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MAGNETORESISTANCE OF n -CdTe IN THE "PERSISTENT" STATE*

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In this paper we present results of measurements done on photoexcited carriers in high purity n -CdTe at liquid helium temperature. The photocurrent under near band gap illumination was measured, as well as the long term (≈ 15 hours) photoconductive decay after switching off the light. The transverse magnetoresistance was measured in high magnetic fields in two cases: 1) under external illumination, 2) in the "persistent" state after ≈ 15 h of photocurrent decay. It was shown that in high magnetic fields this magnetoresistance exhibits a quadratic dependence on magnetic field ($\Delta\rho/\rho \approx B^2$) in both cases.

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The "persistent" state of semiconducting compounds is a relatively well-known phenomenon [1, 2]. The state of an illuminated sample is different from the "dark" one. After switching the light off, the transformation to the "dark" state occurs. In certain materials it can be very slow, with characteristic time of the order of hours or days. Such a phenomenon, called persistence, is manifested as a permanent increase in conductivity with respect to the "dark" state. The investigation of such induced conductivity versus time and external magnetic field is presented in this paper. The sample used in our experiments was high-purity n -type CdTe grown by the vertical zone melting method. Its dark resistance at liquid helium temperature was greater than $10^{12} \Omega$, and the mobility at 15 K was in the range of $80000 \text{ cm}^2/(\text{Vs})$ [3]. The sample was in the shape of a rectangular bar of dimensions $5 \times 1 \times 0.5 \text{ mm}^3$ with two nonrectifying contacts at the ends of the sample. The applied electric field was perpendicular to the external magnetic field. The sample was illuminated by a monochromatic light through a fiber-glass light guide.

The experimental procedure was as follows: starting from room temperature, the sample was cooled down in total darkness. A dc voltage in the range of 0.2–10 V was applied after reaching the temperature of $T = 4.2 \text{ K}$. The light was then switched on and the photoconductivity of the sample increased gradually. After

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reaching the saturation value of the photocurrent (PC), the light was switched off and the PC decay was measured. Measurements of the sample magnetoresistance were done during the same experiment. They were obtained for two states of the sample: 1) under illumination, 2) about 15 hours after switching off the light. Every new measurement, as described above, was started at room temperature to ensure the same initial state of the sample.

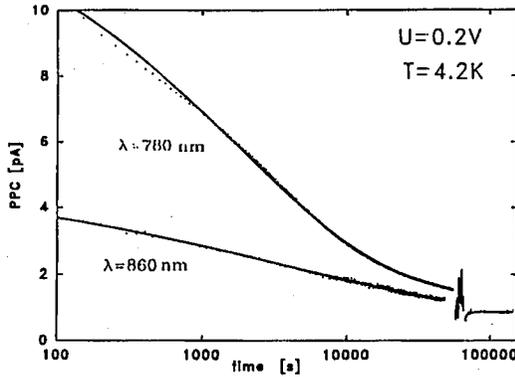


Fig. 1. The decay curves obtained for different wavelengths of excitation light. (1) $\lambda = 780$ nm, (2) $\lambda = 860$ nm, (3) the continuation of curve 1 after applying high voltage (≈ 40 V) to the sample. Points are experimental results. Solid lines — fitted values for the stretched exponential formula.

TABLE

Curve in Fig. 1	I_0 [pA]	I_t [pA]	τ [s]	β [1]	PC under illumin. [pA]
1	1.38	12.2	1740	0.41	1800
2	0.77	4.2	3500	0.29	8.5

Figure 1 shows decay curves obtained for different excitation wavelengths. Experimental points can be fitted very well in a wide range of time by the stretched exponential formula

$$I(t) = I_0 + I_k \exp[-(t/\tau)^\beta], \quad (1)$$

where τ is the relaxation time constant and β — the decay exponent. Such a dependence is characteristic of slowly relaxing, strongly interacting systems [4], such as electrons in a fluctuating potential. Similar behaviour in photocurrent decay curves was observed in other semiconducting compounds such as $Zn_{0.3}Cd_{0.7}Se$

and $\text{Al}_{0.3}\text{Ga}_{0.7}\text{As}$ [1], although the fitting parameters were different from ours. The obtained values of the fitting parameters are presented in Table. For every measurement, after a period of time much longer than τ , the photocurrent approached the value I_0 , which was significantly higher than the dark current (i.e., before illumination). The value of the "dark" current was less than 0.1 pA. As we can see from a comparison of the decay times (see Table), the band gap illumination leads to a shorter carrier lifetime, after switching the light off, than does the below band gap light. This can be interpreted as a result of the conduction mechanism in such a crystal. It cannot be described by the effective mass theory and flat band diagram. Due to the existence of the local potential fluctuations [5, 6], band bending occurs. The photoexcited carriers are separated in real space and can-

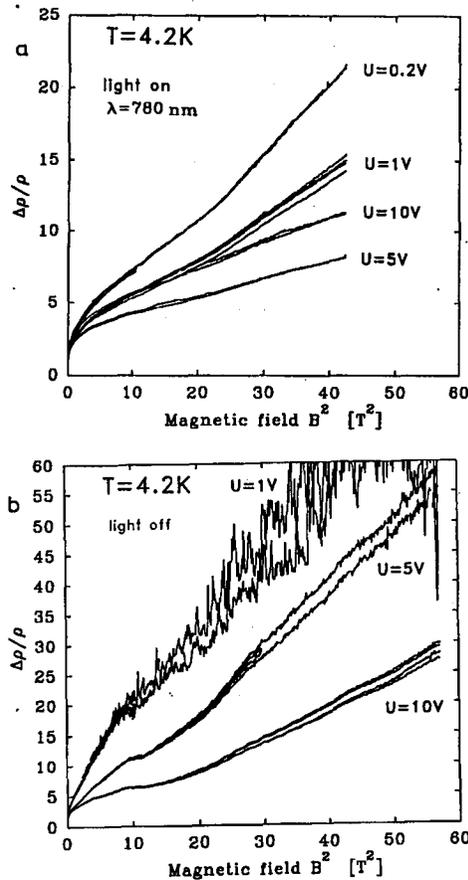


Fig. 2. Relative increase in resistance $\Delta\rho/\rho$ versus magnetic field, where ρ is the resistivity for $B = 0$ and $\Delta\rho = \rho(B) - \rho$ under illumination with light ($\lambda = 780\text{ nm}$) (a), 15 hours after switching the light ($\lambda = 780\text{ nm}$) off (b). The different curves are marked with the value of the voltage applied to the sample (constant during the whole measurement). Note that horizontal scale is not linear.

not recombine. We therefore observe the conduction which is enhanced relative to the "dark" state. As a conduction mechanism one should consider the percolation path conductivity, where electrons are subjected to local "valleys" and "hills" of the potential. In such an approximation all electron traps on the percolation path are filled, and the rest of the electrons (which cannot reach their origins due to potential barriers) contribute to the flowing current. After applying high voltage (≈ 40 V) to the sample, a reconfiguration of the local barriers takes place and thus the percolation paths change. We notice this as a certain decrease in the current (compare curve 2, 3 in Fig. 1). To explain the observed difference in the lifetimes, we have to consider the situation during illumination. Applying band gap illumination, we obtain electrons with higher energies in the conduction band. These electrons can reach higher energies in potential "valleys" and thus can penetrate a wider space along the "valleys" of the percolation paths. Recombination with the parent centres is more probable, due to the larger number of such available centres.

The magnetoresistance under illumination and in the "persistent" state about 15 hours after switching off the light are presented in Fig. 2a and Fig. 2b, respectively. The measurements were done for different applied voltages. In all cases the magnetoresistance shows a quadratic dependence on the magnetic field for fields higher than ≈ 4 Tesla.

$$U/I(B) = AB^2 + C,$$

where B is the magnetic field and U — applied constant voltage.

In both cases (presented in Fig. 2a, b) parameter A exhibits a strong sensitivity to the applied voltage and decreases with increasing electric field. In magnetic fields lower than ≈ 4 T deviations from the quadratic behaviour were observed. The nature of these deviations was different under illumination and in the persistent state. These preliminary results show that there is a significant difference with respect to the simple model, with flat conduction and valence bands. It seems reasonable to take into account the model of a band perforated in real space as the one which could explain the observed behaviour of the sample. The existence of the local potential fluctuations in the sample is the only way of understanding the conduction mechanism(s) in this material.

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