Raman analysis of $Zn_{1-x}Mn_xTe$ polycrystalline films

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ABSTRACT

In this paper, we have investigated some structural properties, Raman spectra of $Zn_{1-x}Mn_xTe$ films deposited by the closed space vacuum sublimation under different growth conditions. The obtained results of the Raman spectroscopy and XRD analysis show single phase composition of the samples. The presence of phonon replicas in the Raman spectra of the films indicates their high structural quality. The manganese content (about 7 %) in the layers was determined according to shifting the relative peaks positions.

Keyword: Raman spectroscopy, surface morphology, x-ray diffraction, lattice parameters, solid solution of $Zn_{1-x}Mn_xTe$, closed space vacuum sublimation

1. INTRODUCTION

The semimagnetic semiconductor solid solutions are promising materials for the micro-, optoelectronics, photovoltaics and spintronics due to their unique photoluminescent, magnetic and magneto-optical properties [1, 2]. However, the properties of solid solutions $Zn_{1-x}Mn_xTe$ thin films are not well studied because of difficulty in thin layers deposition.
The obtaining of the $Zn_{1-x}Mn_xTe$ films with controllable Mn content and optimized characteristics is complicated by the substantial difference in components' pressures. Thus, typical methods for the $Zn_{1-x}Mn_xTe$ films depositions are laser [3] and flash evaporation [4], high frequency magnetron scattering [5], metal-organic deposition [6]. These methods are characterized by the high non-equilibrium of the growth process. As a result the layers have low crystal quality which is not suitable for application in photodetectors, hard radiation detectors and solar cells. In some cases, the manganese is not incorporated into the crystal lattice which is lead to formation of Mn precipitates or MnTe secondary phase. It has strong influence on films performance. Along with the X-ray diffractometry the Raman spectrometry is widely used for the analysis of the chemical and phase composition of the material.
The goal of present work is to study Raman and photoluminescence spectra of the $Zn_{1-x}Mn_xTe$ solid solutions thin films with the different Mn concentration, obtained by the closed space vacuum sublimation under different growth conditions. This method allows to obtain high-quality thin films under close to equilibrium conditions [7-8]. The results were compared with the data obtained for the undoped ZnTe thin films.

2. EXPERIMENTAL

Thin films $Zn_{1-x}Mn_xTe$ were prepared on cleaned glass substrates under growth pressure in the chamber no more than $5 \cdot 10^{-3}$ Pa. The detailed description of the experimental setup for the CSVS technique is presented in [9-10]. The charge of the semiconductor purity degree containing 10% Mn was evaporated. The evaporator temperature was T_e = 800 ^{0}C. The substrate temperature was changed in the interval T_s = (150-550) ^{0}C. The typical condensation time was about t = 15 min.

TEM technique (REMMA-103-01) was used to investigate the morphology of the surfaces of the films. The arbitrary grain size (D) in condensates was determined according to the Jeffries method. Structural characteristics were examined by using films with the thickness l~ (2-4) μm, this value was determined from the photo-images of the cleavage surface of the condensates.

The structural investigations of $Zn_{1-x}Mn_xTe$ films were performed by the XRD unit DRON 4-07 in Ni-filtered K_α radiation of the copper anode in the angle range 2θ from 10^0 to 80^0, where 2θ is the Bragg angle.The Bragg-Brentano method was used to focus of the X-ray radiation. The experimental curves were normalized by the intensity of (111)

Hard X-Ray, Gamma-Ray, and Neutron Detector Physics XV, edited by Michael Fiederle, Arnold Burger, Larry Franks, Ralph B. James, Proc. of SPIE Vol. 8852, 88521G · © 2013 SPIE
CCC code: 0277-786X/13/$18 · doi: 10.1117/12.2023280

2. The lattice parameter *a* of the $Zn_{x-1}Mn_xTe$ films is changed from 0.60998 to 0.61043 nm and it is less than for ZnTe films obtained at same growth conditions. It could be explained by the incorporation of the Mn atoms into Zn sublattice

3. A number of intense lines at 176.5, 206, 416 and 621 cm^{-1} were observed in the Raman spectra. These lines were interpreted according to reference data as 1TO, 1LO, 2LO, and 3LO phonon modes. The presence of several orders of phonon replicas in the spectra of solid solution films indicates their high structural quality.

4. According to the shift of the relative position of the peaks in Raman spectra of the $Zn_{x-1}Mn_xTe$ comparatively to the undoped ZnTe allow us to estimate Mn concentration in a samples (about 1-3 %).

ACKNOWLEDGMENTS

This work performed under the state budget project №0113U000131 Ministry of Education and Science of Ukraine and with the support of the State Agency for Science, Innovation and Informatization of Ukraine.

REFERENCES

[1] Kossut, J., Gaj, J.A., [Introduction to the Physics of Diluted Magnetic Semiconductors, Springer Series in materials science], Warsaw, 469 p. (2010).

[2] Avdonin, A., [Properties of ZnMnTe alloy doped with oxygen and chromium], Warsaw, 96 p. (2010).

[3] H.J. Masterson, J.G. Lunney, "Comparison of epitaxial films of $Zn_{1-x}Mn_xTe$ on (111) and (100) GaAs produced by pulsed laser deposition" Appl. Surf. Scien. 86(1), 154-159 (1995).

[4] G. Romera-Guereca, J. Lichtenberg, A. Hierlemann, D. Poulikakos, B. Kang, "Explosive vaporization in microenclosures", Experimental Thermal and Fluid Science, 30, 829-836 (2006).

[5] D. Zeng, W. Jie, H. Zhou, Y. Yang, "Effects of deposition temperatures on structure and physical properties of $Cd_{1-x}Zn_xTe$ films prepared by RF magnetron sputtering", Nuclear Instruments and Methods in Physics Research A, 614, 68-71 (2010).

[6] A. Zozime, M. Seibt, J. Ertel, A. Tromson-Carli, R. Druilhe, C. Grattepain, R. Triboulet, "Influence of a ZnMnTe buffer layer on the growth of ZnTe on (001)GaAs by MOVPE", J. Crystal Growth, 249, 15-22 (2003).

[7] Lopez-Otero, A. "Hot-wall epitaxy", Thin Solid Films 49, 3–57 (1977).

[8] Kalinkin, I.P., Aleskovskij, V.B., [Epitaxial A_2B_6 films], LGU, Leningrad, 310 p. (1978) (in Russian).

[9] Kosyak, V. V., Opanasyuk, A.S., Bukivskij, P.M., Gnatenko, Yu. P. "Study of the structural and photoluminescence properties of CdTe polycrystalline films deposited by closed space vacuum sublimation", J. Cryst. Growth 312, 1726–1730 (2010).

[10] Kurbatov, D., Khlyap, H., Opanasyuk, A. "Substrate-temperature effect on the microstructural and optical properties of ZnS films obtained by close-spaced vacuum sublimation", Phys. Stat. Sol. A 206 (7), 1549-1557 (2009).

[11] [Selected powder diffraction data for education straining (Search manual and data cards)], Published by the International Centre for diffraction data, USA. 432 p. (1988).

[12] Bowen, D.K., Brian Tanner, K., [X-Ray Metrology in Semiconductor Manufacturing]. Taylor & Francis Group, 270 p. (2006).

[13] Umanskij, Ja.S., Skakov, Ju.A., Ivanov, A.N., Rastorgujev, L.N., [Crystallogaphy, X-ray graph and electron microscopy], Metallurgy, Moskow, 632 p. (1982) (in Russian).

[14] Weinberg F.,[Devices and methods of physical metallurgy], Moscow, 427 p. (1973) (in Russian).

[15] Kurbatov, D., Kosyak, V., Kolesnyk, M., Opanasyuk, A., Danilchenko, S. "Morfological and structural characteristics of II-VI semiconductor thin films (ZnTe, CdTe, ZnS)", Integrated Ferroelectrics 103(1), 32-40 (2009).

[16] Danilchenko, S.M., Kolesnyk, M. M., Opanasyuk, A. S. . [et al.], "Structural properties of the films ZnTe obtained by close-spaced vacuum sublimation", Vesnik Sumy State University. Series: Physics, Mathematics, Mechanics 1, 115-124 (2007) (in Ukrainian).

[17] Kurbatov, D., Kolesnyk, M., Opanasyuk, A. [et al.] "The substructural and optical characteristics of ZnTe thin films", Semicond. Phys. Quant. Electr. Optoelectron 12(1), 35-40 (2009).

[18] B. Oles, H. G. von Schnering, "Raman and infrared studies of optical phonons in $Zn_{1-x}Mn_xTe$ mixed crystals", J. Phys. C: Solid State Phys. 18, 6289-6296 (1985).

[19] W. Zaleszczyk, E. Janik, A. Presz et al., "Growth and Properties of ZnMnTe Nanowires", Acta Physica polonica A. 112, №2, 351-356 (2007).