Int.J.Nano Dim. 2(3): 177-183, Winter 2012
ISSN: 2008-8868

Contents list available at **IJND**

International Journal of Nano Dimension

Journal homepage: ***www.IJND.ir***

The effect of substrate temperature on fabrication of one-dimensional nanostructures of tellurium

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Received: 17 February 2011
Accepted: 02 May 2011

ABSTRACT

Tellurium nanostructures have been prepared by physical vapor deposition method in a tube furnace. The experiments were carried out under argon gas flow at a pressure of 1 mbar. Tellurium powder was evaporated by heating at 350°C and 430°C and was condensed on substrates at 110–250°C, in the downstream of argon gas flow. The products were characterized by field emission scanning electron microscopy (FESEM) and X-ray diffraction (XRD). FESEM revealed that most of the products have one dimensional structure. X-Ray diffraction (XRD) patterns show that the products are crystalline with hexagonal structures.

Keywords: *Tellurium, Nanotubes, Thermal evaporation, Nanostructures.*

INTRODUCTION

In recent years considerable attention has been drawn towards one-dimensional nanostructure materials, such as nanotubes, nanorods and nanowires, because of their interesting physical properties and their wide-ranging potential applications in nanodevices [1] such as applications in electronics, photonics, and catalysis [2]. One of the elemental materials of interest is tellurium which has several interesting chemical and physical properties including photoconductivity and catalytic activity as well as piezoelectric, thermoelectric and non-linear optical responses [3-5]. Tellurium is a narrow-band gap semiconductor with band gap energy of 0.35 eV [6]. The crystal structure of Te is highly anisotropic with covalently bonded atoms forming unique helical chains. These chains are bound through weak van der Waals interactions and form hexagonal lattices. This anisotropic structure induces Te toward 1D growth [7, 8]. Many approaches such as Solvothermal [9], hydrothermal synthesis [6, 10], Surfactant-Assisted Method [11] and Microwave-Assisted in Ionic Liquid Method [12] have been used to synthesize tellurium nanostructures.

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Few groups have reported the growth of Te nanostructures by vapor phase techniques [13-15]. Each technique has its own advantages and limitations and thus might give very different outcomes.

Chemical methods may provide a more promising route to nanostructures in terms of throughput cost, and the potential for large-scale production but they are often limited in morphological control [2]. The simple method of thermal evaporation of Te and condensation of the vapor at a suitable temperature onto a substrate leads to highly pure nanostructures in high yields [7]. In this paper, we report the preparation of 1D tellurium nanostructures using the vapor deposition technique under argon gas flow at a pressure of 1 mbar.

EXPERIMENTAL

Tellurium nanostructures were synthesized in a 7.2 cm diameter and 75 cm length horizontal alumina tube furnace. To prevent contamination of the alumina tube due to evaporation, a 7.0 cm diameter and 75 cm length quartz tube was placed in Alumina tube. Schematic diagram of the experimental setup is shown in Figure 1.

The boat containing Tellurium powder (Merck, 99.99% purity) was placed in the hot zone of the tube furnace. The substrates that were cleaned for 10 minutes in acetone and then 10 minutes in distilled water by ultrasonic system were placed along the quartz tube in the downstream direction of argon flow. The tube was long enough to produce different temperature zones along its length.

Before the start of heating, the chamber was evacuated to 10^{-3} mbar and then purged with argon (Ar) gas at a flow rate of 40 ml/min. The flow of argon gas was controlled by a needle valve and measured using a flowmeter. In the steady state, the Ar flow rate and the pressure of the chamber were 40 ml/min and 1mbar, respectively. Then in the first experiment the hot zone of the furnace was heated to 350°C in 70 minutes. The evaporated tellurium was being deposited on glass substrates for 20 minutes. In the second experiment at the same pressure and with the same flow of gas, the hot zone of the furnace was heated to 430°C in 110 minutes. The deposition time was 90 minutes for the latter experiment.

A Hitachi S-4160 field emission scanning electron microscope was used for characterization of the morphology of the synthesized structures and an X-ray diffractometer was used to obtain structural information. X-ray diffraction (XRD) pattern of the specimen was recorded on a D8 Advanced Bruker operated at 35 kV voltage and 30 mA current with monochromatic CuKα (λ =1.54 Å) radiation in the scan range of 2θ between 20 to 70 with a step size of 0.04(2θ/S).

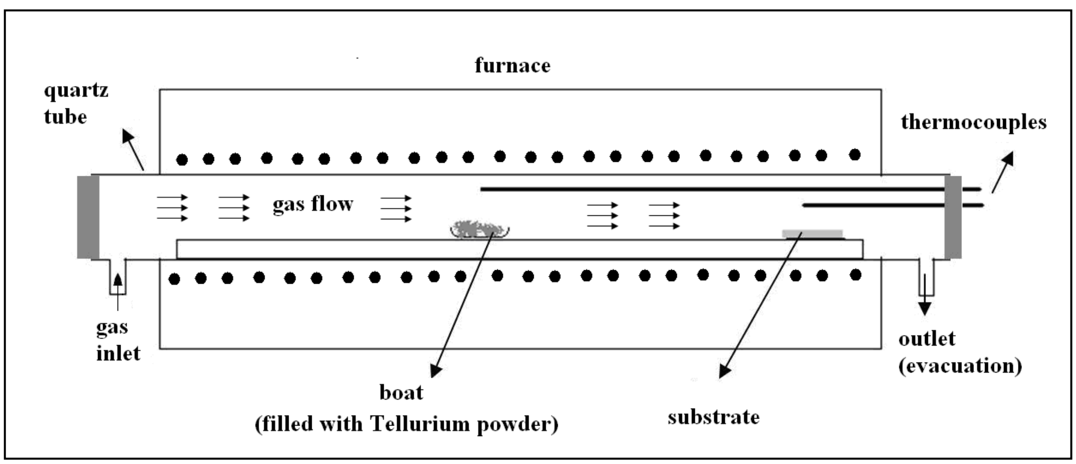

Fig. 1. Schematic diagram of the experimental setup showing the tubular furnace with gas flowing arrangement.

RESULTS AND DISCUSSION

Te structures were grown at different temperature zones along the horizontal tube. Thermal evaporation of Te below its melting point at a low pressure of 1mbar, and condensation of the vapor onto a substrate at a suitable temperature led to highly pure nanostructures. Figure 2a-b shows the FESEM images of the synthesized Structures on 110°C glass substrate placed at 37 cm distance from the boat for the first experiment that the boat was heated to 350°C. As it is seen in Figure 2a a uniform distribution of one dimensional nanostructures has grown on the substrate. Most of these structures are in the form of nanotube but Presence of some nanorods among these nanotubes is probable. Diameters of these nanotube-like structures are about 100 nm.

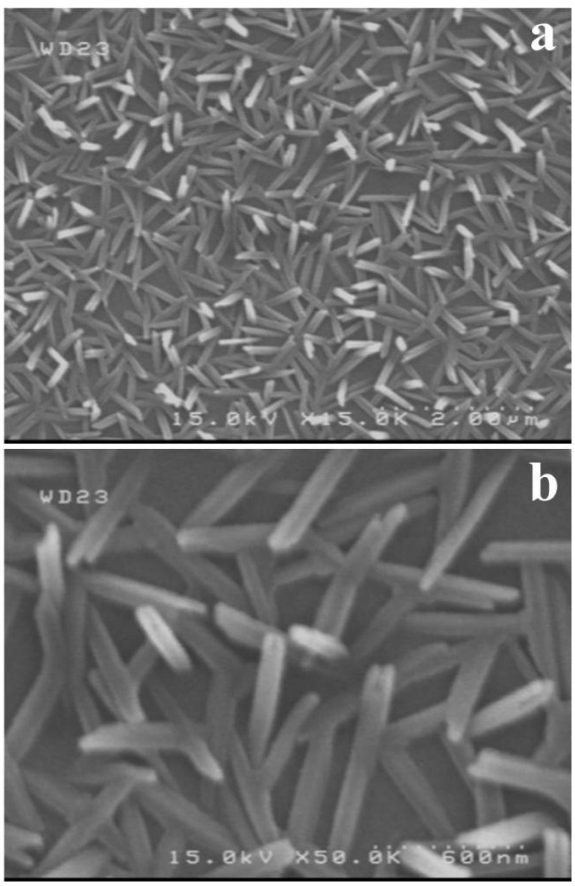

Fig. 2. FESEM images of grown structures in 1 mbar pressure on 110°C glass substrate at 37cm distance from the boat in the downstream direction of argon flow.

Figure 3 shows XRD pattern of this specimen. It shows that the structures are crystalline with the preferred orientation of (102). All the observed peaks in the diffractogram were successfully indexed assuming the hexagonal crystal structure.

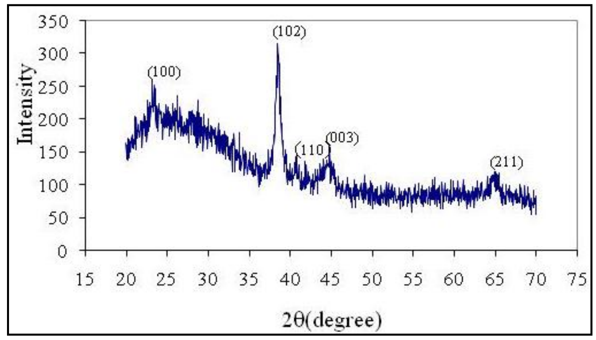

Fig. 3. XRD pattern of the synthesized tellurium nanostructures in 1 mbar pressure on 110 ºC glass substrate at 37cm distance from the boat in the downstream direction of argon flow

In the second experiment the boat was heated to 430°C the Ar flow rate and the pressure of the chamber were 40 ml/min and 1mbar respectively. The Te structures were grown at 4 different substrate temperatures to study the effects of different substrate temperatures on fabrication of Te structures. Figure 4 shows the FESEM images of the synthesized Structures on 250°C glass substrate placed at 26 cm distance from the boat. As it is seen in Figure 4a most of the substrate surface is covered with a continuous layer of tellurium. Although hexagonal rods can be seen in some parts of the substrate in Figure 4b, most of these rods are more than several hundred nanometers in diameter.

Figures 5a and 5b are FESEM images of the synthesized Structures grown on 210°C Aluminum substrate at 29 cm distance from the boat. These figures show that the continuity of layer was decreased and discrete one dimensional structures with several hundred nanometers diameter are formed.

Figures 6a and 6b are the FESEM images of the synthesized Structures grown on 156°C glass substrate at 33 cm distance from the boat. These figures show that all the structures are one dimensional. The size of the structures has been decreased and the number of the discrete one dimensional structures was increased. Many of these structures are nanotube. Figure 6b shows a high magnification FESEM image of one of these nanotubes.

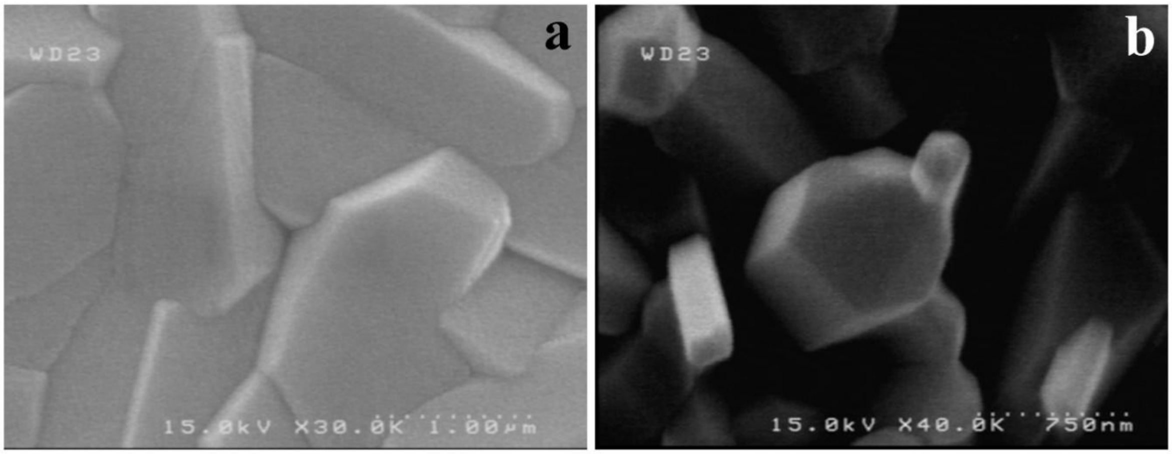

Fig. 4. FESEM images of grown structures in 1 mbar pressure on 250°C glass substrate at 26 cm distance from the boat in the downstream direction of argon flow

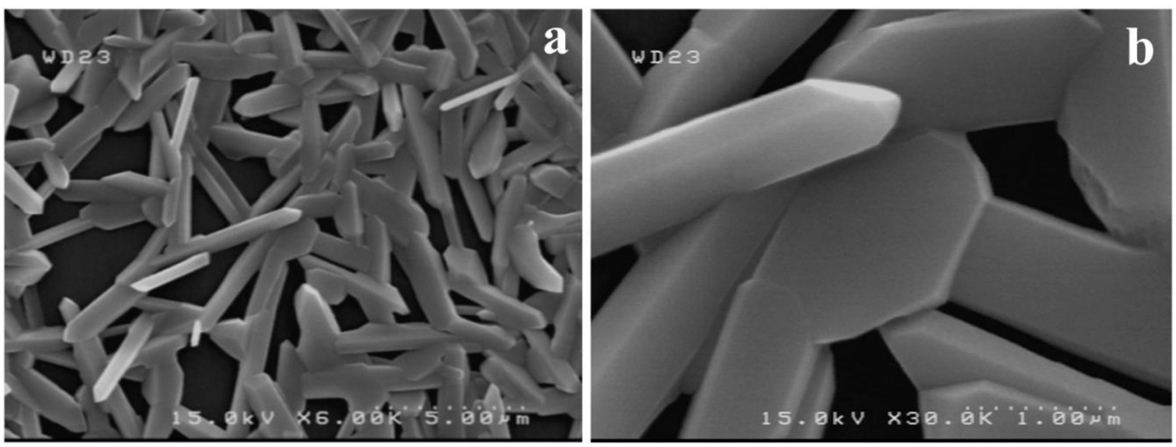

Fig. 5. FESEM images of grown structures in 1 mbar pressure on 210°C Aluminum substrate at 29 cm distance from the boat in the downstream direction of argon flow

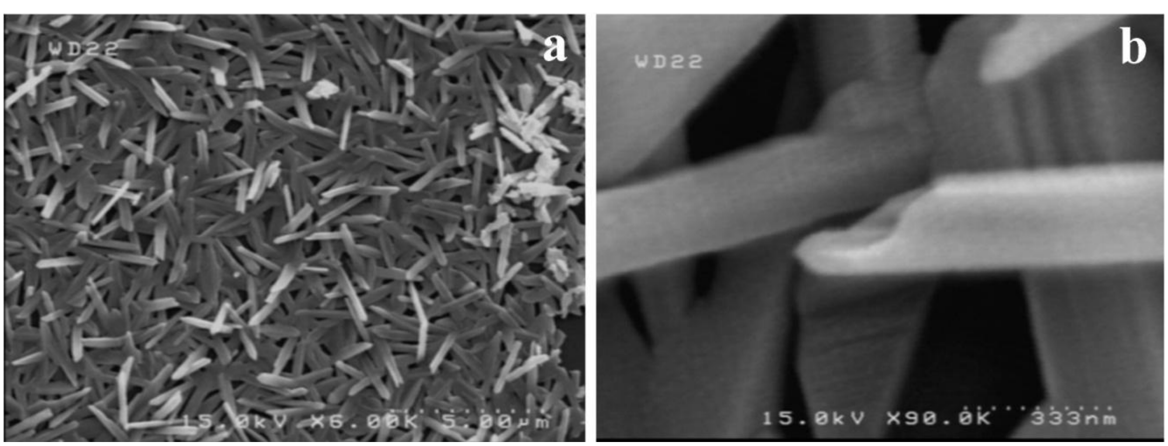

Fig. 6. FESEM images of grown structures in 1 mbar pressure on 156°C glass substrate at 33 cm distance from the boat in the downstream direction of argon flow

Figures 7a and 7b are the FESEM images showing the Structures synthesized on 148°C glass substrate at 35 cm distance from the boat. Most of these structures are nanotube and as it can be seen in Figure 7a all the structures have almost the same size. A high magnification FESEM image of a single nanotube is shown in Figure 7b. The diameter of this nanotube is about 300 nm and the thickness of its wall is about 30 nm.

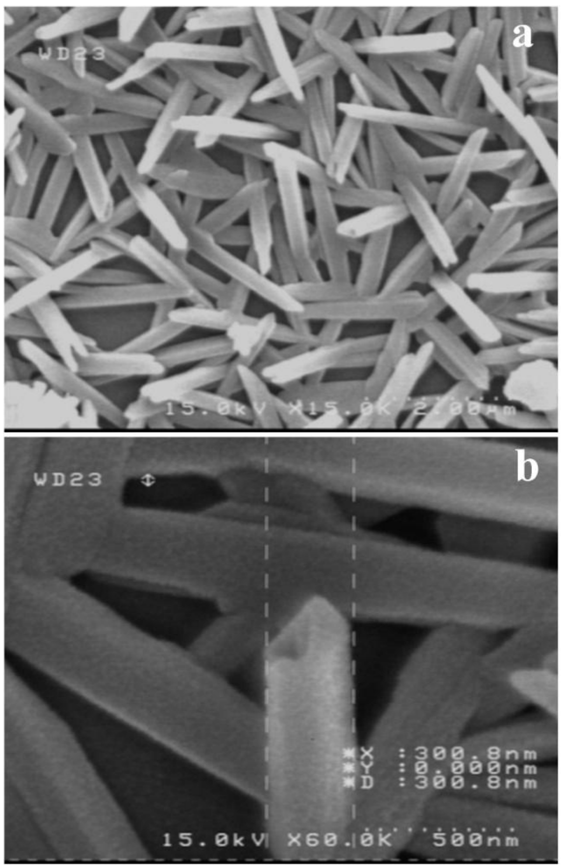

Fig. 7. FESEM images of grown structures in 1 mbar pressure on 148°C glass substrate at 35cm distance fromthe boat in the downstream direction of argon flow

Figure 8 shows XRD pattern of the Structures grown on 148°C glass substrat. It is seen that the nanotubes have crystalline structure with a preferred crystallographic direction. All the observed peaks in the diffractogram were successfully indexed assuming the hexagonal crystal structure. The preferred crystallographic orientation in this specimen is (100). Shashwati et al reported the same result for Tellurium Nanostructures Synthesis by Physical Vapor Deposition [13].

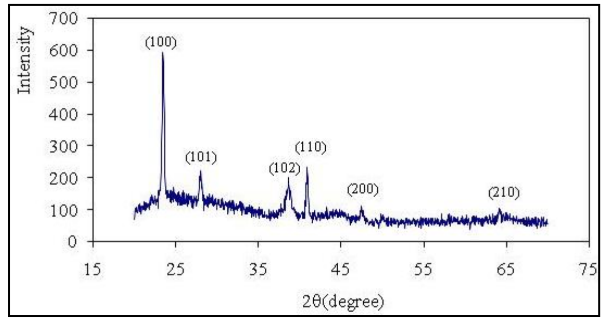

Fig. 8. XRD pattern of the synthesized tellurium nanostructures in 1 mbar pressure on 148°C glass substrate at 35cm distance from the boat in the downstream direction of argon flow

As it is seen, with increasing the substrate distance from the boat that causes decreasing the substrate temperature, synthesized structures approach more closely to one dimensional nanostructures. On 250°C substrate a few rod structures were formed with diameters varied between 200–800 nm. But on 148°C substrate one dimensional nanostructures, that many of them are nanotube, were formed.

Since all of the experimental conditions such as the boat temperature, ambient pressure, and gas flow kept constant in this experiment and the only difference was the substrate temperature, it can be said that the differences in final Tellurium structures are due to the substrate temperature. Therefore we expect size reduction of structures by decreasing the substrate temperature.

Figures 9a and 9b are the FESEM images showing the synthesized Structures on 117°C aluminum substrate at 40 cm distance from the boat. These images show that all the products are one dimensional structures with diameters between 150–200 nm. This observation is in accordance with the previous conclusion about the effect of substrate temperatures. It is seen in Figure 9b that the walls are a little apart from each other at the end of the nanotubes. It seems that they were going to be curved at the end part.

We didn't observe significant influence of glass and aluminum substrates on grown structures in our experiment. Nanotubes were synthesized on both glass and aluminum substrate. As Mohanty et al has reported it is not very clear whether there is a correlation between the substrate structure and the morphology of the synthesized Te nanotubes [7]. Further study is required to accomplish the influence of different substrates on the morphology of the synthesized nanostructures.

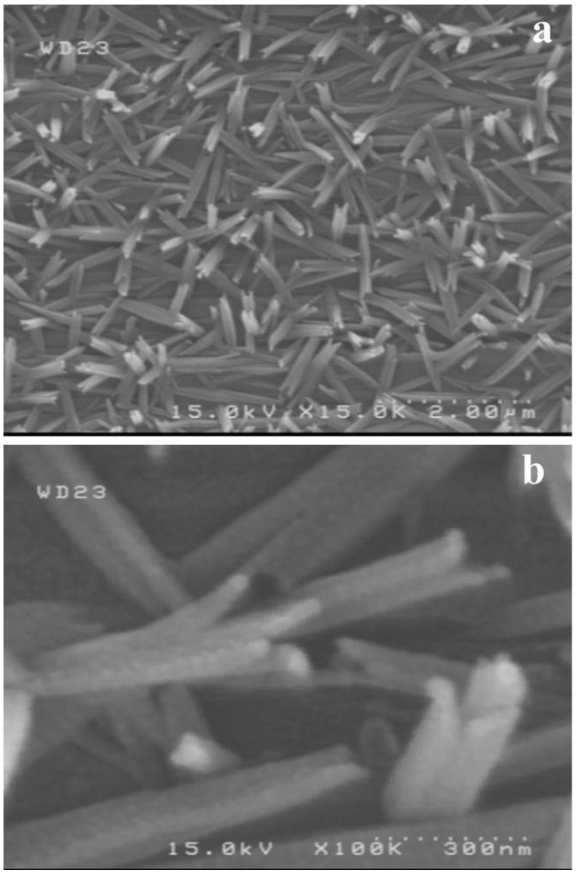

Fig. 9. FESEM images of grown structures in 1 mbar pressure on 117°C aluminum substrate at 40cm distance from the boat in the downstream direction of argon flow

CONCLUSION

One dimensional Te nanostructures have been grown by thermal evaporation of Te powder in a tubular furnace under argon gas flow in 1 mbar pressure. The diameters of synthesized Structures on 110°C glass substrate placed at 37 cm distance from the boat when the boat was heated to 350°C were about 100 nm. These structures had uniform distribution on the substrate surface. When the boat was heated to 430°C, all of the experimental conditions kept constant and only the substrate temperature was altered, we observed that with increasing the substrate distance from the boat that causes decreasing the substrate temperature, synthesized structures approached more closely to one dimensional structures and their size decreased. In other words, lower substrate temperatures results in one dimensional nanostructures with smaller diameters. The XRD patterns indicate that well crystallized hexagonal tellurium structures were obtained. No significant influence of glass and aluminum substrates was observed on the morphology of the grown products.

REFERENCES

[1] Liu, Zhaoping., Hu, Zhaokang., Xie, Qin., Yang, Baojun., Wu, Ji., & Qian, Yitai. (2003).Surfactant-assisted growth of uniform nanorods of crystalline tellurium. *J. Mater. Chem*, 13, 159–162.

[2] Mayers, Brian., & Xia, Younan. (2002). One-dimensional nanostructures of trigonal tellurium with various morphologies can be synthesized using a solution-phase approach. *J. Mater. Chem*, 12, 1875–1881.

[3] Zhao, A.W., & Ye, C.H. (2003). Tellurium nanowire arrays synthesized by electrochemical and electrophoretic deposition *J. Mater. Res*, Vol. 18, No. 10

[4] Wang, Qun., Li, Guo-Dong., Liu, Yun-Ling., Xu, Shuang., Wang, Ke-Ji., & Chen, Jie-Sheng. (2007). Fabrication and Growth Mechanism of Selenium and Tellurium Nanobelts through a Vacuum Vapor Deposition Route. *J. Phys. Chem. C*, 111, 12926-12932.

[5] Qin, Ai-Miao., Fang, Yue-Ping., & Su, Cheng-Yong. (2004). One-step fabrication of selenium and tellurium tubular structures. *Inorganic Chemistry Communications*, 7, 1014–1016.

[6] Liang, Fengxia., & Qian, Haisheng. (2009). Synthesis of tellurium nanowires and their transport property. *Materials Chemistry and Physics*, 113, 523–526.

[7] Mohanty, Paritosh., Kang, Taejoon., & Kim, Bongsoo. (2006). Synthesis of Single Crystalline Tellurium Nanotubes with Triangular and Hexagonal Cross Sections. *J. Phys. Chem. B*, 110, 791-795.

[8] Gautam, Ujjal K., & Rao, C. N. R. (2004). Controlled synthesis of crystalline tellurium

nanorods, nanowires, nanobelts and related structures by a self-seeding solution process. *J. Mater. Chem*, 14, 2530 – 2535.

[9] Wei, Guodan., Deng, Yuan., Lin, Yuan-Hua., & Nan, Ce-Wen. (2003). Solvothermal synthesis of porous tellurium nanotubes. *Chemical Physics Letters*, 372, 590–594.

[10] Mo, Maosong., Zeng, Jinghui., Liu, Xianming., Yu, Weichao., Zhang, Shuyuan., & Qian, Yitai. (2002). Controlled hydrothermal synthesis of thin single-crystal tellurium nanobelts and nanotubes. *Adv. Mater*, 14, No.22.

[11] Liu, Zhaoping., Hu, Zhaokang., Liang, Jianbo., Li, Shu., Yang, You., Peng, Sheng., & Qian, Yitai. (2004). Size-Controlled Synthesis and Growth Mechanism of Monodisperse Tellurium Nanorods by a Surfactant-Assisted Method. *Langmuir*, *20*, 214-218.

[12] Zhu, Ying-Jie., Wang, Wei-Wei., Qi, Rui-Juan., & Hu, Xian-Luo. ().Microwave-Assisted Synthesis of Single-Crystalline Tellurium Nanorods and Nanowires in Ionic Liquids. *Angew. Chem. Int. Ed*, 43, 1410 –1414.

[13] Sen, Shashwati., Bhatta, Umananda M., Kumar, Vivek., Muthe, K. P., Bhattacharya, Shovit., Gupta, S. K., & Yakhmi, J. V. (2008). Synthesis of Tellurium Nanostructures by Physical Vapor Deposition and Their Growth Mechanism. *Crystal Growth & Design*, Vol. 8, No. 1.

[14] Me´traux, C., Grobe´ty, B. (2004).Tellurium nanotubes and nanorods synthesized by physical vapor deposition. *J. Mater. Res*, Vol. 19, No. 7.

[15] Li, Xiao-Lin., Cao, Guang-Han., Feng, Chun-Mu., & Li, Ya-Dong. (2004). Synthesis and magnetoresistance measurement of tellurium microtubes. *J. Mater. Chem*, 14, 244 – 247.