Strength of irradiated single-crystal silicon

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The irradiation in the cardinal image changes a condition of a subsystem of structural defects and, accordingly, influences physico-mechanical properties of monocrystal silicon. Influence of an irradiation on microhardness of semiconductor materials is investigated in detail enough [1, 2]. However the influence isovalent impurity on mechanical characteristics of irradiated silicon monocrystal was not investigated.

In the present work it was investigated influences of an electron (4 MeV, $\Phi = 5.10^{12}$-1.10^{15} sm^{2}) and neutrons ($\Phi = 5\cdot10^{16}$ - $5\cdot10^{18}$ sm^{2}) irradiation on strengthing properties of the silicon single crystal doped by germanium at cultivation from melt by Czochralski method. The germanium concentration (N_{Ge}) was determined by neutron activation analysis and was varied in a range $3\cdot10^{18}$ - $1{,}7\cdot10^{20}$ sm^{3}. The interstitial oxygen concentration was measured on IR absorption spectra and was $9\cdot10^{17}$ sm^{3} in all investigated samples. Single crystals had nominal resistivity of ~10 Ω·cm. The strength of the single crystal was assessed using microindentation method. Microhardness (H) was measured by a standard technique using a PMT-3 tester. The measurements results were analyzed using statistical methods. The microhardness data were found to follow a normal (Gaussian) distribution. Microfragility was determined by a standard technique. Factor of viscosity of destruction (K_{IC}) paid off the length of a radial crack at a print.

It is established, that Ge doping was reduced microhardness both initial and the irradiated crystals of silicon. The most strongly given effect is expressed in the neutron-irradiated samples. The Ge doping was suppresses effect of radiating hardening in silicon. The effect of radiating hardening was observed only in not Ge alloyed samples. At $N_{Ge} > 3.10^{19}$ cm^{-2} the electron irradiation did not change microhardness. In the samples irradiated with neutrons width of casual distribution of microhardness was increased. That testifies to heterogeneity of a material and presence in silicon of defect congestion with the sizes ~1-5 microns, comparable with a size of a print at small loadings.

It is revealed, that isovalent Ge impurity reduces crack stability of silicon crystals. The Ge doping leads to increase in microfragility of silicon. Experimental results are explained in view of influence of fields of the elastic pressure created by Ge atoms in single crystals of silicon. It is shown, that the spatial charge, which formed at neutrons irradiation, increase microfragility of single crystals of silicon. Isovalent Ge impurity was suppresses the specified effect.

References

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