

## INVESTIGATION OF INFLUENCE OF $\text{Co}^{60}$ $\gamma$ - QUANTA TO RECOMBINATION PROPERTIES OF THE COPPER DOPED SILICON

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The aim of the work is to study the influence of post-thermal diffusion and  $\gamma$ - irradiation to the recombination properties of rapid and slow cooled copper doped silicon.

As an initial material the n-Si<P> with  $\sim 5$  and 2000 Ohm·cm specific resistance was used. The dislocation density is taken to be  $\sim 10^4 \text{ cm}^{-2}$ . Doping of silicon by copper carried out in the temperature range of 1050÷1300 °C with succeeding I and II type cooling those rapidity was 30-40 deg/min (I type samples) and 250-300 deg/min (II type samples). At the same time it is investigated n-Si<P> samples which were under analogically heat treatment but without copper doping. The life-time of the charge carriers was determined using the stationary photoconductivity method.

A new series of results are obtained.

They are: it is revealed that by increasing of the copper concentration in p-Si<P,Cu> and n-Si<P,Cu> the magnitude of  $\tau$  increases in comparison with control silicon. The effect is explained by intensification of micro-heterogeneity on conductivity in the compensation process of the material.

It is shown that by electro physic and recombination properties in the I type n-Si<P,Cu> and p-Si<P,Cu> samples the thermo stability in 350 – 500 °C is observed.

It is discovered that the changing of  $(\tau/\tau_0)$  appreciably differs one from other in I and II type samples after irradiation by  $\gamma$ - quanta. In the rapid cooled samples  $\tau$  is more radiation stable than slow cooled samples up to dose  $\sim 2 \cdot 10^8 \text{ R}$  and this effect is explained with a high concentration of electroactive copper atoms in the samples. Last ones connected with post diffusion cooling. At that by increasing of copper atoms concentration the radiation stability increases.



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## ORIENTATION OF QUARTZ NANOCRYSTALLITES IN THE SILICON LATTICE

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Basing on the study of medium angle diffuse X-ray scattering from silicon single crystals, it was supposed to be due to rod like oxygen precipitates [1]. It was shown by us later, that depending on the growth conditions, as-grown silicon single crystals contain quartz crystal inclusions at an amount of 0.3 ÷ 0.5 wt. % [2]. Since it has not been done before, the aim of this



work was to study the shape and orientation of quartz inclusions relative to a chosen axis of the silicon crystal lattice.

We studied p-Si single crystals of one crucible origin with the specific resistance  $\rho_0 \approx 1 \div 10$  Ohm-cm with different cut surfaces parallel to the crystal planes (100), (110) and (111). All the samples were cut and polished in the bar form with the sizes of  $20 \times 12 \times 1.5$  mm<sup>3</sup>. The dislocation density was  $N_D \approx 10^1 \div 10^3$  cm<sup>-2</sup>, the concentrations of oxygen and boron were  $N_O \approx 2 \div 4 \times 10^{17}$  cm<sup>-3</sup> and  $N_B \approx 3 \cdot 10^{15}$  cm<sup>-3</sup>. Structure was analyzed at the set-up DRON-3M ( $\lambda_{CuK\alpha} = 0.1542$  nm) at the room temperature in the angle range of angles  $2\Theta = 10 \div 70^\circ$ .

The diffraction spectrum of the sample cut in (111) includes 5 selective reflections and the only diffuse one at  $2\Theta \approx 20^\circ$  ( $d/n \approx 0.3136$  nm), having a large width 0.1032 rad, which is due to presence of amorphous SiO<sub>x</sub> precipitate in the surface layer of silicon single crystal. The dominative selective line with  $d/n \approx 0.3136$  nm at  $2\Theta \approx 28.5^\circ$  belongs to reflection from {111} planes of the silicon lattice and the second less intensive one comes from the same planes with Cu<sub>K $\beta$</sub>  radiation. Another selective reflection of a medium intensity at  $2\Theta \approx 59^\circ$  with  $d/n \approx 0.1568$  nm is its second order (222) and forbidden by the weakening laws. The rest narrow but weak lines with  $d/n \approx 0.3345$  nm at  $2\Theta \approx 26.6^\circ$  and 0.2468 nm at  $\approx 36.6^\circ$  correspond to the diffraction reflections (101) and (110) from the crystal quartz lattice SiO<sub>2</sub>. It means that they are caused by optimally oriented quartz particles with the normals coinciding with that of reflecting (111) plane of the silicon matrix. Besides, there also occurs modulation of the background level in the scattering angle range  $2\Theta \approx 43-70^\circ$  with some maximum about  $52^\circ$ , which is indicative of other quartz particles with the normal parallel to another crystal axis. The maximum observed at  $52^\circ$  did not appear by case, since the angle between (111) and (100) planes is  $\sim 54^\circ$  in a diamond like structure, and may relate to the enhanced background modulation in the samples cut on (100).

Indeed, the X-diffraction pattern for the samples cut on (100) contains 4 intensive selective peaks and 2 diffuse reflections. The selective peak with  $d/n \approx 0.1358$  nm at  $2\Theta \approx 69.3^\circ$  belongs to the main reflection (400) from the silicon matrix. The other with a medium intensity at  $\approx 61.2^\circ$  is its  $\beta$ -component. The structure peaks with  $d/n \approx 0.2711$  nm at  $33^\circ$  and  $\approx 0.5431$  nm at  $\approx 16.2^\circ$ , having a medium intensity too, are the second (200) and the first (100) orders of the main reflection (400). They are forbidden for diamond structures by the weakening laws, yet they can be observed experimentally in this case. Thus, all selective reflections observed in this orientation belong to the silicon lattice. Therefore in this case there the quartz particles do not exist with the optimal orientation coinciding with (100) of silicon crystal, so it is impossible to see their selective reflections. The first diffuse reflection of a medium intensity with  $d/n \approx 0.493$  nm occurred at  $2\Theta \approx 18.2^\circ$  belongs to amorphous SiO<sub>x</sub> on the surface of silicon crystal. The second diffuse reflection with  $d/n \approx 0.246$  nm at  $42.5^\circ$  is due to these particles, but in the sample bulk, which are oriented mainly along [110] direction, because the angle of this peak coincides with that  $\sim 45^\circ$  between the (100) and (110) planes.

The diffraction spectrum of silicon cut along (110) contains 5 selective reflections and one diffuse scattering. The analysis has shown that the most intensive selective peak with  $d/n \approx 0.1358$  nm at  $2\Theta \approx 47.5^\circ$  belongs to reflection from (220) planes of silicon lattice, while a line at  $\approx 42.5^\circ$  is its  $\beta$ -component. The rest selective reflections come from the crystal lattice of silicon dioxide particles, among them (202) peak with  $d/n \approx 0.1669$  nm at  $2\Theta \approx 54.8^\circ$  dominates, (211) peak with  $d/n \approx 0.1538$  nm at  $60^\circ$  is medium, and (100) with  $d/n \approx 0.4254$  nm at  $\approx 20.8^\circ$  is weak. It is indicative that the normal [110] of the (110) plane of the silicon lattice almost coincides with that [202] of (202) plane of the quartz crystal particle with the characteristic size of  $\sim 14.5$  nm, therefore the peak (202) is high intensive. Normals [211] and [100] to planes (211) and (100) of



quartz particles make the angles of 30 and 45° with the normal [110] of the corresponding plane of silicon lattice. Diffuse reflection with  $d/n \approx 0.271$  nm at  $2\Theta \approx 33^\circ$  is due to  $\text{SiO}_x$  precipitates at the Si-SiO<sub>2</sub> boundary.

Thus, it was shown from the analysis of selective reflections of silicon crystals cut along (111) and (110) that SiO<sub>2</sub> quartz crystal nano-particles are oriented along [110] direction of the silicon matrix.

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## STUDY OF GAS-SOLID EXCHANGE PROCESSES IN HIGH-TEMPERATURE PROTON CONDUCTORS

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Properties of oxides with perovskite structures are of interest both from applied and scientific points of view. It is well known that properties of the oxides depend dramatically on oxygen stoichiometry. Often it is necessary to create oxygen vacancies in the oxide lattice to get the needed oxide properties such as proton conductivity. As a rule vacancies in oxide lattice are created by partial substitution of cation B in oxide with ABO<sub>3</sub> structures by cation with lower valence. Further it is considered that properties of the oxides, for example, proton conductivity depend mainly on cation-dopant nature not on structure and state of electron subsystem. But some results indicate that both "fine" features of lattice structure (symmetry group) and features of electron structure due to e.g. mixed valence states of cations of transition elements are responsible for wide variety of the oxide properties.

Special role of oxygen in proton conductivity is caused by the fact that oxygen ion in the oxide lattice serves both as a trap for hydrogen and preferable way of hydrogen migration. That is why it is necessary to know states and mobility of oxygen in the oxide lattice.

Analysis and comparison of the results received by different methods allows getting new interesting information about processes of gas-oxide exchange.

In this work the results on oxygen exchange for barium cerates received by equilibrium and non-equilibrium methods are discussed. As a result a model for description of oxygen nonstoichiometry of barium cerates as a function of PO<sub>2</sub> is suggested.

Thermodesorption spectra of oxygen molecule release from barium cerates for different sample treatments are shown in fig.1.