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Synthesis of SnO_2 nanowires on one-dimensional carbonization cotton fabric

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Abstract Tin-oxide (SnO_2) nanowires have been synthesized on one-dimensional (1D) carbonization cotton fabric using chemical vapour deposition method. One-dimensional (1D) carbonization cotton fabric has been synthesized from cotton fabric using annealing process in nitrogen gas at 1000°C. The SnO_2 nanowires are single-crystalline rutile structures with 20 nm in diameter and 10 μm in length. Scanning electron microscopy (SEM), x-ray photoelectron spectroscopy, Raman spectroscopy, transmission electron microscopy and photoluminescence (PL) spectroscopy were utilized to characterize the as-synthesized products.

Key words Carbon, Zation, Cotton fabric, SnO_2 Nanowires

1. Introduction

One-dimensional (1-D) nanostructures have been attracting much attention in recent years because of their possible application for inter-connection in nano-devices. Usual recent commercial nano-imprint inter-connection is based on thin film technology and semiconductor processing methods. Although present commercial technology continues to be the structure choice for semiconducting circuit applications, one-dimensional (1-D) nanostructures have been attracting much attention in recent years because of their possible application for inter-connection in nano-devices.

Tin oxide (SnO_2) is a stable n-type wide band gap semiconductor (Eg = 3.6 eV, at 300 K) with excellent optical and electrical properties. Various nano-devices of one-dimensional SnO_2 nanowires have been extensively investigated, such as transparent conductive electrodes and transistors [1-4], Li ion batteries [5, 6], dye-sensitized solar cells [7], and chemical gas sensors [8-13]. The growth methods of nanowires; thermal, hydride vapor phase epitaxy, metal organic vapor phase epitaxy and chemical vapor deposition, and growth mechanisms such as vapor-liquid- solid (VLS) and vapor solid (VS) methods of growing nanowires have been researched [14, 15]. Most of nanowires have been synthesized such as Al_2O_3, SiO_2, GaN, and graphene substrates. Because of lattice mismatching between nanowires and substrates, substrates selection for nanowires fabrication is an important issue for the growth of nanowires [16, 17]. Regarding to the substrates for the growth of well-aligned NW arrays, the selection of the substrates is very important for the growth because the matching in lattice parameters and crystal structure between nanowires and substrate. Well-aligned SnO_2 NW arrays were synthesized on several substrates, such as sapphire [14, 15].

In this work, SnO_2 have been directly synthesized on the carbonization of cotton fabric substrate. When SnO_2 nanowires have been synthesized on one-dimensional carbonization cotton fabric, SnO_2 nanowires expect to inter-connection in nano-devices.

2. Experiment

Carbonization cotton fabric substrates have been fabricated using high temperature electric oven. To fabricate carbonization cotton fabric, cotton fabric has been annealed in electric furnace at 1000°C, using nitrogen gas for 5 hours. After electric furnace was cooled down naturally, carbonization cotton fabric has been obtained.

After fabrication of carbonization of cotton fabric substrates, SnO_2 nanowires have been synthesized on carbonization cotton fabric using chemical thermal evaporation method. An alumina boat with the metal Sn powders (purity: 99.9 %) was placed in the middle of a quartz tube inserted in a horizontal tube furnace. On top of the boat, a piece of the carbonization cotton fabric substrate has been situated with the deposition side downwards. Before evaporation process of Sn metal powder, the

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tube was evacuated to 0.01 Torr by using a rotary pump, and also platinum (Pt) (about 150 nm) catalysts have been deposited by sputtering on the carbonization cotton fabric substrates. SnO_2 nanowires have been synthesized at 900^{o}C for 10 and 30 minute, with the percentages of the O_2 partial pressure in ambient gas (Ar + O_2) set to approximately 3 %. O_2 gas has been used in argon (Ar) at a constant total pressure of 1 Torr.

The SnO_2 nanowires were characterized by a scanning electron microscope (SEM), X-ray diffraction (XRD), high-resolution transmission electron microscope (HR-TEM), Raman spectroscopy. Surface analysis by X-ray photoelectron spectroscopy (XPS) (Thermo VG Microtech, UK) was performed by irradiating the sample with Mg Kα X-ray (1253.6 eV).

3. Result and Discuss

Figure 1 shows the SEM image of SnO_2 nanowire grown on the carbonization carbon fabric substrates. Figure 1(a) shows SEM image of carbonization cotton fabric and SnO_2 nanowires. Figure 1(b) shows SEM image of synthesized SnO_2 particles on carbonization carbon fabric substrates for 5 min. Figure 1(c) shows SEM image of synthesized SnO_2 particles on carbonization carbon fabric substrates. SnO_2 particles have around 50 nm diameter on the carbonization carbon fabric substrates. Figure 1(d) shows SEM image of synthesized SnO_2 nanowire on carbonization carbon fabric substrates for 30 min. SnO_2 nanowires have between 80 and 150 nm width and several tens to hundreds of micrometers length. All these nanowires were smooth and uniform along the fiber axis.

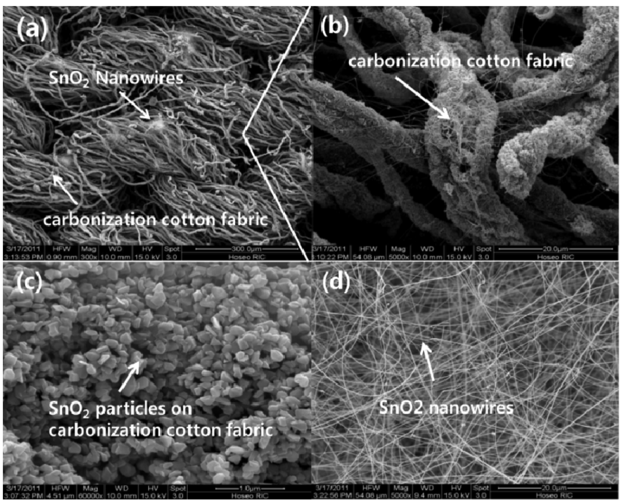

Fig. 1. (a) shows SEM image of carbonization cotton fabric and SnO_2 nanowires. (b) shows SEM image of synthesized SnO_2 particles on carbonization carbon fabric substrates for 5 min. 1(c) shows SEM image of synthesized SnO_2 particles on carbonization carbon fabric substrates. 1(d) shows SEM image of synthesized SnO_2 nanowire on carbonization carbon fabric substrates for 30 min.

Figure 2(a) shows TEM images of SnO_2 nanowires. The high-resolution TEM (HRTEM) image of Fig. 4(b) shows single crystalline of SnO_2 nanowires, and the measured inter-planar spacing is about 0.33 nm. The selected-area electron diffraction (SAED) pattern of Fig. 2(d) was recorded with the electron beam along [-113]. The SAED pattern of Fig. 2(d) corresponds to the (110) plane of rutile SnO_2 lattice as result that compare with simulated SAED pattern of Fig. 4(c). Thus, SAED pattern revealed that as-synthesized nanowire is a mono-crystal

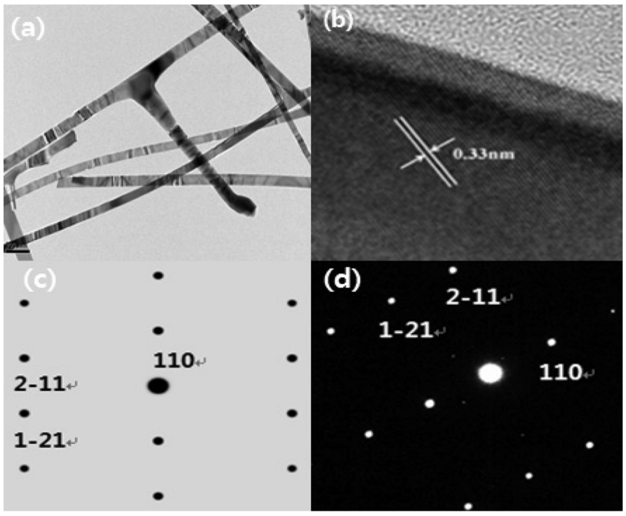

Fig. 2. (a) TEM image of the SnO_2 nanowire. (b) HRTEM image of the straight SnO_2 nanowire. (c) Simulated SAED pattern of mono-crystal with a tetragonal structure. (d) SAED pattern of as-synthesied SnO_2 nanowire.

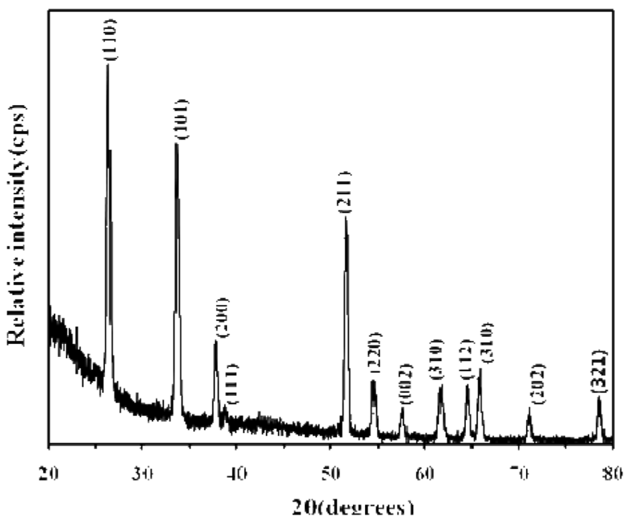

Fig. 3. X-ray diffraction patterns of SnO_2 nanowire.

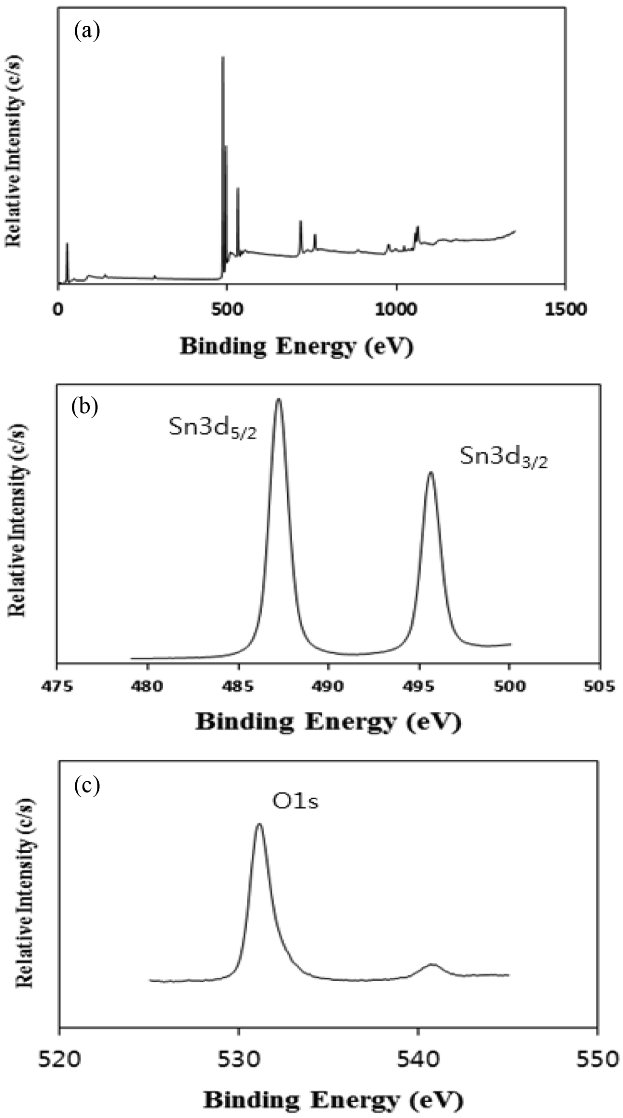

Fig. 4. The XPS analysis of the as-prepared SnO_2 nanowire; (a) survey, (b) Sn region, (c) O region.

with a tetragonal structure.

Figure 3 shows an X-ray diffraction (XRD) pattern of SnO_2 nanowires. The XRD pattern of the SnO_2 nanowires is correspond with a tetragonal rutile structure (JCPDS 41-1445), which belongs to the space group P42/mnm (number 136). The SnO_2 lattice constants obtained by refinement of the XRD data for the as-prepared nanowire are a = 4.732 Å and b = 3.184 Å. The typical lengths of the SnO_2 nanowires range from several tens to several hundreds of micrometers.

Figure 4(a) shows the XPS spectra of SnO_2 obtained from synthesized SnO_2 nanowire. Figure 4(b) and (c) show XPS spectra taken from the Sn and O regions of the sample. The peaks at about 495.78 and 487.38 eV are attributed to $Sn3d_{1/2}$ and $Sn3d_{5/2}$ (Fig. 4(a)), respectively, which are close to the data for Sn(3d) in SnO_2. The gap between the $Sn3d_{3/2}$ and $Sn3d_{5/2}$ level is 8.4 eV that is approximately the same as in the standard spectrum of Sn. The peak at about 531.28 eV can be indexed to O1s (Fig. 4(b)). Peak area of the Sn(3d) and O(1s) cores were measured and used to calculate the chemical composition of the sample. Areas were determined by fitting each of the curves using a nonlinear least squares curve fitting program and taking the area of the fitting peak. The quantification of the peaks gives the atomic ratio of Sn : O is nearly 1 : 2. Clearly, this result proved that the sample is single phase SnO_2 with rutile structure.

4. Conclusions

In summary, SnO_2 nanowires have been successfully synthesized on carbonization cotton fabric by chemical vapor deposition method. The as-synthesized SnO_2 nanowires are structurally uniform, and single crystalline. Carbonization technique has been used to fabricate long one-dimensional nano-structures. Therefore, long one-dimensional nanostructures of carbonization cotton fabric have potential application in nano-devices.

References

[1] C. Goebbert, M.A. Aegerter, D. Burgard, R. Nass and H. Schmidt, "Ultrafiltration conducting membranes and coatings from redispersable, nanoscaled, crystalline SnO_2 : Sb particles", J. Mater. Chem. 9 (1999) 253.

[2] S. Mathur, S. Barth, H. Shen, J.C. Pyun and U. Werner, "Size-dependent photoconductance in SnO_2 nanowires", Small 1 (2005) 713.

[3] Z.Q. Liu, D.H. Zhang, S. Han, C. Li, T. Tang, W. Jin, X.L. Liu, B. Lei and C.W. Zhou, "Laser ablation synthesis and electron transport studies of tin oxide nanowires", Adv. Mater. 15 (2003) 1754.

[4] E.N. Dattoli, Q. Wan, W. Guo, Y.B. Chen, X.Q. Pan and W. Lu, "Fully transparent thin-film transistor devices based on SnO_2 nanowires", Nano Lett. 7 (2007) 2463.

[5] Y. Idota, T. Kubota, A. Matsufuji, Y. Maekawa and T. Miyasaka, "Tin-based amorphous oxide: A high-capacity lithium-ion-storage material", Science 276 (1997) 1395.

[6] M.S. Park, G.X. Wang, Y.M. Kang, D. Wexler, S.X. Dou and H.K. Liu, "Preparation and electrochemical properties of SnO_2 nanowires for application in lithium-ion batteries", Angew. Chem. Int. Edn. 46 (2007) 750.

[7] S. Ferrere, A. Zaban and B.A. Gregg, "Dye sensitization of nanocrystalline tin oxide by perylene derivatives", J. Phys. Chem. B 101 (1997) 4490.

[8] Q.Y. Pan, J.Q. Xu, X.W. Dong and J.P. Zhang, "Gas-sensitive properties of nanometer-sized SnO_2", Sensors

Actuators B 66 (2000) 237.
[9] Q. Dong, H.L. Su, J.Q. Xu and D. Zhang, "Influence of hierarchical nanostructures to the gas sensing properties of SnO_2 biomorphic films", Sensors Actuators B 123 (2007) 420.
[10] F. Li, J.Q. Xu, X.H. Yu, L.Y. Chen, J.M. Zhu, Z.R. Yang and X.Q. Xin, "One-step solid-state reaction synthesis and gas sensing property of tin oxide nanoparticles", Sensors Actuators B 81 (2002) 165.
[11] E. Comini, G. Faglia, G. Sberveglieri, Z. W. Pan and Z. L. Wang, "Stable and highly sensitive gas sensors based on semiconducting oxide nanobelts", Appl. Phys. Lett. 81 (2002) 1869.
[12] Y.L. Wang, X.C. Jiang and Y.N. Xia, "A solution-phase, precursor route to polycrystalline SnO_2 nanowires that can be used for gas sensing under ambient conditions", J. Am. Chem. Soc. 125 (2003) 16176.
[13] X.C. Jiang, Y.L. Wang, T. Herricks and Y.N. Xia, "Ethylene glycol-mediated synthesis of metal oxide nanowires", J. Mater. Chem. 14 (2004) 695.
[14] H.T. Shi, L.M. Qi, J.M. Ma and H.M. Cheng, "Polymer-directed synthesis of penniform $BaWO_4$ nanostructures in reverse micelles", J. Am. Chem. Soc. 125 (2003) 3450.
[15] Z.P. Zhang, X.Q. Shao, H.D. Yu, Y.B. Wang and M.Y. Han, "Morphosynthesis and ornamentation of 3D dendritic nanoarchitectures", Chem. Mater. 17 (2005) 332.
[16] F. Li, J.B. He, L.L. Zhou and J.B. Wiley, "Synthesis of porous wires from directed assemblies of nanospheres", J. Am. Chem. Soc. 125 (2003) 16166.
[17] Z.L. Wang and Z.W. Pan, "Junctions and networks of. SnO nanoribbons", Adv. Mater. 14 (2002) 1029.