

## Study Optoelectronic Properties of Ag<sub>2</sub>O Heterojunction Prepared by Thermal Oxidation Technique

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### Abstract

Highly (101)-oriented p-Ag<sub>2</sub>O 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 Ag<sub>2</sub>O/Si isotype 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** Ag<sub>2</sub>O/si; heterojunction ;thermal oxidation ;photovoltaic

(101)

Ag<sub>2</sub>O/Si

1.4eV

3.9

900nm, 750nm

### Introduction

Silver oxide (Ag<sub>2</sub>O) 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 Ag<sub>2</sub>O 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 Ag<sub>2</sub>O 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.

### 2. Experiment

In this study the substrate material used has an area of 25mm<sup>2</sup>, and is a mirror-like (111-oriented) p-type

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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 onto clean Si and glass substrate by thermal resistivity technique Ag<sub>2</sub>O film is obtained by thermal oxidation of silver film in static air using tube quartz furnace. Figure 1 shows TO system. the temperature-time oxidation cycle is shown in Figure 1 the condition used in this study to prepare Ag<sub>2</sub>O was 300°C/15min. Ohmic contacts are made by vacuum **evaporation of Au and Al on Ag<sub>2</sub>O and Si consequently**, since the Au/Ag<sub>2</sub>O contact has good ohmic characteristic.

Figure 2 displays the cross-sectional view of the final heterojunction. Seebeck coefficient measurement was carried out to investigate the conductivity type of the Ag<sub>2</sub>O film.

The X-ray diffraction (XRD) spectrum of the film recorded with X-ray diffractometer operates with 1.5417Å monochromatized CuKα radiation with Ni filter. The electrical dark resistivity at 300k of Ag<sub>2</sub>O 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 Ag<sub>2</sub>O film deposited on film substrate in the spectral range 500 to 1000 nm

I-V and C -V measurements of fabricated Ag<sub>2</sub>O/ Si were examined using a potential sweeper and LCZ meter (100 kHz), respectively. A monochromator was employed to investigate the spectral response of the Ag<sub>2</sub>O/Si heterojunction after making power calibration. Photovoltaic properties were measured at different illumination levels.

## Results and Discussion

### Ag<sub>2</sub>O film characteristics

The XRD spectrum of 420 is shown Fig. 3. It is clear that the grown film has a good degree of crystallinity at highly (101)-oriented crystallites of Ag<sub>2</sub>O with hexagonal structure. Moreover, neither Ag peaks nor other suboxides of silver peaks have been detected despite the high cooling rate (7C°/s). The evaluated lattice constant of this film is 3.3 Å, close to the bulk Ag<sub>2</sub>O ASTM data card 19-1155 (3.072Å), suggesting a better crystallinity. These results confirm the formation of stoichiometric Ag<sub>2</sub>O thin film. The grain size (GS) calculated from the Scherrer formula is found to be 37nm. A recent study shows that the Ag<sub>2</sub>O prepared by dc magnetron sputtering is of a cubic structure with preferred orientation along (111) (see Ref. 4).

The optical band gap of the Ag<sub>2</sub>O 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 500-1000nm. This behavior seems to be a window. The band gap of Ag<sub>2</sub>O measured from the plot of the square of αhν versus photon energy hν (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 Ag<sub>2</sub>O. This strongly depends on the preparation method.

The Ag<sub>2</sub>O 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 exhibit, good adhesive properties to the substrate.

### Electrical and photovoltaic properties of Ag<sub>2</sub>O /Si.

Fig. 6 shows dark I-V characteristics of Ag<sub>2</sub>O /Si heterojunction, it is clear that the heterodiode this rectification ( $I_f/I_r > 40$  at 9 V). The forward current exhibits high series resistance due to high series resistance due to match lattice constant between Ag<sub>2</sub>O 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 result in the increase in the photocurrent, indicating good linearity characteristics Figure 8 shows the measured Isc-Voc of the heterojunction. The ideality factor  $\beta$  was , calculated from Fig.8 and found to be 3.9 at  $V < 0.24V$ . The large  $\beta$  value suggests that it the recombination in these device occurs primarily in the junction interface[8].

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

Figure 10 displays the spectral responsivity curve of Ag<sub>2</sub>O 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 Ag<sub>2</sub>O through band -band absorption , while the other at near 1000nm which is due to the Si band gap the Fig.(11) photocurrent characteristics of Ag<sub>2</sub>O-Si heterojunction using 1mW He-Ne laser and diode laser the Fig. shown photocurrent of laser He-Ne more than laser diode because of He-Ne wavelength near the peak photoresponse of the heterojunction.

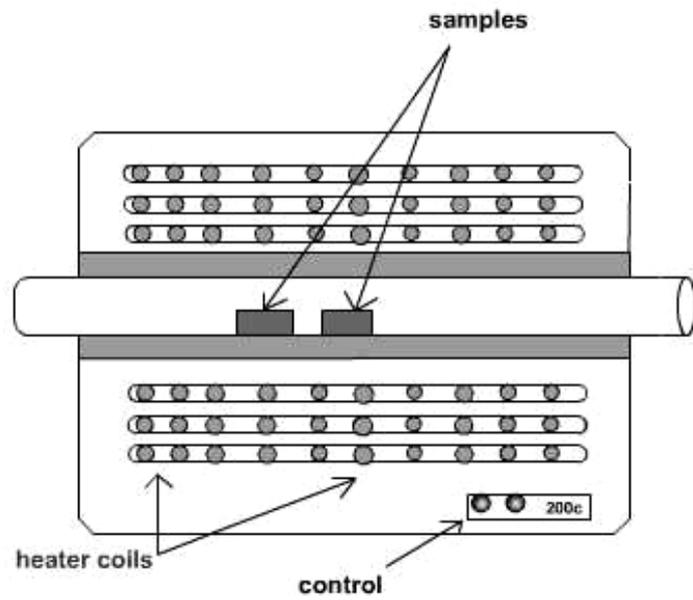
The value of spectral responsivity is low compared to those common silicon base transparent conductive oxides heterojunctions. E.g. SnO<sub>2</sub>/Si ,In<sub>2</sub>O<sub>3</sub> ,ZnO/Si ,and CdO/Si may be due to 1-high resistivity of Ag<sub>2</sub>O contributing to high series resistance. 2-large lattice mismatch between Ag<sub>2</sub>O and Si which produce traps charges at recombination centers.

### Conclusions

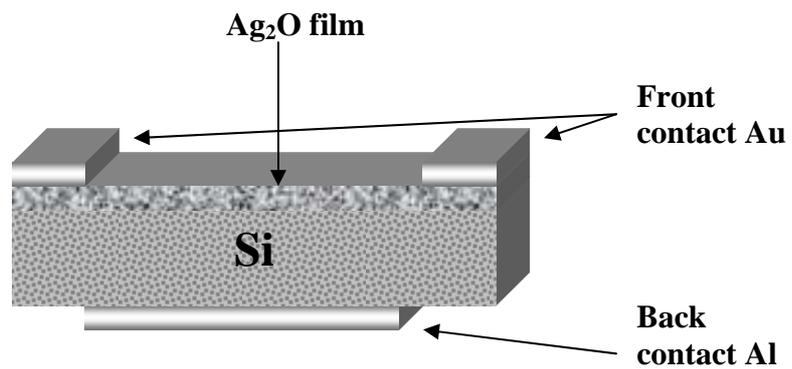
Despite the large lattice mismatch, isotope abrupt Ag<sub>2</sub>O/Si 11.1 with encouraged photovoltaic characteristics was obtained using the TO technique. The structural and optoelectronic properties of Ag<sub>2</sub>O/Si in were studied. The values of both Voc and Isc show that the single phase Ag<sub>2</sub>O 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. Rollins T. L. and Weichmai F. L., Phys. Status Solid.. 7.5 (1996) 233.
2. Kreeingold F. I. and Kulinkin, B. S. Son Phys. Semicond. 4 (1971) 2022.
3. Tominaga J.; .J. Phys.: Condens. Matter 25 (2003) .
4. Barik U. K., S. Srinivsan; C. L. Nagendra and Subrahm A. unyam; Solid Films 429 (2003) 129.
5. Hecht,D. P. Borthen and H. Strehblow; Sin-f. Sri. 365 (1996) 263.
6. Petteresson L.A. A. and Snyder, P. G. Thin Solid Films 270 (1995) 69.
7. Barik U. K. and A. Subrahmanyam, in Proc. 11th Int. Workshop Phys. Semiconductor Devices. eds. V. Kumor and Basu P. K., 11-15 December 2000, New Delhi, India, pp:12.
8. Song, D. ,I. Zhao, A. Wang. P. Widcnborg, AV. Chin and Aberle A. G., 17th Ear. PV Conf. (Munich, 2001)



**Fig.1** Schematic diagram of furnace system.



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

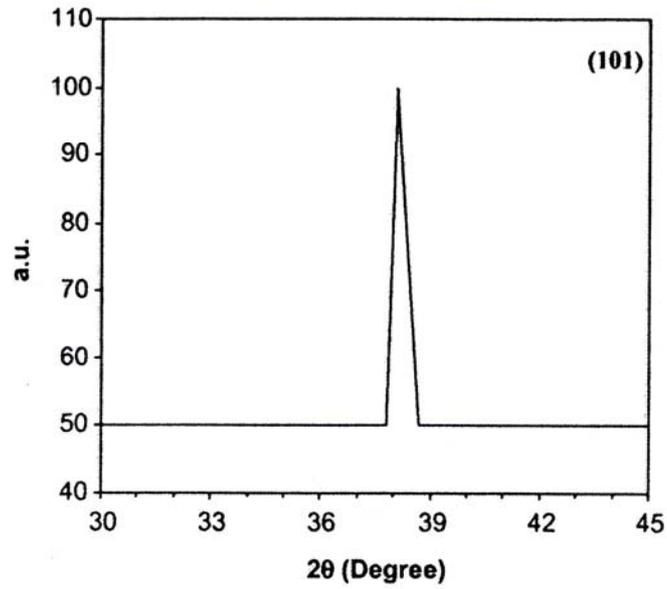


Fig.3 XRD pattern of Ag<sub>2</sub>O thin film.

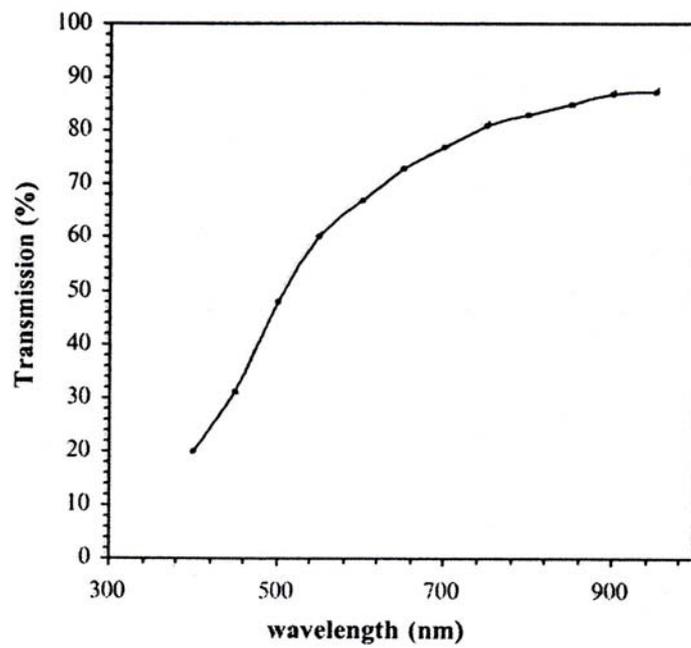
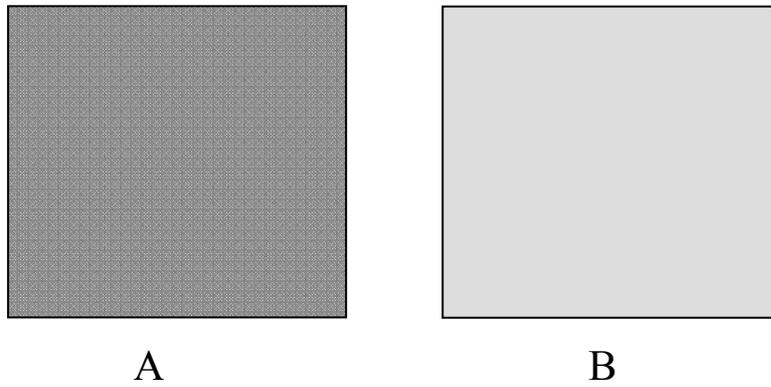
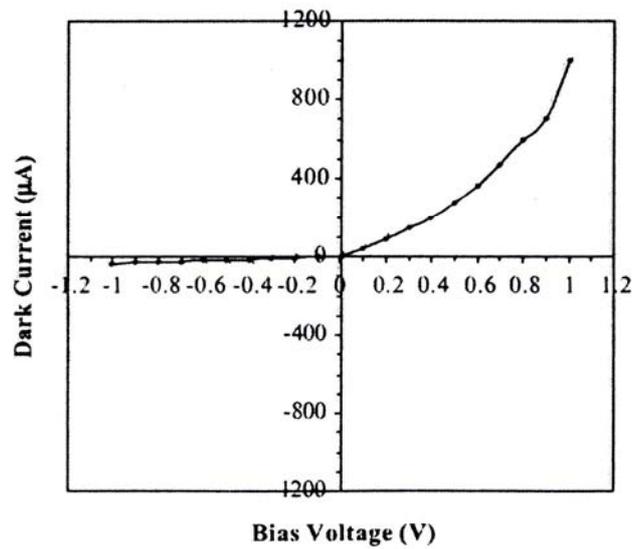


Fig.4 Transmission spectrum of Ag<sub>2</sub>O film.



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



**Fig. 6 I-V characteristics of Ag<sub>2</sub>O/p-Si isotype HJ.**

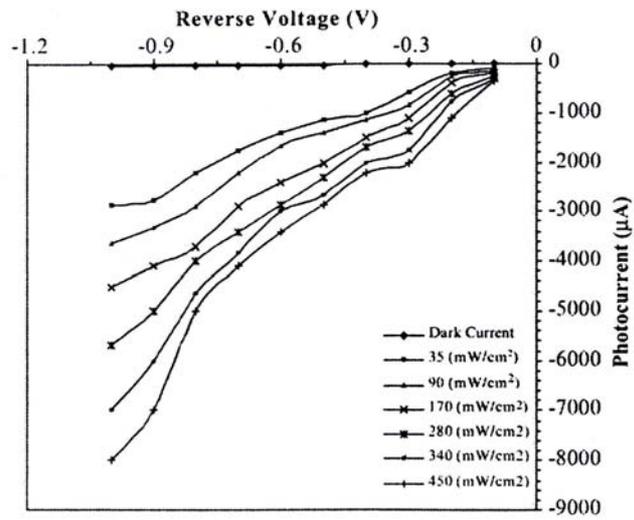


Fig. 7. I-V characteristics under illumination conditions.

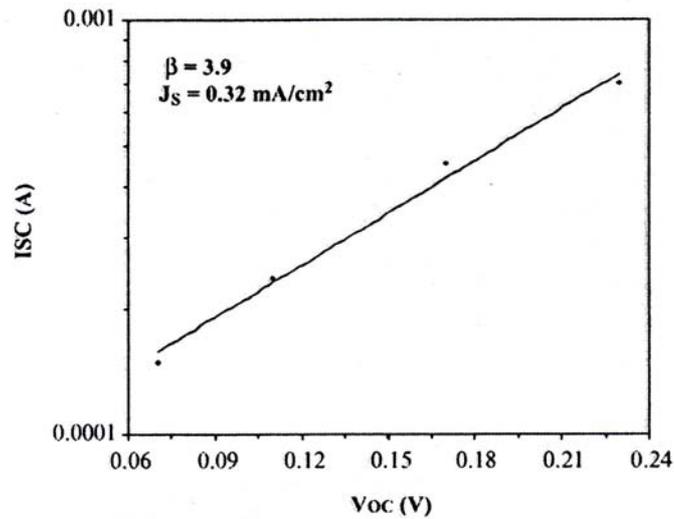


Fig. 8 Isc-Voc curve under different illumination condition

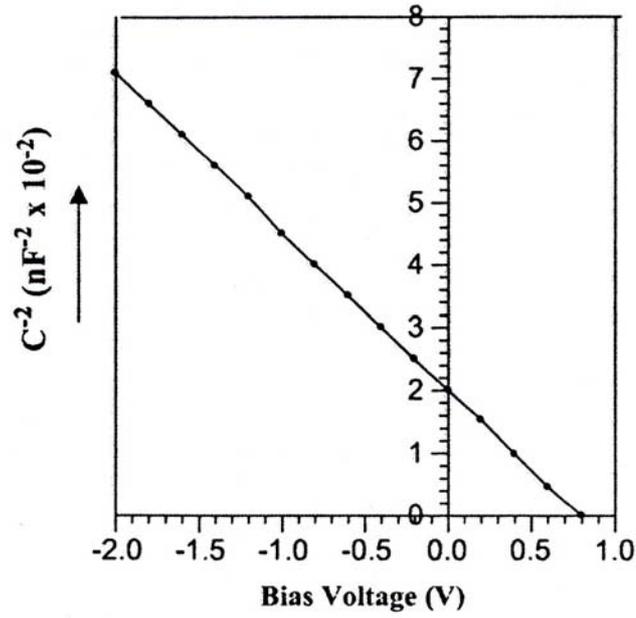


Fig.9  $C^{-2}$  -V of Ag<sub>2</sub>O/Si H.J

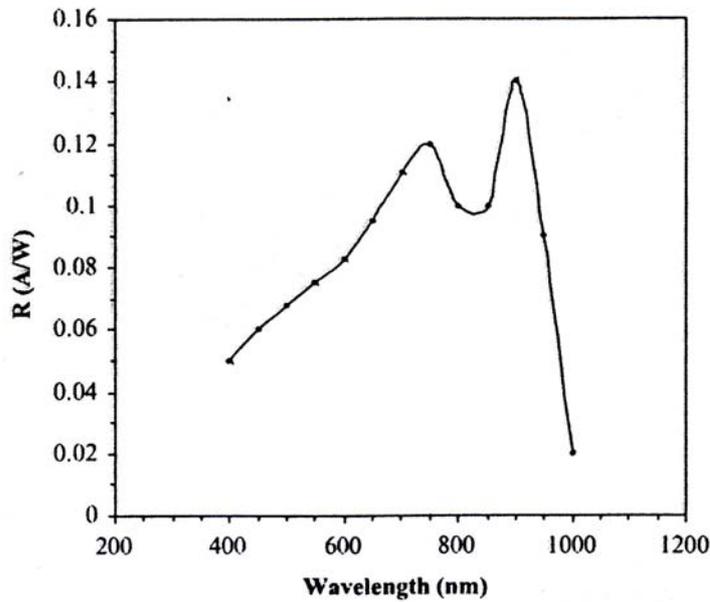
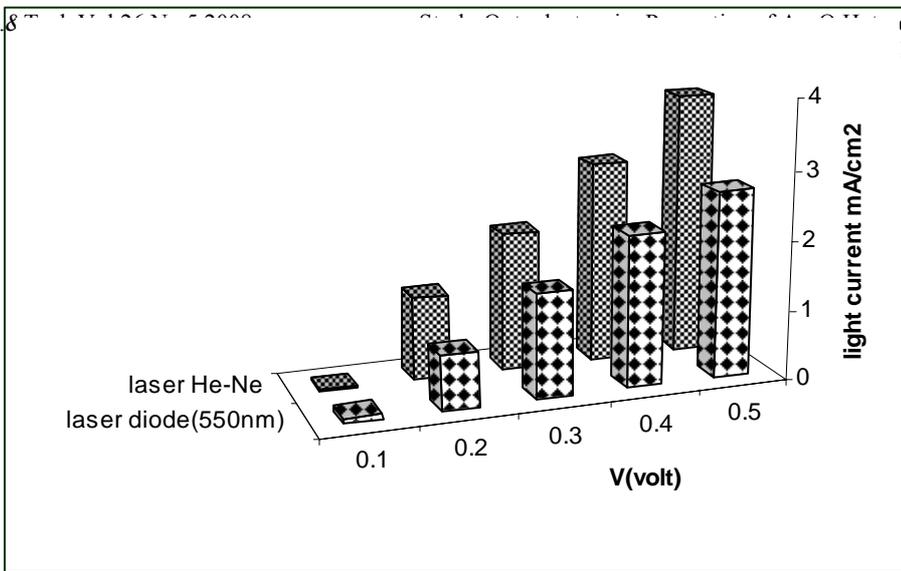


Fig.(10) show responsivity as function of the wavelength



**Fig. (11) light current characteristics of Ag<sub>2</sub>O-on-Si heterojunction using 1mW He-Ne laser and 1mW diode laser(550nm).**