ANALYSIS OF I-V CHARACTERISTICS OF CADMIUM - TELLURIDE RADIATION DETECTORS

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ABSTRACT

This paper presents the I-V characteristics of two CdTe detectors, manufactured on the basis of semi-insulating CdTe single crystals with golden contacts. One of these detectors has non-transparent contacts, so it was illuminated from side. The other one has semi - transparent contacts and it was directly illuminated through the contact area. With aim to estimate the effect of illumination and operating temperature changes on electrical properties of investigated detectors, the measurements were carried out under various light conditions and different temperatures.

1. INTRODUCTION

Because of Cadmium-Telluride high photoelectric absorption coefficient, Cadmium-Telluride is suitable material for sensitive detectors of high energy radiation, such as Gamma or X-ray radiation, which can work at room temperatures. Cadmium Telluride (CdTe) is very promising material in radio diagnostics. For example, apart from conventional scintilactic layer, which is used as X-ray detector in conventional radiodiagnostic devices, CdTe detectors convert X-ray radiation directly into electric signal, without necessity to focus the light in optic layer and following conversion to electrical signal. The resulting images are sharper with higher resolution. Also, the CdTe detectors can be used in safety systems in the nuclear power industry.

2. ANALYSIS

Compared with conventional semiconductors, such as silicon, CdTe crystallizes in more complicated Zinc-Blende lattice structure. This feature brings difficulties in manufacturing process. CdTe is more susceptible for structural defects and intrusion of impurities. The impurities act as traps. The undesirable effect of traps is the generation–recombination like noise in semiconductor devices is caused by the random fluctuation of carriers between the conduction band and defect energy level (caused by impurities) [1]. The result is deteriorated mobility of charge carriers.

The main problem of CdTe radiation detector is stability of electrical properties in time and model description of charge carrier transport. The nature of transport changes if the detector is exposed to ionizing radiation hasn’t been fully described. To explain its behavior in various operating conditions and explain aging factors, non-destructive measuring methods are utilizable. In our case, the electrical properties of CdTe radiation detectors will be investigated by measuring I-V characteristics.

2.1. MEASURING APPARATUS

The experimental apparatus shown in Fig. 1 measures carrier transport characteristics of the samples. The sample and a load resistor are placed into the cryostat, which also works as a parasitic electric field shielding. Programmable D/A converter Agilent E3631A is used for I-V characteristics measurements. Also, this D/A is used for automated temperature control inside the cryostat. Separated measuring dots are interconnected by data acquisition unit Agilent 34970A with plug-in module Agilent 34902A, which is used for A/D conversion and is connected with PC.

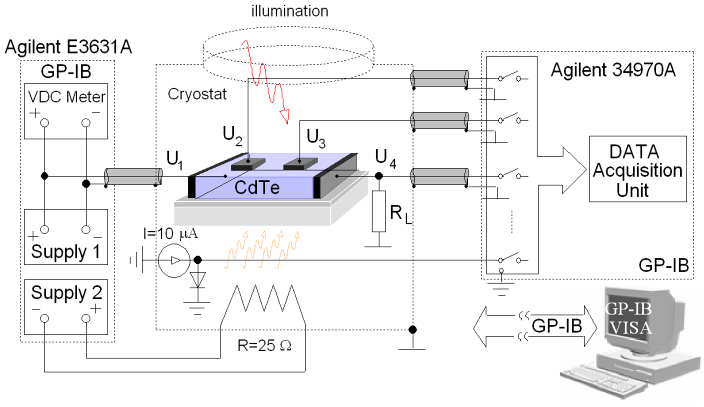

Figure 1: Measuring setup for I-V characteristics measurements

2.2. MEASURING RESULTS AND DISCUSSION

In this paper, semi-insulating CdTe sample E29D1G with semi-transparent contacts and semi-insulating sample with non-transparent contacts, S1C2H will be presented. These samples are manufactured at Institute of Physics at Charles University.

We suppose differences in carrier concentration in crystal bulk. The levels are given by the intensity of illumination at contact area and intrusion of photons among crystal bulk. In case of non-transparent contact, two main means of charge transport appears. The first nature of charge transport is diffusive. The domination of diffusive move changes into drift move. In this area, electric field is stronger and charge carriers are accelerated. The effect of motion change has to be accompanied by the recombination process. Our presumption of expression, which would describe the I-V characteristics, is

$$i = I_0(1-\mathrm{e}^{-\beta U}) + GU \quad , \qquad (1)$$

where $(1-\mathrm{e}^{-\beta x})$ is diffuse part and GU is drift part of sample current. G represents additional conductivity given to the sample as a result of presence of free charge carriers. It's obvious that equation (1) comes from the Shockley equation for ideal diode,

$$I = I_0 \exp(\frac{U_\mathrm{d}}{kT/e}) - 1 \quad . \qquad (2)$$

So, the parameter β is the exponent of equation (2). U_d is the diode voltage, $k = 1.38 \cdot 10^{-23}\,\mathrm{JK}^{-1}\mathrm{s}^{-1}$ is the Bolzmann constant and $e = 1.602 \cdot 10^{-19}\,\mathrm{C}$ is the elementary charge of electron.

On the other hand, for sample with semi-transparent contacts, as a result of full intersection of photons in sample bulk, we expect diffusive nature of charge carrier transport with no processes of recombination.

In Fig. 2, the first sets of I-V are demonstrated. These characteristics were measured at room temperature 300 K and samples were illuminated by monochromatic light with wavelengths of 700 nm, 830 nm and 950 nm. The photon energy with wavelength 830 nm is $E = hc/\lambda = 1.5$ eV. It is the band gap energy of CdTe [2].

The I-V characteristics in Fig. 2 shows obviously higher influence of irradiation for sample with semi-transparent contacts. Also, it is remarkable that at applied voltage approx. 7 V, inflection point appears. For semi-transparent sample, the shape of characteristics reminds power function.

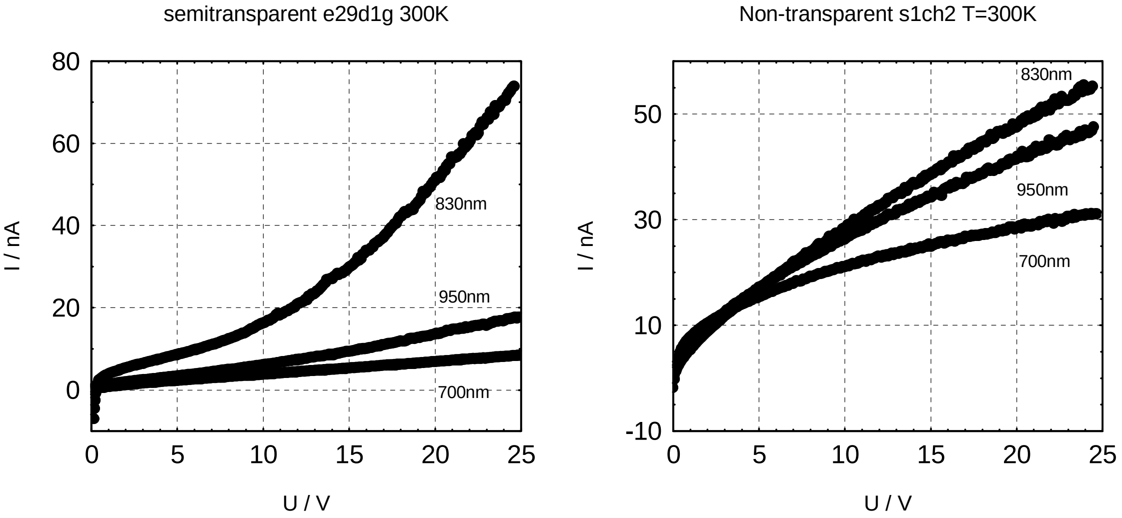

Figure 2: I-V characteristics of semi-transparent (left) and non-transparent CdTe detector samples measured at room temperature

The I-V characteristic of irradiated sample at operating temperature 348 K fitted by equation (1) is shown in Fig. 3.

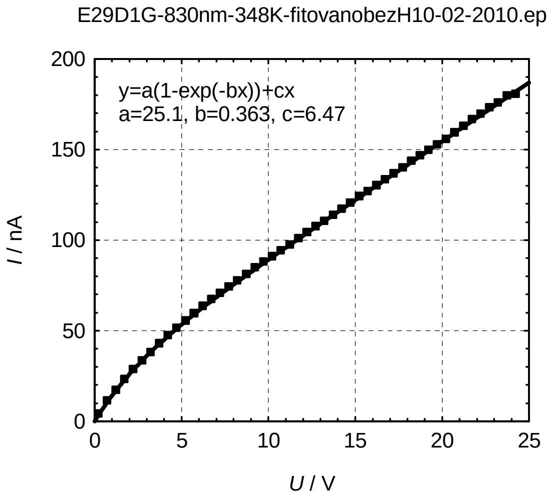

Figure 3: I-V characteristics of E29D1G sample with semi-transparent contact illuminated by 830 nm light at temperature 348 K

From the first sight, the power character of the I-V curves seems to be effect the of interaction of photons in whole sample bulk, but further measurements showed that at higher intensity of illumination this effect disappears and the shape of I-V characteristics become similar to characteristics of the sample with semi-insulating contacts. For the I-V characteristics in Fig. 4, the sample was directly illuminated by the 20 W wolfram bulb.

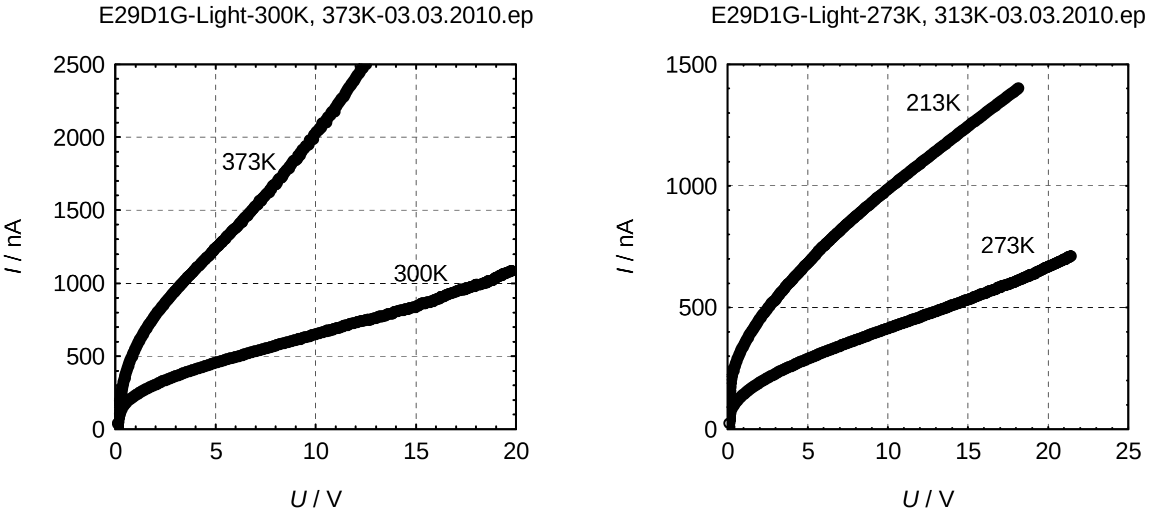

Figure 4: I-V characteristics of semi-transparent of illuminated CdTe sample at various operating temperatures

The I-V characteristics of illuminated sample with light of higher intensity (Fig. 4), shows from approximately 3 V nearly linear characters at room temperature. At temperature 373 K, the power character of I-V curve is apparent again. These findings lead us to carry out further measurements at lower temperatures.

The last measurement was carried out at temperature 273 K and 213 K. These measurements proved the power character disappearance at lower temperatures.

3. CONLUSION

The recent measurements showed the necessity of higher illumination intensity, because low intensity interacted only with swallow area bellow detector contacts. Illumination with light of wide spectra has advantage of complex interaction of CdTe sample with light. Spectral compounds with higher wavelength than 830 nm passes through whole crystal, the 830 nm compound generates photoelectrons and compounds below 830 nm are absorbed and cause thermal generation of charge carriers [3]. Nevertheless, it’s crucial to take into account that also impurities, which cause parasite energy levels in forbidden band of CdTe, are activated. But still, for exact description of charge transport properties of illuminated CdTe radiation it’s necessary to illuminate samples by light of certain energies. For this reason, it’s necessary to explain the influence of light at various photon energies on CdTe material.

From I-V measurement we carried out, we can estimate that the power shape of characteristics, which appear above inflexion point (at applied voltage 5÷7 V) is caused by thermal generation of charge carriers. To prove this assumption, further measurements on more samples with semi-transparent contacts will be carried out. To get better information qualities of measurements, we find necessary use light source with balanced spectrum of emitted light to assure constant intensity of illuminating light at various wavelength.

ACKNOWLEGEMENT

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