CADMIUM TELLURIDE RADIATION DETECTORS RELAXATION TIME

Alexey Andreev
Doctoral Degree Programme (3), FEEC BUT
E-mail: xandre00@stud.feec.vutbr.cz

Supervised by: Lubomír Grmela
E-mail: grmela@feec.vutbr.cz

ABSTRACT

Resistance of CdTe radiation detectors was measured during long time interval with an applied voltage $U = 16$ V. Detectors were placed into a cryostat. That allowed to hold the temperature constant during the measurements and eliminate the illumination influence. The temperature of the samples was 300 K at first and after some period of time (approximately 1 day) it was sharply raised to 390 K. We observed the resistance slow decreasing with time with temperature T = 300 K and T = 390 K. All the samples have very high value of relaxation time.

The presented samples must have not one but four acceptor or donor levels, some of them are deep levels. We have discovered that the interactions between the valence band and deep acceptor levels or between the conductivity band and deep donor levels cause this long value of relaxation time.

1. INTRODUCTION

In the last years, single crystals of cadmium telluride (CdTe) have become useful as a nuclear radiation detector, an electrooptical modulator, and as an optical material in the infrared range [1, 2]. Therefore, CdTe will not impact on the semiconductor market as silicon has. However, the interest in the above important applications, along with other not so promising using CdTe (electroluminescence and microwave devices, high power laser windows, etc.) has stimulated considerable basic research on single crystals of this material.

We have carried out transport measurements of CdTe single crystals, prepared by Institute of Physics, Charles University in Prague. These crystals are used as radiation detectors. Two low-ohmic samples were used for measurements: F33B8 (*p*-type conductivity) and F35C3 (*n*-type conductivity) and one high-ohmic sample 452B (*n*-type conductivity). Every sample has four contacts: current contacts U_1, U_4 and voltage contacts U_2, U_3. Our measuring set-up allows us a continuing measuring of potential on each contact. The samples were placed into a cryostat, which allows changing the temperature in the range from 77 K to 400 K.

2. MEASURING EQUIPMENT

The measuring equipment is shown in Fig. 1. This equipment is intended for the CdTe detectors transport characteristics study. The studied CdTe samples have voltage and current golden contacts for four-dot measurements method. This method can be used for research of contacts effect on VA characteristics. The equipment allows reading out electric potential from each of contacts. The sample with a load resistor is placed into the cryostat. We can read out the voltage on the resistance, so the current is known. Then we can find the bulk resistance of the sample. The cryostat allows controlling surround work temperature in the range from 77 K to 400 K by a heating spiral. At the same time the cryostat is intended for undesired electrical fields screening.

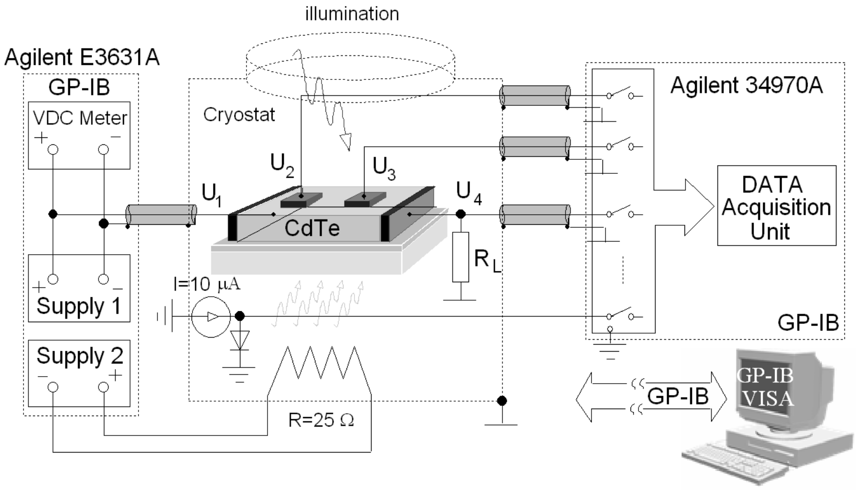

Fig. 1. Block diagram of the experimental set-up.

Programming D/A converter Agilent E3631A is used for VA characteristics and current versus time measurements. D/A converter is also used for automated temperature control into the cryostat. Separated measuring dots are connected to a multiplexer Agilent 34970A with plug-in module Agilent 34902A, which used for measured data A/D converting and connected to the PC by GPIB.

3. MEASURING RESULTS

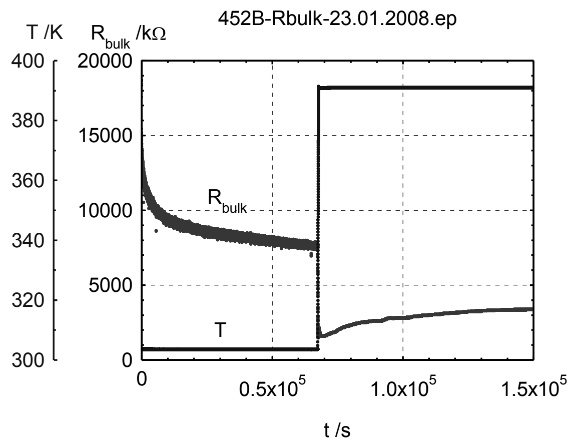

Fig. 2: The bulk resistance of high-ohmic *n*-type sample 452B.

All three samples were measured during long period of time. Applied voltage $U_{ext} = 16V$. The temperature changed twice during measurements: from 303 K to 393 K and then back to 303 K. The relaxation time is very high as we can see from Fig.2 – Fig.4. The resistance changes with temperature changes.

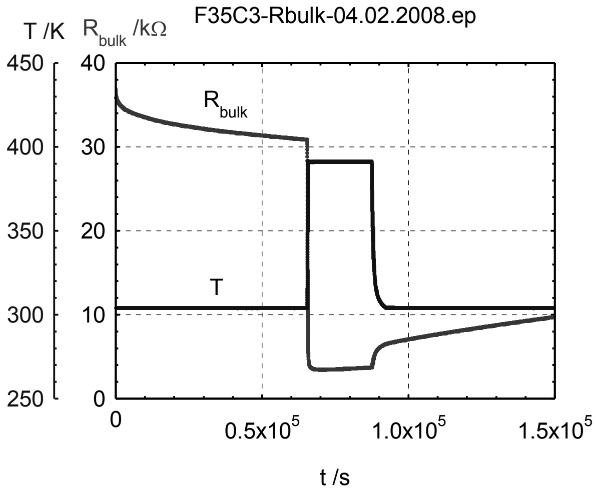

Fig. 3: The bulk resistance of low-ohmic *n*-type sample F35C3

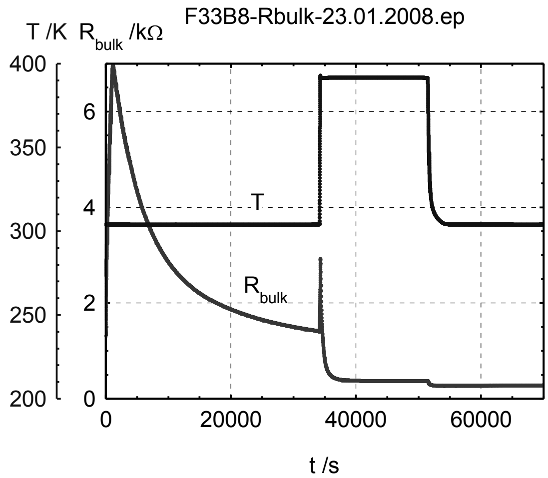

Fig. 4: The bulk resistance of low-ohmic *p*-type sample F33B8

The sample bulk resistance decreased with constant temperature T = 300 K after the measurements started. The parts of graphs with constant temperature T = 300 K are shown in Fig. 5 (high-ohmic *n*-type sample 452B) and in Fig. 6 (low-ohmic *p*-type sample F33B8). All these curves were fitted with sum of four exponents with four different times constant. (Tab.1). This result means, that there are four main donor or acceptor levels in the samples.

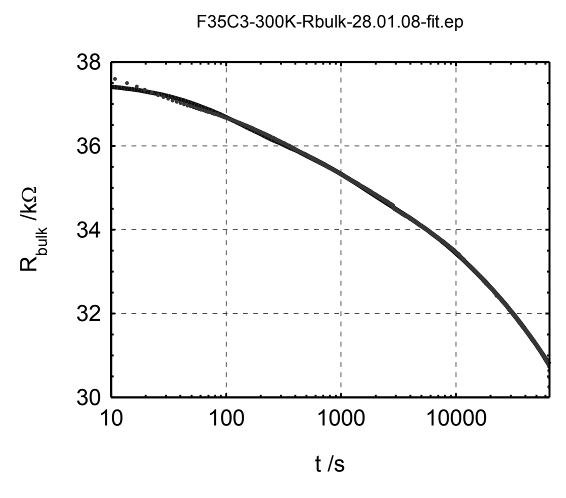

Fig. 5: Bulk resistance of low-ohmic *n*-type sample F35C3. T = 300 K.

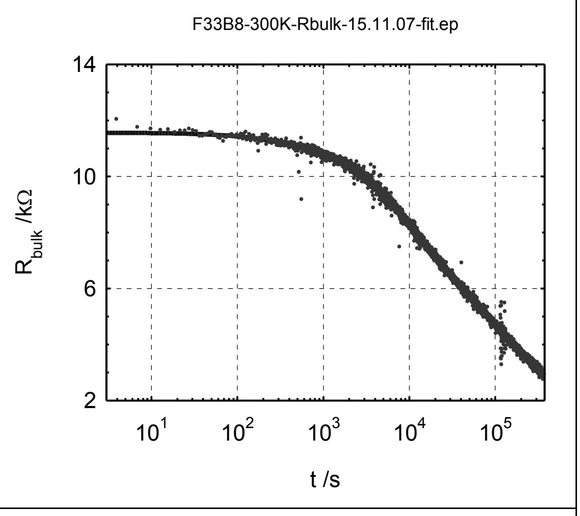

Fig. 6: Bulk resistance of low-ohmic *p*-type sample F33B8. T = 300 K.

At the beginning of measurement, a first level, with time constant $\tau \approx 100$ s in *n*-type samples, and $\tau \approx 400$ s in *p*-type sample, dominates. Time dependence of resistance was measured many times and always time constant had the same value. Then the second level dominates with time constant $\tau \approx 1000$ s in *n*-type samples and $\tau \approx 7500$ s in *p*-type samples. The *n*-type samples have the same values of relaxation time, and it does not depend on the sample resistance. The *p*-type has all values of relaxation time higher than the *n*-type samples.

With temperature increasing, the samples resistances were changing. In *p*-type sample the resistance at first increased and then it started decreasing when the temperature was almost adjusted to 390 K. As it was shown in [3], the holes concentration changes very slowly and the resistance increased at first due to the holes mobility increasing. Then the sample resistance decreases due to the holes concentration slow increasing. The resistance of *n*-type samples was decreasing with temperature increasing.

Sample	Temperature	Fitting curve
452B *n*-type	300 K	y=6.3exp(-x/88)+2.07exp(x/996)+2.6exp(x/4835)+ +2.9exp(x/63000)+6.6
	390 K	y=0.36exp(-x/291)+0.5exp(-x/1143)+1e-4exp(-x/7500)+ +1.67*(1-exp(-x/11990))+1.20
F33B8 *p*-type	300 K	y=0.4exp(-x/406)+2.95exp(-x/7764)+2.25exp(-x/35440)+ +3.7exp(-x/216800)+2.23
	390 K	y=0.12exp(-x/61.65)+1.6exp(-x/286)+0.5exp(-x/910)+ +0.03exp(-x/3314)+ 0.35
F35C3 *n*-type	300 K	y=1.1exp(-x/103)+1.3exp(-x/999)+1.25exp(-x/6897)+ +4.7exp(-x/63000)+29.1
	390 K	y=0.2exp(-x/240)+0.34exp(-x/905)+0.66exp(-x/7447)+ +1.09*(1-exp(-x/16130)) +2.25

Tab. 1. Fitting curves equations for the samples.

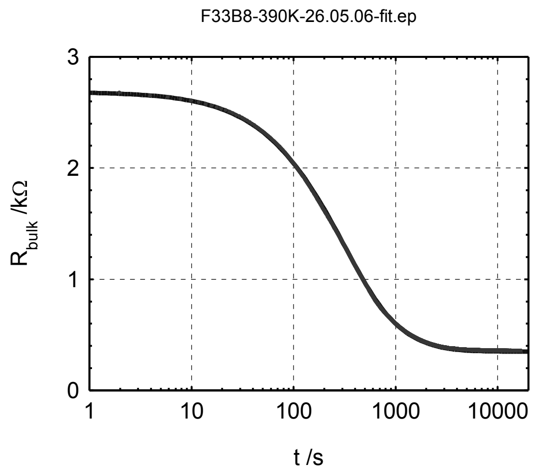

Fig. 7: Bulk resistance of low-ohmic *p*-type sample F33B8. T = 390 K.

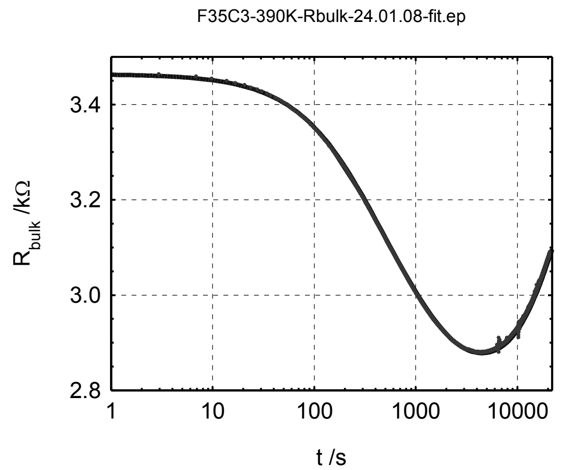

Fig. 8: Bulk resistance of low-ohmic *n*-type sample F35C3. T = 390 K.

After the temperature had adjusted to T = 390 K, the resistance of *p*-type sample decreased slowly (Fig. 7). The resistance of *n*-type samples began to increase after decreasing (Fig. 8). These curves were fitted with four exponents, too. The time constants are the same for *n*-type samples. The *p*-type sample has lower values of time constants. All the fitting curves values are in Table 1.

4. CONCLUSION

Resistances of three CdTe detectors were measured during long time period. Low-ohmic n-type, high-ohmic n-type and low-ohmic p-type detectors were used for the measurements. The measurements show that relaxation time for each of the samples has very high value. Each resulting curve can be fitted with sum of four exponents with four different time constants. That means that there exist at least four dominant donor or acceptor levels. After the measurements has started dominates one of the impurity levels with time constant $\tau \approx 100$ s for n-type samples and $\tau \approx 400$ s for p-type samples. Then dominate the other impurity levels with time constant from 1000 s to 250 000 s.

One of the samples was measured during one week and its resistance decreased during all this time and nevertheless it didn't reach equilibrium state.

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