Structure and nanomechanical properties of deuterium-implanted monocrystalline silicon

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Silicon is the most common material of modern electronics. Implantation of hydrogen into the silicon and subsequent annealing are applied (Smart-cut technology) to create microelectronic devices. Improving the characteristics of the resulting structures was achieved by implantation of deuterium instead of hydrogen [1]. Nanomechanical properties of silicon studied in detail [2], but the depth profile of mechanical properties modified by ion-beam irradiation was rarely reported.

In this work, the mechanical properties were investigated on crystalline silicon (111) samples irradiated by D_2^+ ion beam (energy of 24 keV, fluences from 1×10^{16} to 1×10^{18} D/cm^2 at temperature 293 K). Nanoindentation performed on Nano Indenter G200 device using CSM option which controls the hardness and elastic modulus of the depth of indentation during the loading segment.

The method of Raman spectroscopy showed that at implantation doses $\leq1\times10^{17}$ D/cm^2 deuterium is bound to defects such as vacancies and formed a small percentage of amorphous silicon phases, after increasing the implantation dose $\geq$ 5×10^{17} D/cm^2 dominant phase is amorphous silicon. The ratio between the amorphous and crystalline phases in the implanted layer significantly affects the mechanical properties of silicon. Nanohardness of initial silicon is at 11.8 ± 0.3 GPa, the presence of bound vacancies implanted deuterium results in increased nanohardness to 14.2 ± 0.4 GPa, and the presence of a large number of amorphous phase in contrast leads to a drastic reduction of silicon nanohardness to 3.6 ± 0.1 GPa. Determined width of "buried" layer near the surface of the silicon, which is ~ 100 nm.

1. *Misra D., Jarwal R.K.* Metal-oxide-silicon diodes on deuterium-implanted silicon substrate // Appl. Phys. Lett.-2000.-76, N 21.-P. 3076-3078
2. *Domnich V., Gogotsi Y., Dub S. N.* Effect of phase transformations on the shape of unloading curve in the nanoindentation of silicon // Appl. Phys. Lett.-2000.-76, N 16.-P. 2214-2216.