

Heat Treatment Conditions for Growth of One-Dimensional Tin Oxide Nanostructures

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Abstract: One-dimensional (1D) tin oxide nanostructures have attracted attention due to their potential applications in gas sensors, transport conducting electrodes, flat display devices, dye based solar cells and catalyst support. In this work, one-dimensional tin oxide nanostructures were synthesized by carbothermal method under different conditions. The crystal structure and morphology of the grown 1D nanostructures were investigated by X-ray diffraction (XRD) and scanning electron microscope (SEM). Results showed that increasing heating rate and Ar gas flow rate through the furnace, resulted in increase of the aspect ratio of the 1D nanostructures. This is an important characteristic in growth and utilization of the 1D nanostructures.

Keywords: SnO₂; One-dimensional nanostructure; VLS mechanism

Introduction

Tin dioxide (SnO₂) is an important semiconductor with a wide band gap. It has potential application in optoelectronic devices including flat panel displays and solar energy cells. This material has been extensively used for gas sensors.¹⁻²

Since one dimensional (1D) nanostructures such as nanowires, nanotubes, nanobelts, nanorods and nanoribbons have high surface to volume ratio, synthesis of these morphologies shows an increasing interest. Up to now, SnO₂ 1D nanostructures have been synthesized by different methods like hydrothermal treatment, thermal evaporation, oxidation technique and spray pyrolysis.³⁻⁵ Herein, we synthesized successfully SnO₂ 1D nanostructures by the simple carbothermal reduction method. Effect of different parameters including the rates of heating, cooling and flow of argon were investigated.

Experimental procedure

Silicon wafers were employed as substrate. Substrates were cleaned and then coated with Au by sputtering at 10⁻³ torr and 17mA electric current. SnO₂ powder (Hopkins & Williams, LTD, England) was thoroughly mixed with activated carbon (Aldrich Chemical Co., Ltd., Gillingham Dorset, England) as the source materials. The mixture was heated up to 950°C at various heating rates (5K/min and 10K/min). The reaction lasted for 1 hour and then samples were cooled down to the room temperature (in and out of the furnace). The reaction was done under the atmospheric air. To investigate the effect of the inert gas flow on morphology, growth was carried out under Ar flow. The as-synthesized products were characterized by

X-ray diffraction (XRD) and scanning electron microscope (SEM, British, 1990, Sterio Scan 360Leica/Cambridge).

Results and Discussion

Fig. 1 shows the SEM image of the sample prepared at heating rate of 5K/min. The aspect ratio of the nanostructures increased when heating rate increased to 10K/min (Fig. 2). Perhaps it related to increasing driving force of the carbothermal reaction or decrease of the activation energy.

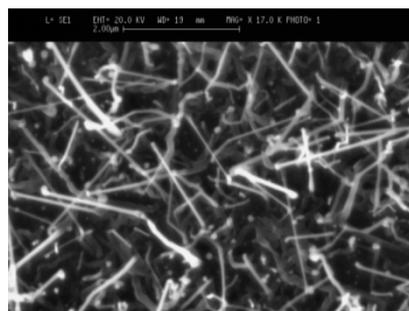


Fig.1 SEM image of SnO₂ nanostructures synthesized by heating rate 5K/min

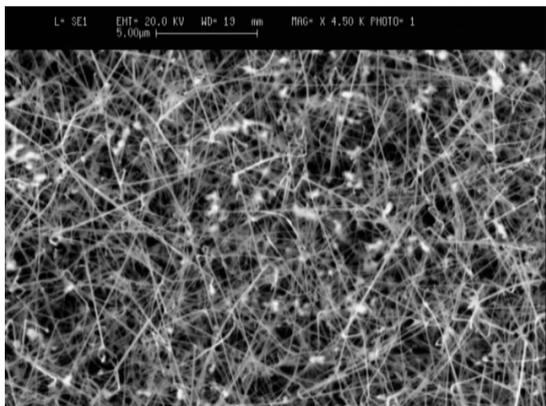


Fig.2. SEM image of SnO₂ nanostructures synthesized by heating rate 10K/min

From Fig.3, it is found that the density of the products intensively decreases by out-furnace cooling down of the sample. By fast cooling, Au/ Sn alloy drops haven't enough time for nucleation and growth; the growth thus stops. The XRD spectrum of the as-synthesized SnO₂ one dimensional nanostructures at 950°C for 1h and cooled down at out of the furnace shows the peak substrate is as one of prime peaks. It also affirms that formed SnO₂ on the Si substrate is low(Not show here).

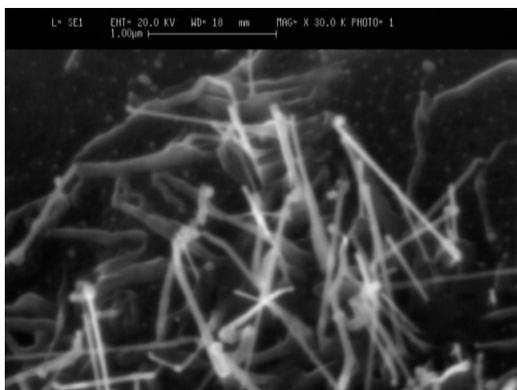


Fig.3. SEM image of SnO₂ nanostructures synthesized at out of the furnace

Ar gas flow in the furnace resulted in raise of the length of the nanostructures up to several hundred micrometers, as shown in Fig. 4.



Fig. 4. SEM image of SnO₂ nanostructures synthesized under the flow of Ar gas

In fact, the flow of Ar gas causes the tin – bearing gas species to transfer to the substrate. Based on the SEM images, growth of the nanostructures follows a Vapor-Liquid- Solid (VLS) mechanism. The essence of VLS mechanism is the presence of the liquid phase. Usually, a noble metal such as Au is used as a catalyst. At high temperatures, Au thin film will coalesce and form spherical particles on Si wafer. The Au particles have a higher sticking coefficient and is a preferred site for deposition of the tin– bearing gas species produced from the carbothermal reaction. With continuous adsorption, Au/Sn alloy supersaturates and growth of SnO₂ occurs⁶⁻⁹. In this work, there are particles at the tip of the 1D nanostructures which confirm the VLS growth mechanism.

Conclusion

Increasing of the heating rate and Ar gas flow in the furnace resulted in raise of the aspect ratio of 1D nanostructures. By out-furnace cooling of the sample, the 1D nanostructures growth decreased. The drops formed at the tip of the nanostructures showed that the synthesized nanostructures grew via VLS mechanism.

References

- [1]. O.Orlandi, A.J.Ramirez, E.R.Leite , E.Longo “Morphological Evolution of Tin Oxide Nanobelts after Phase Transition”, *Crystal growth & design*, 8(2008) 1067-1072.
- [2].H.W.Kim,S.H.Shim “Branched structures of tin oxide one-dimensional nanomaterials”,*Vacuum*, 82 (2008)1395-1399. [3].P.G.Li, M.Lei, W.H.Tang, X.Guo,X.Wang “Facile route to straight SnO₂ nanowires and their optical properties”, *Journal of Alloys and compounds*, doi:10.1016/j.jillcom (2008).
- [4].X.Wu,J.Sui, W.Cai ,F.Qu “Growth of dendritic SnO₂ nanoarchitectures” *Materials chemistry and Physics*, 112 (2008) 325-328.
- [5].Z.Huang,C.Chai“Water-assisted growth and characterization of SnO₂ Nanobelts”,*Materials letters*, 61 (2007) 5113-5116.



- [6].D.Zhao,C.Andreazza,P.Andreazza,J.Ma,Y.Liu,D.Shen
“Temperature-dependent growth mode and
photoluminescence properties of ZnO
nanostructures”,*Chemical Physics Letters*, 399 (2004)
522-526.
- [7].Y.Su, X.Liang
,S.Li,Y.Chen,Q.Zhou,S.Yin,X.Meng,M.Kong “Self-
catalytic VLS growth and optical properties of single-
crystalline GeO₂ nanowire arrays”,*Materials letters*, 62
(2008) 1011-1013.
- [8].M.Lin,T.Sudhirajan, C.Boothroyd , K.Loh “Influence
of Au catalyst on the growth of ZnS
nanowires”,*Chemical physics letters*,400 (2004) 175-178.
- [9].C.Li, G.Fang, Y.Ren,Q.Fu ,X.Zhao “Silver nanoisland
induced synthesis of ZnO nanostructures by vapor phase
transport”,*Journal of nanoscience and nanotechnology*, 6
(2006) 1467-1473.