Effect of Substrate on the Morphology of SnO_2 Nanowire

Gyanendra Prakash Shukla, M. C. Bhatnagar

Abstract. ***Substrate can play crucial rule in the growth of nanostructure for metal oxide (MOS), so variation in substrate can cause variety of nanostructure. In this study, SnO_2 nanowire were grown on alumina, quartz and silicon substrates by thermal evaporation technique at atmospheric pressure. The effect of substrates on surface morphology and length to diameter ratio of tin oxide nanowire is presented in this work. The morphological and structural properties of nanowire have been investigated using scanning electron microscopy and x-ray diffraction.***

Keywords – Tin oxide nanowire, Thermal evaporation Corresponding Author

I. INTRODUCTION

There are varieties of materials available for gas sensing applications, among which metal oxide semiconductor (MOS) is the most important material [1]. This is because of the fact that electrical resistance of a semiconductor is very sensitive to the presence of impurities in its volume or at the surface. Due to increase in industrialization, it becomes necessary to constantly monitor and control pollution in the environment, chemical factories, food processing plants, laboratories and hospitals etc. So many research works are carried out by the researcher to synthesize and characterize the improved materials by opting nanotechnology. Numerous research work has been carried out to optimize the semiconducting gas sensors with respect to their sensitivity, response time, gas selectivity and economic efficiency (low manufacturing cost, low operating temperature and low power consumption) [2]. The basic principles (including physics and chemistry) of semiconducting gas sensors are complex and are still not understood fully. Several factors contribute to its working (including internal and external causes, such as natural properties of base materials, surface areas and on the overall sensor performance, tin microstructure of sensing layers, surface additives, temperature and humidity, etc.) but it is often difficult to separate them from each other in order to study their individual impact. Tin dioxide is typical n-type wide band gap semiconductor (Eg = 3.6eV at 300K), widely used in many application [3, 4] like gas sensing device etc. There are many techniques to synthesize nano materials, one of the versatile methods for synthesis of nonmaterial [5, 6] utilizing bottom up approach of nanotechnology.

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It involves heating of source material in a tubular furnace at high temperature in presence of some carrier gas flow, so that nanosized particles of source material are allowed to condense over substrate surface placed at some distance away from the source in downward flow direction. Growth of the nanostructures strongly depends upon the nature and temperature of the substrate [7, 8]. Nanowire morphology is further affected by pressure, type of the gas, gas flow rate and source to substrate distance during growth. In this work, SnO_2 nanowire were deposited on various substrates by thermal evaporation and successfully demonstrated the effect of substrate on the density and length to diameter ratio of nanowire.

II. EXPERIMENT SETUP

The schematic diagram of the experimental setup for the formation of nanomaterials is shown in Fig 1. The given setup consists of a tubular furnace, quartz tube of 76mm and gas (Ar, inert gas) flow at rate 100 sccm. In order to remove dirt, grease etc. Substrate was first washed by propanol or acetone and DI water and to remove hard oxide impurities all substrate (silicon, quartz and alumina) were ultrasonically cleaned in DI water for half an hour. A mixture of tin oxide (SnO) powder (99.90% pure) and graphite(C) at atmosphere pressure (1 atm) in ratio 1:1 have been taken as a source material. At 1030°c, at constant flow 100 sccm, nanowire deposited on the alumina, quartz and silicon substrate. Depositions have been taken for one hour. Nanowire has been deposited at various distances from source on the substrate.

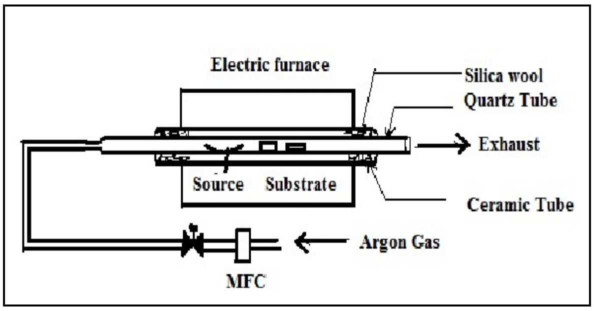

Fig.1 Schematic diagram of experimental setup

III. RESULT AND DISCUSSION

The samples deposited for deposition period for one hour on silicon, alumina and quartz substrate by variation in distance from source material (in cm) are labeled as silicon S1, Quartz Q1, and alumina A1, respectively. The surface topography of samples (S1, Q1, and A1) recorded by scanning electron microscopy (SEM) is shown in Fig.2. SEM micrographs show the controlled growth [7, 8] of high number density

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SnO_2 nanowire on substrates with the length up to (100-200) nm, (50-100) nm and (2000-8000) nm and the thickness of nanwire was about 300 nm, 100 nm and (20-100) nm for S1, Q2 and A1 respectively. It has been observed from SEM micrograph that high length to diameter ratio and large number density of nanowires observed on alumina substrate at distance one cm from source. The growth mechanism in all cases can be understood by self catalysis VLS growth mechanism [1, 3]. The growth of nanowires at 2 cm and 3 cm on all three substrates is shown in Fig 2. On silicon substrate at 2 cm and 3 cm, nothing has been observed.

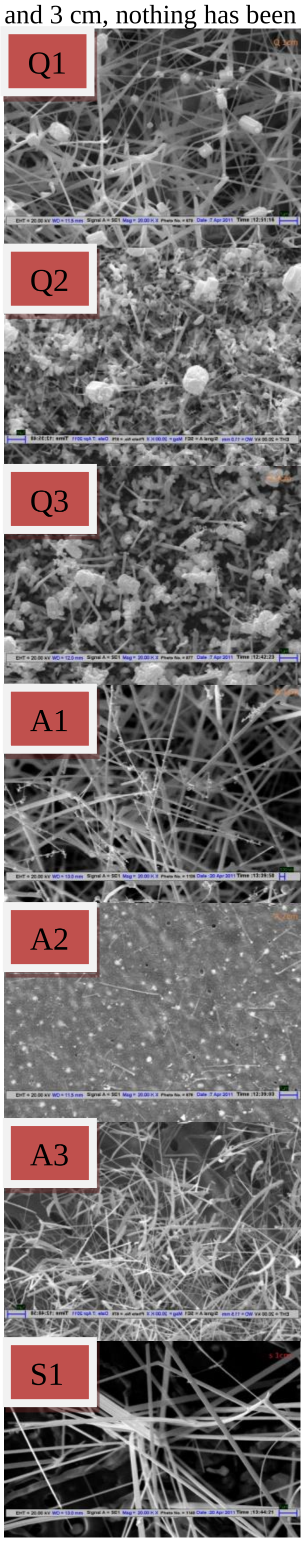

Fig.2 Surface topography recorded for samples Q1, A1 and S1.1, 2 and 3 are showing distance in cm from source to substrate on quartz, alumina and silicon respectively.

Now growth can be understand by self catalyst VLS growth mechanism followed by thermal diffusivity of substrate. As we know that substance with high thermal diffusivity (SI unit m^2/s), heat moves rapidly through it because the substance conducts heat quickly relative to its volumetric heat capacity or 'thermal bulk'.

$\alpha = \kappa / \rho \, c_p$

Where κ is thermal conductivity (W/(m·K)), ρ is density (kg/m^3) and c_p is specific heat capacity (J/(kg·K).Together, ρc_p can be considered the volumetric heat capacity (J/(m^3·K)).

As we know that thermal diffusivity of quartz is low as compared to silicon and alumina (quartz = $1.4 * 10^{-6}$, silicon =$8.8 * 10^{-5}$ and alumina = $1.2 * 10^{-5}$) and quartz contaminate the heat for nucleation of tin droplet, hence, temperature down for decomposition of SnO vapor at quartz substrate, as a result long length naowire observed.

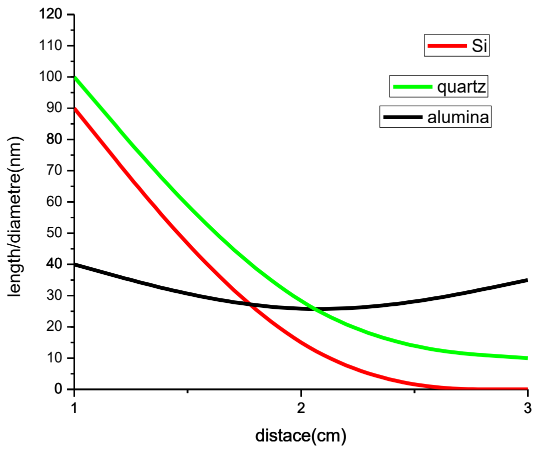

Fig.3 Length to diameter ratio's SnO_2 nanowire on different substrates.

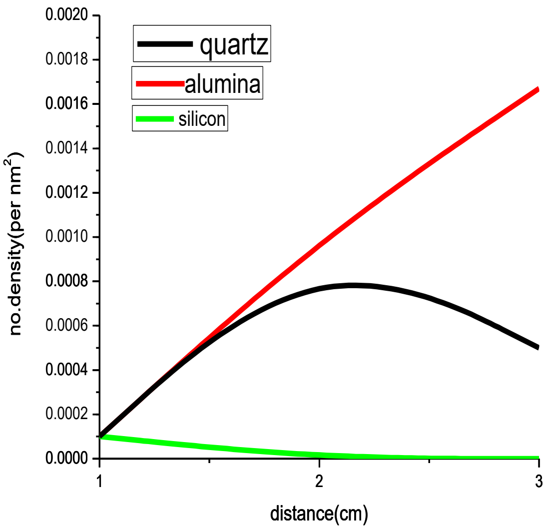

Fig.4 Number density of nanowire on different substrates.

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From Fig 3 and Fig 4, it is clearly shown that nanowire of high length to diameter ratio and no. density can be observe quartz substrate at distance 1cm from source material. As several condition affect growth of nanomaterials, but with this study, we can say that, substrate is one of the most important factor which decides the growth of nanostructures.

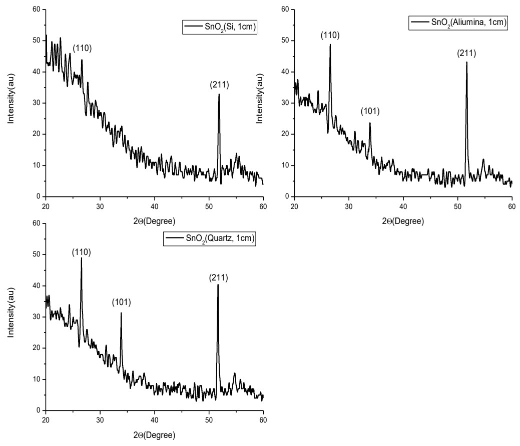

Fig.5 XRD plot of SnO_2 nanowire on silicon, alumina and quartz substrate at 1 cm from source.

The XRD plot of SnO_2 nanowire correspond to single phase of tetragonal crystal structure has been shown in Fig 5. The sharp changes in crystallographic orientation along (110) and (211) are evident in SnO_2 nanostructure deposited for different substrate with variation in intensity. The clear and sharp peaks (211) indicated that the nanowire of SnO_2 having high degree of crystallanity and it shows highest intensity for quartz substrate.

IV. CONCLUSION

In summary, many condition like temperature, pressure inside the quartz tube, deposition time etc, affected to growth of nanowire. By variation in substrate we can observe that high length to diameter ratio and no. density of SnO_2 nanowire has been synthesized on quartz substrate. Distance from source to substrate play a crucial rule in growth of nanowire.

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