Materials Letters 66 (2012) 280–281

Contents lists available at SciVerse ScienceDirect

Materials Letters

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

Pulsed laser deposition of indium tin oxide nanowires in argon and helium

Thian-Khok Yong [a], Sek-Sean Tan [a], Chen-Hon Nee [a], Seong-Shan Yap [a], Yeh-Yee Kee [a], György Sáfrán [b], Zsolt Endre Horváth [b], Jason Moscatello [c], Yoke-Khin Yap [c], Teck-Yong Tou [a,*]

[a] Faculty of Engineering, Multimedia University, Cyberjaya, Selangor, Malaysia
[b] Research Institute for Technical Physics and Material Science, Hungarian Academy of Sciences (MFA), Budapest, Hungary
[c] Department of Physics, Michigan Technological University, 1400 Townsend Drive, Houghton, MI 49931-1295, USA

ARTICLE INFO

Article history:
Received 2 July 2011
Accepted 25 August 2011
Available online xxxx

Keywords:
Thin films
Laser processing
Electronic materials

ABSTRACT

Nanowires of indium tin oxide (ITO) were grown on catalyst-free amorphous glass substrates at relatively low temperature of 250 °C in argon and helium ambient by the Nd:YAG pulsed laser deposition technique. All the ITO samples showed crystalline structure due to substrate heating and the (400) X-ray diffraction peak became relatively stronger as the pressure was increased. The surface morphology was also changed from compact, polycrystalline thin-film layers to a dendritic layer consisting of nanowires for some limited pressure ranges. The transition from the normal thin-film structure to nanowires was likely due to the vapor–liquid–solid mechanism but under catalyst-free condition. These nanowires tended to grow perpendicularly on the glass substrate, as observed with the transmission electron microscopy (TEM), which also confirmed that these nanowires were crystalline.

1. Introduction

Indium tin oxide (ITO) has been used as the transparent conducting electrode and hole injection anode [1]. ITO nanostructures, which include nanowires, nanorods, nanowhiskers and nanocrystal, were prepared by co-evaporating method [2], sol electrophoresis with a template [3], gold catalyst-assisted vapor–liquid–solid growth process [4], and electron beam evaporation [5]. Raluca Save et al. [6] reported on the ITO nanowires obtained by pulsed laser deposition on a catalyst-free silica substrate at 500 °C with nitrogen as the background gas. It was observed that the nitrogen pressure influenced the orientation of nanowire as well as transformation, at 2 mbar, of ITO from nanowires to nano-pyramids. The effects of different background gases on electrical and optical properties of ITO by pulsed laser deposition were previously reported by Thestrup et al. [7] and our group [8], but ITO nanostructures were not observed. In this paper, we report that ITO nanostructures, in particular, nanowires can be prepared by the Nd:YAG pulsed laser deposition in argon at relatively low temperature of 250 °C, and on the catalyst-free glass substrate.

2. Experimental

The deposition was performed with a Q-switched Nd:YAG pulsed laser (EKSPLA, NL301) at 355 nm [8]. The ablation target was a sintered, 2-inch diameter disk of ITO target with a composition of 90 wt.% In_2O_3 and 10 wt.% SnO_2 (Target Materials, Inc., USA). The ITO target surface was first cleaned by ablation for 5 min by unfocused laser beam and the glass substrates were placed at 8 cm away. The deposition rate was estimated to be about 0.5 nm/s and the ITO film thickness was always maintained at 200 nm. The surface morphology of the ITO films was obtained with a field-emission scanning electron microscopy (FESEM) (model Hitachi S-4700). The crystal structures of ITO films were determined by an X-ray diffraction (XRD) and transmission electron microscopy (TEM), namely, the Bruker AXS D8 Discover diffractometer equipped with a 2D position sensitive (GADDS) detector, and the JEOL-2010 TEM equipped with a GATAN TRIDIEM electron energy loss spectrometer (EELS).

3. Results and discussions

The FESEM and XRD patterns of ITO samples grown in Ar and He ambient are shown in Figs. 1 and 2, respectively. All the ITO nanowires have crystalline structure, which exhibit diffraction peaks only from the cubic bixbyite structure of In_2O_3[9]. There are four major diffraction peaks corresponding to (222), (400), (440) and (622) orientations. An obvious trend shown by the XRD diffraction pattern was that the (400) diffraction peak became relatively strong. For He, the nanowires could be transformed to closely arranged, pyramid-like nanocrystals at pressures above 100 mbar.

Fig. 3(a) shows the cross sectional TEM image of ITO deposited at 30 mTorr Ar. The TEM image indicates that the ITO nanostructure consists of two layers of different morphologies. The nanowire was perpendicular to the substrate, typically, with "wire" diameter between

* Corresponding author. Tel.: +60 3 83125278; fax: +60 3 83183029.
E-mail address: tytou@mmu.edu.my (T.-Y. Tou).

0167-577X/$ – see front matter © 2011 Elsevier B.V. All rights reserved.
doi:10.1016/j.matlet.2011.08.085

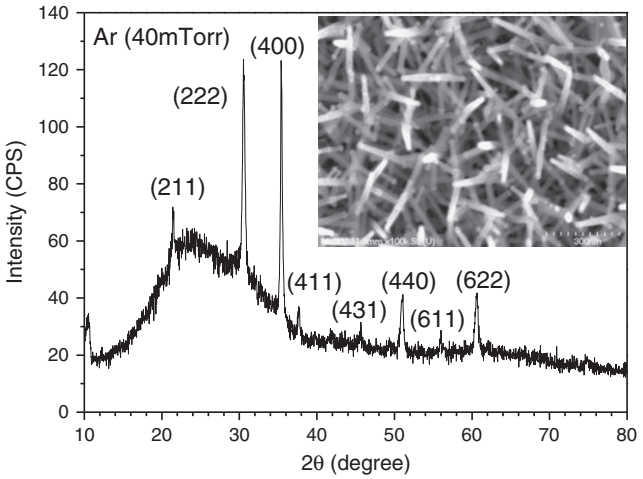

Fig. 1. XRD and SEM of ITO samples grown on 250 °C heated catalyst-free glass substrates in Ar ambient at 30 mTorr.

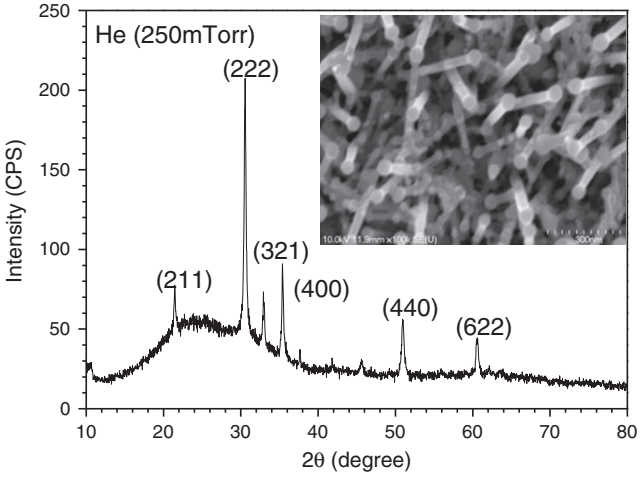

Fig. 2. XRD and SEM of ITO samples grown on 250 °C heated catalyst-free glass substrates in He ambient at 250 mTorr.

20–30 nm and wire length of 700–800 nm. The high resolution image and its fast Fourier transform (inset in (b)) represent that the (400) lattice fringes of 0.256 nm period were parallel to the longitudinal axis of the nanowire. This structural feature, together with the rectangular alignment of the nanowire may explain the measured strong (400) XRD peak for this particular sample (40 mTorr) as compared to the ones deposited either at 30 mTorr Ar or 250 mTorr He.

4. Conclusions

In summary, ITO nanowires have been deposited by the Nd:YAG pulsed laser ablation on glass substrates at a relatively low temperature of 250 °C in Ar and He at appropriate pressures. The growth process as a function of the ambient pressure allowed the fabrication of nanowire ITO with the (400) lattice plane being aligned to the longitudinal axis.

Acknowledgments

This project is supported by the research grants from Malaysia Ministry of Science, Technology and Innovation (MOSTI) (Project no: 03-02-01-SF0082) and Academic of Sciences Malaysia under Brain Gain Program.

References

[1] Hartnagel HL, Dawar AL, Jain AK, Jagadish C. Semiconducting transparent thin films. Bristol and Philadelphia: Institute of Physics Publishing; 1995.
[2] Wan Q, Song ZT, Feng SL, Wang TH. Appl Phys Lett 2004;82:4759–61.
[3] Limmer SJ, Cruz SV, Cao GZ. Appl Phys A 2004;79:421–4.
[4] Nguyen Pho, Vaddiraju S, Meyyappan M. J Electronic Mater 2006;35:200–6.
[5] Pokaipisit A, Udomkan N, Limsuwan P. Mod Phys Lett B 2006;20:1046–58.
[6] Savuand R, Joanni E. Scr Mater 2006;55:976–81.
[7] Thestrup B, Schou J, Nordskov A, Larsen NB. Appl Surf Sci 1999;142:248–52.
[8] Yong TK, Yap SS, Sáfrán G, Tou TY. Appl Surf Sci 2007;253:4955–9.
[9] Marezio M. Acta Crystallogr 1966;20:723–8.

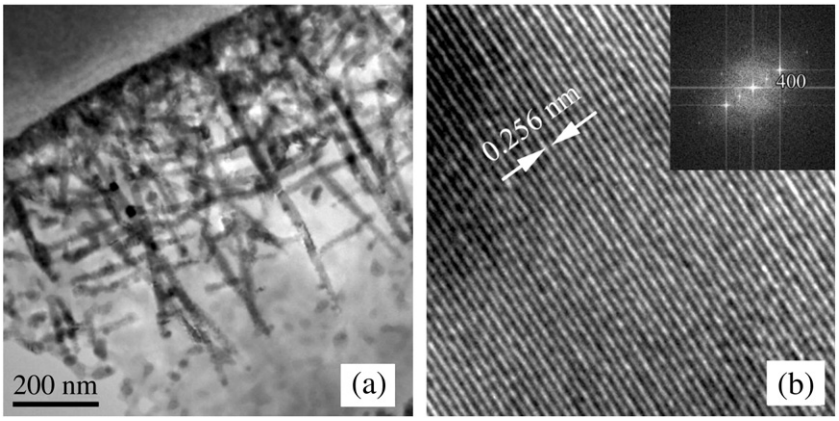

Fig. 3. (a) TEM images of ITO nanowires grown in 40 mbar Ar, (b) fast Fourier transform reveals (400) lattice planes are aligned longitudinally to nanowire.