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Growth of CrO$_2$ Coated Single Crystalline (SnO$_2$) Tin Oxide Nanowires

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Abstract

Single crystalline tin oxide (SnO$_2$) nanowires have been synthesized by carbothermal reduction of SnO$_2$ nanopowder followed by thermal evaporation of the reduced precursor and growth via the vapor-liquid-solid (VLS) growth mechanism. The nanowires are deposited on single crystalline TiO$_2$ substrates of orientations of (100) and (110) that are coated with a thin film and colloids of gold (Au) catalyst. After the SnO$_2$ nanowire growth on TiO$_2$ substrates, the substrates were put inside the another chemical vapor deposition (CVD) system to coat CrO$_2$ on the nanowires. CrO$_2$ coating success on SnO$_2$ nanowires were discussed.

Keywords: Single Crystal SnO$_2$ nanowires, CVD, CrO$_2$, colloid catalyst

PACS: 81.07.-b; 81.10.Bk; 81.16.Rf

1- Introduction

Synthesis and characterization of nanotubes and nanowires constitute an important part of nanoscience since these materials are essential building units for several devices [1]. Binary semiconducting oxides, such as ZnO, SnO$_2$, In$_2$O$_3$, and CdO have distinctive properties and are now used as transparent conducting oxide materials and gas sensors [2].

Wide band gap metal oxide thin films such as ZnO, ZrO$_2$, SnO$_2$, InO$_2$, and CdO have an important role in numerous applications such as energy storage/conversion, liquid crystal displays, gas sensors, and microelectronics. In particular, the single crystalline nanowire form of these materials has been explored recently in nanoscale science and technology using various synthesis science. Although controlling the size and shape of the nanowires can bring about changes in their optical and electronic properties, doping of nanowires either through in-situ or post-processing techniques will provide a far more favorable approach to modulate their properties. However, homogeneous introduction of dopants into the lattice matrices while preserving the structural integrity of the nanowires is a major challenge in metal oxide nanowire synthesis [3]. One-dimensional nanostructured systems have recently attracted much attention due to their novel properties and potential applications in numerous areas such as nanoscale electronic and photonics [4].

Stannic oxide (SnO$_2$) nanowires is an important metal oxide. It has been widely used as electric leads in optoelectronic devices such as flat panel displays and thin film solar energy cells [5]. Doped stannic oxide can also be used as gas sensors to detect various kinds of gases. Undoped and dislocation-free stannic oxide is an insulator. After oxidation, the existence of oxygen
vacancies in the lattice makes the material an n-type semiconductor. The structure and physical properties of SnO\textsubscript{2} single crystal and doped SnO\textsubscript{2} films have been extensively studied. Their low-temperature electrical transport properties were usually explained in terms of a thermal-activation model. Recently, the synthesis of nanostructures of SnO\textsubscript{2} have also been reported. However, the electrical properties of an individual SnO\textsubscript{2} nanowire have not been extensively explored, probably due to the difficulty in fabricating micro-leads onto this nanometer-sized wire [6].

Due to the importance of semiconductor magnetic materials for recording, sensing, and electro-optical applications, we attempted to grow single crystal SnO\textsubscript{2} nanowire and coat them homogeneously with CrO\textsubscript{2}. Growth and characterization of single crystalline tin oxide nanowire has been reported in ref. [7].

2- Experimental Results and Discussion

The SnO\textsubscript{2} nanowires were grown in the laboratory by using the system (CVD) shown in fig.1 schematically. TiO\textsubscript{2}(100) patterned substrate was put gold colloids on them and then they were put inside the quartz tube for nanowire growth at the following conditions: The distance between the substrate and the precursor boat was 5cm, the temperature of the experiment was T=750°C, the N\textsubscript{2} gas flow was 100 sccm, the vacuum inside the tube was 50 Torr, and the nanowire growth time was 1h. After the nanowire growth the same substrate was put inside the different CVD system for CrO\textsubscript{2} growth. Fig.2. shows the CrO\textsubscript{2} coated SnO\textsubscript{2} nanowires on the patterned TiO\textsubscript{2}(100) substrate. The SEM pictures and EDX show that clearly, CrO\textsubscript{2} is growing not only on the wires, but also on the substrate. In fig.2, the number 2 and 3 show the patterns where the nanowires grow. As seen from fig.2, these two parts look gray. If you look at the EDX graph in fig.2, one could see the tin oxide nanowires growth there. The number one shows the gap between the two patterns where there should be no nanowire growth and this part is purely substrate before the substrate was put into the second CVD system for the CrO\textsubscript{2} thin film growth. Nanowires could grow under the catalyst like gold. The numbered places of 1 do not contain any catalyst of gold. But the EDX showed that there is CrO\textsubscript{2} growth in the region 1 in fig.2.
As a second step, 10 nm Au colloid particles were put on the TiO$_2$(100) substrate. This sample was put inside the CVD system for the nanowire growth. The nanowire growth was held at the following conditions: T=700°C, 50 Torr, 100 sccm, 1 hour. The SEM picture in fig.3a shows the behaviors of the nanowire growth. The same substrate was put inside the different CVD system for the CrO$_2$ growth on the nanowires. The SEM picture in fig.3b shows the behavior of the CrO$_2$ coating on the SnO$_2$ nanowires. The round globs fig.3b are the CrO$_2$ coating on the SnO$_2$ nanowires. We want to prepare magnetic semiconductor nanowires by using the CrO$_2$ coating on SnO$_2$ nanowires. SnO$_2$ nanowires are semiconductor itself.

Fig.3. SEM micrographs from (a) SnO$_2$ nanowires, (b) CrO$_2$ coated SnO$_2$ nanowires on TiO$_2$(100) substrate.
As we said before we want to prepare magnetic semiconductor nanowires by using the CrO$_2$ coating on SnO$_2$ nanowires. CrO$_2$ growth on SnO$_2$ nanowires is not very homogeneous on the TiO$_2$(100) substrate. This inhomogeneity could be due to the substrate orientation, CrO$_2$ amount used for growing, the CrO$_2$ growing time, the effect of the surface of the substrate before putting inside the second CVD system for CrO$_2$ growth, etc.

Similarly, 10 nm Au Colloid particles were put on the TiO$_2$(110) substrate. This sample was put inside the CVD system for the SnO$_2$ nanowire growth. The nanowires growth was held at the following conditions: T=700°C, 50 Torr, 100 sccm, 1 hour. The SEM picture in fig.4a shows the behaviors of the nanowire growth. The same sample was put inside the different CVD system for the CrO$_2$ growth on the nanowires. The SEM picture in fig.4b shows the behavior of the CrO$_2$ coating on the semiconductor itself. The round globs fig.4b is the CrO$_2$ coating on the SnO$_2$ nanowires. As seen from the fig.4b, the CrO$_2$ growing is not very homogeneous on the TiO$_2$(110) substrate but it looks more homogeneous than the growth on TiO$_2$(100) substrate. This
inhomogeneity could be due to the substrate orientation, CrO$_2$ amount used for growing, the CrO$_2$ growing time, the effect of the surface of the substrate before putting inside the second CVD system for CrO$_2$ growth, etc.

CrO$_2$ coated SnO$_2$ nanowires on TiO$_2$ patterned substrate have been shown also in fig.5a and 5b to give an idea about the length and coating conditions. Fig.5c shows the AFM image of the same nanowires on the TiO$_2$ substrate.

3- Conclusion

Our attempt was to get homogeneously magnetic thin film coated single crystal nanowires for the magnetic, optical and electronic applications. By this study, we succeeded at least to coat the single crystal nanowires with the magnetic thin film of CrO$_2$. We will continue to get better results and will show them in our future studies.

References