

PHOTOELECTRIC PROPERTIES OF SELF OXIDE/ $\text{Cd}_{1-x}\text{Mn}_x\text{Te}$ HETEROSTRUCTURES

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The new technology of energy barrier fabrication by thermal treatment of $\text{Cd}_{1-x}\text{Mn}_x\text{Te}$ solid solution crystal wafers was proposed. By the first time the self oxide/ $\text{Cd}_{1-x}\text{Mn}_x\text{Te}$ ($x = 0.00 - 0.70$) heterostructures with rectifying and photosensitive properties was fabricated. The relative quantum efficiency of photoconversion of fabricated by the first time heterostructures was investigated. The nature of the interband optical transitions and values of the band gap in $\text{Cd}_{1-x}\text{Mn}_x\text{Te}$ was determined.

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I. INTRODUCTION

The $\text{Cd}_{1-x}\text{Mn}_x\text{Te}$ solid solutions that arise at CdTe-MnTe quasibinary cut by a controlled substitution of Cd on Mn are quite a wide group of dissolved magnetic semiconductors. This solid solutions combine ordinary semiconductor properties with a strong magnetism which generates in them new properties: (a) giant Zeeman and Faraday effect; (b) magnetic polaron effect compared to the nonmagnetic solid solutions.

During more than thirty years an intensive growth of the investigations on the bulk and nanocrystalline magnetic semiconductors has been noticeable, in particularly on the optical phenomena caused by the interband and inner-central radiation transitions in unfilled 3d-bands of magnetic ions [1, 2]. The photoelectrical phenomena in dissolved magnetic semiconductors and in structures thereon remain almost neglected. This paper is devoted to the fabricated by the first time photosensitive heterojunctions on the basis of $\text{Cd}_{1-x}\text{Mn}_x\text{Te}$ of solid solutions single crystals and the study of their photoelectrical properties.

II. THE SELF OXIDE/ $\text{Cd}_{1-x}\text{Mn}_x\text{Te}$ HETEROSTRUCTURE FABRICATION

The initial material for the heterostructure fabrication was $\text{Cd}_{1-x}\text{Mn}_x\text{Te}$ ($x = 0.00 - 0.70$) homogeneous single crystals growth from vapour phase or by Bridgman method ($v = 1.75$ mm/h), and for high-heat compositions ($x \geq 0.4$) by temperature-gradient zone melting with tellurium as the solvent.

The plane-parallel single crystal wafer, ~ 2 mm thick with the mirror-smooth surface prepared by cleaving from the middle part of $\text{Cd}_{1-x}\text{Mn}_x\text{Te}$ bulk ingot were used for thermal treatment. The uniformly colored self oxide (n -Ox) film formation with the mirror-smooth surface on initial wafers surface in time of thermal treatment was observed. The adhesion between the film and

$\text{Cd}_{1-x}\text{Mn}_x\text{Te}$ substrate was high for most of the structures. The n -Ox oxide film thickness and color was easily controlled by the time and temperature of thermal treatment. The n -Ox/ p - $\text{Cd}_{1-x}\text{Mn}_x\text{Te}$ heterostructures photosensitive for all x values from 0.00 to 0.70 was fabricated by adjusting time (10–500 min.) and temperature (573–973 K) of thermal treatment. The $\text{Cd}_{1-x}\text{Mn}_x\text{Te}$ wafers thermal treatment in vacuum ($P \sim 10^{-3}$ Pa) did not lead to the n -Ox film formation on the wafer at the same temperature conditions and time expositions. Thus oxidation is definitely the basic mechanism of the film formation on the $\text{Cd}_{1-x}\text{Mn}_x\text{Te}$ surface.

The ohmic contacts were fabricated by the indium soldering of a thin wire (Pt or Ag, diameter ~ 20 μm) to self oxide (n -Ox) films. The ohmic contacts to surface of $\text{Cd}_{1-x}\text{Mn}_x\text{Te}$ were fabricated by Au film deposition from the HAuCl_3 acid.

III. PHOTOELECTRICAL PROPERTIES OF n -Ox/ p - $\text{Cd}_{1-x}\text{Mn}_x\text{Te}$ HETEROSTRUCTURE

The photovoltaic effect was observed in n -Ox/ p - $\text{Cd}_{1-x}\text{Mn}_x\text{Te}$ heterostructures under illumination on the part of the oxide film. In all fabricated structures the n -Ox film was negatively charged. The value of photo electromotive force was much higher for structure illumination by oxide compared to that by the from semiconductor side. In the best structures under the incandescent lamp illumination (~ 5 mW $\cdot\text{cm}^{-2}$) the $U_{oc} = 0.2$ V, $I_{sc} = 5 \cdot 10^{-6}$ A and volt sensitivity 30 V $\cdot\text{W}^{-1}$ at $T = 300$ K were reached.

The sign of photovoltage turns out to be insensitive to incident photons energy and localization of light probe (diameter ~ 0.5 mm) on the photoreceiving plane of heterostructure. At the same time the sign of photovoltaic effect was in agreement with the sign of the structure direct bias on time of the current-voltage measurement. The peculiarities counted above are an additional argument that rectifying and photovoltaic properties

of the $n\text{-Ox}/p\text{-Cd}_{1-x}\text{Mn}_x\text{Te}$ heterostructure are caused by an energy barrier located on interface of $n\text{-Ox}$ with $\text{Cd}_{1-x}\text{Mn}_x\text{Te}$ solid solutions single crystal surface.

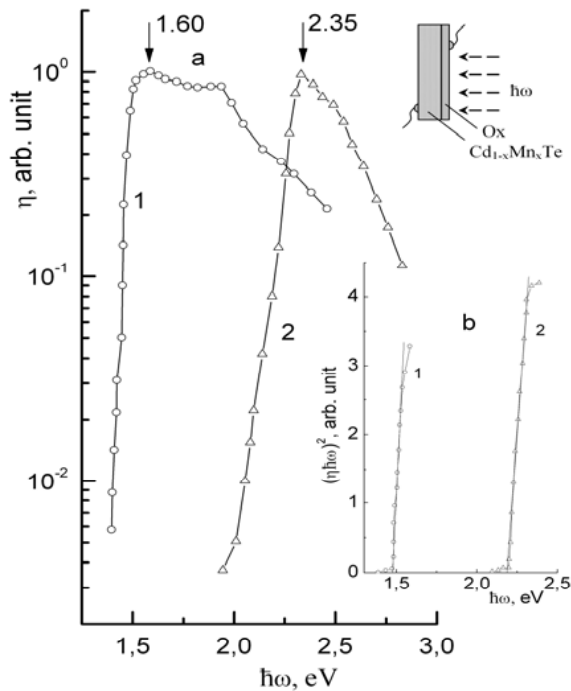


Fig. 1. The relative quantum efficiency of photoconversion $\eta(h\nu)$ – a and $(\eta h\nu)^2 = f(h\nu)$ – b of $\text{Ox}/\text{Cd}_{1-x}\text{Mn}_x\text{Te}$ ($x = 0 - 1$, $x = 0.4 - 2$) structures.

The spectra of relative quantum efficiency dependences $\eta(h\nu)$ for two heterostructures fabricated on $\text{Cd}_{1-x}\text{Mn}_x\text{Te}$ single crystal wafers with different compositions (x) were investigated (Fig. 1,a). It can be seen that with an x increase the maximum of $\eta(h\nu)$ curve is

shifting to a short wave region of spectra in with the comparison to $\eta(h\nu)$ curve of Ox/CdTe structure. This behaviour is related to an increase of $\text{Cd}_{1-x}\text{Mn}_x\text{Te}$ solid solution band gap value in consequence of Mn content increases. The long wave edge of the relative quantum efficiency curve can be approximated to the line in $(\eta h\nu)^2 = f(h\nu)$ coordinates (Fig. 1,b). This indicates [3, 4] direct optical band transitions for both structures. The energy of the direct band transitions $E_g = 1.47$ and 2.2 eV at $T = 300$ K for solid solution compositions $x = 0$ and 0.4 was calculated from the $(\eta h\nu)^2 \rightarrow 0$ extrapolation. The $\eta(h\nu)$ sharp decrease in a short wave region is observed under the illumination of $n\text{-Ox}/p\text{-Cd}_{1-x}\text{Mn}_x\text{Te}$ structures from the substrate side. In these conditions FWHM ($\delta_{1/2}$) of $\eta(h\nu)$ spectra have the value $\delta_{1/2} \cong 20 \div 30$ meV and decrease with the $\text{Cd}_{1-x}\text{Mn}_x\text{Te}$ wafer thickness increase. The FWHM value of $\eta(h\nu)$ curve drastically increases in the case of $n\text{-Ox}/p\text{-Cd}_{1-x}\text{Mn}_x\text{Te}$ structure illumination on the $n\text{-Ox}$ film and reach values 0.6 eV for $x = 0$ and 0.3 eV for $x = 0.4$.

CONCLUSIONS

The technology basis of the energy barrier fabrication in the $\text{Cd}_{1-x}\text{Mn}_x\text{Te}$ solid solutions by the thermal treatment of $\text{Cd}_{1-x}\text{Mn}_x\text{Te}$ ($x = 0.00 - 0.70$) homogeneous crystalline wafers in air conditions was developed. Thus, for the first time the $n\text{-Ox}/p\text{-Cd}_{1-x}\text{Mn}_{1-x}\text{Te}$ ($x = 0.00 - 0.70$) heterostructures with rectifying photovoltaic properties and with good reproducibility of physical properties were fabricated.

The oxidation process possibility for the photoconverters fabrication on the basis of $\text{Cd}_{1-x}\text{Mn}_x\text{Te}$ dissolved magnetic semiconductor single crystals was demonstrated.

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ФОТОЕЛЕКТРИЧНІ ВЛАСТИВОСТІ ГЕТЕРОСТРУКТУР ВЛАСНИЙ ОКСИД/ $\text{Cd}_{1-x}\text{Mn}_x\text{Te}$

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Запропоновано нову технологію формування енергетичного бар'єра на основі кристалів твердого розчину $\text{Cd}_{1-x}\text{Mn}_x\text{Te}$ і вперше отримано випрямляючі фоточутливі гетероструктури власний оксид/ $\text{Cd}_{1-x}\text{Mn}_x\text{Te}$ ($x = 0.00 - 0.70$). Досліджено спектри відносної квантової ефективності фотоперетворення нових гетероструктур. Визначено характер міжзонних переходів і ширину забороненої зони $\text{Cd}_{1-x}\text{Mn}_x\text{Te}$.