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

A.A. Leontyev[1], K.A. Kuznetsov[1], G.B. Galiev[2], G.Kh. Kitaeva[1], V.V. Kornienko[1], E.A. Klimov[2], A.N. Klochkov[2], S.S. Pushkarev[2], and P.P. Maltsev[2]

[1] Lomonosov Moscow State University, Moscow 119991, Russia, aa.leontjev@physics.msu.ru
[2] Institute of Ultrahigh Frequency Semiconductor Electronics, RAS, Moscow 117105, Russia

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, InGaAs 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 Er^{3+} 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 10^{17}–10^{19} 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 photo-excited 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.

The 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 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.

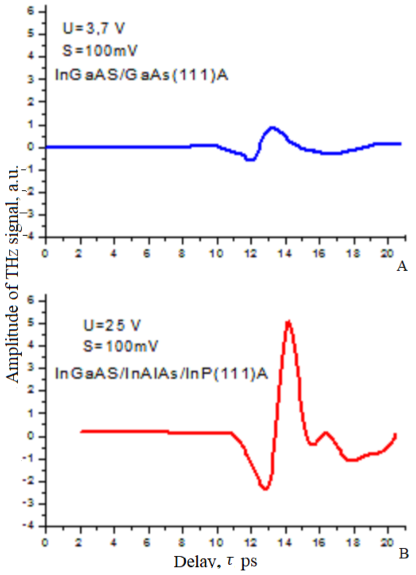

Fig.1. Time-domain waveforms detected for the following antenna materials: A) LT-InGaAs B) LT-InGaAs/InAlAs.

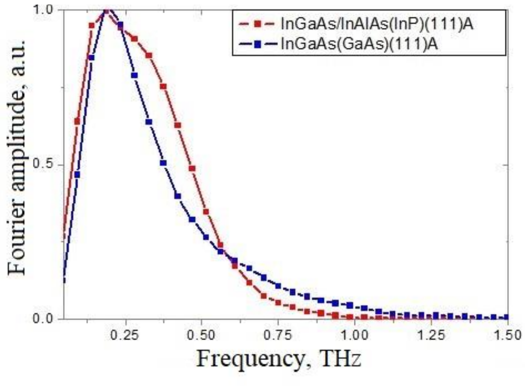

Fig. 2. Compare spectral amplitudes by antenna materials LT-InGaAs(Blue line), LT-InGaAs/InAlAs (Red line).

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-exponentional model for description experimental curves. On figures τ_1 is an electron capture time (capture by charge As_{Ga} defects) [18,19], τ_2 is a recombination time of captured electrons and holes [17].

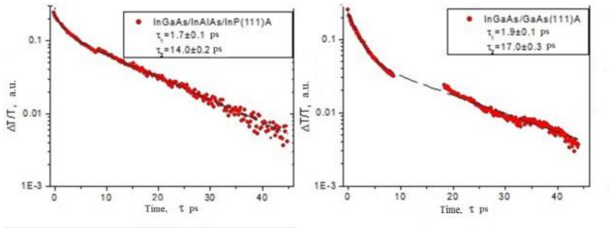

Fig. 3 Change the transmission coefficient in the time domain.

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.

This study was performed under the support of the RFBR grant № 16-02-258a.

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