Heavy-ion irradiated GaAs crystals for high-efficient generation of terahertz radiation

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Abstract - **GaAs crystals with nanochannels produced as a result of heavy-ion irradiation at the energy of 100 MeV demonstrate a giant (more than 15 times) increasing of efficiency of the THz surface emission. The efficiency strongly depends on the fluence, orientation of nanochannels and temperature. Mechanisms of the efficiency increasing are discussed.**

I. INTRIDUCTION

Efficiency of resonance optical rectification in semiconductor surface emitters increases in materials with irregular or defective structures that can be explained by appearance of intracrystalline fields and decreasing of the carrier relaxation time.

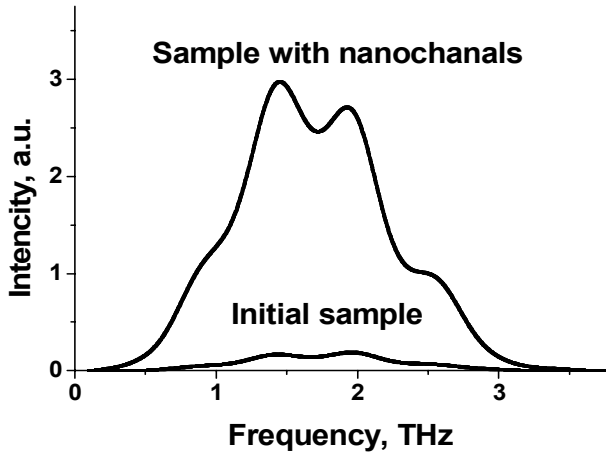
Defects in materials can be caused by the crystal growth procedure: nano-scale inhomogeneous structures appear inside the crystals during their growth at temperatures that are close to the crystallization ones. These bulk defects lead to an increase of efficiency of the THz-radiation generation. It should be noted that the formation and parameters of such bulk structures can not be controlled carefully.

The high-energy ion-beam technique provides a unique possibility of formation of low-dimension structures near the surface of a semiconductor crystal. Irradiation of semiconductor materials with swift heavy ions leads to formation of zones of crystal structure destruction, which are localized around the ions trajectories (tracks or other types of defects). Actually, these destructed areas are one-dimensional defects – nanochannels - somewhat reminding quantum wires according to their properties.

Creation of these defect structures leads to modification of different parameters of an initial sample and, in particular, to changing of the near-surface optical properties and the surface topography. Since the main parameters of irradiation, such as type of the ions, their energy, orientation of channels with respect to a surface, and irradiation density, can be strongly varied, high-ion irradiation is a potential method of the modification of the crystal properties.

II. EXPERIMENTS AND RESULTS

The GaAs crystals were irradiated by 90 MeV Kr ions at fluences up to 10^{13} cm^{-2} , incidence angles of 0^0 or 45^0, and the room temperature. AFM experiments demonstrate an appearance of defects at the surface of crystals. As a result, we have obtained the defects which are located in the vicinity of the Kr-ion trajectory.



The initial non-irradiated crystal, and the heavy-ion-irradiated crystals with different fluences and orientations of channels, were exposed by femtosecond laser pulses (λ=795 nm, pulse duration τ=100 fs,). The results on the THz spectral waveform obtained for both crystals are shown in the figure. Intensity of THz generation from the crystals with the channels obtained by heavy-ion irradiation increases in more than 15 times in comparison with the non-irradiated samples. The generation efficiency depends substantially on the temperature and on the orientation of nanochannels with respect to the semiconductor surface and the laser beam.

Increasing of the THz generation efficiency can be explained by emergence of electric fields at the boundaries between the crystalline semiconductor and the amorphous semiconductor areas that appear in the channels after heavy-ion irradiation. Besides, the orientation of these fields and of the field-induced micro-currents can improve the emission of THz radiation from a semiconductor sample.

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