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ZnO / c-Si Solar cell Fabricated through Sol-Gel and Spin Coating

Sajid Farooq[1)], Syed S. Hussain[1)], Saira Riaz[1,2)] and Shahzad Naseem[1)]

[1)]*Centre of Excellence in Solid State Physics, Punjab University, Lahore 54590, Pakistan*

[2)]saira_cssp@yahoo.com

ABSTRACT

ZnO is a transparent conducting oxide that is being considered in fabrication of solar cells. Sol-gel technique has been demonstrated to be capable of depositing device quality coatings at a lower processing cost and temperature. We have prepared a number of oxide coatings through sol-gel route in our group, and now we are investigating their use in devices. Si based solar cells are still the most sold devices in the market. The device efficiency can be increased and the cost can be lowered by going to heterojunction approach using a wide band semiconductor with single crystal Si. We have prepared and optimized thin films of ZnO using spin coating of the synthesized sol. The variation in morphological, structural, electrical, and optical properties of nanostructured films with sol conditions is investigated in detail. The characterization techniques used were SEM, AFM, XRD, SCS, and spectroscopic ellipsometer. It was found from the I–V characteristics of ZnO/Si heterojunction that the average short-circuit current density was about 8 mA/cm^2. The correlations between the composition, microstructure of the films and the properties of the solar cell structures are discussed.

1. INTRODUCTION

In the last few decades, wide band gap semiconductor material such as zinc oxide (ZnO) is a good choice for optoelectronic applications due to direct wide band gap material (E_g = 3.37 eV). ZnO is economical and shows no harm to environment. It can be a good option for the solar cells applications (Liu 2011). ZnO thin films and nanomaterials are used in different semiconductor devices. The most important applications are SAW devices, gas sensors, piezoelectric devices, light emitting diodes (Blue, UV), varistors (Look 2001, Triboulet 2003, Kim 2005, Shaoqiang 2005, Ye 2005, Ghosh 2005, Makino 2000). ZnO has large exciton binding energy, which allows this material to work at room temperature as absorption and recombination can occur at room temperature, and also as temperature quenching is inversely proportional to the band gap of semiconductor, which makes ZnO temperature insensitive and can be used in the temperature insensitive optoelectronic devices (Triboulet 2003, Kim 2005, Shaoqiang 2005, Ye 2005, Ghosh 2005, Makino 2000). In the past few years, ZnO nanostructures have been considered for solar cell applications; mostly used nanostructure are nanowires / nanorods, nanotubes, and these nanostructures are synthesized by different fabrications techniques such as MOCVD (Baxter 2006, Lee 2004), Vapor liquid solid method, (Tang 2001, Li 2000), electro deposition, (Cembrero

2004, Liu 2003), chemical-spray pyrolysis (Krunks 2008) pulsed laser deposition (PLD), gas reactions (Hulteen 1997). Mainly, ZnO nanowires are fabricated by two methods, chemical and physical deposition methods. Both have advantages, such as by means of physical deposition method we can achieve unidirectional, high level crystal quality of nanowires. On the Other hand chemical means is also quite attractive choice as we can produce nanowires on large scale and also at relatively low temperature so we have freedom of using different substrates.

In our work, we have attempted to use sol-gel method and spin coating to fabricate ZnO/c-Si solar cell. This would then be extended to sol-gel deposited nanowires onto Si substrate.

2. EXPERIMENTAL DETAILS

Sol for ZnO films was synthesized locally by using research grade materials. Two solutions (A and B) were prepared before the final synthesis according to previous work (Riaz 2011). Solution A was prepared by dissolving 0.6 g of 99.8% pure zinc acetate $[Zn(CH_3CO_2)_2.2H_2O]$ in 40 mL of de-ionized water whereas, solution B was prepared by mixing 2 mL of triethylamine (TEA) in 70 mL of isopropyl alcohol (IPA). 5 different sols were prepared by changing the synthesis conditions.

Single crystal Si (100) and glass substrates were used for deposition of ZnO thin films. An ultrasonic bath for 20 min with acetone and 20 min with IPA was given to the substrates in order to make them free of any contamination and gas residues on the surface (Riaz 2009). Uniform thin films were deposited by spin coating at 3,000 rpm for 30 s; thickness of around 150 nm or less was achieved in this way. These samples were dried at room temperature for 24 h and were then subjected to heat treatment at different temperatures for varying times. As-deposited and annealed ZnO thin films were characterized structurally with the help of Rigaku D/MAX-IIA X-ray Diffractometer using Ni filtered CuKα (λ = 1.5405 Å) radiation. The target was operated at 35 kV and 25 mA with a step width of 0.05 on the chart recorder.

3. RESULTS AND DISCUSSION

Fig. 1 shows XRD pattern of annealed ZnO thin film. Diffraction peaks observed in the patterns confirm that ZnO thin film has hexagonal (wurtzite) structure. The particle size calculated using Scherer formula is 15-20nm for as-deposited and annealed films.

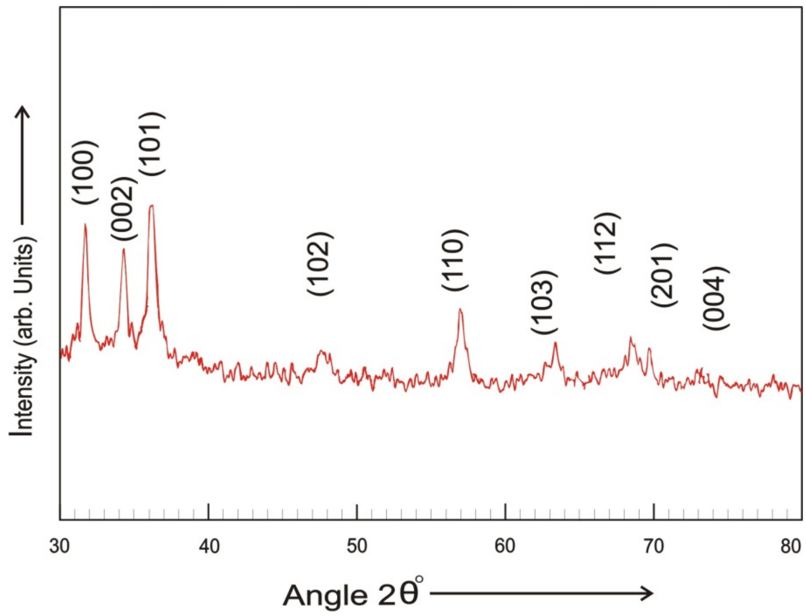

Fig. 1 XRD pattern of ZnO thin Film

ZnO thin films deposited on glass substrate show high transmission in the visible and UV range with average transmission ranging between 85-93% with variation in sol's synthesis conditions as shown in Fig. 2. Higher transmission value of ~93% was observed for ZnO thin film prepared from sol D. Enhanced transmission might be due to less scattering in the thin films and can be used as transparent window materials in many optoelectronic devices (Ma 2007). Furthermore, it should be mentioned that Li (2010) found that the transmission of ZnO thin films prepared by sol -gel method is 83% in the visible range.

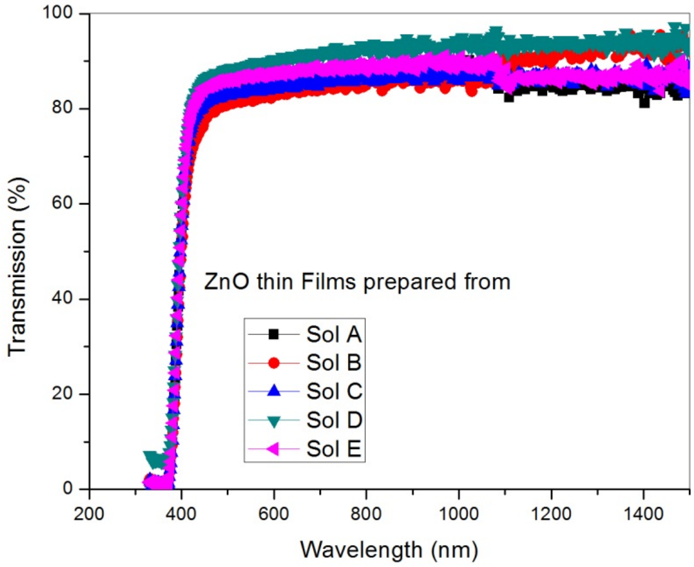

Fig. 2 Transmission plots of ZnO thin Films prepared from different sols

The transmission data was then used to calculate absorption coefficient. A plot of α^2 vs hν is used to calculate the band gap, and one such plot of ZnO prepared by sol gel is shown in Fig. 3, which shows a direct band gap value of 3.67eV.

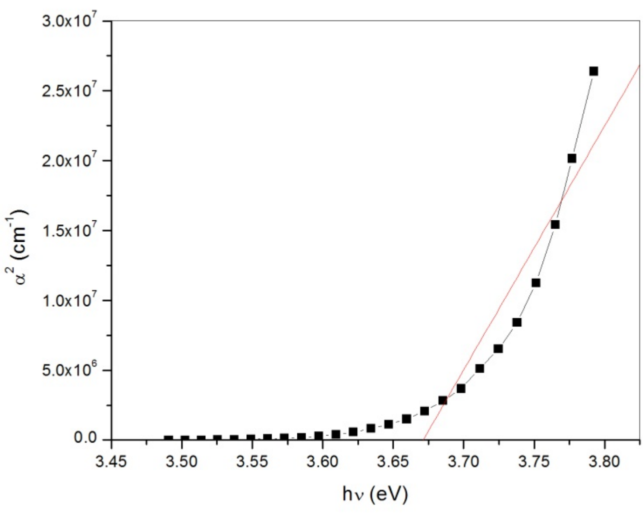

Fig. 3 Band gap plot ZnO thin film

A solar cell was fabricated using the ZnO prepared by sol gel method optimized and described above. Al was used as an ohmic contact to p-type single crystal Si substrate (5mmX3mm). There was no grid contact at the front, rather the ZnO film was point-probed in order to measure the current-voltage characteristics of this device. The I-V plot of this device is shown in Fig. 4.

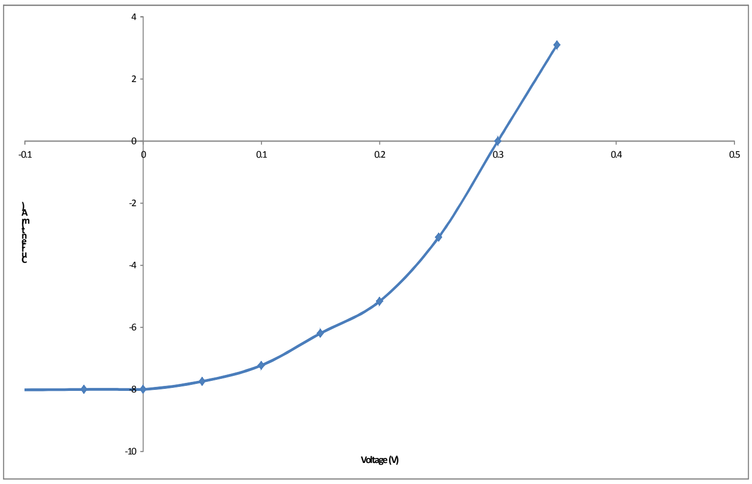

Fig. 4 Current Voltage plot of ZnO/c-Si solar cell

Although the results of this device are not of very high quality, it is to be mentioned here that the devices have not been optimized as yet. The ZnO thin film is to be replaced with nanowires and then it is expected that good quality device can be produced after optimization of the process steps.

CONCLUSION

Fabrication of sol gel deposited thin film of ZnO on c-Si has been attempted. The quality of sol gel deposited ZnO thin film has been optimized using XRD, SEM and optical characterizations. This optimized thin film was then spin deposited onto p-type crystalline Si substrate to which Al contacts had been deposited earlier. The solar cell thus fabricated was characterized electrically, and a current density of around 8mA/cm^2 was measured. Although the initial device properties are not of high quality it is expected that high quality device will be fabricated once the parameters are optimized.

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