Proceedings of the IX International Conference ION 2012, Kazimierz Dolny, Poland, June 25–28, 2012

Effect of Cu Negative Ion Implantation on Physical Properties of $Zn_{1-x}Mn_xTe$ Films

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The paper deals with the investigations of structural properties of $Zn_{1-x}Mn_xTe$ films, which were fabricated under various deposition conditions using the thermal evaporation method in a closed volume. The surface morphology of the samples was studied, the phase analysis of their structures was performed, the elemental analysis of the films and the crystal lattice constant were investigated. The texture perfection of the films before and after copper ion implantation was evaluated.

DOI: 10.12693/APhysPolA.123.939

PACS: 61.05.cp, 61.72.uj

1. Introduction

At present, the interest of specialists working in the field of materials science, more specifically in semimagnetic solid solutions $Zn_{1-x}Mn_xTe$ has developed since their photoluminescence, magnetic and magnetooptical properties were unique allowing fabrication of a number of effective instruments for micro-, opto-electronics, solar power engineering, and spintronics [1, 2]. Copper is traditionally employed as a doping impurity activating the photoluminescence, as well as for fabrication of doped ZnTe films of high conductivity [3–5]. The ion implantation is considered to be the most efficient method allowing introduction of this impurity to A_2B_6 compounds [6]. However, the influence of Cu impurity on the properties of $Zn_{1-x}Mn_xTe$ solid solutions is poorly studied. The work reports the structural properties and the elemental composition of the $Zn_{1-x}Mn_xTe$ films deposited using close-spaced vacuum sublimation (CSVS) before and after copper ion implantation.

2. Methodology of film preparation and investigations

The thin $Zn_{1-x}Mn_xTe$ films were deposited on the glass substrates at over 5×10^{-3} Pa pressure of the residual gases in the chamber. The detailed description of device, which was employed for the film deposition using the CSVS method, was reported in [7, 8]. The mix material of a semiconducting purity containing 10% of manganese was evaporated. The temperature of the evaporator was $T_e = 800\,^\circ$C. The substrate temperature varied within the interval $T_s = 150$–$550\,^\circ$C. The deposition time was normally $t = 5$–15 min, and the layer thickness was 2–8 μm. Surface morphology of the films was studied using scanning electron microscopy (REMMA-103-01).

Elemental analysis of films was performed using X-ray characteristic radiation induced by a proton beam [9]. The studies were carried out using the electrostatic accelerator Sokol with the energy of a proton beam up to 2 MeV (Institute of Applied Physics, NAS of Ukraine, Sumy) [10]. Summed-up spectra from several areas of the sample surfaces (particle induced X-ray emission, PIXE) were scanned and point-by-point spectra were studied using the micro-beam (μ-PIXE). The scanned film area was usually 200×200 μm^2. The transverse size of the probe was 4×4 μm^2, charge $Q = 4 \times 10^{-10}$ C/pixel, raster was 50×50 pixels, and the scanning step was 4 μm. The proton energy E_p was 1.5 MeV. The obtained PIXE spectra were processed using the GUPIX 3 program. The samples fabricated under optimal conditions ($T_s = 350\,^\circ$C) were subsequently doped by implantation of negative Cu ions of 60 keV energy and the 10^{14} cm^{-2} fluence using the ion source (NIMS, Tsukuba, Ibaraki, Japan).

Structural studies of the films were performed with the X-ray diffraction device RINT2500MDG in K_α-emission of the chrome anode. Shooting was performed within 2θ angles from 10° to 160° (2θ is the Bragg angle). X-ray radiation was focused according to Bragg–Brentano. Curves were normalized to the peak (111) intensity of a cubic phase. Phase analysis was carried out by comparing the interplanar spacings and relative intensities of X-ray peaks of the studied samples and the standards of JCPDS [11]. The film textures were measured by the Harris method [12–14]. The $Zn_{1-x}Mn_xTe$ powder was used as the standard of a non-textured sample. The lattice constant value of $Zn_{1-x}Mn_xTe$ films was determined by the position of K_{α_1} component of all most intensive lines present in the diffraction patterns. Subsequently, to obtain precise values of constants, we used

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