Nanocomposites and nanomaterials

Formation of nanoclusters and electrically-active centers in Czochralski silicon with carbon low-energy ion implantation

B. Romanyuk[1], V. Melnik[1], V. Popov[1], V. Litovchenko[1], V. Babich[1], V. Il'chenko[2], V. Kladko[1], O.Efremov[1]

[1] V. Lashkarev Institute of Semiconductor Physics NAS of Ukraine. 03028, Prospect Nauki 41, Kyiv, Ukraine.
E-mail: romb@isp.kiev.ua

[2] Radiophysical Faculty, National Taras Shevchenko University of Kyiv, 03022, Glushkov av., 2, building 5, Kyiv, Ukraine.

Heat treatment of silicon wafers with a high content of oxygen (Czochralski-Si, Cz-Si) in the temperature range of 400 to 1200°C leads to formation of the numerous types of microdefects, including electrically-active thermodonors (TD). Significant influence on these processes gives carbon impurity. Carbon inclusions in Si matrix gives rise tensile stresses in Si around carbon atoms that stimulate the formation of SiO_x nano-inclusions with TD activity. Therefore, there are a possibility for formation of super-shallow p-n junctions (<100 nm) with low-energy ion implantation C+ ions into crystalline silicon.

Boron doped Cz-Si (100) wafers with oxygen concentration of $8x10^{17}$ cm^{-3} were implanted by C^+ ions with energies in the range of 20 to 140 keV and dose D within $6x10^{12}$-$1.3x10^{15}$ cm^{-2}. To study the kinetics of electrically-active center formation it was carried out annealing at T = 550 - 750°C for 1-300 min in argon ambient. The current-capacity and current-voltage characteristics and photovoltaic properties of the formed diode structures with the TD centers have been measured. For information about the type, size and concentration of structure defects the methods of the X-ray diffraction curves of reflection and diffuse scattering, and electron microscopy techniques have been used.

It was determined the TD center concentration dependence on the implantation mode and annealing temperature. The center activation energy is 0.012 eV, which is a typical value for the single-charged TD in Cz- Si. It is shown that during annealing of the carbon implanted samples the spherical amorphous clusters are formed. The cluster size is about 1 nm and concentration ~ $5 \cdot 10^{16}$ cm^{-3} (close to TD concentration). There is a strong correlation between the concentration of interstitial type defects of and concentration of thermodonor centers.

The changes in the critical cluster radius, depending on the dose implantation of carbon and interstitial oxygen concentration have been determined.