Terahertz luminescence of charge carriers in silicon at uniaxial elastic deformation

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Effective generation of coherent electromagnetic radiation in terahertz range of electromagnetic spectrum is an essential problem of modern solid-state electronics. The first silicon lasing experiments had been realized with infrared excitation of n-Si by CO_2 laser at T = 4.2K [1]. The host Si crystal was doped with shallow donors (P, Bi, As), whose inverted excited states stipulated generation of terahertz radiations in the wave band of $\nu \sim 180\ cm^{-1}$. Further attempts to increase the efficiency of the THz generation in the most perspective semiconductor-Si, gave rise new approaches to the problem [2]. In this work the results of research on THz radiations in the infrared excited n-Si in strong electric fields at uniaxial elastic deformation (UED) and T=4.2 K are presented. Research were carried out for samples Si <P> with concentration of impurity $N_D - N_A = 10^{12}$, $4.0{\cdot}10^{13}$, $2.0{\cdot}10^{14}$, $5.0{\cdot}10^{15}$,and $6.0{\cdot}10^{16} cm^3$ oriented and compressed along the [100] directions. Photoexcitation of carriers was carried out in continuous and impulse regime with a source of monochromatic radiation based on infra-red GaAs diodes. Spontaneous emission was registered in a wide spectral interval in the windows of sensitivity for two cooled photodetectors: Ge <Ga> and n-InSb. The emission increased after increase in conductivity of the samples. The maximum of spontaneous radiation intensity has been observed for Si samples with donors in the range of $10^{13} \div 10^{14}\ cm^3$. In Fig. 1 the typical dependences of emission on the electric field for n-Si with concentration of donors $N_D - N_A = 2.0{\cdot}10^{14} cm^3$ in the window of sensitivity of Ge <Ga> photodetector are shown. With increase of pressure to P=4 kbar, the density of a current and intensity of radiation grow. The further increase of pressure results in saturation of intensity of emission and reduction of current density. In Fig.2, the typical snapshot of current and emission pulses are shown. Apparently, in a sample under UED, after the termination of electric field pulse, the maximum of emission ignition is observed. The amplitude of the peak makes from 0.5 to 1.5 of magnitude of the whole radiation intensity. Some samples were made as bars with the sizes of 3.0x2.5x40.0 mm^3, and with diverge of opposite sides not more than - 5 ", being resonators for modes of full internal reflection. The peak of radiation with amplitude from 1 up to 4 fold of the level of spontaneous radiation intensity was observed for these samples upon termination of electric field pulse. The duration of peak comes from 0.5 to 2 μs.

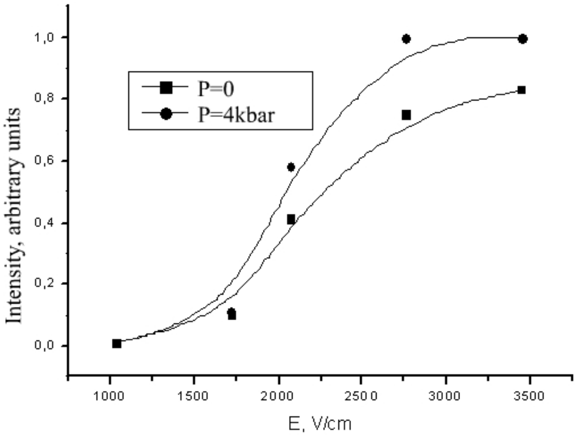

Fig.1 Emission versus electric field for Si <P> with concentration of impurity N_D-N_A=$2.0{\cdot}10^{14} cm^3$ at UED (Ge <Ga> photodetector).

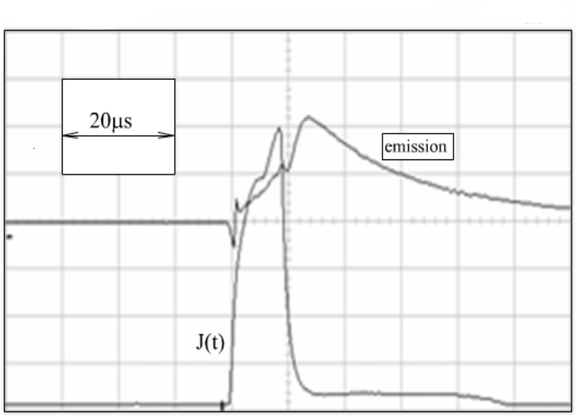

Fig.2 Time dependences of THz emission intensity in a window of a Ge<Ga> photodetector (upper curve) and a current through a sample (lower curve), at E=2200V/cm, P=4kbar.

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[2] S.G. Pavlov, H.W. Hubers, J.N.Hovenier, T.O.Klaassen, D.A.Carder, P.J.Phillips, B.Redlich, and H. Riemann, Phys. Rev. Lett. **96**, 037404 (2006).

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