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Fabrication of Nanostructured Sno_2 Thin Films by A Simplified Thermal Evaporation System

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Metal oxide nanostructures have been extensively investigated for fabrication of nanoscale device applications. In this work simplified thermal evaporation system has been designed for preparing nanostructured thin films. The nanocrystalline SnO_2 thin films are deposited on Au/SnO_2:F substrate by this evaporation method. The nanostructured are confirmed by using field-emission scanning electron microscope. Moreover, the materials used in this system are low cost and available in Bangladesh.

Field of Research: Materials Science and Nanotechnology

1. Introduction

For the last few years, progress in nanotechnology has led to the synthesis and characterization of a variety of nanostructures, i.e., nanowires, nanorods, nanotubes, using a wide range of materials such as metals [Cao, 2008] carbides,[Lee, 2006] nitrides,[Jia, 2003] and oxides[Shaalan, 2011]. Recently, these nanometer-scale structures often possess enhanced optical and electrical characteristics due to quantum confinement effects, as well as high surface-to-volume ratios, offering great prospects as building blocks in electronic and optoelectronic, and sensor devices [Shaalan, 2011, Shaalan, 2011]. Morphology, dimensions, uniformity, growth direction and crystallinity are crucial factors during the synthesis of nanostructures, as these parameters has been ultimately dictate their functionality [Shaalan, 2011, Shaalan, 2011, Chen, 2010].

Integration of nanostructures into devices is important and requires new creative methods for nanomaterials fabrication, stabilization and processing [5].Some of the methods more frequently reported for the synthesis of semiconducting oxide nanostructures, both in powder and thin film forms, include chemical bath deposition [Laake, 2007], hydrothermal synthesis,[Schroer,2010] chemical vapor deposition,[Niemann,2008] thermal evaporation,[Shaalan, 2011, Yamaguchi,2010] sputtering and laser ablation [Kuchibhatla, 2007]. Among the physical deposition methods, the thermal evaporation is widely employed in nanofabrication processes due to its low cost, high yield, and easy implementation [Shaalan, 2011, Chen, 2010, Yamaguchi, 2010]. In spite of the popularity of this technique, most of the results reported were not obtained through an accurate control of the deposition process.

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The most common configurations used for thermal evaporation are either to locate the substrate at a certain distance from the source, [Yamaguchi, 2010] or to place the substrate over the boat containing the raw materials [Shaalan, 2011]. Both approaches have problems, since in the first case the substrate temperature is only approximately known (and includes a thermal gradient along the substrate) and, in the second one, the evaporation and deposition temperatures are the same. In both schemes the substrate temperature and source-substrate distance are not necessarily optimized or even compatible.

Having in mind that nanotechnology represents an important research area and that the thermal evaporation method is one of the main techniques used for fabricating nanostructures, a better controlled process is urgently needed in order to achieve reproducible results that can be easily compared. In this work, a new and simple configuration for the traditional thermal evaporation furnace that allows an accurate control of all the synthesis parameters. The SnO_2 thin films is deposited on Au/SnO_2:F substrate. The surface morphology of SnO_2 film has also been discussed.

2. Experimental Procedures

2.1 Evaporation system details

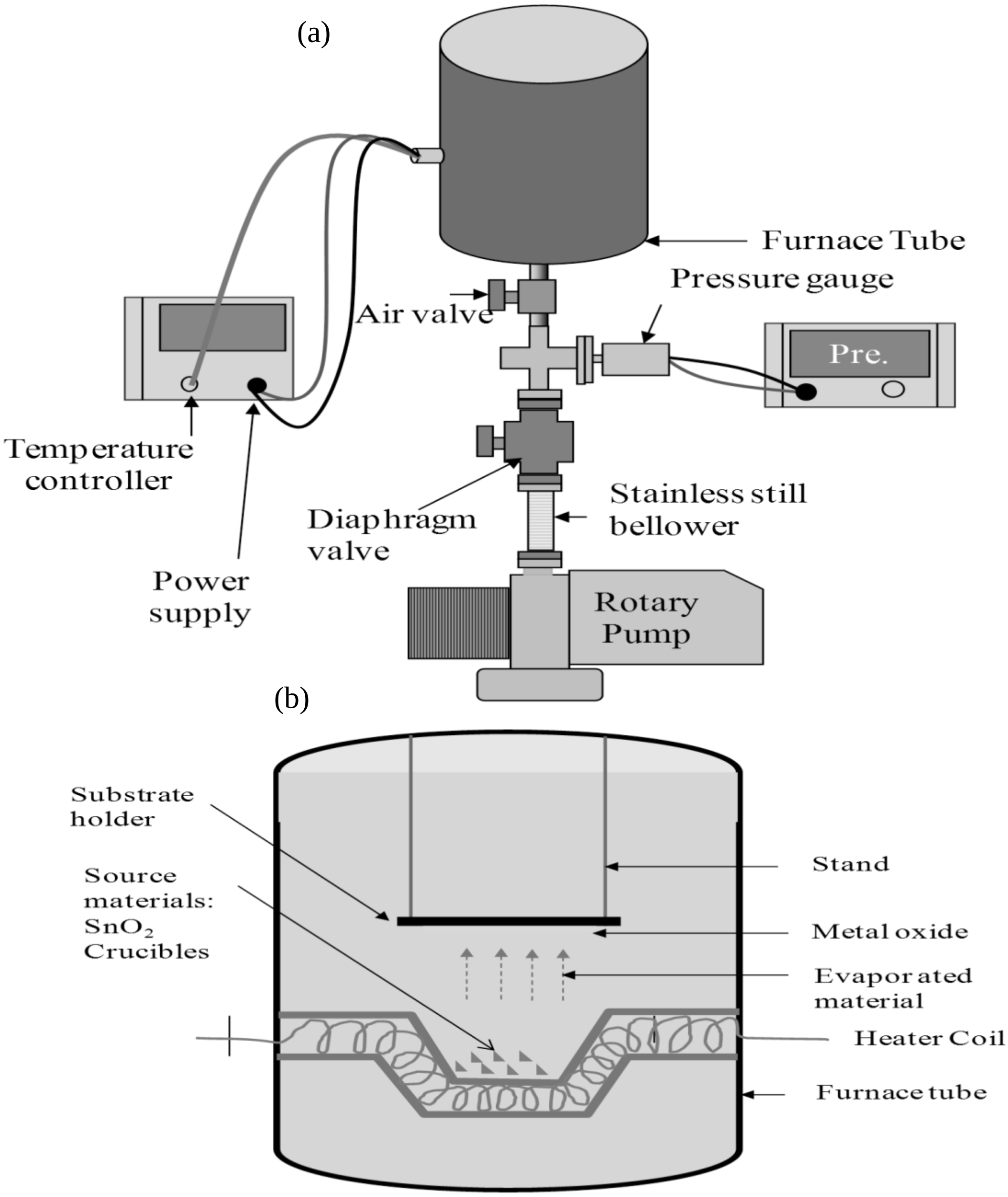
Figure 1(a) represents a schematic diagram for the proposed thermal evaporation system. It consists of vertical tube furnace and a rotary pump system. The bottom end of the vertical tube is connected to the rotary pump. Both ends are sealed by rubber O-rings.

Figure 1(b) shows the internal diagram of the furnace tube where the actual nanostructural growth takes place. The source material(s) is (are) loaded on an alumina boat and one alumina strip plate has been placed upside of alumina boat, which acted as substrates for collecting growth products. The substrate holder is assembling in such a way that it can vary its length. By using a single-zone furnace having a hot region of small dimensions when compared to the length of the tube, it was able to control the substrate temperature independently from the evaporation temperature. This was achieve by varying the distance between the substrate holder and the alumina boat (i.e., between the substrate and the evaporation source). The pressure is determined by a pressure sensor, diaphragm and air valves mounted in a 4-way cross and connected to a rotary vacuum pump. The heater has been coated with a thin cement layer in order to assure electrical insulation of the resistance, preventing also any chemical reaction with the evaporated materials.

2.2 working procedure

The procedure for growing oxide nanostructures begins by loading the raw materials in a ceramic boat. The precursors are either metal granules, or mixtures of a finely ground oxide with a reducing agent (normally graphite). After placing the boat at the hot zone of the furnace, the substrates are positioned on the sample holder, the distance between the boat and the sample holder is adjusted to the desired value, the flanges are closed and the tube is sealed by tightening the screws.

Fig. 1: Schematic Diagram of Thermal Evaporation Set-Up: (A) Complete System, and (B) Cross-Sectional View of Furnace Tube



At this point, the evaporation and deposition temperatures are set and both heaters are turned on. The vacuum pump is then started and the diaphragm valve is fully open in order to evacuate the tube up to its base pressure (5 × 10-2 mbar in our case). This step is necessary for removing the humidity and other gases adsorbed in the raw materials and on the internal surface of the tube. When the desired temperatures have been reached, the valves controlling the flow of gases were opened and the deposition pressure has been adjusted. When the deposition time was completed, the heaters and the gas flow was turn off and the system were allowed to cool down.

2.3 Preparation of SnO_2 thin films

The experiments were carried out in a conventional vacuum evaporation system made of stainless steel work-chamber of about 210 mm in diameter and 300 mm in height [Dai,2003]. The deposition was carried out in a vertically set heating furnace that consisted of a crucible and a heating element, as outlined in Fig. 1(b). First, commercially available SnO_2 powders (15 mg) with purity higher than 99.99% were placed in a small alumina crucible, which was covered by Au/SnO_2:F substrate. The chamber was evacuated using a rotary vacuum pump. The crucible was then heated from room temperature (RT) to about 900 ◦C in 2 or 3 min and maintained at this temperature to 90 min under a pressure of ambient air. The crucible was cooled to RT, leading to a substrate surface coated with a thick layer of white products. The morphology was observed by a field emission scanning electron microscope (FE-SEM) (JEOL JSM-6700F).

3. Results and Discussion

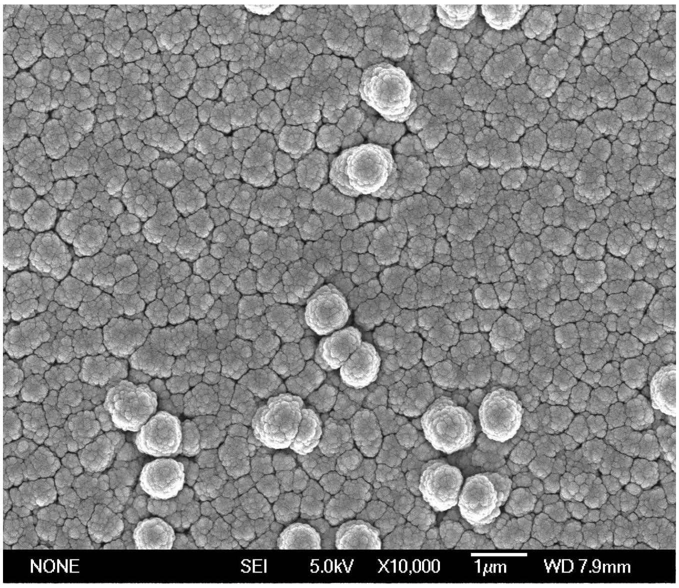
Figure 2 shows the nanostructured SnO_2 thin films. For higher magnification (shown in Fig. 2(a)), the nanocrystalline SnO_2 films are successfully grown on Au/SnO_2:F substrate. It is cleared that surface has uniform and regular size of nanocrystals of SnO_2 films. Figure 2(b) shows the higher magnification image of Fig. 2(a). The crystal size varies from 110 to 180 nm. But the small grain size is around 14 nm.

4. Conclusions

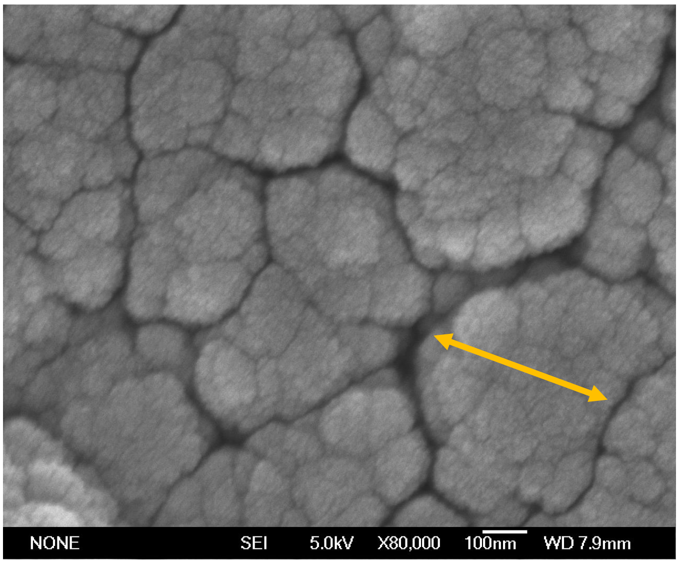
This work was reported the design and assembly of a thermal evaporation system for depositing nanostructured thin films. Nanostructured SnO_2 films had been successfully deposited on Au/SnO_2:F substrate by using this proposed system. The surface morphology of these films was showed the nanocrystals of SnO_2 films. Advantages of such evaporation systems are the simple assembly, operational flexibility and low cost. Moreover, the materials use in this system, which are available in Bangladesh. The proposed system offers good reproducibility, even for a large range of operating conditions. The main benefits of this system are to control the parameters including chamber pressure, substrate temperature, and substrate to target material distance, which may be affected on the properties of nanostructured films. This system can also be applied for fabricating the other metal oxide films (ZnO, TiO_2, and WO_3).

Fig. 2: FESEM Images of Nanostructured Sno$_2$ Films Prepared Thermal Evaporation Method (A) for Low Magnification and (B) for Higher Magnification.

(a)



(b)



5. Acknowledgement

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6. Future Work and Limitations

Further research can be done to deposit different nanostructured thin films by changing the system parameters and conditions. Limitation of this system is to maintain constant evacuation in whole process.

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