Applied Surface Science 258 (2012) 2137–2140

Contents lists available at ScienceDirect

Applied Surface Science

journal homepage: www.elsevier.com/locate/apsusc

Effects of substrate temperature upon the properties of ZnMgTe layer grown by MOVPE

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ARTICLE INFO

Article history:
Available online 22 March 2011

Keywords:
ZnMgTe
MOVPE
Substrate temperature
Optical properties
Surface morphology

ABSTRACT

The effects of substrate temperature upon the optical property, composition and surface morphology have been investigated on nominally undoped $Zn_{1-x}Mg_xTe$ layers grown on (1 0 0) ZnTe substrates by atmospheric pressure metal organic vapor phase epitaxy (MOVPE). It was found that Mg composition increases with decreasing substrate temperature. The result of low temperature photoluminescence (PL) measurement suggests that the optical quality of $Zn_{1-x}Mg_xTe$ layers becomes better with decreasing substrate temperature. On the other hand, there is a narrow range of optimal substrate temperature for a smooth surface morphology. For all the layers, a two-mode behavior with ZnTe- and MgTe-like longitudinal optical phonon modes was confirmed by Raman scattering.

1. Introduction

$Zn_{1-x}Mg_xTe$ ternary alloy is a candidate for an electro-optically active material in green-to-blue range of spectrum and a cladding layer for improving a performance of ZnTe-based pure-green light-emitting-diodes and for realizing ZnTe-based laser diodes. Unfortunately, there are only a few works on $Zn_{1-x}Mg_xTe$ epitaxial layer grown by metalorganic vapor phase epitaxy (MOVPE) [1–5], which is a potential epitaxial growth technique for mass production. In our previous studies, nominally undoped $Zn_{1-x}Mg_xTe$ epitaxial layers have been successfully grown on (1 0 0) ZnTe substrates by MOVPE using dimethylzinc (DMZn), bis-methylcyclopentadienyl-magnesium ($(MeCp)_2Mg$) and diethyltelluride (DETe) [4,5]. It has been found that the Mg composition in the layer drastically increases with decreasing DETe transport rate or with increasing the total carrier gas flow rate [4]. In addition, we have reported on the relationship between the optical quality of the grown layers and the transport rate ratio of group VI source to group II ones [5]. On the other hand, the substrate temperature is also one of the important parameter of growth condition. However, there is no report on the influence on the growth of $Zn_{1-x}Mg_xTe$ layer. In this work, we studied the effects of substrate temperature upon the optical properties, Mg composition, and surface morphology of undoped $Zn_{1-x}Mg_xTe$ layers grown by MOVPE. Furthermore, we report Raman scattering of MOVPE grown $Zn_{1-x}Mg_xTe$ layers for the first time.

2. Experimental

The growth of undoped $Zn_{1-x}Mg_xTe$ layers was performed on gallium-doped (1 0 0) ZnTe substrates using a vertical-type atmospheric pressure MOVPE system in almost the same manner as employed in the previous studies [4,5]. DMZn, $(MeCp)_2Mg$, DETe were used as Zn, Mg and Te precursors, respectively. Hydrogen was employed as a carrier gas with the total flow rate of 800 sccm. The substrate temperature was varied from 340 to 420 °C, while the transport rates of DMZn, $(MeCp)_2Mg$ and DETe were fixed at 15, 2 and 10 μmol/min, respectively. The substrates were ultrasonically cleaned by organic solvents, and etched in a 1 vol% Br–methanol solution. In order to remove the native oxide on the surface of the substrate prior to the growth, it was cleaned by a thermal annealing in hydrogen flow at 420 °C for 30 min. The growth time was set on 2 h.

The Mg composition was measured using a scanning electron microscopy (XL-30 FEG, Philips) with energy dispersion X-ray (EDX) spectrometer (INCA x-sight, Oxford Instruments). The surface morphology and root mean square (rms) roughness were characterized by an atomic force microscopy (AFM) system (MultiMode AFM with Nanoscope IIIa, Veeco Instruments and Digital Instruments) with silicon tip in tapping mode over scan areas of 20 μm × 20 μm and 80 μm × 80 μm, respectively. Photoluminescence (PL) measurement was performed at 4.2 K using a blue-violet laser diode at 405 nm as an excitation source. The PL signal was dispersed by a conventional 1 m type gratin spectrometer and detected by a photomultiplier. Raman spectra were measured at room temperature in the backscattering configuration using a micro-Raman system (LabRAM HR 800UV, Jobin Yvon) equipped

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doi:10.1016/j.apsusc.2011.03.085

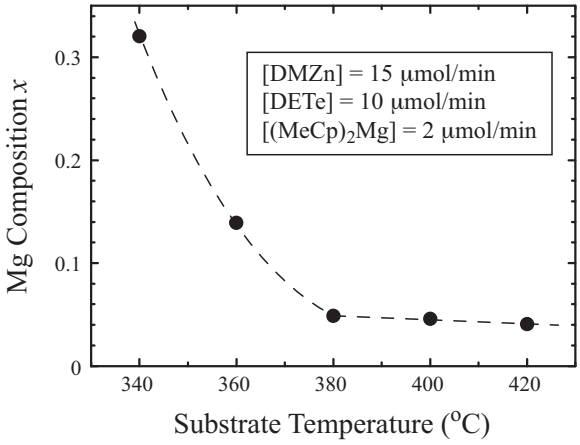

Fig. 1. Dependence of the Mg composition of $Zn_{1-x}Mg_xTe$ layers on the substrate temperature.

with a charge-coupling-device detector using 325 line of a He-Cd laser.

3. Results and discussion

Fig. 1 shows the substrate temperature dependence of Mg composition of the $Zn_{1-x}Mg_xTe$ layers estimated by EDX analysis. The Mg composition decreases considerably with increasing substrate temperature up to 380 °C, and then results in lower limit. The decrease of Mg composition with substrate temperature may be due to the increase of Mg losses caused by parasitic reaction between DETe and $(MeCp)_2Mg$ within the heated gas phase region above the surface, and/or the influence of the different reduction rate in decomposition efficiencies of the precursors on the surface. It is noteworthy that the critical substrate temperature around 380 °C in Fig. 1 is consistent with the activation energy of ZnTe

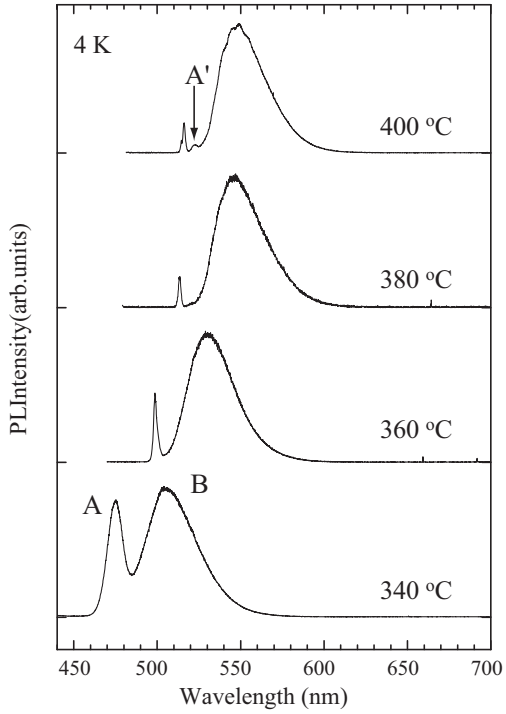

Fig. 2. Low temperature PL spectra of $Zn_{1-x}Mg_xTe$ layers grown at different substrate temperatures.

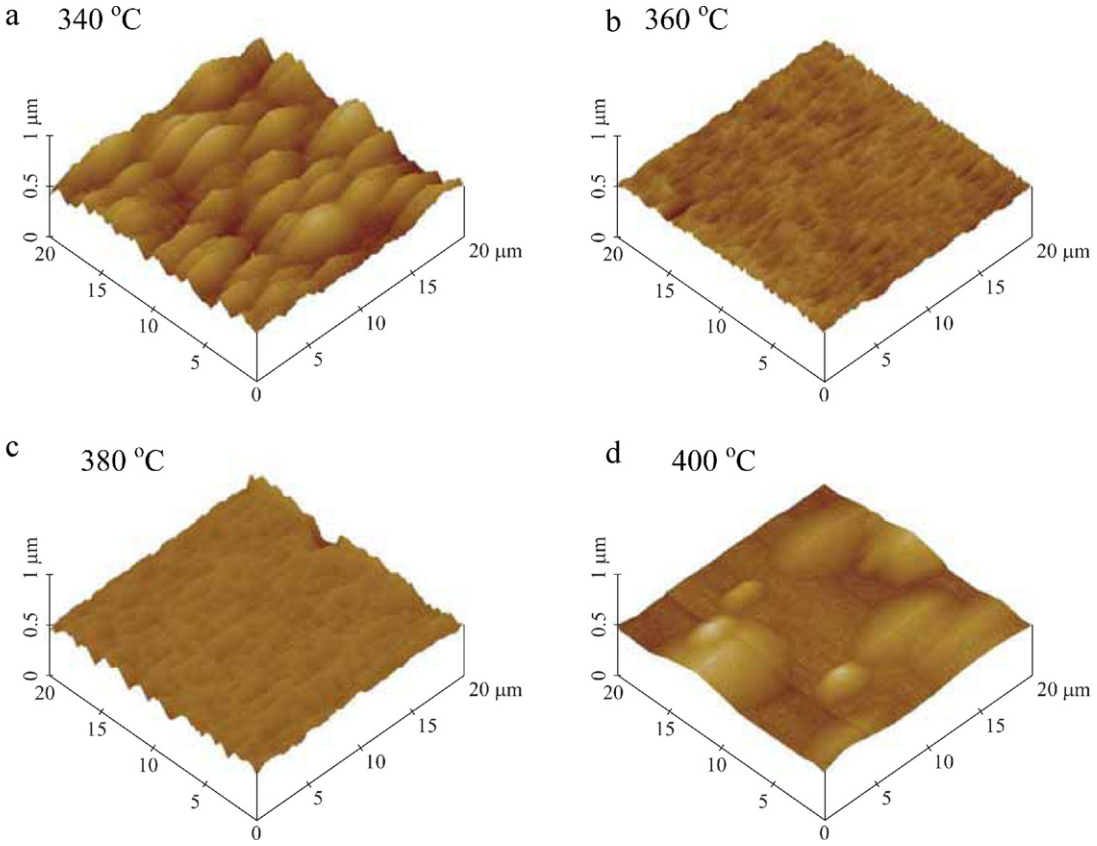

Fig. 3. Three dimensional AFM images of $Zn_{1-x}Mg_xTe$ layers grown at different substrate temperatures: (a) 340, (b) 360, (c) 380, (d) 400 °C.