Generation of THz radiation by photoconductive antennas on based thin films InGaAs and InGaAs/InAlAs.

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Epitaxial low-temperature grown (LT) semiconductor arsenides (Al, Ga, In)As are widely used as materials for photoconductive antennas (PCA) generators and detectors of pulsed radiation in the terahertz (THz) frequency range [1–3]. It is the combination of subpicosecond carrier lifetime, relatively high mobility and high resistivity that makes LT-materials suitable for PCA applications. Lately, In-GaAs has been investigated as a potential candidate for THz-PCA photoconductive material due to room-temperature band gap of 0.74 eV, which allows for 1.56 μm optical excitation with Er³⁺ fiber laser femtosecond pulses [4–6].

The low substrate temperatures result in a non-stoichiometric growth with the incorporation of excess arsenic in the crystal structure. The most common non-stoichiometry-related point defects in LT-arsenides are arsenic antisites with concentrations in the range 10¹⁷–10¹⁹ cm⁻³ depending on the substrate temperature and arsenic overpressure [7–10]. Antisite-related defect band in the semiconductor energy bandgap play a significant role in carrier dynamics. Fast non-radiative recombination of photogenerated electrons and holes through antisite centers results in sub-picosecond carrier lifetimes in LT-materials at optimized growth and annealing conditions [11, 12]. It is generally agreed that main traps of photoexcited electrons are ionized antisite defects [13–15].

A possible approach to increase the resistivity of LT-InGaAs structures is to employ LT-InGaAs/InAlAs superlattices [6,13,16,17]. LT-InAlAs layers have a higher dark resistivity as compared to LT-InGaAs and exhibit deep trap states that are situated energetically below the antisite defect levels of adjacent InGaAs layers that results in a reduction of residual carrier concentration.

Fig.1 shows the amplitude of THz radiation in time domain. It is seen that the signal from an InGaAs /InAlAs-based structure is 5-6 times higher due to a higher bias voltage, which is possible (without sample breakdown) due to higher sample resistance and lower dark current.

Fig.2 shows a comparison of the Fourier amplitude according to the materials of the antennas LT-InGaAs/InAlAs and LT-InGaAs. It is seen that on the spectrum of the LT-InGaAs /InAlAs sample is slightly wider in the range from 0.1 THz to 0.6 THz than that of the LT-InGaAs sample. We explain this effect by the difference between the characteristic relaxation times of electrons in the transition from the conduction band to the antisites.

We determined the characteristic times of electron relaxation by the "pump-probe" spectroscopy method. Fig.3 shows the dependence of the normalized transmission in time domain for the samples of LT-InGaAs and LT-InGaAs / InAlAs. We used 2-exponential model for description experimental curves. On figures τ₁ is an electron capture time (capture by charge AsGa defects) [18,19], τ₂ is a recombination time of captured electrons and holes [17].
Due to the experimental fact that the characteristic relaxation times for the LT-InGaAs/InAlAs sample are less than for the LT-InGaAs, we observed the difference in the spectra for these samples. Summing up, it was found that THz generation is about 5-6 times more efficient in the case of LT-InGaAs/InAlAs superlattice than LT-InGaAs generation. It is found that due to the shorter electron relaxation time in the superlattice, the spectrum of these samples is wider in the range of 0.1-0.6 THz.

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