Development of photoconductive semiconductor switches based on GaAs doped with Cr and Fe

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Photoconductive semiconductor switches (PCSS) can be used as switching devices. They permit to produce a huge current and voltage drops for short periods of time (0.1-1 ns) and are driven by optical signal. PCSS are being used in a variety of electrical and optical short pulse applications. The switches represent S-diodes based on multilayer GaAs-structure doped with deep impurity centers (Fe or Cr) [1-2].

In this paper, results of research of GaAs switches with a switching voltage up to 800 V and a pulse current up to 500 A will be described.

Switching avalanche S-diodes are manufactured by epitaxial-diffusion technology with twice Fe and Cr impurity doping and have n^+-π-ν-n structure. This technology have been used because provides low residual resistance [3].

At experiments with the optical triggering circuit single S-diodes were used (with a lines form) with size of 0.3x0.5 mm^2. Laser irradiation has been fallen perpendicular to the surface of the side with 0.5 mm length. The optical spot with almost circle form was ≈1 mm diameter. Measurements of the optical triggering parameters were carried out in oscillator mode. The main scheme principle is as follows. When the DC voltage U_0 is applied, the delay line is charged through the resistance in time ≈ (2-3)•R_0C (C ≈ 1 nF – the capacitance of delay line). One end of the line is open because the diode is in the closed state and has the high resistance (more than 100 MOhm). When the optical pulse from the optical system reaches over the S-diode, the line closes per the own switching time of diode and discharge occurs on the load resistance R_H. Under impedance matching condition a square pulse is generated. The pulse repetition frequency was 10 Hz. Laser wavelengths were 350-500 nm and 690-1000 nm, laser pulse duration and pulse energy were 10-30 ns and 1-40 mJ respectively.

Fig.1 shows voltage pulses at the load for different triggering pulse energies in oscillator mode generation. The rise time doesn't exceed 0.5-1 ns (the frequency limit of the oscilloscope is 0.5 ns). It should be noted that energy has slight effect on S-diodes residual resistance at voltages closed to the avalanche breakdown. With an increase in energy by two orders of magnitude, the residual resistance decreases by no more than 10%. At lower applied voltages ($U \leq (0.3\text{-}0.6)\cdot U_{breakdown}$) the pulse shape is modified, the rise time becomes larger. When the energy is increased by two orders of magnitude, the amplitude of the voltage increases by 1.5-2 times.

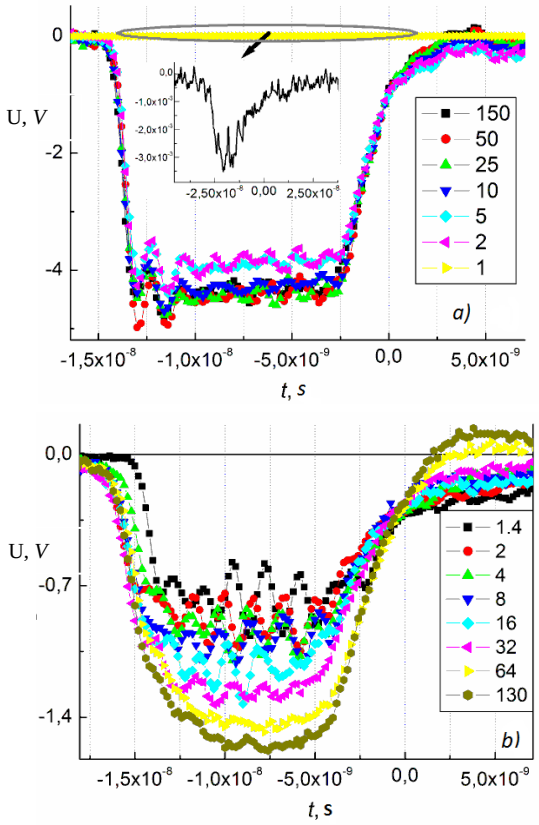

Fig. 1. The voltage pulses at the load of 0.94 Ohms at different optical pulse energies (μJ): (a) 450 nm wavelength at a voltage of 180 V (b) 785 nm wavelength at a voltage of 50 V.

When the energy of laser pulse is below the some threshold value, a photocurrent pulse is observed, which repeats the shape of the optical pulse (insert, Fig. 1a). In this case, the S-diode operates as a photodetector and has a large residual resistance (more than 5 kOhm). It should be noted that the switching of structures occurs due to inherent absorption, and penetration depth of light at the intrinsic absorption coefficient $\alpha \geq 10^4$-10^5 cm^{-1} is not greater than 1 micron.

[1] I.A. Prudaev et al., Instruments and Experimental Techniques, p. 530, Vol. 53, No. 4, 2010
[2] I.A. Prudaev et al., Instruments and Experimental Techniques, p. 521, Vol. 54, No. 4, 2011
[3] S.S.Khludkov et al., editor-in-chief O.P. Tolbanov. – Tomsk : Publishing House of Tomsk State University, 2016. – 258 p