SnO₂ Fiber: Morphology, Optical Property

Gyanendra Prakash Shukla and Mukesh Chandra Bhatnagar*

Physics Department, Indian Institute of Technology, New Delhi 110016, Indian

Abstract: In this paper, we have deposited microstructure (straight wire like shape some time name as fiber) of tin oxide on silicon substrate by simplest known technique thermal evaporation. It is observed that these fibers have same property like tin oxide material (nanowire) and size were approximate in micron. Diamond peak found in X-ray diffraction pattern in toward higher glancing angle. Observed tin oxide fibers were characterized by using scanning electron microscopy, X-ray diffraction and optical property have been measure by ultra violet visible diffuse reflection spectroscopy.

Key words: Tin oxide NWs, thermal evaporation.

1. Introduction

Recently nanostructure has been prepared for their interesting optical and electrical property [1] from the family of metal oxide such as SnO₂, ZnO, In₂O₃, etc. Nanocrystalline SnO₂ (doped or un-doped) have many application such as gas sensing, solar cell, etc [2]. In this study, tin oxide fiber have prepared successfully by thermal evaporation method and application of this tin oxide fiber become in silent mode. As dimensions shrink from micro dimensional or larger (i.e. bulk) to the nanodimensional, a number of unexpected deviations from the properties observed in their “bulk” form occurs, namely, electrical, optical and mechanical properties change. Briefly, the reduction from micro to nanodimensional crystallite size affords an increase in surface area to volume ratio. One dimensional tin oxide nanostructure has attached substantial interest because of their various morphology such as nanowire, nanotube, nanospring and nanoflower. Our study was focused on synthesized of tin oxide nanostructure. We have shown the growth of self catalysis tin oxide fiber by optimize condition for thermal evaporation chamber.

2. Experimental

A commercial one surface polished n-type Si (1 0 0)

oriented 2in. diameter wafer with resistivity 1-20 Ω cm and thickness $525 \pm 25 \mu\text{m}$ was used as a substrate and source of silicon for the growth of SnO₂/Si nanofiber. The Si wafer was cut into dimensions of 0.5 cm × 0.5 cm before being cleaned by standard RCA cleaning method. Alumina boat, on which deposition has been taken, cleaned with propanol along with acetone. I have taken SnO₂ powder (99.99% pure) along with graphite fine powder (99.50% pure) in 1:1 ratio as a precursor. Ar gas had taken at constant flow rate of 80 sccm. Prior of heating, pressure inside the furnace keeps on atmosphere pressure. Furnace was heated up to 1,030 °C and maintained it till 2 h. The set up of atmospheric sintering furnace is shown on Fig. 1.

3. Characterization of Fiber

Product obtained was subjected to characterization by X-ray diffraction, Scanning electron microscope, Raman spectra, Ultra violet and visible diffuse reflection spectra. Crystal structure can be understood by X-ray diffraction peaks which response the tetragonal phase of tin oxide. The crystallite size (t) was calculated from the FWHM (Full width half maxima) of the maximum intense diffraction peak of the XRD pattern by using the Debye-Scherrer formula [3] given by:

$$t = 0.9 \lambda / \beta \cos \theta \quad (1)$$

where, λ is the wavelength of the X-rays used, β is the

*Corresponding author: Mukesh Chandra Bhatnagar, associate professor, research fields: material science and chemical sensor.

FWHM, θ is the Bragg angle, and t is the average crystallite size. From Eq. (1), crystalline size of SnO₂ fibers have been found 133 nm. Fig. 2 shows the XRD patterns of the fiber. The products are crystalline and the diffraction peaks can be indexed as the tetragonal rutile structure, which was consistent with the reported data (JCPDS). No other phases were detected.

Now surface morphology was investigated by SEM and SEM image shows the growth of OF's on Si substrate. The diameter of F's is about 800 nm to several microns and length was approximately several hundred of microns shown in Fig. 3a and Fig. 3b. Corresponding E-DEX spectra for confirmation of tin oxide are shown in Fig. 4.

Again from Raman spectroscopy, two fundamental Raman peaks at 632 and 774 cm⁻¹ corresponding to the A_{1g} and B_{2g} vibration modes, respectively, are observed,

Fig. 1 Schematic diagram of thermal evaporation chamber.

Fig. 2 XRD image of tin oxide F's shows tetragonal structure.

in good agreement with those for the rutile bulk SnO₂ (Fig. 5) but spectra corresponding to E_g vibration mode was not observed (very weak signal). Thus, these peaks further confirm that the synthesized SnO₂ fiber possess the characteristics of the tetragonal rutile structure [4].

4. Result and Discussion

Band gap of SnO₂ fiber were studied by UV-Vis absorption spectroscopy. The UV-Vis diffuses reflection spectra of tin oxide F's are presented in Fig. 6.

The band gap energy was calculated using Kubelka-Munk (K-M) model [3, 5] (Tandon and Gupta 1970) which at any wavelength is given by:

$$F(R) = (1-R)^2 / 2R = k/s = Ac/s \quad (2)$$

$F(R) = \alpha$ is the K-M function and R is the percentage of reflectance. A graph is plotted between $[F(R) \cdot hv]^2$

(a)

(b)

Fig. 3 (a) and (b) are SEM images of tin oxide F's at 1,030 °C.

Fig. 4 E-DEX image of tin oxide F's at 1,030 °C.

Fig. 5 Raman spectra of tin oxide F's.

Fig. 6 Diffuse reflection spectra of tin oxide fibers on silicon substrate at 1,030 °C.

versus $h\nu$ and the x-intercept value yields the band gap energy. Though this plots, we can calculate the band gap energy from the UV-Vis spectra, we have used the K-M plot for this purpose. The band gap energies were calculated by intercept on X-axis is approximate 2.35 eV for tin oxide fiber in Fig. 7.

Resistance of these fibers show purely insulator behaviour at some lower temperature but at temperature approximate 400 °C, these fibers show behaviour of semiconductor material by resistance 2.23 MΩ. In order to calculate the refractive index of the tin oxide fiber, we recorded reflectance spectra of the fiber by putting single fiber between two visible glass samples. The refractive index of the fiber was calculated by the following relation [6]:

$$n = \frac{(1+R)}{(1-R)} + \sqrt{\left(\frac{4R}{(1-R)^2} - \kappa^2\right)} \quad (3)$$

where, R is the reflectance and κ ($\alpha\lambda/4\pi$) is the extinction coefficient. The refractive index dependence of wavelength was shown in Fig. 8. The refractive index decreases with increasing wavelength. This suggests that the films show normal dispersion.

Fig. 7 Calculation of band gap energy plot.

Fig. 8 Refractive index variation with wavelength.

So from growth of fiber at low gas flow rate 80 sccm compared to in growth of nanostructure, structure converted in fiber. The mechanism behind in growth of fiber is silent.

5. Conclusions

On some certain special condition inside the thermal evaporation chamber i.e., 1,030 °C temperature and 80 sccm strength of gas flow, these (nanofiber) fiber

of tin oxide have been observed on Si substrate. There were also many parameters which exist in PVD technique by which growth can cause significant change in the growth of nanostructure. By optimizing some parameter in synthesis chamber; these straight wire like shape of tin oxide were observed. It was confirmed by repeatability of this experiment by many times. It may possible that growth can be affected by environmental condition depend upon location.

Acknowledgement

We acknowledge the financial support from CSIR grant 086(0954)/09/EMR-I.

Reference

- [1] Lu, J. G., Chang, P. C. and Fan, Z. Y. 2006. "Quasi-One-Dimensional Metal Oxide Materials-Synthesis, Properties and Applications." *Materials Science & Engineering R* 52 (1-3): 49-91.
- [2] Watson, J. 1984. "The Tin Oxide Gas Sensor and Its Applications." *Sensors and Actuators* 5: 29-42.
- [3] Brajesh, N., Venugopal, B., Amirthapandian, S., Panigrahi, B. K. and Thangadurai, P. 2013. "Effect of Pd Ion Doping in the Band Gap of SnO₂ Nanoparticles: Structural and Optical Studies." *J Nanopart Res* 15: 1999.
- [4] Wang, W. Z., Xu, C. K., Wang, G. H., Liu and Y. K. and Zheng, C. L. 2002. "Synthesis and Raman Scattering Study of Rutile SnO₂ Nanowires." *J. Appl. Phys.* 92: 2740.
- [5] Tandon, S. P. and Gupta, J. P. 1970. "Measurement of Forbidden Energygap of Semiconductors by Diffuse Reflectance Technique." *Phys Status Solidi* 38: 367.
- [6] Ilican, S., Caglar, Y., Caglar, M., Kundakci, M. and Ates, A. 2009. "Photovoltaic Solar Cell Properties of Cd_xZn_{1-x}O Films Prepared by Sol-Gel Method." *International Journal of Hydrogen Energy* 34 (12): 5201-7.