

Study Optoelectronic Properties of Ag₂O Heterojunction Prepared by Thermal Oxidation Technique

Khalid Z. Yahia*

Received on: 4/9/2007

Accepted on:3/4/2008

Abstract

Highly (101)-oriented p-Ag₂O thin film with high electrical resistivity was grown by thermal oxidation (TO) on clean monocrystalline p-type Si without any post-deposition annealing. From optical transmittance and absorbance data, the direct optical band gap was found to be 1.4eV. The electrical and photovoltaic properties of Ag₂O/Si isotope heterojunction were examined in the absence of any buffer layer. Ideality factor of heterojunction was found to be 3.9. Photoresponse result revealed that there are two peaks located at 750 nm and 900nm.

Keywords: Ag₂O/si; heterojunction ;thermal oxidation ;photovoltaic

-

(101)

3,9

Ag₂O/Si

1.4eV

.900 nm750nm,

Introduction

Silver oxide (Ag₂O) is a p-type semiconductor with direct band gap around 1.4eV that is used in photography[1], optical memory[2], and as solar energy converters[3]. Many techniques have been used to grow Ag₂O films; furnace thermal and anodic oxidation of silver[5] thermal evaporation,[6] reactive electron beam[7],and reactive dc magnetron sputtering [4]. No data have been reported on Ag₂O made by thermal oxide (TO) technique using furnace system.

The TO process has a number of advantages over other methods such as:

1. Being simple and cheap.
2. Having good controlled over working conditions
- 3.exhibits highly oriented films.

Experiment

In this study the substrate material used has an area of 25mm²,and is a mirror-like (111-oriented)p-type silicon wafer with electrical resistivity of 1-3Ωcm. The Si substrate is dipped in HF(5%) diluted acid for 10s and then in DI water rinse for 5 min. High purity silver film of 100nm thickness was deposited into clean Si and glass substrate by thermal resistivity technique Ag₂O film is obtained by thermal oxidation of silver film in static air using tube quartz furnace . Figure I shows TO system. the temperature-time oxidation cycle is shown in Figure 1 the condition used in this study to prepare Ag₂O is 300°C/15min.Ohmic contacts are made by vacuum evaporation of Au and Al on Ag₂O and Si consequently, since the

* School of Applied Sciences, University of Technology

Au/Ag₂O contact has good ohmic characteristic.

Figure 2 displays the cross-sectional view of the final heterojunction.

Seebeck coefficient measurement is carried out to investigate the conductivity type of the Ag₂O film.

The X-ray diffraction (XRD) spectrum of the film recorded with X-ray diffractometer operates with 1.5417Å monochromatized CuK α radiation with Ni filter. The electrical dark resistivity at 300K of Ag₂O film was measured using a Keithly 616 digital electrometer. A double-beam spectrophotometer (Shimadzu) was used to measure the transmission and absorption spectra (in the normal incidence mode) of Ag₂O film deposited on film substrate in the spectral range 500 to 1000 nm.

I-V and C-V measurements of fabricated Ag₂O/Si were examined using a potential sweeper and LCZ meter (100 kHz), respectively. A monochromator was employed to investigate the spectral response of the Ag₂O/Si heterojunction after making power calibration. Photovoltaic properties were measured at different illumination levels.

Results and Discussion

Ag₂O film characteristics

The XRD spectrum of Ag₂O is shown in Fig. 3. It is clear that the grown film has a good degree of crystallinity at highly (101)-oriented crystallites of Ag₂O with hexagonal structure. Moreover, neither Ag peaks nor other suboxides of silver peaks have been detected despite the high cooling rate (7°C/s). The evaluated lattice constant of this film is 3.3 Å, close to the bulk Ag₂O ASTM data card 19-1155 (3.072 Å), suggesting a better crystallinity. These results confirm the formation of stoichiometric Ag₂O thin film. The grain size (GS) calculated from the Scherrer formula is found to be 37 nm. A recent study shows that the Ag₂O prepared by dc magnetron

sputtering is of a cubic structure with preferred orientation along (111) (see Ref. 4).

The optical band gap of the Ag₂O film was calculated from the transmission and absorption spectra. Figure 4 displays the transmission as a function of wavelength. It is obvious that the film gives good transparency characteristics at spectral range 500-1000 nm. This behavior seems to be a window. The band gap of Ag₂O measured from the plot of the square of $\alpha h\nu$ versus photon energy $h\nu$ (where α is the absorption coefficient) by extrapolating the linear part of the curve toward the photon energy axis is found to be the value of the optical band of Ag₂O. This strongly depends on the preparation method.

The Ag₂O film exhibits good transparency characteristics and a smooth surface and is depicted in Figure 5. The figure shows a photograph of Ag thin films before and after oxidation, which exhibits good bandpass characteristics. The film exhibits good adhesive properties to the substrate.

Electrical and photovoltaic properties of Ag₂O/Si.

Figure 6 shows the dark I-V characteristics of Ag₂O/Si heterojunction. It is clear that the heterodiode shows rectification ($I_f/I_r > 40$ at 9 V). The forward current exhibits high series resistance due to the mismatch of lattice constants between Ag₂O and Si (the lattice mismatch is calculated to be 48%).

The illuminated I-V under different light levels is depicted in Fig. 7. Increasing intensity of light results in an increase in the photocurrent, indicating good linearity characteristics. Figure 8 shows the measured I_{sc} - V_{oc} of the heterojunction. The ideality factor β was calculated from Fig. 8

and found to be 3.9 at $V < 0.24$ V. The large β value suggests that the recombination in these devices occurs

primarily in the junction interface[8].

Figure 9 show the C-2-V plot of Ag₂O/Si HJ at 20Hz. the intercept of the linear part to the x-axis(0.81v)essentially equal to the diffusion potential within Ag₂O side .

Figure 10 displays the spectral responsivity curve of Ag₂O H.J..There are two distinct peaks located at 750 and 900nm furthermore the spectral response curve exhibits two steep falloffs. The one at $\lambda=800\text{nm}$ is due to parasitic light absorption in Ag₂O through band -band absorption , while the other at near 1000nm which is due to the Si band gap the Fig.(11) photocurrent characteristics of Ag₂O-Si heterojunction using 1mW He-Ne laser and diode laser, the Fig. shows photocurrent of laser He-Ne more than laser diode because of He-Ne wavelength near the peak photoresponse of the heterojunction.

The value of spectral responsivity is low compared to those common silicon base transparent conductive oxides heterojunctions. E.g. SnO₂/Si ,In₂O₃ ,ZnO/Si ,and CdO/Si may be due to 1-high resistivity of Ag₂O contributing to high series resistance. 2-large lattice mismatch between Ag₂O and Si which produce traps charges at recombination centers.

Conclusions

Despite the large lattice mismatch, isotope abrupt Ag₂O/Si 11.1 with encouraged photovoltaic characteristics

was obtained using the TO technique. The structural and optoelectronic properties of Ag₂O/Si in were studied. The values of both Voc and Isc show that the single phase Ag₂O film fabricated by TO is attractive to c-Si solar cell applications. Annealing and doping films to enhance the photovoltaic properties are underway.

References

- [1] T. L. Rollins and F. L. Weichmai, Phys. Status Solid.. 7.5 (1996) 233.
- [2] F. I. Kreeingold and B. S. Kulinkin, Son Phys. Semicond. 4 (1971) 2022.
- [3] J. Tominaga; .J. Phys.: Condens. Matter 25 (2003) .
- [4] U. K. Barik, S. Srinivsan; C. L. Nagendra and A. Subrahmanyam; Solid Films 429 (2003) 129.
- [5] D. Hecht, P. Borthen and H. Strehblow; Sin-f. Sri. 365 (1996) 263.
- [6] L.A. A. Petteresson and P. G. Snyder, Thin Solid Films 270 (1995) 69.
- [7]U. K. Barik and A. Subrahmanyam, in Proc. 11th Int. Workshop Phys. Semiconductor Devices. eds. V. Kumor and P. K. Basu, 11-15 December 2000, New Delhi, India, pp:12.
- [8].E.Tselepis and E.Fortin, J.Mater. Sci.:21(1986).
- [9]D. Song, ,I. Zhao, A. Wang. P. Widcnborg, AV. Chin and A. G. Aberle, 17th Ear. PV Conf. (Munich, 2001)

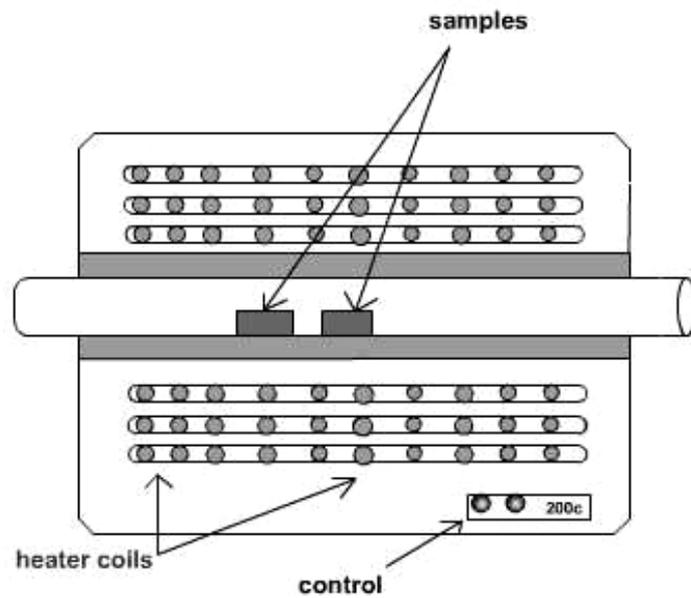


Fig.1 Schematic diagram of furnace system.

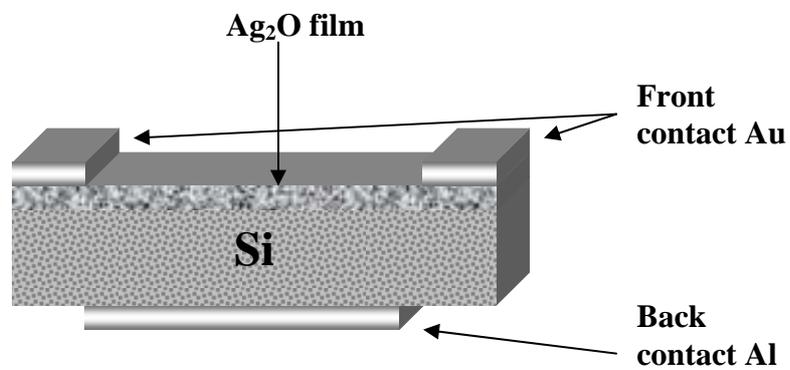


Fig.2 Cross-section view of the final HJ.

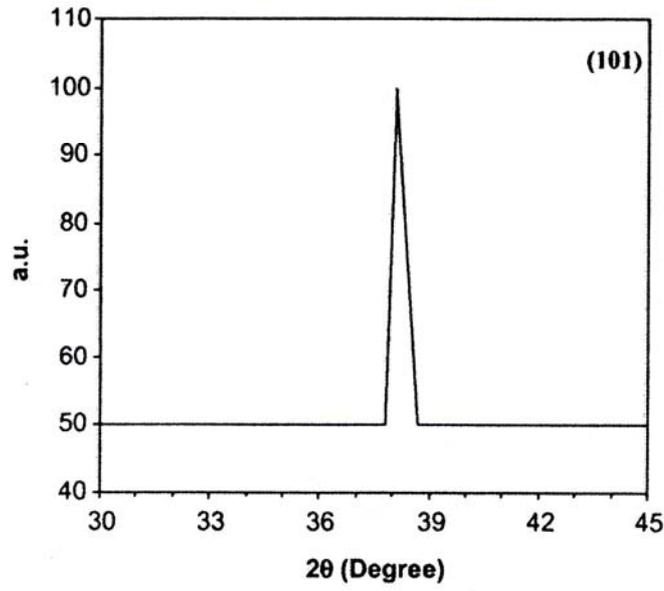


Fig.3 XRD pattern of Ag₂O thin film.

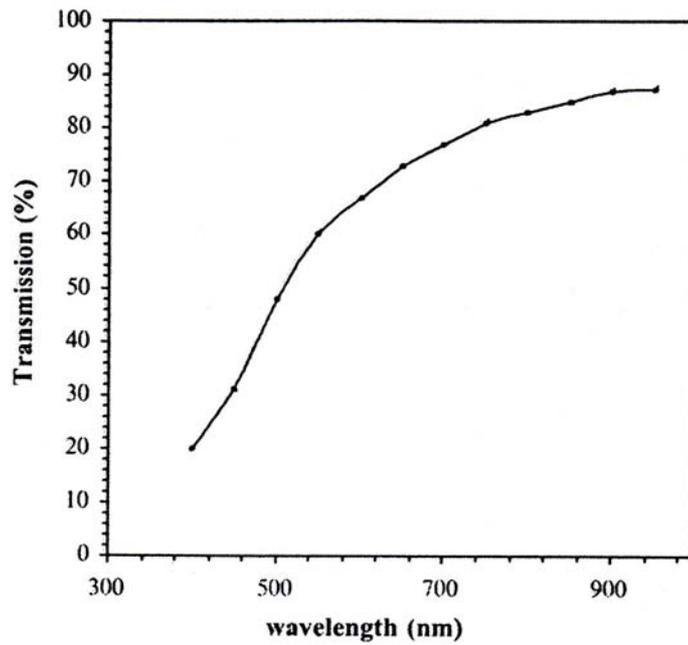


Fig.4 Transmission spectrum of Ag₂O film.

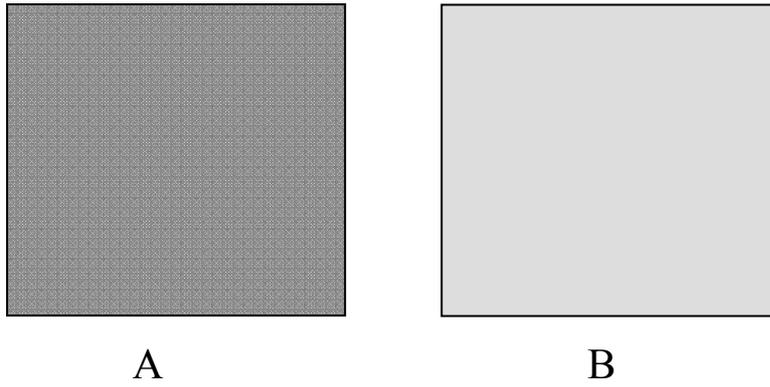


Fig.5 (A).Photograph of Ag before thermal oxidation and (B). Photograph Ag after thermal oxidation thin films .

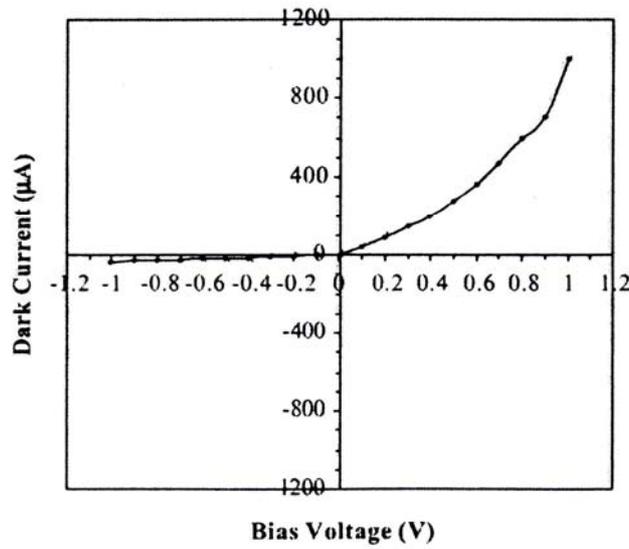


Fig. 6 I-V characteristics of Ag₂O/p-Si isotope HJ.

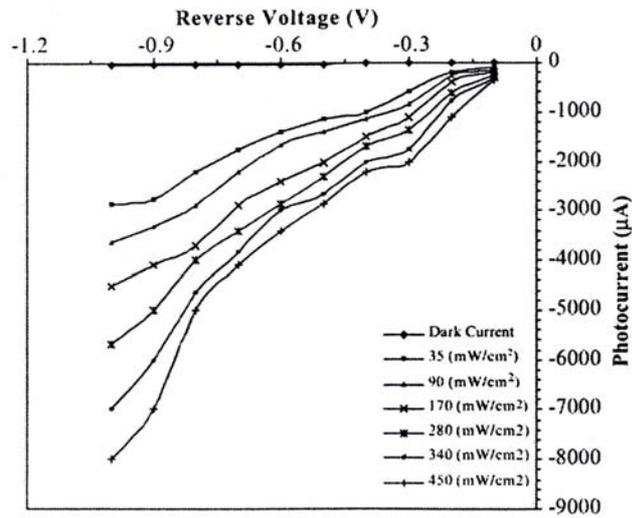


Fig. 7. I-V characteristics under illumination conditions.

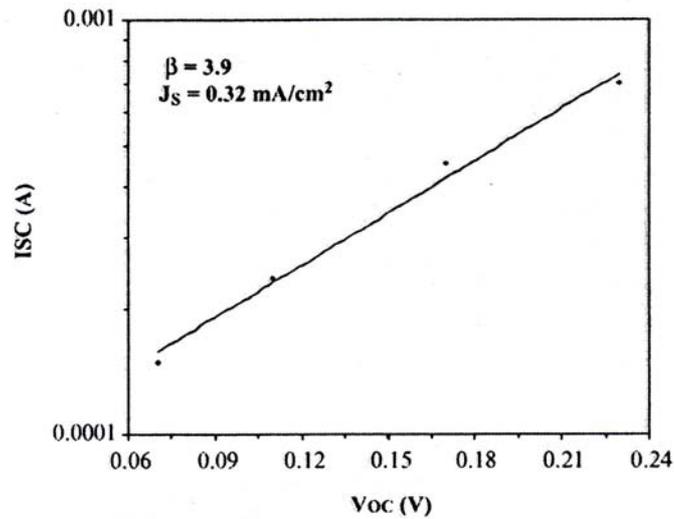


Fig. 8 Isc-Voc curve under different illumination condition

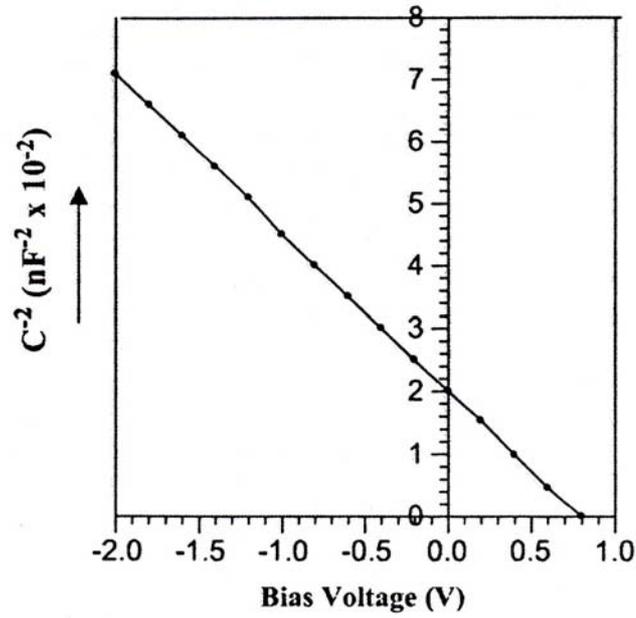


Fig.9 C⁻² -V of Ag₂O/Si H.J

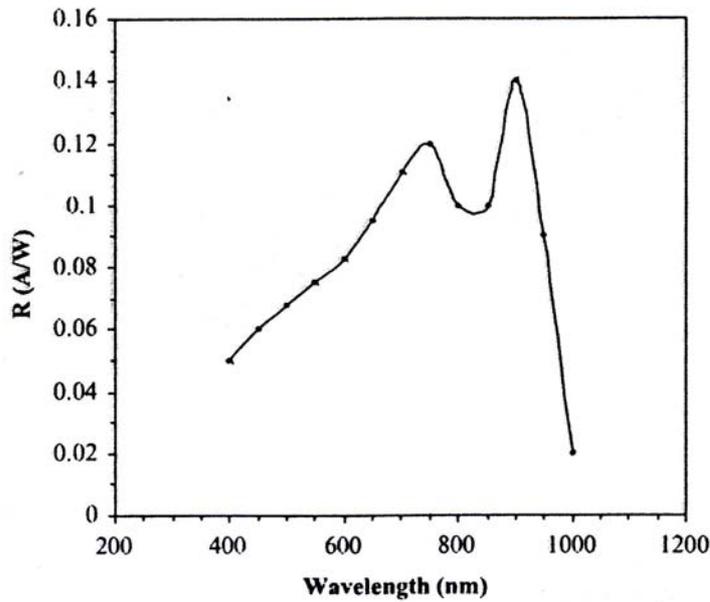


Fig.(10) show responsivity as function of the wavelength

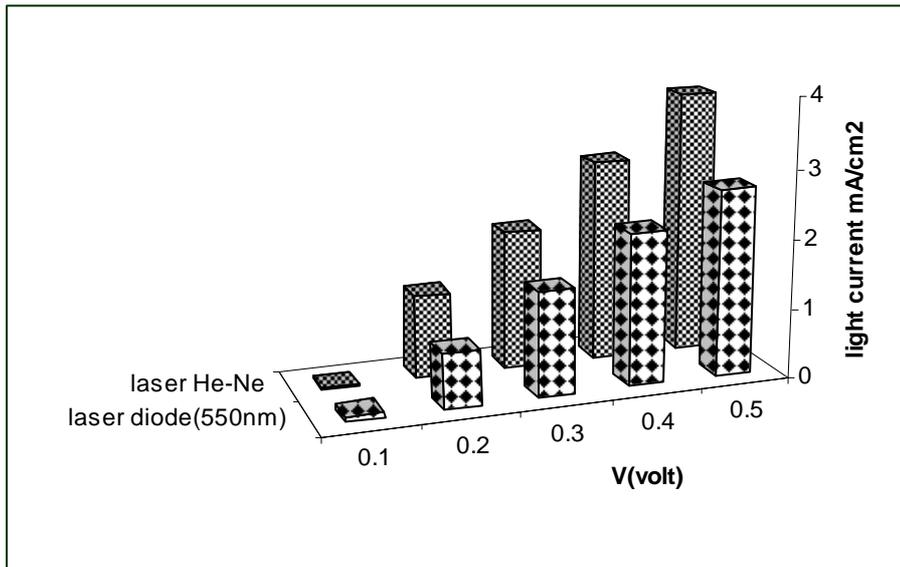


Fig. (11) light current characteristics of Ag₂O-on-Si heterojunction using 1mW He-Ne laser and 1mW diode laser(550nm).