Advance Physics Letter

Preparation and Characterization of Hydrothermally Grown ZnO Nanorods for Photoconductive Sensors Applications

[1]Shaivalini Singh, [2]C. Periasamy, [3]Sumit Vyas, [4]P. Chakrabarti and [5]Si-Hyun Park

[1,5]Dept. of Electronic Engineering, Yeungnam University, Gyeongsan, South Korea
[2]Dept. of Electronics & Comm. Engineering, Malaviya-NIT, Jaipur, India
[3]Dept. of Electronic & Comm. Engineering,
[4]Motilal Nehru-NIT, Allahabad, India
Email: [1]shivi.phy@gmail.com; [5]sihyun_park@ynu.ac.kr, [2]cpsamy78@gmail.com, [3]sumit.clooney@gmail.com; [4]director@mnnit.ac.in

Abstract —ZnO nanorods (NRs) were deposited on p-type silicon (Si) wafers by low-temperature hydrothermal method. The structural morphology of the ZnO-NR films were characterized by X-ray diffraction (XRD) and scanning electron microscopy (SEM) respectively. The ZnO-NR films exhibit wurtzite ZnO structure and the average length of the ZnO-NRs were in the range from 750 nm to 800 nm. The electrical characterization of the Al/ZnO-NR contacts was studied by using microprobe arrangement. The study demonstrates that Al/ZnO-NR ohmic contact fabricated by a simple and inexpensive method can be used for fabrication of photoconductive sensors applications.

I. INTRODUCTION

Zinc oxide (ZnO) is a wide band-gap semiconductor material with 3.37 eV bandgap and 60 meV exciton binding energy [1, 2]. ZnO has one more good quality, that it can be grown in the form of different types of one-dimensional (1-D) nanostructures. There are various reported nanostructures of ZnO, such as nanowire, nanorod, nano tips, or nanoneedle etc [2]. These ZnO nanostructures can be used to design and develop various kind of devices, like light emitting diodes (LEDs) [3], biosensors [4] and gas sensors [5] etc. The 1-D nanostructures of ZnO have been grown by using various synthesis methods such as RF-sputtering [6], pulsed laser deposition [7] and hydrothermal method [5, 8] etc. It is observed that the preparation of ZnO-NRs with hydrothermal growth method is an easy and low-cost method that can be performed at low temperature [5, 8]. Further for fabricating good-quality ZnO-NR films based devices, high quality Schottky or ohmic contacts are very important. Metals like aluminum (Al) and indium (In) have work-function (w.f.) less than electron-affinity of ZnO, make ohmic-contact with ZnO [9]. Many research-groups have reported ZnO thin film based photoconductive-sensors using Al as metal contact [6, 10]. Jian et. al. reported RF-sputtered Al-doped ZnO based photoconductive-sensors working in ultraviolet (UV) region [6]. Shinde et. al. reported Ga-doped ZnO based photoconductive-sensors using Al as metal contacts [10]. Basically, these ZnO based photoconductive-sensors require good quality of ohmic-contacts. The purpose of this current research is to report systematic study and characterization of ZnO-NRs and subsequently characterization of Al/ZnO-NR contacts for photoconductive-sensor as the future application.

II. EXPERIMENT

Before growth of ZnO-NRs, the p-type silicon (Si) wafers were cleaned ultrasonically by using acetone and methanol. And then the wafers were rinsed with deionized water (DI) (with resistivity ~18 MΩ cm). Later all the wafers were dried using dry nitrogen blow. After cleaning the wafers, seed layer of ZnO was deposited on Si wafers. The seed layer solution has zinc acetate dehydrate powder and ethyl alcohol in 60 mM

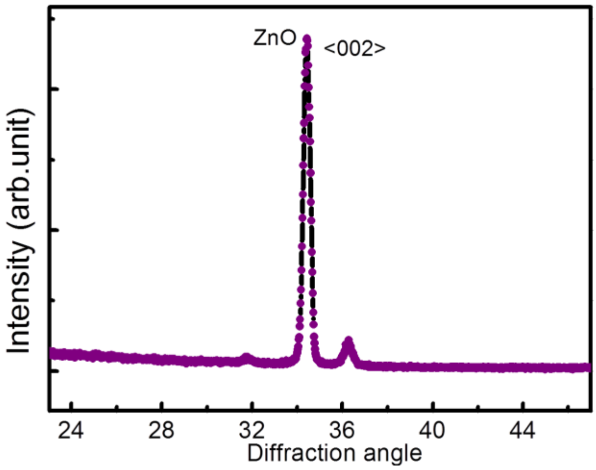

Fig. 1. XRD of ZnO-NR thin films.

concentration. Zinc nitrate hexahydrate, hexamethylenetetramine and DI water with 30 mM concentration was used as the solution for main growth of ZnO-NRs.

III. CHARACTERIZATION

The structural characterization of ZnO-NR thin film samples were done by using X-ray diffraction (XRD) from PANalytical Cukα operated at 30 mA and 40 kV. The morphology of the surface of ZnO-NR samples was examined by scanning electron microscope (SEM) from HITACHI, S-4800 manufactured in Japan. The (I–V) characteristics of the Al/ZnO-NR contacts were measured by using the semiconductor parameter analyzer (Agilent B1500A).

IV. RESULTS AND DISCUSSION

Fig. 1 shows the XRD spectra of the ZnO-NR thin film samples. It can be seen from Fig. 1 that the XRD spectra show high intensity for (002) peak of ZnO at diffraction angle 2θ =34.42°. The other low intensity peaks are visible at diffraction angle 2θ =31.70° and 36.30°, which corresponds to the (100) and (101) planes of the hexagonal wurtzite ZnO structure respectively [8].

Fig. 2 shows the SEM images of ZnO NRs, the growth of uniform NRs can be clearly seen in the image. The diameter of the ZnO-NRs was in the range of 40 to 50 nm, as it can be seen from the Figure 2. The length of these NRs was approximately 750-800 nm measured from SEM image [8].

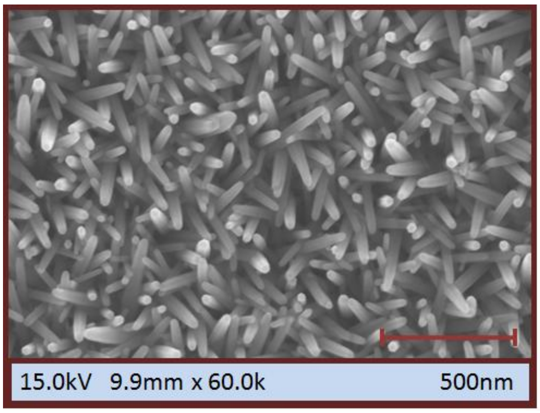

Fig. 2. SEM image of ZnO-NR thin films.

The schematic cross-sectional view of Al/ZnO-NR contacts is shown in Fig. 3. After depositing ZnO-NRs thin films by hydrothermal method few samples were kept for structural characterization while few samples were used for fabricating Al/ZnO-NR contacts.

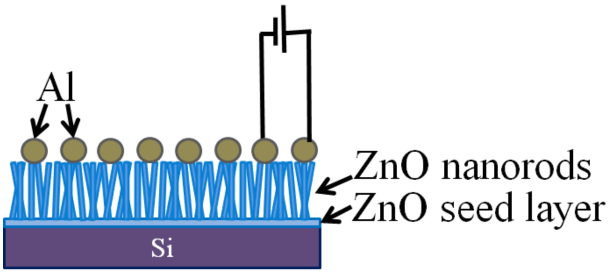

Fig. 3. Schematic cross section of Al/ZnO-NR contacts

With help of shadow-mask, circular Al metal contacts were made above ZnO-NR films by thermal evaporation unit. The diameter and thickness of Al metal were 0.5 mm and 90-100 nm respectively. The measured I–V characteristic for Al/ZnO/Al contacts is shown in the Fig. 4. The current of Al/ZnO/Al contacts were measured in the voltage range from -3 volts to +3 volts. It can be seen from Fig. 4 that the I–V characteristic for Al/ZnO/Al contacts shows linear behavior. The current is increasing linearly with the increase of voltage from -3 to +3 volts.

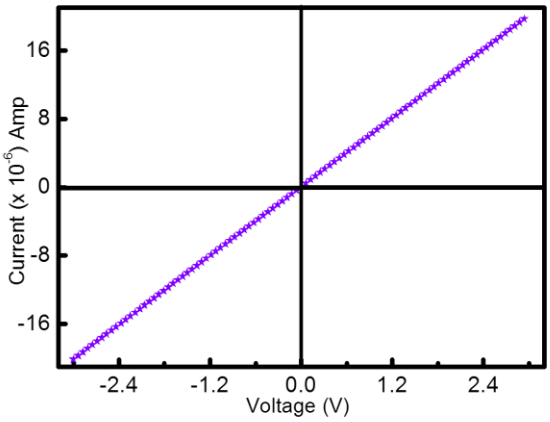

Fig. 4. I-V characteristics of Al/ZnO-NR contacts

It confirms the formation of ohmic-contact between Al metal and ZnO-NR thin films. The value of current at +3 volts is approximately 19.6 micro-amperes. These studies could be useful for fabricating ZnO-NRs based photoconductive ultraviolet (UV) sensors with employing Al as a metal contact. Many groups have used Al as a metal contact for fabricating ZnO based photoconductive-sensors in the recent past. Sun et. al. fabricated RF-sputtered Ga-doped ZnO based metal–semiconductor–metal photoconductive-sensors using Al as metal contacts [11]. Liu et. al. reported N-doped ZnO based metal–semiconductor–metal UV-photoconductive sensors. ZnO was deposited by metalorganic chemical vapor deposition and Al was used as metal contacts [12]. Till now no any group has worked for hydrothermally grown ZnO-NR based UV photoconductive sensors. Hence this work could be useful for fabricating UV-photoconductive sensors in future.

V. CONCLUSION

In summary, ZnO NRs were grown on Si wafers substrates by low-temperature hydrothermal method. The structural characterizations of ZnO NR films were done systematically by using SEM and XRD measurements respectively. The study revealed that ZnO-NR films grown by this simple inexpensive technique have uniform surface morphology with high-density and high-quality. Al/ZnO-NR based ohmic contacts were fabricated by depositing Al metal contact over ZnO-NR thin films. This work shows an example for the progress of low-cost and good quality Al/ZnO-NR contacts for UV photoconductive-sensor applications.

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