, E, D*) are low, and in chromium-doped samples, these levels are invisible in the DLTS spectra against the background of charge exchange of chromium levels. In the course of irradiation, the chromium concentration decreases monotonically at a comparatively low rate; when the dose changes from 2.10^{15} to 5.10^{18} cm-2, the concentrations of levels E_1 (A)=E_c-0,21 эB, E_3 (C)=E_c-0,43 eV and E_4 (D)=E_c-0,52 eV fall by about 15-20% (see Figure 1, curve 4).

This shows that, upon irradiation, chromium atoms pass into an electrically inactive state without the formation of stable complexes with primary RDs. The increase in N (B) in n-Si (Cr) at high irradiation doses is apparently due to the electrical activation of neutral chromium atoms. It should be emphasized that the decomposition of a defect (complex) during HT depends not only on its properties but also on the properties of other defects present in the crystal and participating in reactions. Chromium HCs in Si are annealed at a relatively low temperature. After HT of the irradiated diodes ($\Phi = 5.10^{18}$ cm^{-2}) at 250 °C for 20 minutes, the chromium level $E_t(A) = E_c - 0{,}21$ eV is almost completely annealed. However, in the process of HT, the formation of stable complexes associated with chromium did not occur.

Further continuation of the annealing leads to a rapid decrease in N (Q) and the final decay of the RD. The concentration of chromium levels C and D also noticeably decrease (see Fig. 1, curve 4).

CONCLUSION

It is shown that the parameters of chromium levels practically do not change as a result of gamma irradiation and chromium atoms do not form complexes with radiation defects in noticeable concentrations. Part of chromium atoms under the influence of gamma irradiation goes into an electrically inactive state. It was found that the presence of chromium increases the rate of RD formation in silicon.

In particular, the rate of A-center formation in n-Si (Cr) diodes is about 8-10 times higher than in the control ones. It is possible that chromium atoms prevent the direct annihilation of Fresnel pairs, the concentration of vacancies increases and, accordingly, the concentration of defects associated with vacancies increases.

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