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# DC magnetron sputtering: Impact of partial $O_2$ pressure on the characteristics of $Ag_2O$ films

**Nagendra Vara Prasad M[1], Jeevan Kumar R[2] and Munikrishna Reddy Y[1*]**

[1]*Faculty of Physics, S S B N Degree College (Aided & Autonomous), Anantapur 515001, A.P, India*
[2]*Faculty of Physics, S K University, Anantapur 515003, A.P, India*

[*]Corresponding author; Tel: +91 9440243514; E-mail: ymkredi60@gmail.com

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## Abstract

In the present work, $Ag_2O$ films are deposited at room temperature using DCMS (Magnetron Sputtering) method with the variation of pressure of $O_2$ during the development of film. The pressure of $O_2$ in the DCMS unit chamber is arranged between $2X10^{-2}$ and $6X10^{-2}$ Pa. Transmission and absorption spectrum are recorded to assess the impact of increasing thickness on certain optical parameters such as indirect band gap, direct band gap, dielectric constant etc. As $O_2$ pressure is varies between $2X10^{-2}$ Pa and $6X10^{-2}$ Pa, optical energy band gap shows a decreasing trend between 1.041 eV and 0.942 eV. It is also observed that the absorption transmittance of the deposited films increases with the increase of thickness of the film. This way, the study reveals that all the parameters are affected by varying pressure of $O_2$. The effective useful of these O2-rich films is also discussed keeping in view the increasing importance of the modern technological applications such as photovoltaic cell fabrication. Thus, this technique can also be applied to produce films using other metal oxides. Copyright © 2017 VBRI Press.

**Key words:** DCM sputtering, $Ag_2O$, oxygen partial pressure, thin film, optical energy band gap.

### Introduction

$Ag_2O$ films are effective applications in order to study higher optical storage device approach like cathode in high rate battery devices [1]. As we know that the silver element belongs to d-orbital electrons and it exists in different states of oxides like $Ag_2O$, $Ag_2O_3$, $Ag_3O$ and AgO. Among these phases, $Ag_2O$ is thermodynamically most stable one. In many cases, the deposition of oxides on films depends upon the growth of film, time, substrate temperature and the availability of oxygen [2]. The literature felicitates the preparation of $Ag_2O$ films using various methods like laser method, CBD, rf sputtering, solgel and DCMS method. Of all the techniques, DC magnetron sputtering (DCMS) can be a suitable one to prepare silver oxide films [3]. This technique is more advantageous to get uniform large area substrate, more rates of deposition, chemical composition control and various physical characteristics. The effect of chamber temperature on the properties of $Ag_2O$ films formed by DCMS technique was reported earlier [4]. N. Ravi Chandra Raju et all fabricated $Ag_2O$ thin films on glass substrate using Pulsed Laser Deposition (PLD) method. They also reported that the thickness, optical band gap and work function were found to be varying with $O_2$ pressure [6]. However, PLD is expensive and alteration of oxygen pressure is proved to be a difficult task. Also, the properties of $Ag_2O$ structure are established to be more dependent on the growth of oxygen and, therefore, it would be of great interest to examine the alternative techniques to fabricate the films needed for industrial photovoltaic applications. In the present work, $Ag_2O$ films are formed on substrate by DCMS method at varying $O_2$ pressures. The role of $O_2$ pressure on the properties of $Ag_2O$ films is keenly observed and the observations are vividly reported.

### Experimental

#### *Materials*

Metallic silver (99.6%) of 1 inches radius and 2 mm thick purchased from SISCO India Ltd is used as a sputtering target. All the $Ag_2O$ layers are deposited on a glass substrate (75mm X 25mm X 1.35mm) obtained from Polar Industrial Corporation, India.

#### Preparation of thin films

The deposition conditions to prepare oxide films are mentioned in **Table 1**. At first the glass substrate is radiated up to 423 K and the pressure of the chamber is decreased to a base pressure of $5X10^{-6}$ Torr by using diffusion and rotary pump. Argon (Ar) of 99.999% is injected into the chamber as the sputter gas. $O_2$ of

99.999% purity is also employed as the reactive one. In the initial stage, the dc power is turned off temporarily allowing $O_2$ and Ar gases to generate partial atmospheric pressure. After deposition, partial oxygen pressure ($PO_2$). It is recorded switching off the flow of argon. The thin films are deposited for 5 - 10 minutes to remove any contaminant on the target surface. The optical transmittance of the films deposited is recorded employing Perkin-Elmer Lambda 950 UV-VIS-NIR spectrophotometer in the examined wavelength region between 300 nm - 2000 nm. The optical and electrical properties are deployed out to observe the physical behaviour of deposited films.

**Table 1.** Deposition conditions for $Ag_2O$ films.

| **Parameter** | **Value** |
|---|---|
| Deposition Method | DC Magnetron Sputtering |
| Sputtering Target | Pure Silver (50.8mm diameter and 5mm thick) |
| Target to Substance Distance (mm) | 70 |
| Base Pressure (Torr) | $5X10^{-6}$ Torr |
| $O_2$ Partial Pressure (Pa) | $2X10^{-2}$ - $6X10^{-2}$ |
| Sputtering Pressure (SCCM) | 25 |
| Substance Temperature (K) | 423 |
| Power (Watt) | 40 – 80 W |
| Deposition Time (min ) | 5 - 10 |
| Microscope glass slides | 25.4 mm X 76.2 mm X 1.5 mm |

## Results and discussion

The optical spectra of $Ag_2O$ deposited at various $O_2$ pressure is shown in **Fig.** 1.The plots of graph indicate that oxygen-rich signifies the effect of transmittance. The curves in the graph are not the same in their behaviour. But rapid increase of transmittance in the high energy is observed due to electronic transition dependence. A low optical transmittance is founded at a pressure of $2X10^{-2}$ Pa. The percentage of transmittance at $2X10^{-2}$ Pa is 40% while at $6X10^{-2}$ Pa this raises to 80%. The transmittance percentage is almost constant between $4X10^{-2}$ Pa - $6X10^{-2}$ Pa.

It is also found that the absorption edge of the films moved to lower region of wavelength due to increase of $O_2$ pressure. Thus, the graph gives optical transmittance (T) providing the absorption coefficient (α) with the following relation.

$$\alpha = \frac{1}{t} l\ nT$$

where t = thickness of the deposited film.

Graphical relation between $(\alpha h\nu)^2$ Vs $Ag_2O$ photon energy (hν) at various $O_2$ pressure is shown in **Fig. 2**. The graph is used to compute $Ag_2O$ optical energy band gap using Tauc's equation [5]

$$(\alpha h\nu) = A(h\nu - E_g)m$$

The direct band gap transitions take place for these films at m = ½.

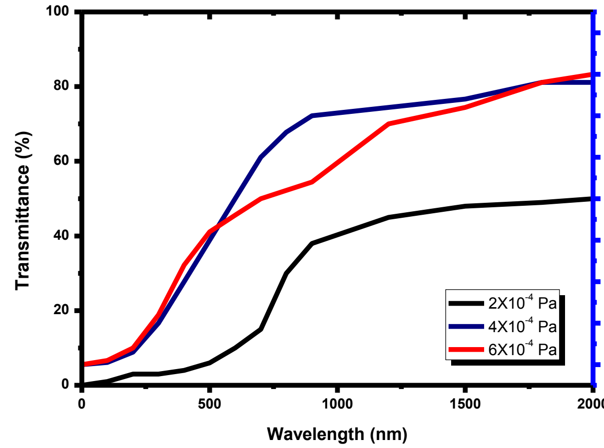


**Fig. 1.** Spectra of optical transmittance at various $O_2$ pressure.

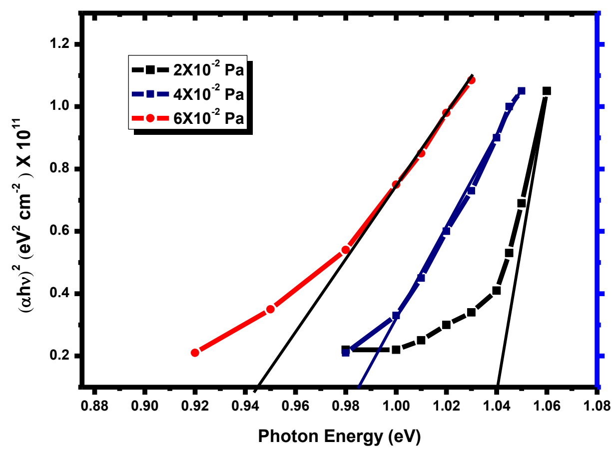


**Fig. 2.** $(\alpha h\upsilon)^2$ Vs hυ of $Ag_2O$ films at various $O_2$ pressure.

From the above graph, the extrapolation of the linear portion at α = 0 provided the optical energy band gap ($E_g$). As a result, $E_g$ value is decreased between 1.041eV and 0.942 eV while $O_2$ pressure is varied between $2X10^{-2}$ Pa and $6X10^{-2}$ Pa. Due to crystal enhancement of pure $Ag_2O$ film, it is observed that $E_g$ value increases from 2.05 to 2.13 eV with the same $O_2$ pressure variation. However, the film formed at $4X10^{-2}$ Pa show 1.92 eV and this is due to the presence of multi phases of $Ag_2O$. In the study, the $E_g$ of $Ag_2O$ film by means of Ag target decreases from 1.041 to 0.942 eV as $O_2$ pressure varied between $2X10^{-2}$ Pa and $6X10^{-2}$ Pa. at the same time, it is also noted that the $E_g$ value increases to 0.984 eV at $O_2$ pressure of $7X10^{-2}$ Pa. in this method, the literature value shows the $E_g$ value as 2.24 eV deposited at the substrate temperature 523K [1-2]. It is observed that a single phase $Ag_2O$ is formed at the pressure of $2X10^{-2}$ Pa. However, the films deposited at or above $4X10^{-2}$ Pa are transformed into metallic silver. The present work suggests that $E_g$ of $Ag_2O$ films decreases with the increase of $O_2$ pressure.

## Conclusion

$Ag_2O$ films prepared at $2X10^{-2}$ Pa are of single phase while those deposited at $4X10^{-2}$ Pa are transformed into metallic silver. Also, $E_g$ of investigated $Ag_2O$ films decreases with the increase of $O_2$ pressure.

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