NOISE IN CDTE CRYSTALS

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ABSTRACT

Experimental studies of transport and noise characteristics of CdTe (Cl doped) crystals, prepared by traveling heater method (THM), have been carried out. The VA characteristics and noise spectral density was measured at room temperature under dark and illumination. The values of 1/*f* noise parameter α range from 4×10^{-4} to 2.5×10^{-3}. The signal to noise ratio improves if the electric field strength in the CdTe detector is set to a higher value.

1 INTRODUCTION

The cadmium telluride (CdTe) is a II–VI semiconductor material useful for the detection of high energy radiations, such as X rays and gamma rays [1].The main application of CdTe consists in high-resolution detection of radiation. A fairly wide gap E_g = 1.5 eV makes room operation of these detectors possible, the detector therefore needs not to be cooled. High atomic number and high stopping power are the main advantage of such a radiation detector. The band gap of CdTe is large and the intrinsic carrier concentration is low. The resistivity is high enough to operate the devices at room temperature.

We have performed transport and noise measurement of CdTe detectors [1], prepared by Physical Institute of Charles University in Prague. The basic material is *p*-type and features the following parameters:

(i) Sample 1 - F2651A has hole concentration $p = 9 \mathrm{x} 10^{11}$ cm^{-3}, hole mobility $\mu = 74$ cm^2.V^{-1}.s and specific resistivity $\rho = 9.3 \mathrm{x} 10^4$ Ωcm

(ii) Sample 2 - F33B1 hole concentration $p = 1.2 \mathrm{x} 10^{15}$ cm^{-3}, hole mobility $\mu = 73$ cm^2.V^{-1}.s, specific resistivity $\rho = 70$ Ωcm. The device dimension was: cross-section area 3.3x3.3 mm^2 and length 14 mm.

2 EXPERIMENTAL SET-UP

The block diagram of the apparatus is shown in Fig. 1. The sample is fed from dry cells, which proved to exhibit a low own noise, negligible with respect to the background noise of the selective nano-voltmeter. The sample current was measured by DC nano-voltmeter, the noise voltage by a sampler and transformed into the corresponding current noise spectral density using FFT - a method similar to that described in [3]. In some experiments an analog noise measurement method in the range from 1 Hz to 100 kHz was used [4]. Our set-up allows us to measure the sample current and noise voltage simultaneously without any effect on the noise. The whole set-up (with exception for instruments) was placed in a steel box, which serves to eliminate the electromagnetic smog. The measured values were recorded and analysed in a PC.

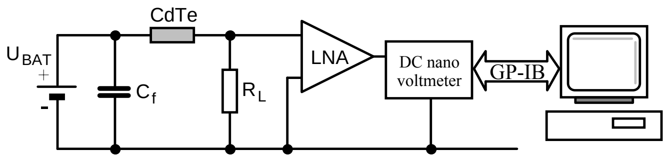

Fig. 1: *Block diagram of the experimental set-up*

3 VA CHARACTERISTICS

VA measurements in the dark were carried out at the room temperature and standard measuring set up is in Fig. 2.

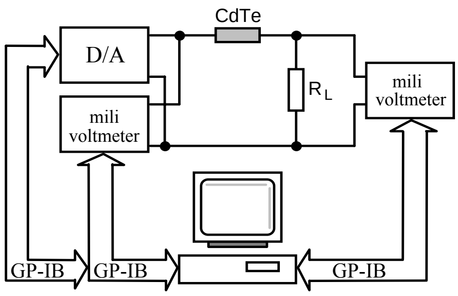

Fig. 2: *VA characteristic measuring set up*

Result of measurements for sample 1 is in Fig. 3. VA characteristic is non-linear. There can be observed forward and reverse direction. While in reverse direction the sample resistance does not depends on light illumination $R_r = 25$ MΩ, in forward direction the dark resistance $R_d = 1.25$ MΩ and resistance under illumination $R_d = 1.14$ MΩ. Light illumination was 200 Lx. In this sample we found that contacts are non-ohmic, than for contact noise measurements was applied.

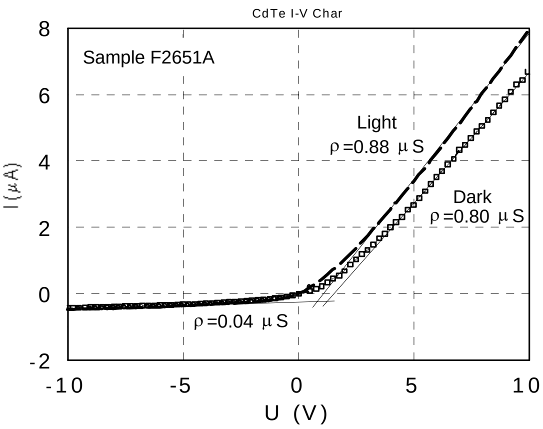

Fig. 3: *VA characteristic in the dark and at the room temperature for sample 1*

4 POTENTIAL DISTRIBUTION

Quality of contact technology preparation was analyzed by potential distribution measurement. Result of this measurement by DisPot for sample 1 is in Fig. 4. The contact resistance on one side is $R_c = 4\ \Omega$, while the second contact has resistance so high that measurement by DisPot contains high noise component.

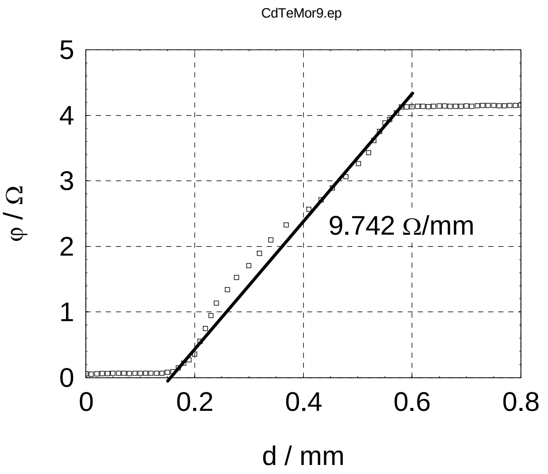

Fig. 4: *Contact resistance was measured by DisPot and result for sample 1*

5 NOISE

Noise measurements in the dark were carried out at the room temperature and measuring set-up is shown in fig. 1. The noise spectral density vs. frequency for DC voltage across the CdTe sample No. 2 as parameter is in fig. 5. We found that in this sample are good ohmic contacts and then measured noise corresponds volume noise sources only.

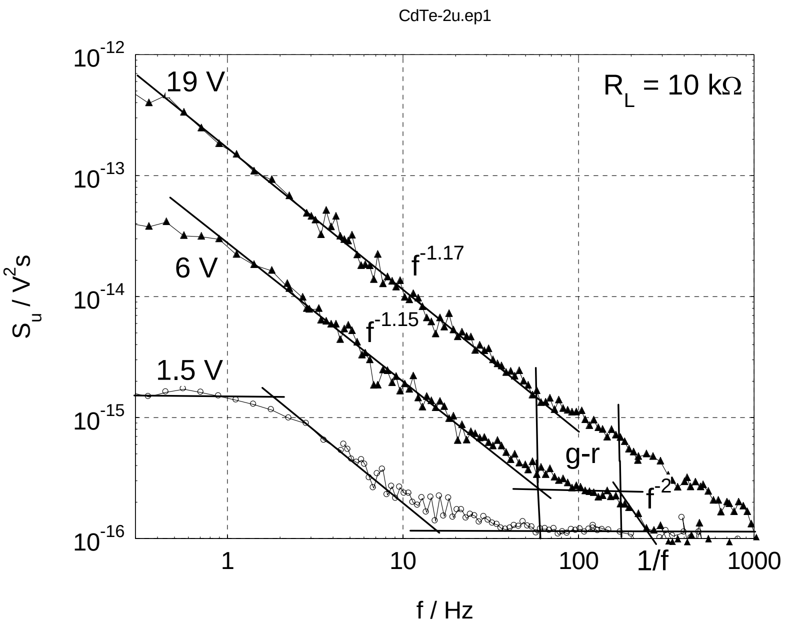

Fig. 5: *Voltage noise spectral density vs. frequency for sample No.2*

Dominant noise source is 1/*f* type. According to Hooge model voltage noise spectral density can by describe by

$$S_u = \frac{\alpha U^2}{Nf}, \quad (1)$$

where α is Hooge constant, *N*-total number of free curriers. Voltage noise spectral density is proportional to the square of applied voltage as is shown in fig. 6 for sample No. 2. In this Fig. correction on measuring background noise was not applied, then noise spectral density value for 1.5 V is higher than corresponds to approximation line.

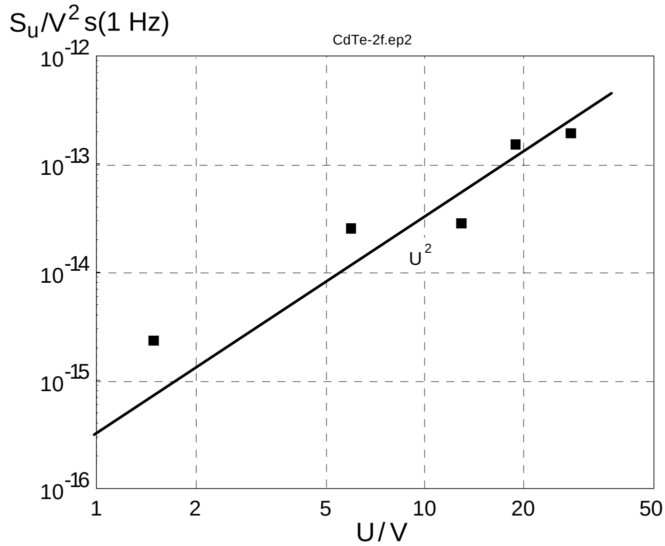

Fig. 6: *Voltage noise spectral density vs. applied voltage for sample No. 2*

From previews figures Hooge constant for our sample No. 2 can by find. Sample volume V = 0.152 cm^3, total number of charge curriers is $1.8x10^{14}$ then Hooge constant α=$5.5x10^{-2}$. This value is slightly higher than $\alpha_H = 2x10^{-3}$ proposed by Hooge [1]. Measured noise depends on contact quality and then high ohmic contacts are good sources of excess noise as is shown in fig. 7. The measurements were carried out for both electrics field directions, curves 1 for contact A positive and curves 2 for negative one. For sample No.1 measured noise spectral density depends on DC voltage orientation. In frequency range from 1 Hz to 10 kHz noise spectral density has frequency exponent *n* = 1.14. This type of noise is called 1/*f* – like noise and then

$$S_u = \frac{\beta U^2}{f^n}, \quad (2)$$

where β is dimensionless constant. For frequency higher than 10 kHz voltage noise spectral density in Fig. 7 is inversely proportion to the third power of frequency. In this case noise measurement was performed by ultra low noise amplifier with background noise spectral density S_{U0} = $3x10^{-19}$ V^2Hz^{-1} This effect is due to amplifier voltage transfer frequency dependence.

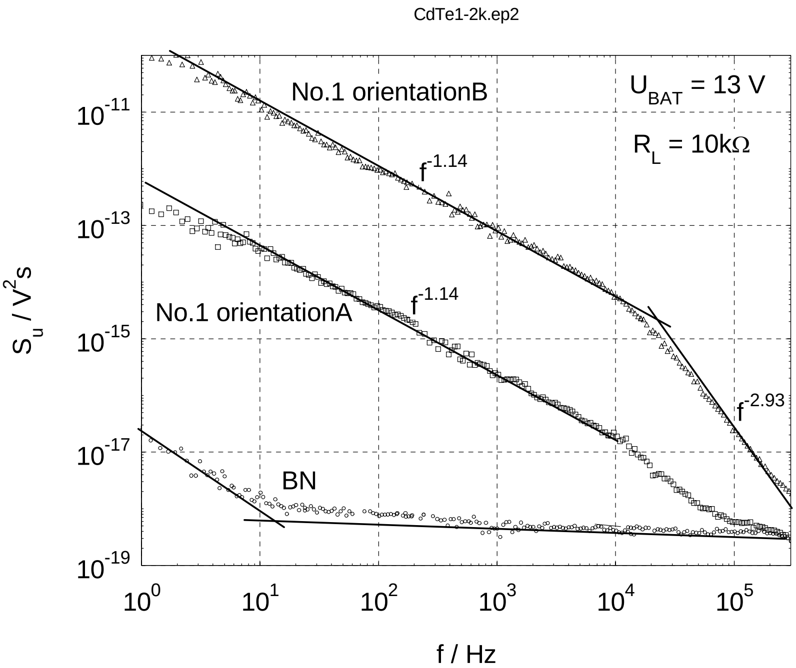

Fig. 7: *Voltage noise spectral density vs. frequency for sample No.1 measured on load resistance R_L=10 kΩ*

6 CONCLUSION

High ohmic sample has non-ohmic contact and V-I characteristic depends on ellectric field intensity orientation. Quality of contact technology preparation can by analyzed by potential distribution measurement. Result of this measurement for sample 1 on one side is R_c= 4 Ω.

We found that in this sample are good ohmic contacts and then measured noise corresponds volume noise sources only. Dominant noise source is 1/*f* type. Hooge constant for our sample No. 2 was found: $\alpha = 5.5\text{x}10^{-2}$. This value is slightly higher than $\alpha_H = 2\text{x}10^{-3}$ proposed by Hooge [1] due to contact noise sources.

ACKNOWLEDGEMENT

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