Morphological changes of structures with surface quantum dots under the gamma irradiation

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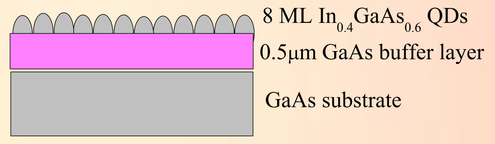
Motivation

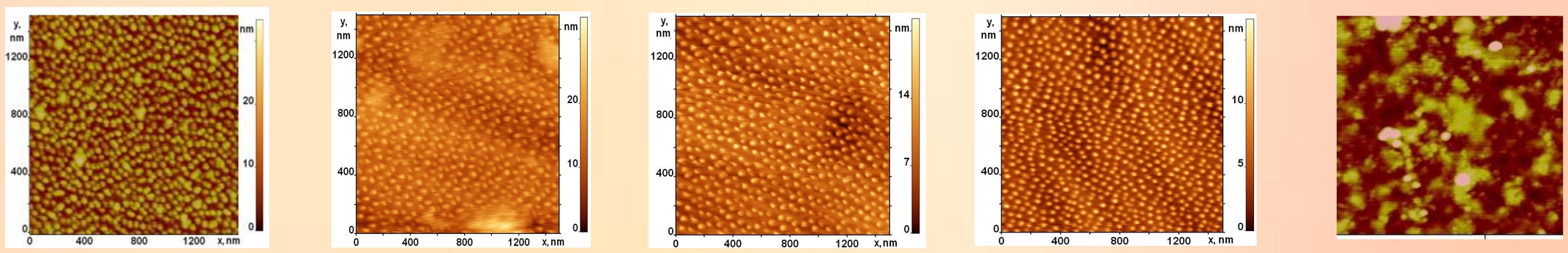
The structures with $In_xGa_{1-x}As$/GaAs quantum dots (QDs) are of considerable interest for researchers due to their wide application as semiconductor lasers and LEDs, photodetectors, solar cells and other optoelectronic devices. When these devices operate in extreme external conditions, radiation damage by electrons, γ-quanta, protons and heavy ions can deteriorate the devices and reduce their service life. Therefore, it is necessary to study the effect of irradiation

- to determine the operational qualities of optoelectronic devices in a radiation-hazardous environment;
- to define the radiation resistance of optoelectronic materials and devices
-to create new radiation technologies by deliberately introducing radiation defects to control the properties of irradiated objects.

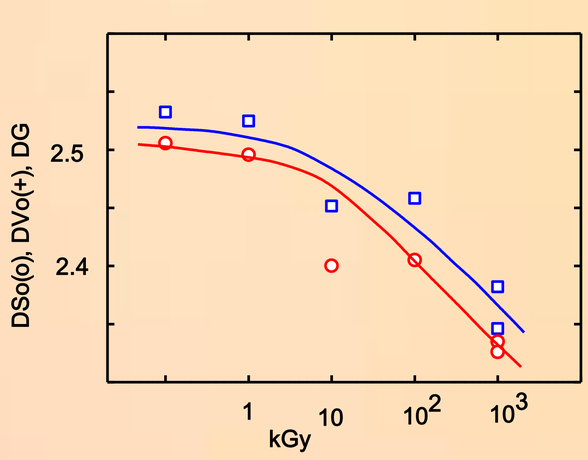
Uncapped $In_xGa_{1-x}As$ single Layer



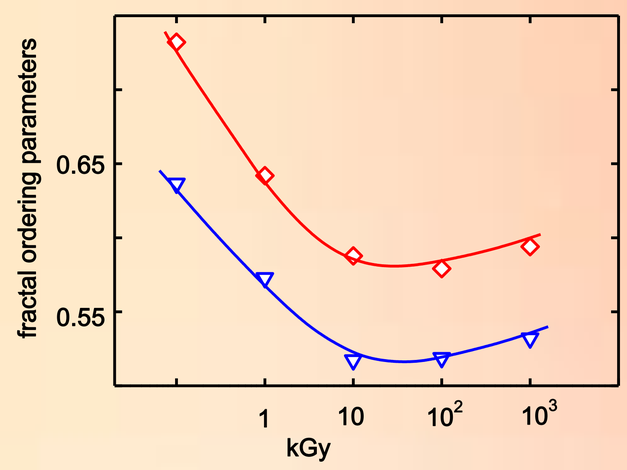
The samples were irradiated by ^{60}Co γ-quanta (quantum energy of 1.2 MeV) at room temperature. The irradiation doses varied in the $1 \div 10^3$ kGy range which corresponded to γ-quanta fluxes of 1.69×10^{14}–1.69×10^{17} quanta/cm^2.



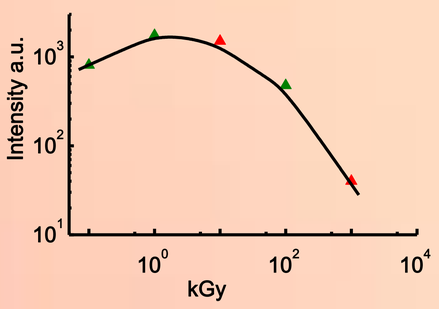
AFM images of the untreated sample (initial) and the irradiated samples



Dose dependences of the Renyi's numbers for the volume (blue) and surface area (red) of surface nanoforms (quantum dots)

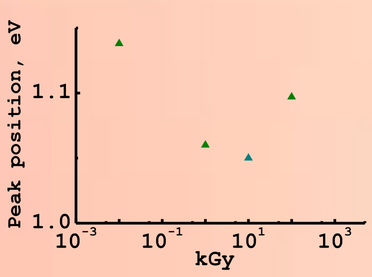


Dose dependences of fractal ordering parameters for volumes (blue) and surface area (red) of surface nanoforms (quantum dots)



Irradiation – related changes of PL

At a dose 1 kGy
-intensity increase
-Red shift of band position
-FWHM invariable
-Ratio I_{rad}/I_{init} increase



At the doses 10-10^2 kGy
-intensity decrease
-Blue shift of band position
-FWHM invariable
-Ratio $I_{rad}/_{init}$ decrease

At dose 10^3 kGy PL quenches

Radiation-induced changes of PL properties of the samples irradiated by γ-quanta: PL intensity and peak position of the PL band.

The effect of gamma-irradiation on morphology and light-emitting properties of the arrays of InGaAs QDs is studied. The MFA method [1] was used to quantify the variation of the geometric parameters of surface nanoforms depending on the dose of γ-irradiation. The dependences of the Renyi's numbers and fractal ordering parameters on the irradiation dose were found. It is shown that :

-There is a blurring (destruction) of interfaces of QD, which correlates quantitatively with a decrease in the values of Renyi's numbers for surface area and volume of surface nanoforms as the radiation dose grows.
-The study of the width of multifractal spectra (fractal ordering parameter) showed the rearrangement of the fractal structure of the surface as the radiation dose grows. The obtained results are in good agreement with the spectral dependences of initial and irradiated structures with surface $In_{0.4}Ga_{0.6}As$/GaAs QDs [2].
-Increase of PL intensity at low irradiation dose 1 kGy can be attributed to low-dose effect, i.e., to the improvement of crystalline quality of the irradiated sample.
-Increasing the radiation dose to 10^3 kGy leads to the formation of new radiation defects near/at the interfaces. Obviously, these defects are the centres of nonradiative recombination, which is the reason for the decrease in the QDs PL intensity.

1. Moskvin P., Kryzhanivskyy V., Rashkovetskyi L., Lytvyn P. // J. Crystal Growth. -2014.-404. -P.204-209.
2. Maslov V., Venger E., Rudko G., Gule E., Strilchuk O. // E-MRS Spring Meeting 2018, June 18-22, Strasburg, France. Symposium K, P.K-17.