Linnaeus ECO-TECH ´10
Kalmar, Sweden, November 22-24, 2010

NEW HETEROSTRUCTURES ON THE BASISE OF $Cd_{1-x}Mn_xTe$ SOLID SOLUTIONS: PHOTOELECTRIC PROPERTIES

Vasiliy Rud,
St. Petersburg State Polytechnic University, Russia
Yury Rud
Ioffe Physicotechnical Institute, Russian Academy of Sciences, Russia
Grygory Il'chuk
Volodymyr Kusnezh
Roman Petrus'
National University „L'vivska Politekhnika", Ukraine

ABSTRACT

The new technology of energy barrier fabrication by thermal treatment of $Cd_{1-x}Mn_xTe$ solid solution crystal wafers was proposed. By the first time the $Ox/Cd_{1-x}Mn_xTe$ (x=0.00–0.70) heterostructures with rectifying and photosensitive properties was fabricated. The relative quantum efficiency of photoconversion of fabricated by the firs time heterostructures was investigated. The nature of the interband optical transitions and values of the band gap in $Cd_{1-x}Mn_xTe$ was determined.

KEYWORDS

Photoconversion; $Cd_{1-x}Mn_xTe$; solid solution; Shottky barrier; heterojunction; quantuum efficiency.

1 INTRODUCTION

The $Cd_{1-x}Mn_xTe$ solid solutions that arise at CdTe–MnTe quasibinary cut by controlled substitution of Cd on Mn are quite wide group of dissolved magnetic semiconductor. This solid solutions combine ordinary semiconductor properties with strong magnetism which generate in them new properties: a) giant Zeeman and Faraday effect; b) magnetic polaron effect, compered to nonmagnetic solid solutions.
During last more than thirty years intensive growth of investigation on bulk and nanocrystalline magnetic semiconductors is observed. In particularly on optical phenomena caused by 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 are still almost not investigated. This paper is devoted to fabrication by the firs time photosensitive heterojunctions on basis of $Cd_{1-x}Mn_xTe$ solid solutions single crystals and investigation of their photoelectrical properties.

https://doi.org/10.15626/Eco-Tech.2010.108

2 THE FABRICATION OF Ox/$Cd_{1-x}Mn_xTe$ HETEROSTRUCTURE

The initial material for heterostructure fabrication was $Cd_{1-x}Mn_xTe$ (x=0.00–0.70) homogeneous single crystals growth from vapour phase or by Bridgman method (υ=1.75 mm/hour), and for high-heat compositions (x≥0.4) by temperature-gradient zone melting with tellurium as the solvent.
The plane-parallel single crystal wafer, ~2 mm thick with mirror-smooth surface prepared by cleaving from middle part of $Cd_{1-x}Mn_xTe$ bulk ingot, were used for thermal treatment. The uniformly colored self oxide (n-Ox) film formation with mirror-smooth surface on initial wafers surface in time of thermal treatment was observed. The adhesion between film and Cd1-xMnxTe substrate was high for most of structures. The n-Ox oxide film thickness and color was easily controlled by time and temperature of thermal treatment.
The Ox/$Cd_{1-x}Mn_xTe$ 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 Cd1-xMnxTe wafers thermal treatment in vacuum (P~ 10-3 Pa) did not lead to n-Ox film formation on the wafer at the same temperature conditions and time expositions. Thus oxidation is definitely the basal mechanism of film formation on $Cd_{1-x}Mn_xTe$ surface.
The ohmic contacts were fabricated by indium soldering of thin wire (Pt or Ag, diameter ~20 μm) to self oxide (Ox) films, while to free surface of Cd1-xMnxTe by deposition of Au film from $HAuCl_3$ acid.

3 EXPERIMENTAL RESULTS AND DISCUSSION

The photovoltaic effect was observed in Ox/$Cd_{1-x}Mn_xTe$ heterostructures under illumination from side of oxide film. In all fabricated structures the Ox film was negatively charged. The value of photo electromotive force was much more for structure illumination from oxide side compared to illumination from semiconductor side. In best structures under incandescent lamp illumination (≈5 mW/cm^2) the U_{oc}=0.2 V, $I_{sc}=5\cdot10^{-6}$ A and volt sensitivity 30 V/W at T=300 K was reached.

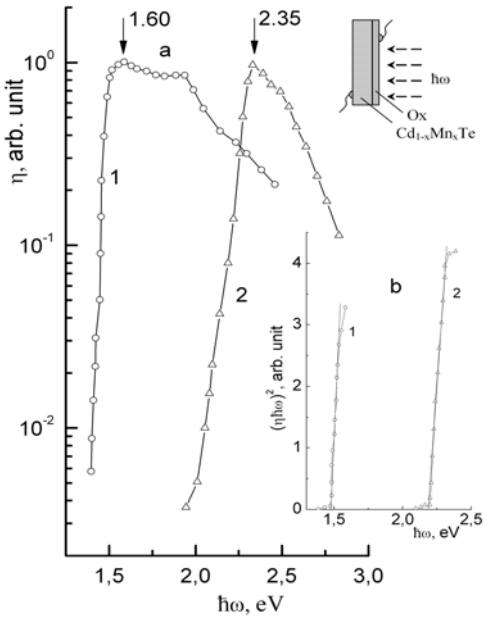

Figure. 1. The relative quantum efficiency of photoconversion η(ħω) – a and (ηħω)2=f(ħω) – b of Ox/Cd1-xMnxTe (x=0 – 1, x=0.4 – 2) structures.

The sign of photovoltage turn out to be insensitive to incident photons energy and localization of light probe (diameter ~0.5 mm) on photoreceiving plane of heterostructure. In the same time, sign of photovoltaic effect was in agreement with sign of structure direct bias in time of current-voltage measurement. The peculiarities counted above are additional argument that rectifying and photovoltaic properties of Ox/$Cd_{1-x}Mn_xTe$ heterostructure are caused by energy barrier located on interface of n-Ox with $Cd_{1-x}Mn_xTe$ solid solutions single crystal surface.
Spectra of relative quantum efficiency dependences η(ħω) for two hetorostructures fabricated on $Cd_{1-x}Mn_xTe$ single crystal wafers with different composition were investigated, Figure. 1. a. It can be seen that with x increase the maximum of η(ħω) curve is shifting to short wave region of spectra in comparison to η(ħω) curve of Ox/CdTe structure. This behaviour is related to increase of Cd1-xMnxTe solid solution band gap value in consequence of Mn content increase. The long wave edge of relative quantum efficiency curve can be approximated by line in $(\eta\hbar\omega)^2=f(\hbar\omega)$ coordinates, Figure. 1. b. This indicate direct optical band transitions for both structures. The energy of 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 $(\eta\hbar\omega)2\rightarrow0$ extrapolation. The η(ħω) sharp decrease in short wave region is observed under illumination of Ox/$Cd_{1-x}Mn_xTe$ structures from substrate side. In this conditions FWHM ($\delta^{1/2}$) of η(ħω) spectra have value $\delta^{1/2} \cong 20\div30$ meV and decrease with the $Cd_{1-x}Mn_xTe$ wafer thickness increase. The FWHM value of η(ħω) drastically increase in case of Ox/$Cd_{1-x}Mn_xTe$ structure illumination on Ox film, and reach values 0,6 eV for x=0 and 0,3 eV for x=0.4.

4 CONCLUSIONS

The technology basis of energy barrier fabrication in $Cd_{1-x}Mn_xTe$ solid solutions by thermal treatment of $Cd_{1-x}Mn_xTe$ (x=0.00–0.70) homogenous crystalline wafers in air conditions was developed. Thus by the firs time the Ox/$Cd_{1-x}Mn_xTe$ (x=0.00–0.70) heterostructures with rectifying, photovoltaic properties and with god reproducibility of physical properties was fabricated.
The oxidation process possibility for photoconverters fabrication on basis of $Cd_{1-x}Mn_xTe$ dissolved magnetic semiconductor single crystals was demonstrated. Such heterostrustures on the basise of $Cd_{1-x}Mn_xTe$ could be used for photovoltaic applications.

REFERENCES

43. Agekyan V.F. Intracenter transitions of iron-group ions in II–VI semiconductor matrices / V.F. Agekyan // Physics of the Solid State. – 2002. – Vol. 44, N 11. – P. 2013–2030.
44. Exciton and intracenter luminescence in Cd0.6Mn0.4Te/Cd0.5Mg0.5Te quantum-well structures / V. F. Agekyan, N. N. Vasil'ev, A. Yu. Serov, N. G. Filosofov and G. Karczewski // Physics of the Solid State. – 2005. – Vol. 47, N 11. – P. 2162–2168.
45. C.M. Sze. Physics of semiconductor devices (John Wiley and Sons, New York, London, Sydney, Toronto, 1969);
46. Jacques I. Pankove. Optical processes in semiconductors (Courier Dover Publications, 1975).