Terahertz Sensitivity of $Pb_{1-x}Sn_xTe$:In

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It is well known that narrow band gap semiconductor $Pb_{1-x}Sn_xTe$ doped with In behaves like an isolator at liquid helium temperatures. It takes place when its composition is close to x=0.26 and In content is about 1-3 at. %. In this case dark currents are less than 10^{-11}-10^{-12}A for the film thickness equal to 1 μ approximately and bias voltage about 1 V. At the same time $Pb_{1-x}Sn_xTe$:In demonstrates high photosensitivity not only within the fundamental spectral range (up to 20-25 μ) but also far beyond it [1,2].

At T_C≈18-20 K, a ferroelectric phase transition occurs in $Pb_{1-x}Sn_xTe$:In with x=0.26; as a result, the static permittivity decreases from ε≈200000 at T=T_C to ε≈2000 at T=4.2 K [3]. According to [4, 5] this transition is caused by anharmonicity of one of the branches of transverse optical vibrations at the center of the Brillouin zone. This anharmonicity results in instability of vibrations and a decrease in their frequency (the mode softening) down to zero at T=T_C; the frequency increases as the temperature decreases further and as the transition occurs to the ferroelectric phase with a low symmetry. These inferences for $Pb_{1-x}Sn_xTe$ are confirmed by Belogorokhov et al. [6].

After transition to the dielectric state, dark currents in the $Pb_{1-x}Sn_xTe$:In films at T≤20 K are limited by the space charge and the charge-carrier injection from contacts [7]. In addition, the films contain traps that capture nonequilibrium electrons.

The current limited by the space charge before the transition to the conditions of completely saturated traps is written as

$$I = I_0 \cdot q = ee_0 mw \cdot \frac{V^2}{L^3} \cdot \frac{gN_c}{N_t} e^{\frac{E_t - E_c}{kT}} \quad ; \qquad (1)$$

ε is the relative static permittivity of $Pb_{1-x}Sn_xTe$:In, μ is the mobility of electrons, w is the gap length between the electrodes, V is applied voltage, L is gap width,

$$q = \frac{gN_c}{N_t} e^{\frac{E_t - E_c}{kT}}$$

is the quantity that defines the ratio of currents limited by space charge before and after filling of the traps, g is the spin degeneracy factor, E_t and E_c are the energy location of the traps and conduction-band bottom, N_t and N_c are the trap concentration and effective density of states in the conduction band.

The discussed model of terahertz (THz) sensitivity of $Pb_{1-x}Sn_xTe$:In is taking into account its ferroelectric peculiarities. Estimations of THz detectivity were based on the data obtained at T=4.2K using 336.8 μ (f≈0.9 THz) laser radiation as well as 100-200 μ free electron laser radiation. An increase in the current (Fig. 1, curve 2) is related to the absorption of photon accompanied with the generation of one or, more likely, two transverse optical phonons at the center of the Brillouin zone in the phonon branch responsible for the ferroelectric phase transition. Generation of phonons under laser irradiation results in increased low-frequency permittivity and increased total current that is limited by the space charge.

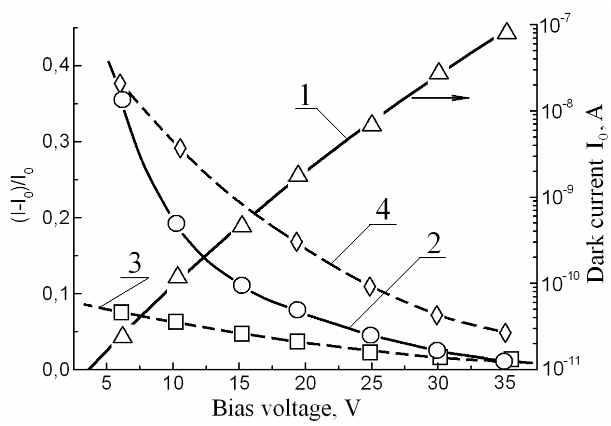

Fig. 1 (1) Experimental current-voltage characteristic of PbSnTe:In sample without illumination; (2) relative variation in the current $(I-I_0)/I_0$ as the result of exposure to the submillimeter laser radiation (λ=336.8 μ); and (3, 4) the calculated relative variation in the current $(I-I_0)/I_0$ as the result of an increase in the sample temperature (induced by the laser radiation) by ΔT=(3) 0.045 and (4) 0.14 K.

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