Nano-phase Formation at Ion-Beam Synthesis

Litovchenko V.G., Melnik V.P., Romanyuk B.M., Popov V.G.

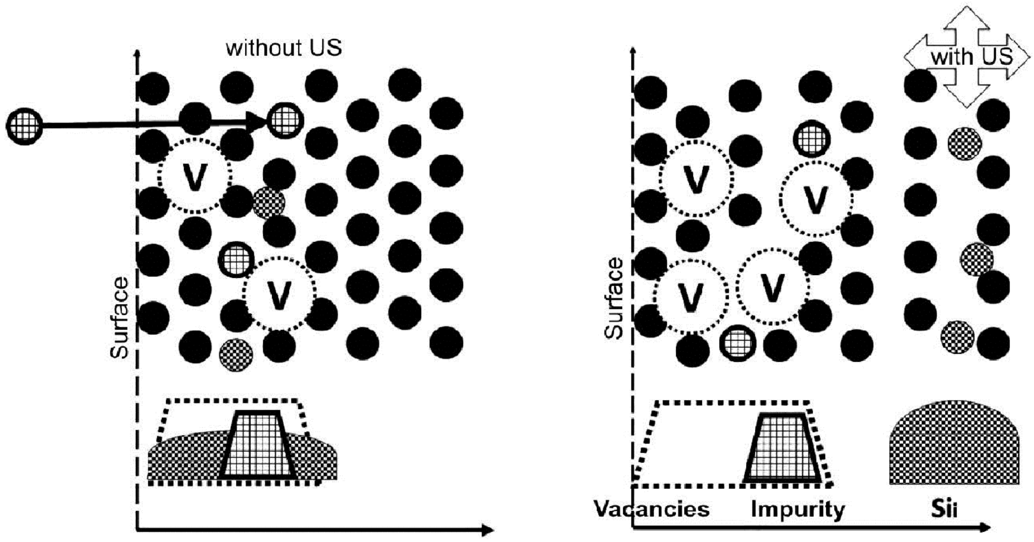
V. Lashkarev Institute of Semiconductor Physics NAS of Ukraine, Kyiv, Ukraine.

Intensive research of the nanocluster-conteining structures is caused by unique properties inherent to such structures that are not characteristic for a bulk material. One of such character of silicon nanoclusters (Si-nc) is the emission of light in the visible and near-infrared region of the spectrum.

At combined use of a number of technological procedures, such as ion-induced formation of nanoclusters, modifications of the Si-nc/SiO_2 interfaces, passivation of non-radiative recombination centers, it is possible significantly (by more than an order of magnitude) increase the photoluminescense efficiency compared with the traditional method of formation of luminescent structures (thermal decay of non-stoichiometric SiO_x film, etc.).

We have investigated the effect of implantation a number of impurities (H, C, N, Al, Ti) on the formation and modification of luminescent structures containing silicon nanoclasters, embedded in the dielectric matrix. It was established that implantation of carbon, nitrogen and aluminum (stimulants of the SiO_x phase decay) and the next high-temperature annealing (1100-1200 °C) during the formation of Si-nc in silica matrix significantly accelerates the nucleation and growth processes of silicon nanoclusters. The basic mechanisms of this effect is the binding of excess oxygen in the region of Si-nc growth, and reduction (offset) of local mechanical stress during silicon nano-inclusion growth. Controlled introduction of these impurities (at 0.1 - 2 atomic %) can influence the size and concentration of nano-clusters and thus change the spectral characteristics of the luminescent structures. In particular, the introduction of carbon and nitrogen increases the concentration of smaller clusters accompanied by increased (several times) photoluminescence intensity in the short-wave region of the spectrum that is consistent with the predicted quantum-dimensional mechanism. In addition, nitrogen effectively passivates non-radiative recombination centers, which leads to a general increase in the intensity of radiative recombination. Aluminum, intensely absorbing oxygen, creats conditions for rapid Si-nc nucleation in the early stages of their high-temperature formation.

Another way to influence the growth of nc-Si is proposed combined method of acoustic-stymulated ion beam doping (synthesis) of solid targets that can accelerate the redistribution of radiation defects generated by the interaction of accelerated particles with solid (Figure 1). This allows you to influence the rate of quasi-chemical reactions in nanoscale structures, stimulate (accelerate or reduce) processes of mass transport and thus change the conditions of the formation, growth and decay of the phases in solid matrices. The introduction of ultrasonic waves at ion-beam synthesis of metal clusters in SiO_2 matrix, as it is shown by our experiments, leads to increased formation of metallic nanoclusters (Cu, Ag), Figure 2. The average size of clusters may be increased almost twice.



a *b*

Fig. 1. Distributions of radiation-induced defects after the implantation (a) without and (b) with the in situ US treatment.

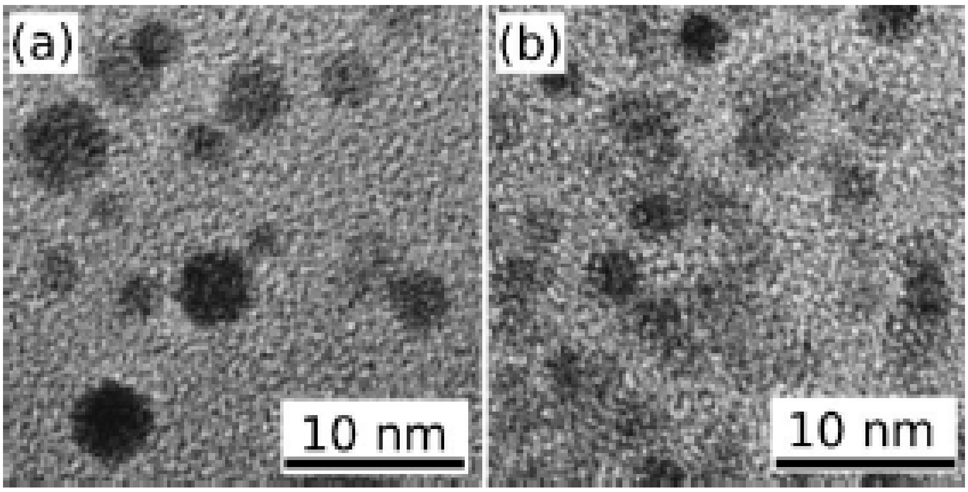


Fig. 2. TEM images of copper clusters in the SiO_2 film synthesized by implanting $^{63}Cu^{+}$ ions to the dose $D_{Cu} = 5\times10^{15}$ cm^{-2}: implantation (a) with and (b) without US treatment.