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Ion Beam Synthesis and Characterization of A^3B^5 Nanocrystals in Si and SiO_2/Si for Optoelectronic Systems

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We have studied the ion-beam synthesis of InAs, InSb and GaSb nanocrystals in Si and SiO_2/Si by high-fluence implantation of (As + In), (Sb + In) and (Ga + Sb) ions followed by furnace and rapid thermal annealings. In order to characterize the implanted samples transmission and cross-sectional electron microscopy (TEM), Raman spectroscopy (RS) and low-temperature photoluminescence (PL) techniques were employed. It was demonstrated that by varying the ion implantation temperature, ion fluence and post-implantation annealing duration and temperature it is possible to form InAs, InSb and GaSb nanocrystals in the range of sizes of (2 - 80) nm.

Figures 1-5 shows the results of the structural and optical investigations.

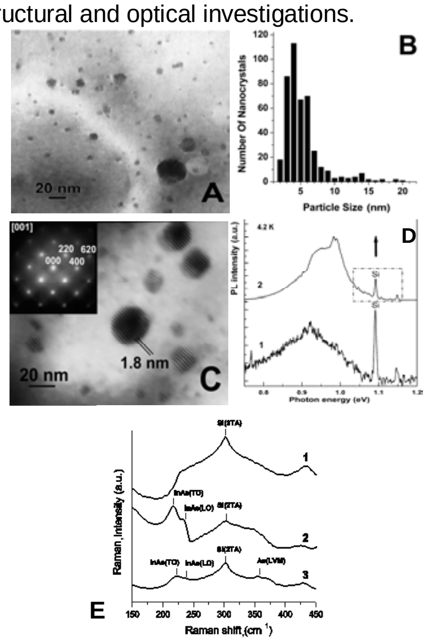

Fig. 1. Si (100) implanted with As (245 keV, 5×10^{16} cm^{-2}) and In (350 keV, 4.5×10^{16} cm^{-2}) at 500 °C. TEM plan-view images and precipitate size distributions of the samples annealed at 900 °C for 45 min (*A – C*), PL spectra (*D*) of the as-implanted sample (curve *1*) and the sample annealed at 900 °C for 45 min (curve *2*), RS spectra (*E*) of the virgin Si (curve *1*), as-implanted sample (curve *2*) and the sample annealed at 900 °C for 45 min (curve *3*)

TEM and RS results confirm the crystalline state of the clusters in the silicon matrix after high-fluence implantation of heavy (As + In), (Sb + In) and (Ga + Sb) ions. A broad band in the spectral region of 0.7 – 1.1 eV is detected in the photoluminescence (PL) spectra of the samples.

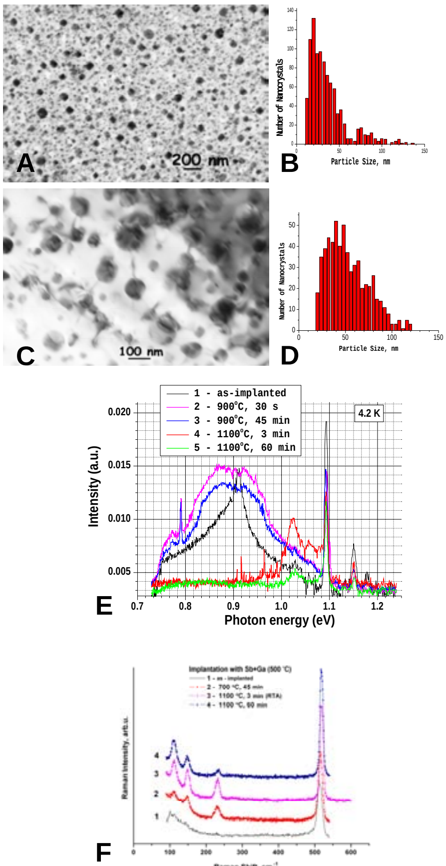

Fig. 2. Si (100) implanted with Sb (350 keV, 5×10^{16} cm^{-2}) and Ga (250 keV, 5×10^{16} cm^{-2}) at 500 °C. TEM plan-view images and precipitate size distributions (A - D) of the samples annealed at 900 °C for 45 min (A, B) and at 1100 °C for 60 min (C, D), PL spectra (E) and RS spectra (F) of the samples annealed in different regimes

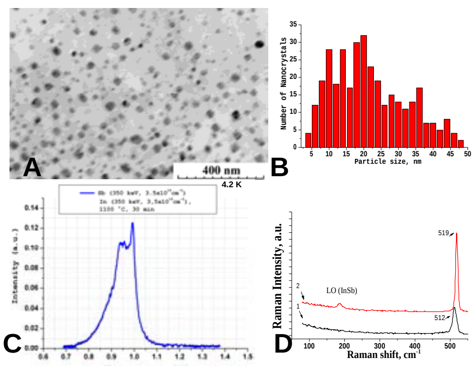

Fig. 3. Si (100) implanted with Sb (350 keV, 5×10^{16} cm^{-2}) and In (350 keV, 5×10^{16} cm^{-2}) at 500 °C and annealed at 1100 °C for 30 min. TEM plan-view image (*A*) and precipitate size distribution (*B*), PL spectra (C*)* and RS spectra (*D*, curve 1 – as-implanted, curve 2 – annealing 1100 °C, 30 min)

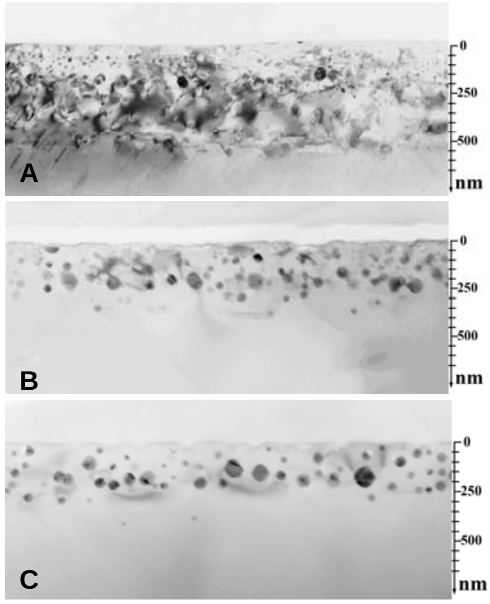

Fig. 4. Si (100) implanted with Sb (350 keV, 5×10^{16} cm^{-2}) and Ga (250 keV, 5×10^{16} cm^{-2}) at 500 °C. TEM cross-section images of the samples annealed at 900 °C for 30 seconds (A), at 1100 °C for 3 min (B) and at 1100 °C for 60 min (*C*)

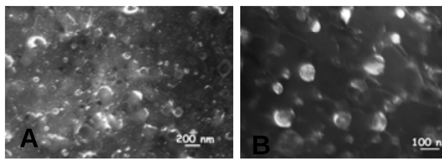

Fig. 5. TEM dark-field plan-view images of Si (100) with A^3B^5 nanocrystals. A – the sample implanted with As (170 keV, 3.2×10^{16} cm^{-2}) and In (250 keV, 2.8×10^{16} cm^{-2}) at 500 °C and annealed at 1050 °C for 3 min, B - the sample implanted with Sb (350 keV, 5×10^{16} cm^{-2}) and Ga (250 keV, 5×10^{16} cm^{-2}) at 500 °C and annealed at 1100 °C for 60 min

We have demonstrated a possibility to produce A^3B^5 nanocrystals in Si by means of high-fluence implantation of ions of fifth and third groups of Periodic Table and thermal processing. It was shown that varying the post-implantation annealing duration and temperature may provide the way to control the nanocrystal sizes and secondary defects formation.

One can see an interesting effect – "lighting" of nanocrystal/Si interfaces at the dark-field images of implanted and annealed samples. We ascribe this effect to a presence of misfit dislocation networks at the A^3B^5/Si interfaces generated as a result of strain relaxation.