incoherent parts of wave fields Γ and extinction length Λ_0 are analogous to received earlier for high-perfect dislocation-free silicon [1,2]: $\tau/\Lambda_0 \to 0$ and $\Gamma/\Lambda_0 \to 0$, thus however the significances of E, describing long-range distortions of a lattice, change in a wider range and can strongly differ from 1. Significance of E appear considerably more, than at account with application of the assumption, that $\Gamma \sim \Lambda_0/E$.

The application of approaches of SDTD to dislocation crystals permits to remove all problems, connected to fact, that the dislocations are defects of II class ($\Lambda_0 \gg 1$), effective susceptibility turn into 0, owing to that as kinematical coherent scattering as dynamical one should disappeare [6,7].

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CHARACTERIZATION OF VACANCY-RELATED DEFECTS INTRODUCED DURING SILICON HEAT TREATMENT BY DLTS AND GAMMA-RAY DIFFRACTION TECHNIQUES

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The concentration of defects introduced by heat treatment into Si is low and usually does not exceed 10^{13} cm^{-3}. Therefore, such highly informative techniques as electron paramagnetic resonance, PTIS, TEM, etc. can not be used for the defect characterization.

To study the vacancy-related defects introduced into n-Si during annealing or aluminium diffusion at high temperatures (1000-1250°C) for $t = 0.5 - 16$ h gamma-ray diffraction techniques and capacitance deep level transient spectroscopy (DLTS) have been used. These techniques were used since they have an advantage in sensitivity over other methods for the investigation of electrically active and structural defects.

Detailed description of the techniques and set-ups is given in [1,2].

Float zone (FZ) and Czochralski (Cz) n-Si grown in $< 111 >$ direction with resistivity 10-1000Ω·cm was studied.

Different nonoxidizing ambients (argon, nitrogen, vacuum and chlorine-containing atmosphere) were used to create a vacancy supersaturation during Si heat treatments.

Three deep level centers whose formation is governed by the presence of vacancies have been identified. They were characterized by the following temperature dependences of the thermal emission rate:

$$e_3 = 7.92 \times 10^7 T^2 exp(-0.455/kT),$$
$$e_5 = 2.64 \times 10^6 T^2 exp(-0.266/kT),$$
$$e_7 = 7.26 \times 10^6 T^2 exp(-0.192/kT).$$

Influence of different factors, such as heat treatment conditions, concentration of oxygen and doping level in initial crystals, on center formation was studied.

Fig. shows relative concentrations of the defects introduced during annealing of FZ Si in argon ambient for 1 h at different temperatures.

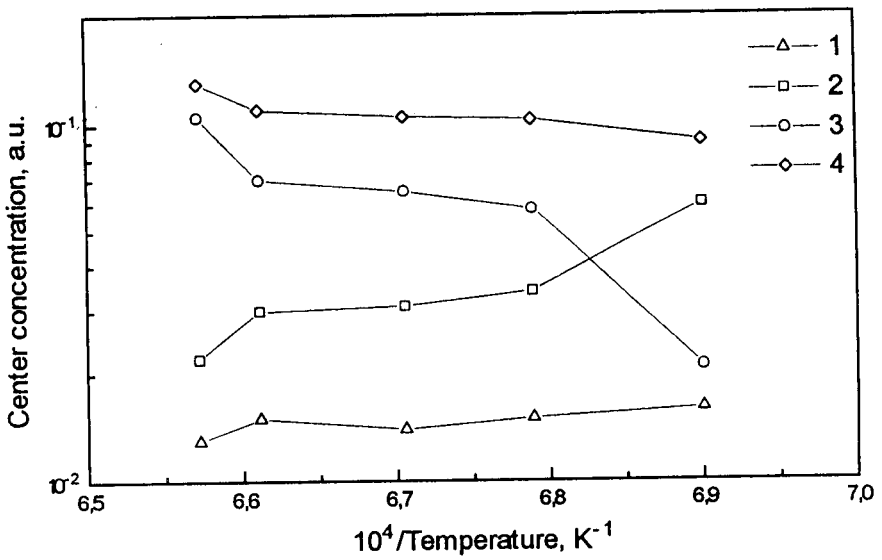

Fig. Temperature dependences of concentration of vacancy-related centers introduced during annealing in argon ambient for 1 h: *1* - E3, *2* - E7, *3* - E5, *4* - (E3+E5+E7)

A decrease of sample cooling rate after heat treatment leads to a decrease of the center concentration. This fact suggests that the formation of the centers depends not on the concentration of excess vacancies generated during heat treatment only, but on the changes of the vacancy supersaturation degree in Si during the sample cooling as well.

An asymmetric diffuse gamma-ray scattering was observed near the surface of the crystals. It appeared most clear in samples FZ Si irradiated by thermal neutrons to a fluence 10^{17} cm^{-2} and annealed in a chlorine-containing atmosphere at T = 1050°C for 4 h. The analysis of the diffuse scattering intensity has shown that the Stokes-Wilson (asymptotic) scattering by the Coulomb-type defects was observed [3]. The type of the asymmetry of the diffuse scattering is related with the formation of structural defects of the vacancy-type. In the same region of the crystal, concentration of E7 center was one order of magnitude higher than that of other deep level centers.

The maximum values of the gamma-ray integrated reflectivity are comparable to the kinematical value in the near-the-surface region and to the dynamical value at greater depths of crystal.

Comparison of the gamma-ray diffraction and DLTS data suggests that the formation of E3, E5 and E7 deep level centers during heat treatments in nonoxidizing or chlorine-containing atmosphere takes place under Si supersaturation with vacancies and excess vacancies play the major role in their formation.

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GAMMA-RAY DIFFRACTOMETRY RESEARCHES OF CHAOTICALLY DISTRIBUTED DISLOCATIONS IN QUARTZ SINGLE CRYSTALS

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Method of the non-destructive control of dislocation density in bulk single crystals, based on measurement of integrated reflectivity (R_i) high-monocromatic short-wavelength gamma-radiation is developed. The researches of a structural perfection degree of the single crystal quartz specimens were carried out by a method of a diffraction of monochromatic gamma-radiation from a source of activated by neutrons ^{198}Au ($E = 412$ keV, $\lambda = 0.03$ Å, $\Delta\lambda/\lambda \leq 10^{-6}$), at the gamma-ray diffractometer of PNPI RAS. Quartz single crystals with dislocation density, varying in a small range $0-200$ cm/cm^3 (by data of etching), were chosen as objects of research.

According to the analysis, carried out in [1], processes of a diffraction of gamma-radiation in low-dislocation quartz single crystals are well-described within the framework of assimptotic variant [2] of the statistical dynamical theory of diffraction (SDTD) [3, 4]. Taking into account a smallness of Bragg angles for gamma-radiation and having cariied out averaging on negligible small thickness oscillaiions of intensity, passing from intensity to integrated reflectivity, from the formula (7) in [5] we obtaine following rather simple expressions:

$$R_i = R_{soh} + R_{inc} ,$$

$$R_{coh} = E \cdot R_{dyn} ,$$

$$R_{inc} = 2(1 - E^2) R_{dyn} t/\Lambda_0 ,$$

$$\Lambda_0 = V_0/(\lambda r_0 F_{hkl}) ,$$

where R_{coh} – coherent part of integrated reflectivity, R_{inc} – incoherent part, E – average lattice phase (in conventional theories it is Debye-Waller static factor), R_{dyn} – dynamical limit of integrated reflectivity, Λ_0 – extinction length, V_0 – elementary cell volume, λ – wavelength of used radiation, r_0 – classical electron radius, F_{hkl} – structural factor, t – effective thickness of specimen in direction of incident radiation.