Advanced Materials Research Vol. 364 (2012) pp 202-205
Online available since 2011/Oct/24 at www.scientific.net
© (2012) Trans Tech Publications, Switzerland
doi:10.4028/www.scientific.net/AMR.364.202

Growth and Characterization of Indium Doped ZnO Nanowires Using Vapor Transport Deposition Method

ABRAR Ismardi[1,a], CHANG Fu Dee[1,b], I. C. Gebeshuber[1,c] and B. Y. Majlis[1,d]

Institute of Microengineering and Nanoelectronics (IMEN) Universiti Kebangsaan Malaysia (UKM)
43600 Bangi, Selangor, Malaysia

[a]abrar_selah@yahoo.com, [b]cfdee@ukm.my, [c]ille.ukm@gmail.com, [d]burhan@eng.ukm.my

Keywords: ZnO, Nanowires, In doped, vapor transport deposition

Abstract. Indium (In) doped ZnO nanowires (NWs) has been grown on silicon substrate without the use of catalyst. In conventional vapor transport deposition method, the ZnO source powder usually mixed with In dopant and placed in the middle of quartz tube. However, in this work, the graphite mixed ZnO source powder on a crucible was placed at the center of the quartz tube. While the graphite mixed In_2O_3 was placed at the downstream of the furnace with a distance of 1 cm from the graphite mixed ZnO powder. Morphological study has been carried out using field emission scanning electron microscopy (FESEM). The result showed that the grown NWs have uniform hexagonal nanostructures. Chemical composition has been examined by energy dispersive X-ray spectroscopy (EDS). XRD spectrum of the In doped ZnO NWs has also been taken to study the crystallinity of the structure.

Introduction

In the recent years, great attention has been focused to the synthesis and characterization of quasi one dimensional nanostructure of metal oxide semiconductor materials, such as nanowires (NWs), nanorods, nanowhisker and nanotubes due to its versatile properties that can be applied in the wide nanodevices applications [1-6]. Among them, ZnO NW is one of the most important one dimensional nanostructure that has provided a wide range of potential applications. It has wide band gap (3.37 eV) and large exciton binding energy (60 meV) at room temperature, it can be applied in many applications such as, short wavelength light emitted, transparent electrode, sensor and actuator and piezoelectric devices [7-9].

The properties of ZnO NWs can be enhanced by introducing with dopant. Among the dopants which have been reported are Au, Cd, Cr, Eu, In and Sc [10-16]. Doping process may improve electrical, optical and gas sensing capabilities of the ZnO NWs. In conventional vapor transport deposition technique, doping process was carried out by mixing ZnO powder and dopant powder and placed together in the middle of tube furnace. However, in our work, a new technique of doping process was proposed where the ZnO and In dopant powder were separately placed in the furnace.

Experimental Method

The growth process was carried out using a quartz tube furnace. The graphite mixed ZnO powder was placed in the middle of quartz tube. Graphite mixed In_2O_3 powder was placed 1 cm from the ZnO source at the downstream as shown in the schematic diagram in Fig 1. Silicon substrate was placed at the downstream of the source powder which was 10 cm from the middle of furnace. The furnace was then heated up to 1000°C for two hours. Nitrogen gas was then introduced as carrier gas with a constant flow rate of 1500 ml/min. After two hours, the furnace was then cooled down to room temperature. A grey color product was found on the substrate. The product was then characterized by using field emission scanning electron microscopy (FESEM), energy dispersive X-ray spectroscopy (EDS) and X-ray diffraction (XRD).

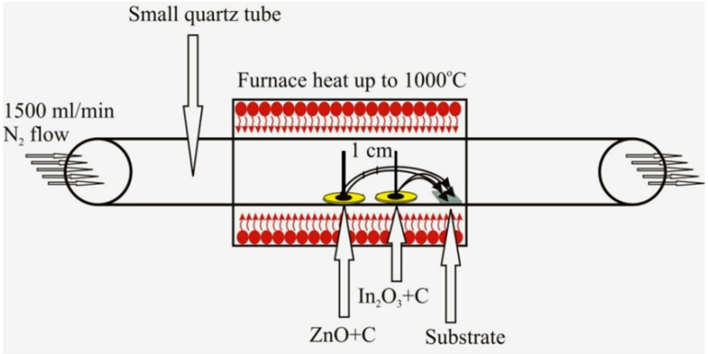

Fig. 1: Schematic diagram for the growth of In doped ZnO NWs. The In dopant was placed 1 cm from the ZnO source powder at the downstream.

Results and Discussion

Fig. 2(a), (b), (c) and (d) respectively show the FESEM images for the In doped ZnO NWs grown on silicon substrate with different magnifications. The as-grown In doped ZnO NWs are straight and basically stretching up within an angular angle of roughly 30° normal to the substrate. A typical hexagonal shape of ZnO NWs was hardly been observed here. The surfaces of the NWs look smooth. The diameters of NWs have been estimated to be within the range of 20 to 100 nm while the lengths in the range of 200 nm to 1 micron.

Fig 3 shows the EDS spectrum of the grown In doped ZnO NWs. Zn, In and O elements were found in the sample. The peaks for Zn, O and In has been found in the spectrum. The compositions for all elements are listed in Table 1. Trace of In element can be found with very low percentage, ~0.11 weight percent as shown in the Table 1. The highest peak is contributed by Si substrate.

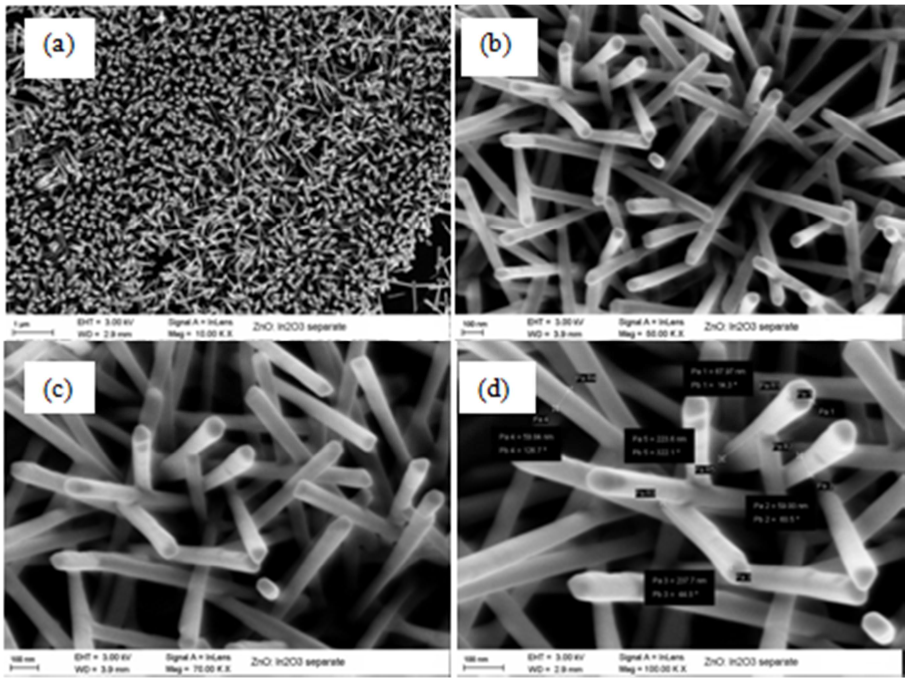

Fig. 2: Morphological structure of In doped ZnO NWs grown on silicon substrate with different magnifications, (a)10K, (b) 50K, (c) 70K and (d) 100K

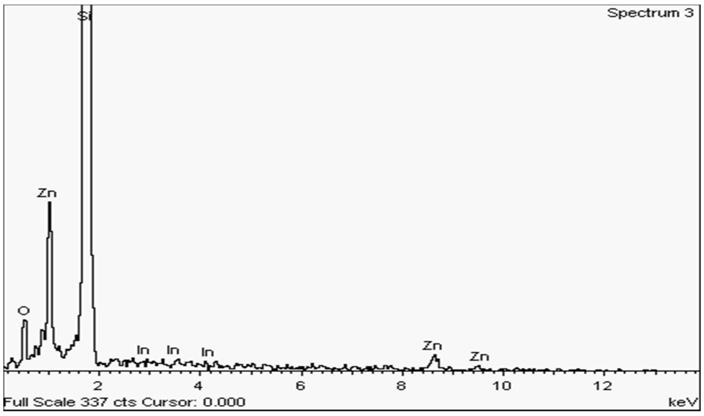

Fig. 3: EDS spectrum of In doped ZnO NWs shows the presence of Zn, O and In elements in the sample

Table 1: EDS elemental composition of In doped ZnO NWs

Element	Weight %	Atomic %
O	8.26	14.69
Si	78.63	79.63
Zn	13.00	5.66
In	0.11	0.03
Total	100	

The XRD spectrum of the In doped ZnO NWs can be seen in Fig 4. High quality of ZnO NWs has been deduced from the sharp and narrow XRD diffraction peaks. Those peaks are assigned to ZnO and In_2O_3. The weak peak for In_2O_3 in the spectrum indicating a trace amount of In_2O_3 found in the sample which is similar to the result provided by the EDS spectrum. The intensity of (002) peak is much stronger than other (100) peak, suggesting the (002) could be the major orientation for the NWs [14].

We expected the doping process may occur in the two possible mechanisms. Firstly, In doped ZnO NWs may happen during the evaporation process. When the temperature of furnace reached their melting point, the In vapor could mix with Zn vapor and then deposited into silicon substrate to form the NWs. In low oxygen pressure, Zn particles evaporated or oxygen deficient ZnO formed due to residual oxygen deposited onto the silicon substrate. Secondly, their vapors were not mixed during the evaporation process, nevertheless the In vapor fall into the ZnO NWs during the deposition process. In this process, the vapor evaporated from the source transfer to the lower region of temperature and forms NWs, so catalyst is unnecessary. In doping was achieved to the process on In substitute Zn atom in ZnO. Continuous feeding of Zn and In atom during the process sustain the growth of In doped ZnO NWs.

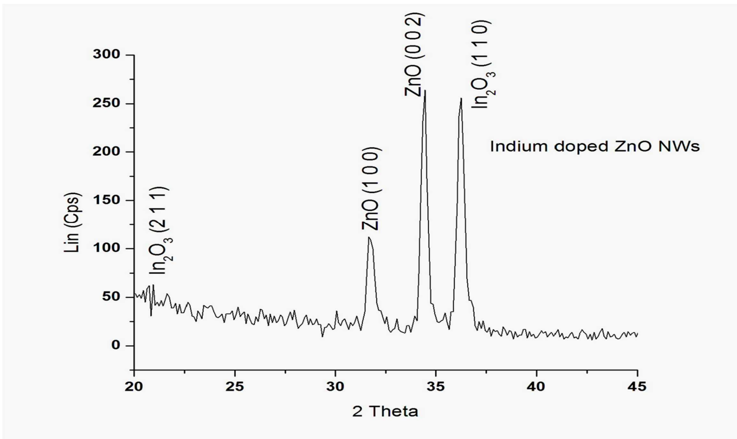

Fig. 4: XRD spectrum of In doped ZnO NWs shows highly crystalline of the nanostructure.

Conclusion

In doped ZnO NWs were grown using vapor transport deposition method by separating the ZnO and In_2O_3 (ZnO+C and In_2O_3+C) source materials in two different crucible with 1 cm apart from each other. Hexagonal shape of In doped ZnO NWs have been grown. EDS spectrum confirmed the presence of Zn, In and O element. XRD diffraction spectrum revealed that In doped ZnO NWs have high crystallinity structure.

Acknowledgement

The author would like to thank the Universiti Kebangsaan Malaysia for the laboratory facilities and for the financial support under the grant no. of UKM-RRR1-07-FRGS0025-2010.

References

[1] J. H. Shin, J. Y. Song and H. M. Park, Materials Letters, 2009. 63(1): p. 145-147.
[2] F. Fang, D. X. Zhao, J. Y. Zhang , D. Z. Shen, Y. M. Lu, X. W. Fan, B. H. Li and X. H. Wang, Materials Letters, 2008. 62(6-7): p. 1092-1095.
[3] H. Y. Ning, S. S. Guang, C. Wuyuan, Li. Xin, Z.C. Chun and H. Xun, Microelectronics Journal, 2009. 40(3): p. 517-519.
[4] A. Umar, S. H. Kim, J. H. Kim, and Y. B. Hahn, Materials Letters, 2008. 62(1): p. 167-171.
[5] C. F. Dee, B. Y. Majlis, M. Yahaya and M. M. Salleh, Sains Malaysiana, 2008. 37(3): p. 281-283.
[6] Y. C. Chin, M. Yahaya, M. M. Salleh and C. F.Dee, Sains Malaysiana, 2008. 37(3): p. 277-280.
[7] M. H. Huang, Y. Wu, H. Feick, N. Tran, E. Weber, and P. Yang, Advanced Materials, 2001. 13(2): p. 113-116.
[8] N. V. Hieu and N. D. Chien, Physica B: Condensed Matter, 2008. 403(1): p. 50-56.
[9] J. Zhang, M. K. Li, L. Y. Yu, L. L. Liu, H. Zhang and Z. Yang, Applied Physics A: Materials Science & Processing, 2009. 97(4): p. 869-876.
[10] N. Hongsith, C. Viriyaworasakul, P. Mangkorntong, N. Mangkorntong and S. Choopun, Ceramics International, 2008. 34(4): p. 823-826.
[11] J. Z. Liu, P. X. Yan, G. H. Yue, J. B. Chang, R. F. Zhuo and D. M. Qu, Materials Letters, 2006. 60(25-26): p. 3122-3125.
[12] D. Chua, Y. P. Zeng and D. Jianga, Solid State Communications, 2007. 143(6-7): p. 308-312.
[13] P. Mohanty, B. Kim. and J. Park, Materials Science and Engineering, 2007. 138(2007): p. 4.
[14] J. Jie, G. Wang, X. Han, Q. Yu, Y. Liao, G. Li and J.G. Hou , Chemical Physics Letters, 2004. 387(4-6): p. 466-470.
[15] J. Zhao, X. Yan, Y. Yang, Y. Huang and Y. Zhang, Materials Letters, 2010. 64(5): p. 569-572.
[16] S.M. Zhou, X.H. Zhang, X.M. Meng, X. Fan, S. K. Wu and S.T. Lee, Physica E: Low-dimensional Systems and Nanostructures, 2005. 25(4): p. 587-591.

Nanomaterials
10.4028/www.scientific.net/AMR.364

Growth and Characterization of Indium Doped ZnO Nanowires Using Vapor Transport Deposition Method

10.4028/www.scientific.net/AMR.364.202