Technological aspects of preparation CdTe (CdZnTe) MESA pixel detectors

Světla Vacková[*], Dominik Chren[*], Tomáš Horažďovský[*], Bruno Sopko[*]

Vladimír Linhart[**], Stanislav Pospíšil[**]

[*]*Faculty of Mechanical Engineering , Institute of Physics,Czech Technical University in Prague, Technická 4, CZ-16607 Prague 6, vackova@fsid.cvut.cz,*

[**]*Faculty of Nuclear Science and Physical Engineering, Czech technical University in Prague, Břehova 7, CZ-11519 Prague 1*

Introduction

The preparation of MESA pixel detector

The polarization effect

Study of Au/p-CdTe contacts, influence of temperature gradient

Introduction

Cadmium telluride (CdTe) and cadmium zinc telluride (CdZnTe) have been regarded as a very promising material for the exploitation in imaging detectors for X-ray and gamma rays spectroscopy not only in high-energy physics but also in astrophysics. There are at least two good reasons for such application, namely high quantum efficiency in comparison e. g. With Si ($Z_{Cd} = 48$, $Z_{Te} = 52$) and large band gap ($E_g = 1{,}5$ eV) which allows in contrast to Si detector operate at room temperature. Due to recent [1] [2] improvements in the technology of crystals production and in the design of electrodes as well, the above mention application is becoming very perspective.

The preparation of MESA pixel detector

The preparation of MESA pixel detector is not for the time being described in the literature in detail, almost comprises planar pixel or strip detector. As known in MESA pixel detectors the interface metal – semiconductor appearing on surface can be better protected.
Our experiment is based (see Fig.1) on the procedure during which etched surface (Br/ methanol) is covered by Au contact (electroless deposition) and than is certain cases few pixels were engraved on it or sample was pinched on small pixels (1 x 1 mm) in (110) crystalografic direction. At first we have started with plasmatic etching of CdTe but in this case we faced the problem of suitable surface masking. Nevertheless we find this technique prospective for MESA pixel preparation and so we proceed the measurements.

The polarization effect

The polarization effect (amplitude degradation of spectra in time) was in literature described, explained and experimentally verified. It is evident that its reduction is possible only during the preparation of starting bulk material of CdTe by suitable temperations (e. g. high resistance samples doped by chlorine). It is true that during the doping procedure self compensation appears by lattice defects but due to the applied external electric field (100 –400 V) the detectors polarize in time and sample detectivity changes. It should be mention that CdTe has 72 percents ionic bond and therefore in scattering effects and in phonon drag effect the dominant role play optical phonons.

Study of Au/p-CdTe contacts, influence of temperature gradient

Many our papers [2-11] were devoted to the measurements of I-V characteristics. Summarizing these measurements we have concluded that the Schottky contact must be described by modified Bethe theory [3].

Interesting results were obtained on the shift of I-V characteristics with temperature gradient on Au/p-CdTe/Au which were published in [5-11]. We have measured simultaneously on these structures Seebeck effect and plausible explanation was found by means of Gurevich theory [4] about the role of non-equilibrium carriers in bipolar semiconductors .

In connection with these measurements probably a question arises - **why are we speaking about temperature gradient ?**

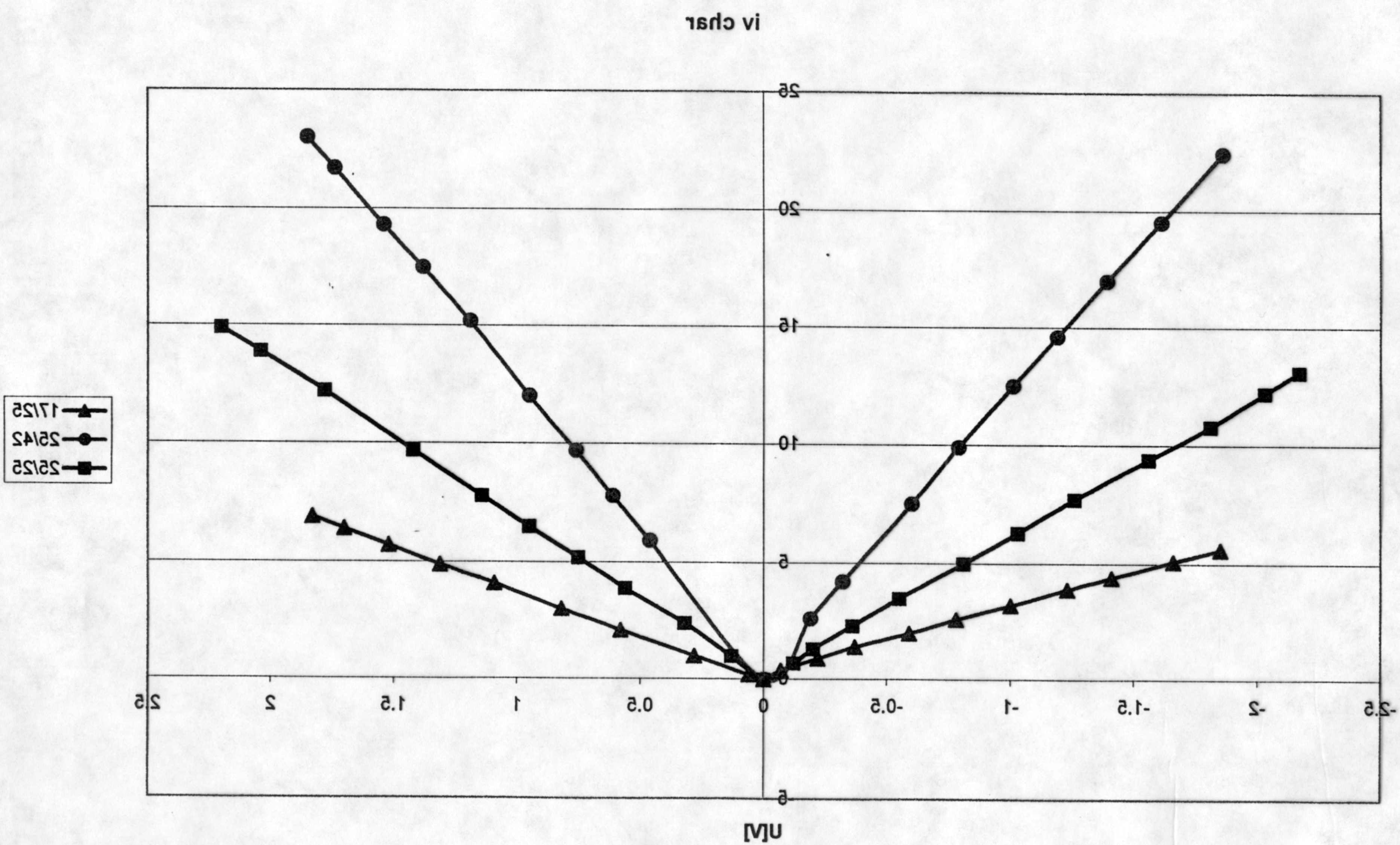
It is known, that thermal conductivity CdTe is 7,5 $Wm^{-1}K^{-1}$ and Si is 145 $W m^{-1}K^{-1}$.

Our detectors thickness is about 3-4 mm. In our detectors temperature gradient can appear quite independently on our expectation. The detector can be warmed-up by electronic circuits which produce a certain amount of heat.

Fig. 1 shows the shift of our measured I –V characteristics due to arisen temperature gradient, while Fig. 2 shows the shift of I –V characteristics due to arisen temperature gradient using device simulator. While temperature difference (17, 25 °C) due to cooling of one end of about 8 C produced five multiple resistivity increase, on the contrary its warming of about 7 C produced resistivity increase (see Tab. 1)

Tab.1

Temperature °C	R.10^{-5} ohm) polarity +	-
25.........25	1,5	1,68
25..........17	6,5	8,1
25..........42	1,12	1,38



iv char
I[uA]
25
20
15
10
5
0
-5
U[V]
-2.5
-2
-1.5
-1
-0.5
0
0.5
1
1.5
2
2.5
17/25
25/42
25/25

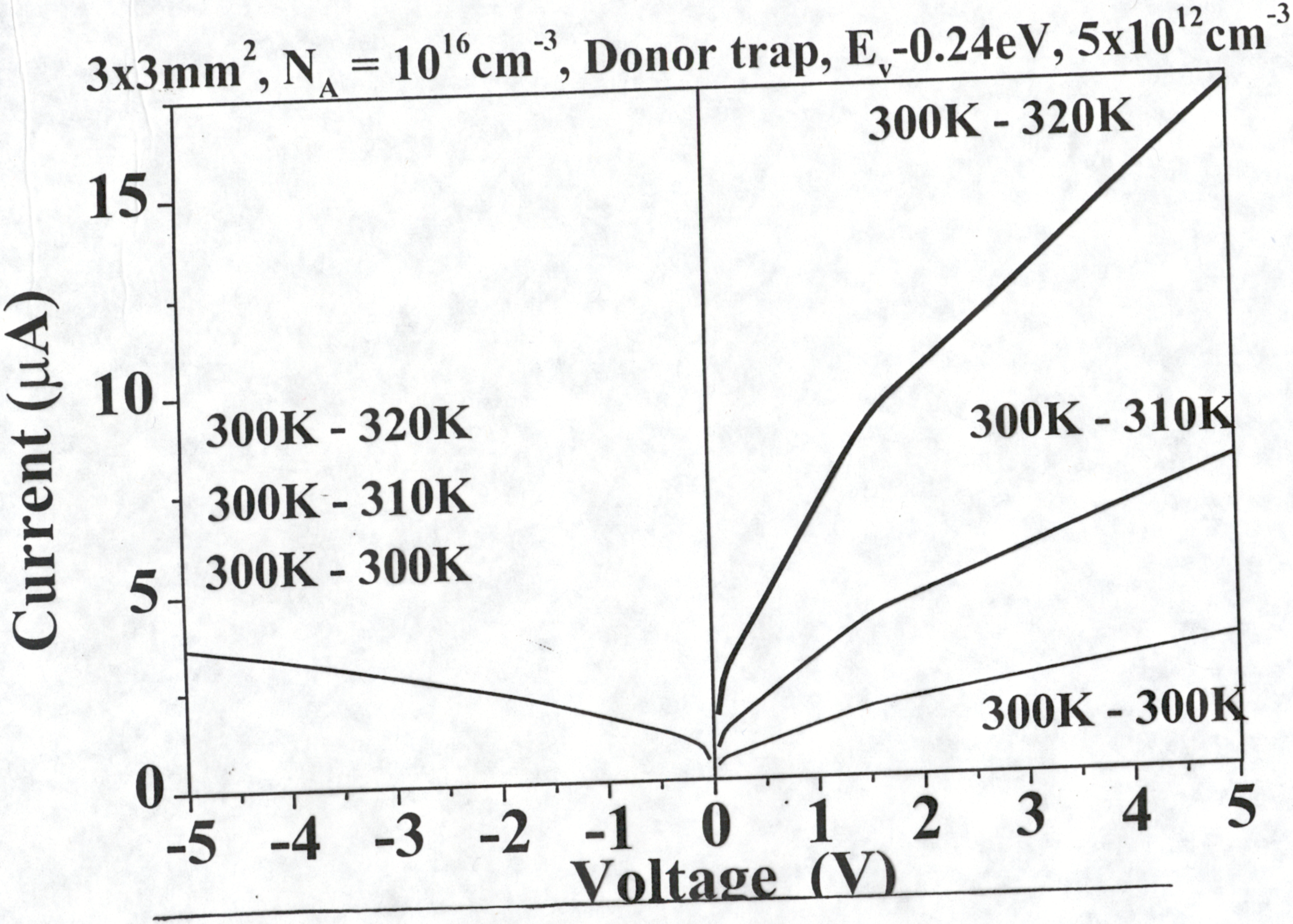


Fig. 2. Simulated dependences of I-U charactristics of the system Au/p-CdTe/Au for different temperature differences
(Simulator BLAZE from SILVACO Int. – prof. Ing. J. Vobecký, DrSc., FEL ČVUT in Prague)

So long as one contact is maintained on constant temperature, its resistance alone does not change, than the other contact is direct bias that means it does not contribute to the resistance of the whole sample and all changes appear in bulk resistance only. **Volume resistance of the sample naturally changes in accordance with the relation**

$$\frac{R}{R_0} = 1 + \frac{\Delta E \, \Delta T}{2k T_0^2} ,$$

where ΔE is activation energy of bulk semiconductor, ΔT is temperature difference, T_0 represents the middle temperature of the sample. The temperature change of contact resistance must be also added. The analysis of our measured changes showed that the found values do not correspond exactly to the just mentioned relation, they are greater or lesser. In agreement with the theory [4] the charge redistribution appear in semiconductor bulk which does not represent homogenous distribution but charge accumulation at one of the contacts. In consequence of this the changes appear also in detector depletion layer which can increase or decrease. We have observed these changes also in CdZnTe, similar effects are not known in other semiconductors as e. g. GaAs.

Conclusion

1) **We have succeeded in the preparation of the first MESA pixel prototypes**
2) **New results have brought the observation of temperature gradient produced on the detector.**

Acknowledgement

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For our investigation we have used as a bulk material monocrystals of p-type CdTe (produced in Chernivtsy National University, Ukraine).

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