Novel Metal Oxide Deposition Method to Fabricate Nanostructures

Mansouri, Robab*,**; Sandooghchian, Mehri**; Mansouri, Mohammad Reza**

* Department of Physic, University of Payame Noor, kooye Golestan, Shiraz, Iran, robabmansouri@yahoo.com

** Kerman Semiconductor Company, Flat no.7, building no25, Sarve Sharghi BLVD., Sa'adat Abad, Tehran-Iran, info@kermansem.com

Abstract

ZnO is well promised for applying in semiconductor nanodevices. In recent years, wide types of various nanostructures were interested and investigated. In this work, we constructed new designed CVD set up (Chemical Vapor Deposition) and then studied about ZnO nanostructures grown on a SnO_2 deposited on a Si wafer, which was deposited by a new method of deposition, to find more sensitivity and selectivity than other nanostructures for applying in gas sensors. SnO_2 is one of the nanomaterials, which is well promised to apply in gas sensors and ZnO too. Likely by applying both of them on a Si wafer, to achieve more sensitivity and selectivity.

Key Words: metal oxide, deposition, ZnO naopillar

1. Introduction

Semiconducting metal oxide have been extensively studied due to their simplicity, sensitivity and applicability in many field. Zinc oxide (ZnO), a n-type metal oxide semiconductor sensing material with a wide band gap (Eg = 3.37 eV at 300 K) and the exciton binding energy of 60 meV, much larger than those of other semiconductors, has been under extensive research owing to its high chemical stability, low cost, and good flexibility in fabrication. Most of the studies up to now are focused on sintered particle or thin-film based devices. Several groups have recently proposed that the nanowires, nanotetrahedral or nanoribbons of semiconducting oxides are very promising sensors, diodes and transistors and some of their results have shown that the devices based on one-dimensional nanostructures have great potential in overcoming the fundamental limitations.

To enhance these properties of nanostructures, we determined to prepare some depositions, such as stannous oxide, zirconium oxide and cobaltous oxide and then growth various nanostructures on them. Here we fabricated only nanostructures of zinc oxide on SnO_2 deposited layer.

Deposition of metals and metal oxides render new properties to nanostructures and were interested by scientists. For example, by proper deposition, new properties are rendered to a nanostructure.

Depositions have been executed by sputtering method so far. It has own advantages and disadvantages on quality of layer. It needs a strong vacuum and it is extremely extortionate specially for wide areas, for example, by this method it is impossible and very expensive to deposit 1 m^2.

By this project, we innovated new approach of deposition of metal oxide layer and executed with stannous oxide on type n of Si wafer to fabricate ZnO nanostructures first, and developed later by other metals. By this method, we could fabricate aligned nanowire of ZnO. Early aligned ZnO nanowire was fabricated on gold-deposited Si wafer and it was expensive.

This new method gives some advantages like Easy process, cheap process, low waste, and fabricating some new nanostructures, for example aligned nanowire of ZnO by deposition of gold has been fabricated in pervious. It gives us an opportunity to have various depositions with cheap and easy process.

2. Experiment

At the out set we prepared Stannous oxide layer on type n of 100 Si wafer by the following explained method. Then we innovated and constructed a new designed CVD set up and after the very zinc oxide nanostructures were fabricated on the very deposited Si wafer by new constructed CVD set up. At terminally stage the sample was investigated by SEM (scanning electron microscope), EDX (electron diffraction X-ray) and chemical analysis. The each single of steps are explained individually by detail.

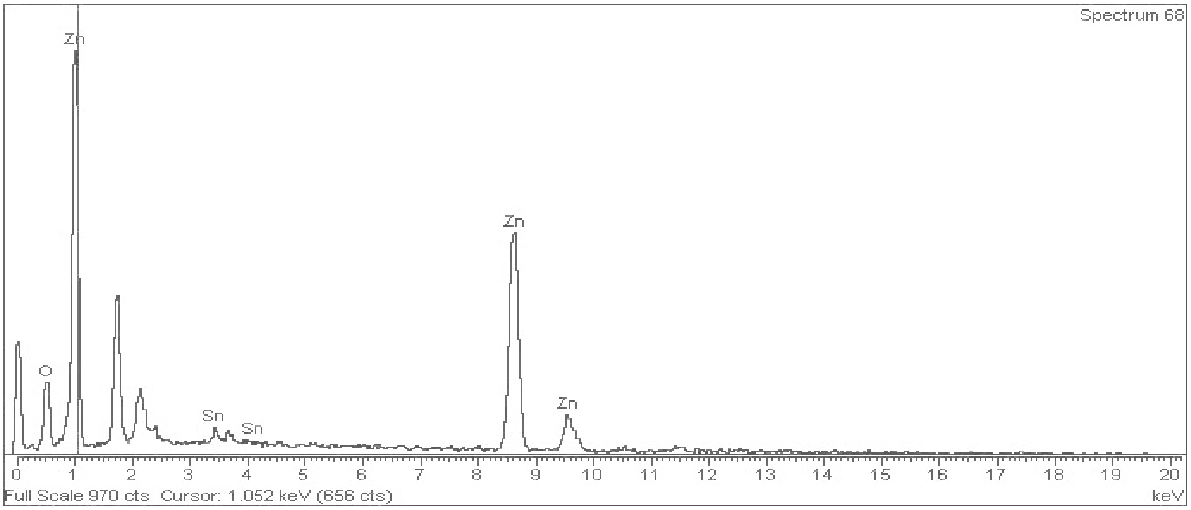

Fig 1: Chemical Analysis of Nanopillars by EDX. Consider on Peaks, They Proof Attendance of Sn, Zn and O On Si Wafer.

2.1 Deposition detail

The deposition is executed by chemical approach. Early, $SnCl_2$ is dissolved into sufficient acetone to make suitable concentration into100 ml volumetric flask. Then Si wafer 100 type n is put on the hotplate and heated up to 300 ˚C. Later the solution is spread on the wafer by proper pipette and dried by heat. This action is repeated for several times. The very wafer is placed into furnace which its temperature is carried out to 900˚C for 2 hours. It causes chlorine is removed and oxygen constitute instead of it. The EDX chemical analysis shows that the layer contains Sn and Cl was completely removed and deposition is complete. The detail of process will be explained following.

3.1. Fabricating of nanostructures

Fabricating of nanostructures was followed by developing and constructing novel Chemical Vapor Deposition setting. The new designed CVD (Chemical Vapor Deposition) set up is somehow differing from the ones constructed before. This setting additional to fabricating some nanostructures can produce powder form of nanostructures in mass form about 0.5-1 gram. Setting would have been capability to produce 1-2 kilograms per run by scaling it up. Additional it has other advantages, which is brought following:

- Well-ordered nanostructures.
- Low energy waste.
- Low cost fabricating of nanostructures procedure.
- Saving time.
- Fabricating of some novel nanostructures.
- High yield

The setup, which was modified several times during this research project, was turned out to be unique enough to be registered as a patent.

This set up includes four main parts, which are:

- A furnace, which its unique design allow us omit thermal gradient. As a result, that is thermally isotropic.
- A Quartz cell, which is lied into the chamber of the furnace on two thin walled alumina tubes in a way that the cell is almost suspended in the

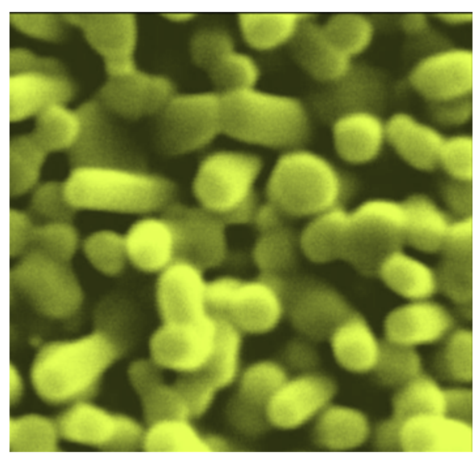

Fig 2: The SEM Image of Prepared Sample Which shows its Top View. Consider on perpendicularity of nanopillars of ZnO, which grows on SnO_2 deposited layer on Si wafer. Also this image shows unclearly hexagonal cross section of grown nanostructures.

chamber. Its unique design renders us to have more and well-ordered nanostructures.

- A narrower Quartz tube, acting as fabrication chamber, into which are placed an n-type (100) Si wafer and mixture of powders. This tube is accommodated into the long quartz chamber.
- Gas supplier includes inlet and outlet.

The quartz cell is put into the furnace which is heated before up to about 900˚C. After putting cell into the furnace, the heat is carried up to 950˚C and temperature is fixed for 30 minutes. After reaching to the predetermined temperature the gas mixture is introduced. The gas flow includes proper mixture of nitrogen about 1000 ml/min and air about 200 ml/min, is introduced into cell and fabricating of nanostructures is launched to grow at predetermined temperature. This situation is fixed for 30 min. At the end of 30 minutes, the air supplying is cut off and the quartz cell is withdrawn out of furnace and wafers are removed to investigate.

3. Results and Conclusion

By considering on EDX (electron diffraction X ray) results, fig 1, shows that the sample contain Zn, O and Sn, and this is not far from of our expectation. According to our executed test existence of Zn,O and Sn is reasonable. The deposition had been executed by $SnCl_2$ solution and existence of Sn is reasonable but absence of Cl is fuzzy. It is assumed that the $SnCl_2$ solution is evaporated on Si wafer and ignition causes to regenerate $SnCl_2$ molecules to SnO_2 molecules and this is proven by EDX image (fig. 1).

$$SnCl_2 + O_2 \longrightarrow SnO_2 + Cl_2$$

Additional chemical analysis for definition of nanostructures was executed. Zinc oxide becomes yellow, when it is ignited. The very sample is ignited and the nanostructures which were deposited on SnO_2 layer and the ignited sample become yellow and confirms the EDX result and existence of zinc oxide.

By considering on taken SEM images (figs. 2, 3, 4 & 5), it is found that nanostructures of zinc oxide are all aligned pudgy hexagonal which are grown on deposited SnO_2 layer. Fig 2 shows conspicuously that the nanostructures are completely aligned however, aligned ZnO nanostructures has been grown by sputtering deposition of gold so far. It is very expensive method and is work only for small areas. Figs 3 & 4 show the launching point of growing of nanostructures. As it is seen they come straight up. Also fig 4 shows this result. The dimension of nanpillars as shown in fig 4, is about 200 nm. Fig 5 reveals that the very nanostructures are hexagonal.

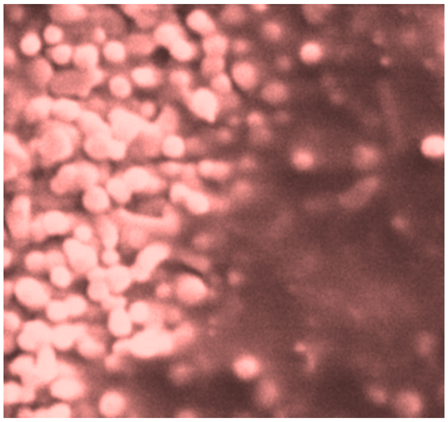

Fig 3: The SEM Image of Prepared Sample, Which Shows Its Top View. Consider on Launching of Growing of Nanopillars. That is arising point.

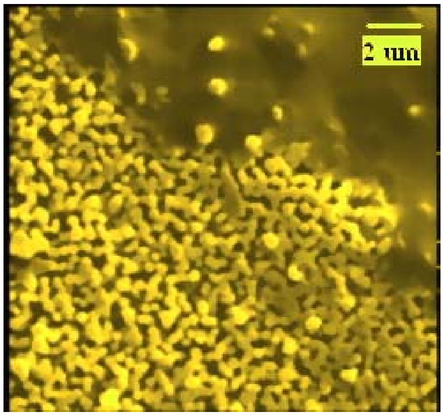

Fig 4: The SEM Image of Prepared Sample, Which Shows Its Top View. Consider on Launching of Growing of Nanopillars. The diameters of nanopillars are about 200 nm.

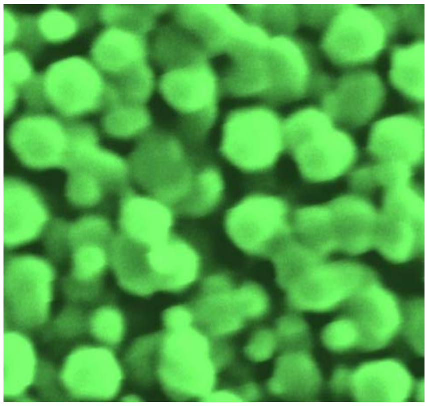

Fig 5: The SEM Image of Prepared Sample from its Top View. Consider on Hexagonal Cross sections of Nanopillars.

As well as known, SnO_2 has orthorhombic crystal structure and during regeneration of deposited layer of $SnCl_2$ solution Sn molecules is laid on Si atoms in flat style by its hexagonal bases. It is supposed that very layer which bounded with Si atoms forms a pattern to growth. The hexagonal of SnO_2 layer act as a pattern to align growing and it is proven by SEM images in figs 2and 5.

It seems that the SnO_2 layer remain on Si wafer surface during the growth because EDX analysis shows Sn peak. Addition, after removing the nanostructures from wafer by ultrasonic the SnO_2 metallic surface of layer is appeared.

However, this new method arise some advantages, which are brought following:

- Easy and cheap process
- Low waste
- Fabricating some new nanostructures, for example aligned nanowire of ZnO by deposition of gold has been fabricated in pervious.

4. Acknowledgment

These schievment would not have been possible without sustained efforts of Narges Arampasand, Morteza Bayati, Ali Sanee and R. Rahimi.

5. References

[1]. Ki-Won Kim, Pyeong-Seok Cho, Sun-Jung Kim, Jong-Heun Lee, Chong-Yun Kang, Jin-Sang Kim, Seok-Jin Yoon "The selective detection of C_2H_5OH using SnO_2–ZnO thin film gas sensors prepared by combinatorial solution deposition" Sensors and Actuators B **123** (2007) 318–324.

[2]. Ji. Haeng Ya. Gyoong, Man. Choa; "Selective CO gas Delection of CuO- and ZnO doped Sno_2 gas sensor"Sensors and Actuators B **75** (2001) 56-61.