Influence of top AZO electrode deposited in hydrogen ambient on the efficiency of Si based solar cell

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Abstract : Al doped ZnO films deposited on glass substrate using RF magnetron sputtering in Ar and Ar+H_2 gas ambient at 100°C. The films deposited in Ar+H_2 were hydrogen-annealed at the temperature of 150~300°C for 1hr. The lowest resistivity of 4.25×10^{-4}Ωcm was obtained for the AZO film deposited in Ar+H_2 after hydrogen annealing at 300°C for 1hr. The average transmittance is above 85% in the range of 400-1000 nm for all films. The absorption efficiency of solar cell was improved by using the optimized AZO films as a top electrode.

Key words : AZO, Hydrogen ambient, solar cell.

1. Introduction

Transparent conducting oxide (TCO) thin films are increasingly investigated for promoting efficiency of photovoltaic (PV) cells, flat-panel displays, and electrochromic windows [1]. An Al-doped ZnO (AZO) film is a promising alternative to ITO which is widely used as TCO and exhibits low cost, remarkable electrical conductivity, and chemical stability that ITO has not these characteristics. Comparing with ITO, AZO film is more useful in the fabrication of thin film solar cells [2]. However, it is difficult to obtain reproducible AZO thin films with these suitable properties at low deposition temperature. However, high deposition temperature may damage the substrates and devices.

In this paper, AZO thin films were deposited at the low temperature of 100°C. The introduction of H_2 to the process of deposition and annealing treatment were carried out to modify the electrical property of AZO thin films. The electrical, optical, and structural properties of films with respect to varying annealing temperature (100-300°C) were examined. The experiment revealed that the AZO films with low resistivity can be obtained at the low growth temperature in Ar+H_2 ambient, without any obvious degradation in transmittance of AZO films compared with in Ar ambient. The efficiency of the solar cell was improved by the top AZO electrode.

2. Experiments

AZO thin films were deposited on glass substrate in Ar and Ar+H_2 respectively at the pressure of 20 mTorr and temperature of 100 °C by RF magnetron sputtering using ZnO: Al_2O_3 (2wt%) ceramic as a target. The H_2/ (Ar+H_2) percentage was maintained at 0.5%. The substrates were ultrasonically cleaned in acetone, alcohol, de-ionized water and nitrogen dry sequentially. Prior to film growth, the chamber was evacuated to 8×10^{-6} Torr, and pre-sputtering time was 10 min. The RF power and deposition time were 150 W and 40 min, respectively. The films deposited in Ar+H_2 were annealed in hydrogen atmosphere for 1hr at various temperatures of 100-300 °C with pressure of 1 Torr. The optimized AZO films were deposited on the pn junction of the solar cell. The influence of hydrogen on crystallinity of films was investigated by X-ray diffraction and SEM. Resistivity, mobility, and carrier concentration were measured by Hall Effect in Van der Pauw configuration, and a spectrophotometer was used for measuring transmittances of the films in the wavelength range of 300-1100 nm. The Vr-Iph property of silicon solar cell with the AZO thin film top electrode is measured by Semiconductor Parameter Analyser (HP 4155A).

3. Results and discussion

All the AZO films show the dominant two theta (002) diffraction peak with the crystal c-axis perpendicular to the substrate in XRD patterns. In Fig. 1. The position of (002) peak shifts toward larger diffraction angles from34.21° to 34.33° as annealing temperature increases. After annealing process, the morphology of the film deposited in Ar+H_2 gets more compact and structured as shown in Fig. 2.

The films deposited in Ar+H_2, the resistivity of as-deposited films is measured to be 7.07×10^{-4} Ωcm which decreases 3 times in comparison to the films

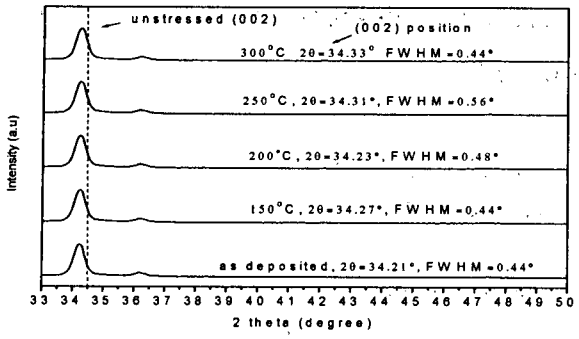
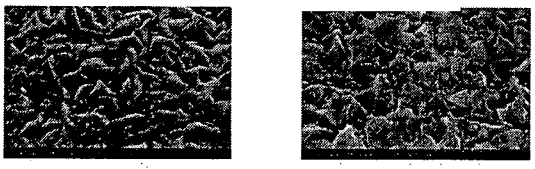


Fig. 1. XRD patterns of as-deposited and hydrogen annealed AZO films deposited in $Ar+H_2$



(a) as deposited films (b) annealed at 300℃

Fig. 2. Surface morphologies of the films deposited in $Ar+H_2$.

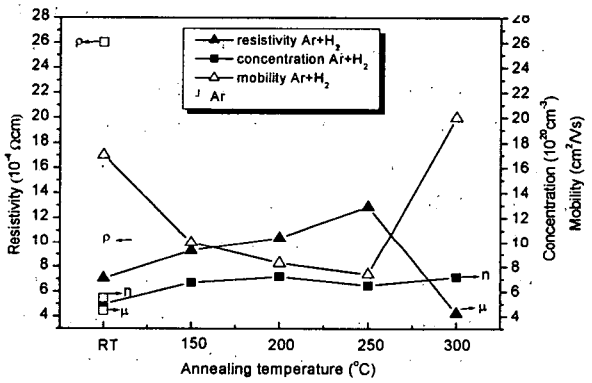


Fig. 3. The electrical properties of films deposited in $Ar+H_2$ as a function of hydrogen annealing temperature. The open square presents the films deposited in Ar.

deposited in Ar shown in Fig. 3. The reduction of resistivity is contributed to the increase of the mobility and carrier concentration. Moreover, the carrier concentration increases with the raising annealing temperature while the mobility decreases as the annealing temperature increases to 250 °C and increases sharply at 300 °C. The minimum resistivity of 4.25×10^{-4} Ωcm is obtained. The AZO film with resistivity of 4.25×10^{-4} Ω cm is suitable to be used as an electrical contact for silicon solar cells.

Transmittance of the as-deposited and the hydrogen-annealed AZO films are shown in Fig. 4. It

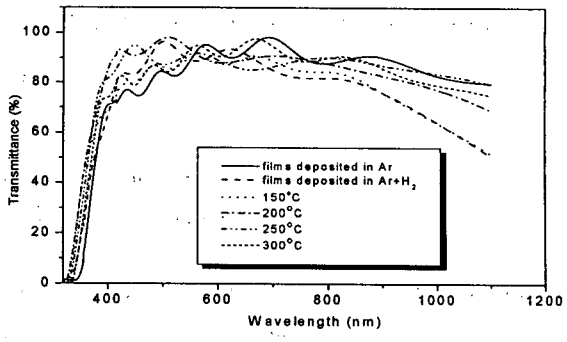


Fig. 4. The transmission spectra of the as-deposited and hydrogen-annealed films.

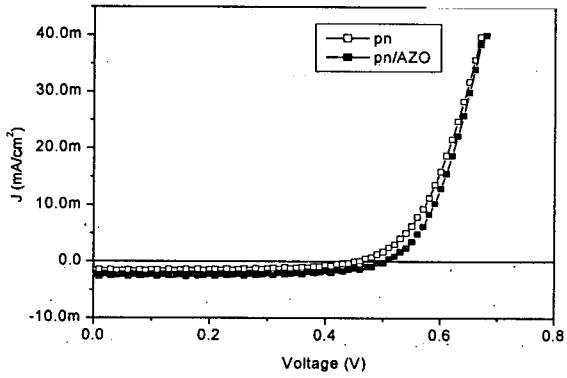


Fig. 5. The Vr-Jph characteristic of solar cell.

can be seen that the average optical transmittance in the range of 400~1100 nm is 80%~90% for all the films.

The efficiency of the solar cell is improved by using the AZO top electrode as shown in Fig. 5.

4. Conclusion

The lowest resistivity of 4.25×10^{-4}Ωcm was obtained for the AZO film deposited in $Ar+H_2$ gas ambient after hydrogen annealing at 300°C for 1hr. The average optical transmittance in the range of 400~1100 nm is 80%~90% for all the films. The optimized AZO films improved the efficiency of solar cell.

Acknowledgement

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