Vol. 79 (1991) *ACTA PHYSICA POLONICA A* No 2–3

Proc. XIX International School of Semiconducting Compounds, Jaszowiec 1990

OPTICAL STUDIES OF HgCdMnTe BICRYSTALS*

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(Received August 8, 1990)

We report preliminary results of optical measurements performed on $Hg_{1-x-k}Cd_xMn_kTe$ grain boundaries. Photovoltaic spectra and *I–V* characteristics under illumination exhibit metastable behavior, confirming our previous conclusions based on transport measurements under high hydrostatic pressure.

PACS numbers: 72.40.+w, 73.40.Lq

1. Introduction

In our previous works [1, 2], we studied inversion layers adjacent to the grain boundaries (GB-s) of $Hg_{1-x-k}Cd_xMn_kTe$ narrow gap mixed crystals. The metastable decrease of the two-dimensional carrier concentration was observed when the GB was cooled under high hydrostatic pressure. Such an effect is typical for systems containing electron traps with large lattice relaxation, which were successfully investigated by means of optical methods in many semiconductors [3]. The purpose of the present work is to examine the optical properties of the HgCdMnTe bicrystals by means of the photovoltaic effect (PVE). Detailed theoretical description of this effect in GB-s and the first measurements for Ge-bicrystals were made by Matare [4].

2. Experimental details

We have been studying GB-s in naturally occurred bicrystals of *p*-type $Hg_{0.75}Cd_{0.23}Mn_{0.02}Te$. Energy gap of the bulk material was determined by light transmission measurements to be 215 ± 5 meV at $T = 100$ K.

GB photoresponse measurements were performed for two different sample configurations. In the first configuration the direction of the incident light beam was parallel to the GB plane (see the inset to Fig. 1). In the second case, the light beam penetrated the GB through the strongly thinned ($20 \pm 10\,\mu$m) single-grain layer (Fig. 2, inset). Such the layer was obtained after several steps of slow etching

*This work was supported by CPBP 01.04.

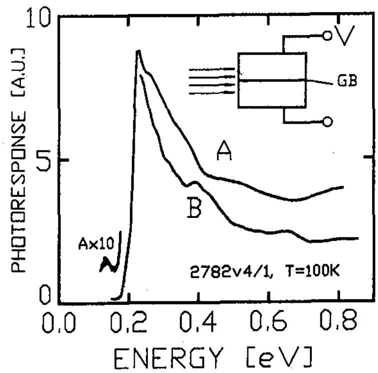

Fig. 1. Photoresponse versus photon energy for HgCdMnTe bicrystal measured in "parallel" configuration (inset). Both curves are obtained after sample cooling in dark, the spectral resolutions are: A) $\Delta E = 0.015$ eV, B) $\Delta E = 0.0015$ eV.

in 2%-Bromine-methanol solution. To measure the photovoltage, indium contacts were placed on opposite sides of the GB. The PVE of the bulk material was several orders of magnitude smaller than that for bicrystals and thus might be neglected.

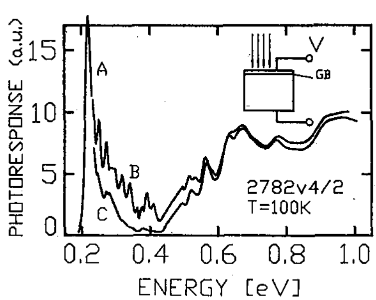

Fig. 2. Photoresponse versus photon energy for HgCdMnTe bicrystal measured in "perpendicular" configuration (inset). A) spectral resolution $\Delta E = 0.015$ eV, cooled in dark; B) $\Delta E = 0.0015$ eV, cooled in dark; C) $\Delta E = 0.0015$ eV, cooled under white light illumination.

To collect the PVE spectra, our samples were placed in an optical cryostat (on the copper rod in contact with liquid nitrogen). To obtain a monochromatic light beam, the globar source and the SPM-2 monochromator with NaCl or LiF prisms were used. The GB photovoltage was measured using standard lock-in technique with the chopper frequency 177 Hz. We also used additional, white light illumination (100 Watt incandescent lamp) with the purpose of inducing different metastable occupation of the GB trap states.

3. Results

Current–voltage characteristics of all our GB-s were measured *in situ* prior to optical measurements. At $T = 100$ K they show typical back-to-back diode behavior caused by the presence of the GB potential well [4]. The near-zero resistance R_0 which, at a constant temperature, is the exponential function of the well depth was found to depend strongly on illumination. After cooling the GB in the dark the value of R_0 exceeds usually $10^4\,\Omega$. In contrast, the cooling under a strong white light illumination results in R_0 values smaller than $2 \times 10^3\,\Omega$. Moreover, when the cooled-in-dark sample is exposed to daylight or electric light, its R_0 value starts to decrease slowly towards the value obtained after cooling under illumination. This low value of R_0 persists while the sample is hold at low temperature. All these effects were perfectly reversible after sample re-heating to room temperature.

PVE spectra for both experimental configurations are presented in Figs. 1 and 2. For all our GB-s, well defined cut-off edges of the PV effect at $E = 220$ meV were observed. This coincides with the energy gap of the host material.

In "parallel" configuration (Fig. 1), the PVE spectra do not show any distinct structure for photon energies $E > E_{\mathrm{g}}$. However, a small photoresponse peak was found at energy $E \approx 0.130$ eV (Fig. 1). A similar low energy peak has been observed for Ge-bicrystals by Matare [4]. It was interpreted in terms of the GB-induced deep defect traps, located within the energy gap. The shape of the spectrum does not depend on the additional illumination, however the whole measured photoresponse signal falls down when the near-zero resistance decreases (after illumination).

The PVE spectra for the "perpendicular" configuration show qualitatively different behavior. A very complex oscillatory structure is observed for photon energies exceeding E_{g} when the GB has been cooled in the dark (Fig. 2 curves A, B). The oscillation pattern observed for energies between 0.22 eV and 0.5 eV nearly disappears when the sample is cooled under illumination (Fig. 2 curve C). This may indicate that electron transitions responsible for these oscillations strongly depend on the GB traps occupation. This is not probably the case for higher energy transitions, since the shape of the spectrum for energies above 0.5 eV does not depend on illumination.

In summary, the obtained PV spectra suggest that the electronic structure of the HgCdMnTe GB-s is very complex and needs in further investigations.

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