Ultraviolet Photo response of Crystallographically Oriented Nanostructured Thin Films of ZnO Grown by Pulsed Laser Deposition

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Abstract. Highly oriented ZnO nanostructured thin films were prepared by pulsed laser deposition method. The *X*-ray diffraction patterns confirm the *c*-axis oriented growth of crystalline ZnO wurtzite structure. The samples were deposited on glass, quartz and silicon(001) substrates in order to compare the growth morphology and the ultraviolet (UV) photoresponse of these films. Scanning electron micrographs confirm the growth of nanostructured films with different surface morphologies. We report here a comparative study of current-voltage (I-V) characteristics and UV photo response of these nanostructured films.

INTRODUCTION

Zinc oxide is naturally*n*-type II-VI semiconductor. Among various semiconductor materials, ZnO has attracted intensive research efforts for its unique properties and applications owing to its direct wide band gap (~ 3.3 eV) and large exciton binding energy (~ 60 meV) [1]. It is a promising material for ultraviolet (UV) photo-detection and transparent electrode applications due to high photoconductivity, strong luminescence and high transparency in the visible region of electromagnetic spectrum [2]. There are various methods reported for the growth of ZnO thin films which includes spin coating, sputtering, pulsed laser deposition (PLD) *etc* [3,4]. PLD is known to be a versatile growth technique for the deposition of stoichiometric, crystalline and oriented ZnO thin films. The photoconductivity of these ZnO films depends on the growth conditions, surface morphology, presence of defects such as oxygen vacancy and zinc interstitials *etc*. These defects generally play a very crucial role in determining the optical property and photoconductivity of ZnO films. The thin films prepared by PLD often do not exhibit such type of defects in a significant amount and therefore the films are suitable for the application in visible-blind ultraviolet photo-detection.Here, we report a synthesis of crystalline ZnO nanostructured films of high quality prepared by PLD method and studied the effects of UV (365 *nm*) light on electrical properties in air and vacuum.

EXPERIMENTAL

ZnO nanostructured thin films were grown on glass, quartz and Si (001)substrates by the pulsed laser deposition method. For this, the bulk sample (target pellet) of ZnO was synthesized using solid state reaction method. Pulsed KrF excimer laser source (Compex Pro 102 F,λ =248 *nm*) was used at an energy fluence of 2.9 J/cm^2 for depositions. The substrate temperature was kept at 400 °Cfor glass and 650 °C for quartz and Si. The samples grown on glass, quartz and Si substrates were coded as *ZnO-G*, *ZnO-Q* and *ZnO-Si* respectively. The crystallographic structure of samples was characterized by *X*-ray diffraction (XRD) with *Cu* Kα radiation (λ= 1.54 Å) using a RigakuSmartLab*X*-ray diffractometer. The surface morphology was investigated by a Field Emission Scanning Electron Microscope (FESEM, Supra 55 Ziess). Photocurrent and I-V characteristics were measured using Keithley

meter, in dark and in UV light (365 *nm*, 4*mW*) illumination in the presence of air and in vacuum at ambient temperature.

RESULTS AND DISCUSSIONS

Figure 1 shows the XRD patterns and SEM images of grown nanostructured thin films. The intense (002) peak in all the samples shows that the grown films are oriented along the *c*-axis of wurtziteZnO. The narrow full width at half maximum (FWHM) and the high intense peak in XRD patterns demonstrate that the grown samples have high crystallinity. The SEM images shown in the inset of fig. 1 confirm the growth of nanostructured films with different surface morphologies.The change in morphology is attributed to the difference in growth temperatures [5]. It has also been reported that the morphology of nanostructure produced varies depending on the nature of substrate surfaces and roughness as well [6]. Clearly, the sample *ZnO-Si* follows the orientation of crystalline Si substrate. Moreover, the samples grown at the substrate temperature of 650 °C(*i.e.ZnO-Q* and *ZnO-Si*) are porous which is clearly reflecting in SEM images. All the samples exhibit highly crystalline nature in spite of different morphologies and different substrates. Additionally, these nanostructures show the connectivity throughout the sample which helps in smooth electrical conduction.

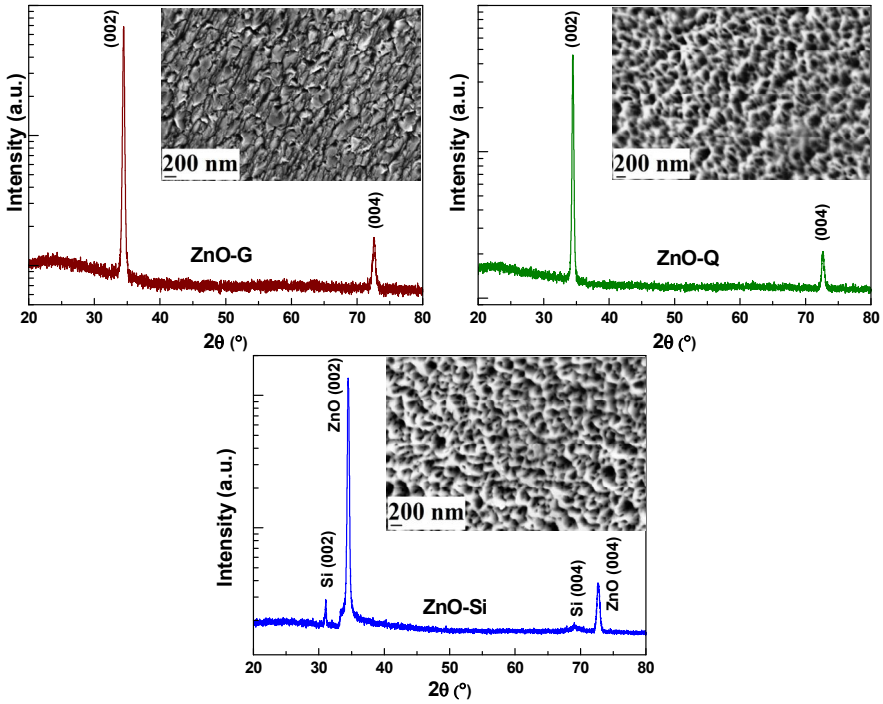

FIGURE 1.XRD patterns and respective SEM images of ZnO nanostructured thin films grown onglass, quartzand Si (001) substrates.

In order to investigate the electrical properties and photoresponse of these nanostructured films, I-V characteristics were studiedfor *ZnO-G* and *ZnO-Q*(Fig. 2). The measurements were carried out in dark and under UV light of wavelength 365 *nm* in the presence of air and vacuum both. When the samples were illuminated with UV light it was observed that the samples have appreciable UV response. The increase in current upon the illumination of UV light is attributed to desorption of oxygen molecules from the surface that governs the generation of free charge carriers for ZnO [7]. In the absence of UV light, oxygen molecules get adsorbed on the surface as negatively charged ions and confines the free electrons, $O_2(\mathrm{g})+e^- \rightarrow O_2^-(ads.)$, thus it creates a depletion layer with low conductivity near the surface. Now, when the UV light with photon energy greater the band gap of the sample is illuminated, it generates the electron-hole pairs ($h\nu \rightarrow e^- + h^+$) and the adsorbed oxygen ions combine with the photo generated holes to produce oxygen molecule that desorbs from the surface, $h^+ + O_2^-(ads.) \rightarrow O_2$.

The dark-current and photocurrent is greatly enhanced when the samples were kept in vacuum during the measurements. The observed increase in dark-current and photocurrentis attributed to vacuum-assisted easy

desorption of oxygen molecules from the sample's surface.The change in current characteristics clearly indicating the photoresponse to originate from surface related process. It is observed that both the samples have strong influence of UV light. However, relatively higher photocurrent is observed for the sample *ZnO-G* which may be due to the less porosity and better connectivity because of different morphology.We could not perform the measurement for *ZnO-Si* due to the high charge conductance of Si substrate compared to ZnO material which hinders the measurement of actual results.

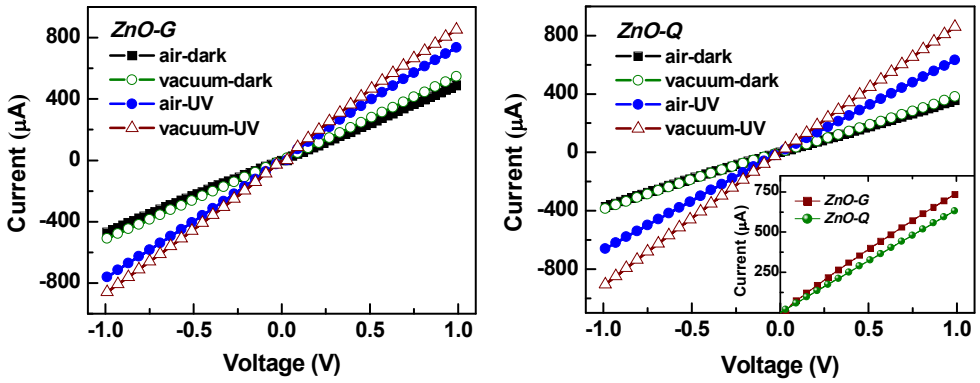

FIGURE 2. Current versus voltageplots of *ZnO-G*and*ZnO-Q* samples. The inset figureshows comparison of photocurrent for both samples in air.

SUMMARY AND CONCLUSIONS

Highly-oriented crystalline ZnO nanostructured thin films were successfully grown on glass, quartz and Si (001) substrates by pulsed laser deposition method. The SEM images confirm the growth of nanostructured films with different morphologies. The films grown on glass and quartzsubstrates show strong absorption of UV light and the change in current in air and in the presence of UV light is attributed to the adsorption and desorption of oxygen. In addition, vacuum also assists for the easy desorption of oxygen molecules and consequently the photocourrent is increasedwhich clearly indicating the photoresponse to originate from surface related processes.The photoconductivity properties clearly demonstrate the suitability of ZnOnanostructured thin films grown by PLD for UV photo detectors.

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