# Preparation and Characterization of $SiO_2$ Thin Films as an Antireflective Layer

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## Abstract

Uniform layers of $SiO_2$ were prepared using thermal evaporation technique under high vacuum ($10^{-5}$ mbar). Many characterizations were investigated using these films as antireflective layers. The morphological, crystal structural and optical properties of the layers were investigated by using SEM, XRD, and UV-Vis instruments.

**Key words:** thin films, thermal evaporation, $SiO_2$, antireflection.

# تصنيع اغشية رقيقة من ثنائي اوكسيد السيليكون كطبقة مضادة للانعكاس ودراسة خواصها

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## الخلاصة

تم تحضير اغشية متجانسه لثنائي اوكسيد السيليكون على الزجاج باستخدام منظومة التبخير الحراري بوجود الفراغ تحت ضغط ($10^{-5}$ mbar). لقد تم دراسة طبيعة السطح للغشاء باستخدام المجهر الالكتروني الماسح، كما تم دراسة الخواص التركيبية له باسخدام حيود الاشعة السينية، اما الخواص البصرية فقد تم دراستها ضمن نطاق الاشعة المرئية وفوق البنفسجية باستخدام مطياف الاشعة المرئية وفوق البنفسجية.

**كلمات مفتاحية:** اغشية رقيقة، التبخير الحراري الفراغي، السليكا، مضادات الانعكاس.

## Introduction

Anti-reflection coatings are often used to reduce surface reflection of desirable wavelengths from the cell, and allow more light to reach the semiconductor film layer, leading to enhancement of performance of the solar cell efficiency. One of the several inorganic materials, $SiO_2$ films are the more favorite materials for various applications, such as solid state electronics and optoelectronic devices [1]. In addition to the electronic applications, $SiO_2$ can be used as a dispersion barrier on various plastic packaging materials [2]. Thermal vacuum evaporation is very suitable method for the deposition of $SiO_2$ thin films; for the production of thin films on various substrates and can be applied on a many kind of solar cells and electronic applications. Silica ($SiO_2$) thin film has been used for surface passivation and diffusion masking during fabrication processes of planar silicon (Si) devices [3]. Therefore, such insulating films have been applied to many types of electronic devices such as the static randomly memory devices as a metal-oxide- semiconductor in field effect transistors, insulated gates thin films transistors and as metal-insulator-semiconductors structure [4]. Silica thin film has been vastly used for protective layers and optical coatings as anti-reflection films for solar cell applications [5]. Furthermore, $SiO_2$ can be used for various microelectronic structures, as diffusion barriers and insulating layers with additional planarization capability [6]. The physicochemical properties of silica thin coatings were applied in different methods to enhance photovoltaic devices, as encapsulate coatings or to insulate electrical connections in the cells [7-8].

In order to increase the transmittance of incident light and prevent disorders of external light, antireflective technologies are vastly utilized in optical components such as displays, solar cells, automotive glass, thermo-chromic windows, and so on [9]. In present work, silica thin films were applied on glass substrates using thermal vacuum evaporation under $10^{-5}$ mbar.

## Experimental

In this study, $SiO_2$ powder was evaporated by thermal evaporation system (homemade) under $10^{-5}$ mbar to be deposited on glass substrate. The setup was used in this paper contains vacuum system consists of rotary pump and diffusion pump to create high vacuum in the chamber by controlling valves as shown in figure 1.

A little amount of $SiO_2$ powder was weighed (0.4 gm) and placed in a tungsten boat in the vacuum chamber and then heated to the Sublime degree by high current system to evaporate and then deposit on the glass substrate which has been cleaned by acetone and distilled water and after dried placed a (15 cm) over the tungsten boat. The structural studies of the prepared $SiO_2$ films were discussed by X-ray diffraction method by using Shimadzu diffractometer (XRD - 6000). The optical properties for $SiO_2$ thin films deposited on glass substrates were analyzed using the Metertech SP-8001 UV-Visible Spectrophotometer; the scanning electron microscope SEM used for morphology studies is (Tescan Vega 3B).

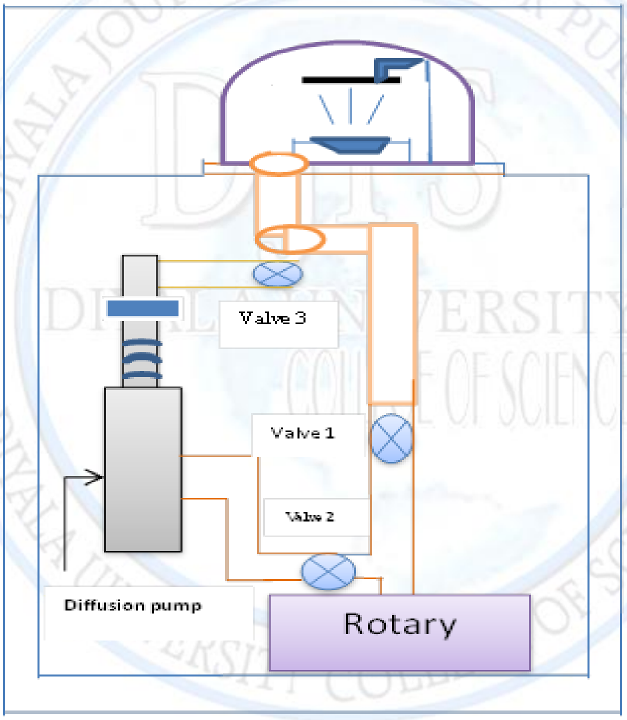

**Figure 1:** Schematic diagram of vacuum evaporation system

## Results and Discussions

### 1. XRD measurement

Figure 2 shows the X-ray diffraction for the synthesized $SiO_2$. As it is seen in the figure, the broad hump ranging between 15° and 38° in 2θ angle indicates that, the deposited silica is amorphous in nature and that no crystalline structure appeared [10,11]. As shown, there are no peaks referring expected impurities, confirmed the high purity for the obtained silica.

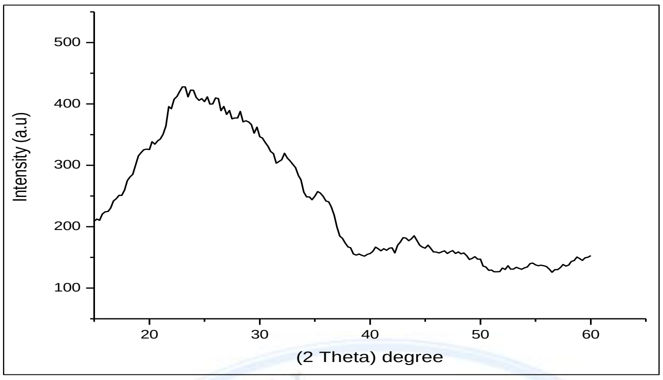

**Figure 2:** XRD characterization of SiO2 film

## 2. SEM measurement

The surface nature of the film has been studied by scanning electron microscopy (SEM) which is widely used to study the surface morphology of thin films. The figures 3 & 4 show the silicon dioxide deposited on glass.

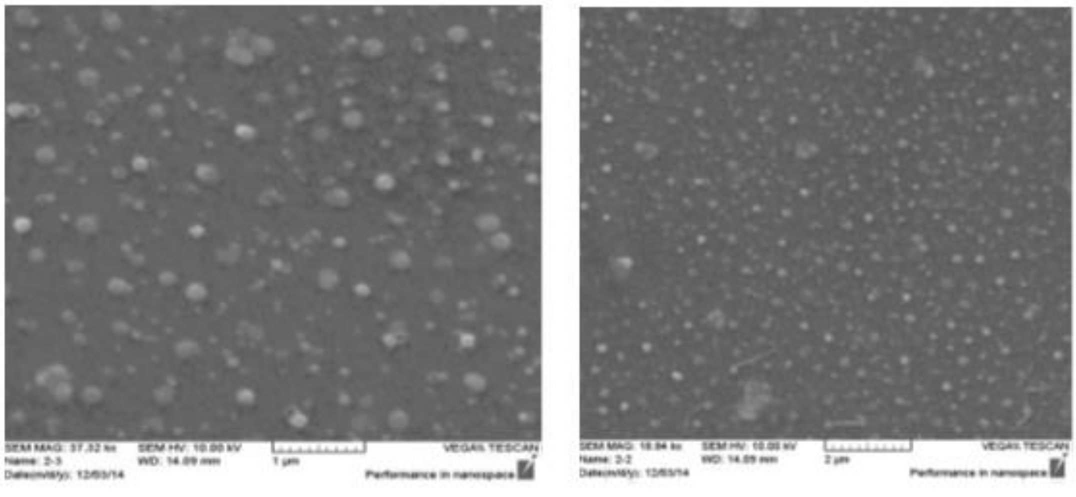

**Figure 3:** Scanning electron microphotograph of deposit $SiO_2$ Films in 1 µm and 2µm magnification

From figures, it can be seen that the silicon dioxide was uniformly deposited on glass, and it is clearly observed that the films were dense and compact in nature. The average particle size of synthesized $SiO_2$ was found to be 90 nm.

## 3. Optical properties

Figure 4 shows the UV-visible transmittance spectrum of the deposited films. As shown in the figure, the transmittance (T) of the Silica ($SiO_2$) film was about 85% was achieved at almost 600 nm wavelength, can we know from transmittance the material can act as antireflectance or window layer.

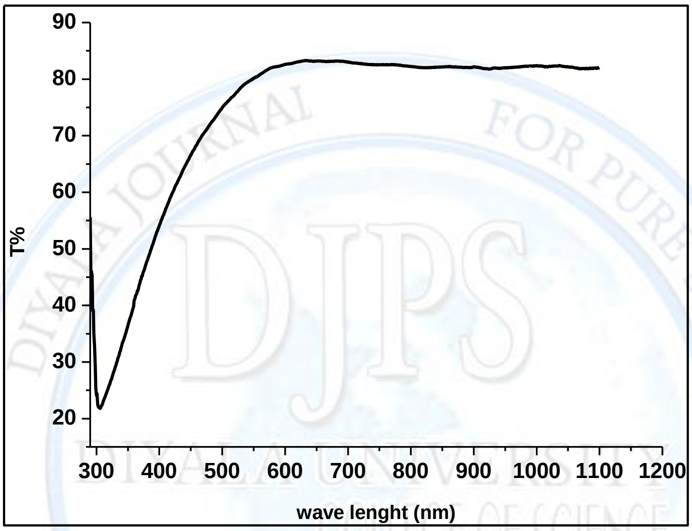

**Figure 4:** Optical transmittance spectrum of the sample

and the reflectance ($R$) at normal incidence can be calculated from the transmittance (T) and absorbance (A), provided that no light scattering occurs [12],

$$T+A+R=1 \quad (1)$$

Figure 5 shows the absorbance (A) and reflectance spectrum (R) of the coated silica, the figure revealed low absorbance and low reflectivity almost (8%) for the synthesized silica film, due to difference in refractive indices for the film and substrate, In order to achieve a zero reflectance or complete transmittance, the film must meet Eq. (2), [13]:

$$n_1 = (n_o n_s)^{1/2} \quad (2)$$

Where $n_o$, $n_1$ and $n_s$ are refractive indices of air, thin film and substrate, respectively.

For light reflected off of a material in air [14]:

$$R= \frac{(n-1)^2+k^2}{(n+1)^2+k^2} \quad (3)$$

The extinction coefficient (k) is frequency dependence. We may assume a very small (k) for a single weakly absorbing media. Also, (k) vanishes at a very high frequency i.e k → 0, [14].

$$R=\frac{(n-1)^2}{(n+1)^2} \tag{4}$$

Refractive index (n) figure 6, obtained considering the absorbance being approximately zero, using relation (5) [15]:

$$n= \frac{1+\sqrt{R}}{1-\sqrt{R}} \tag{5}$$

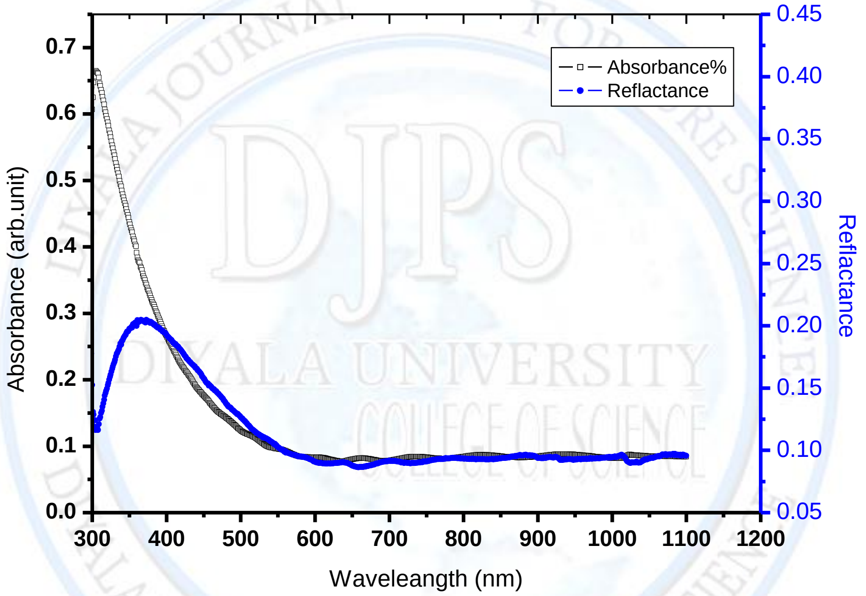

**Figure 5:** The absorbance and reflectance spectrum of the sample

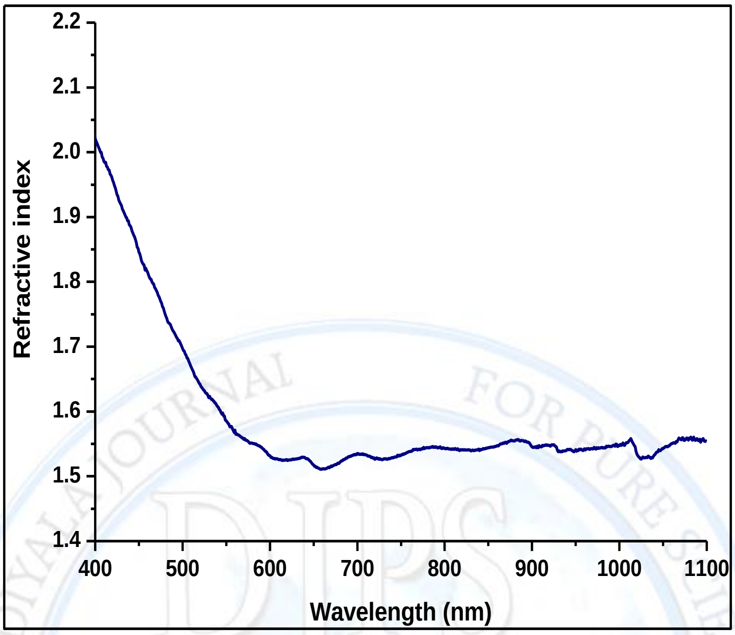

**Figure 6:** Refractive indices of $SiO_2$ film deposited on glass

It is found that refractive indices for $SiO_2$ remains almost constant in the wavelength range between (600-1100) nm.

## Calculation of film thickness:

The thin film thickness was calculated by the mass of the coated film if the area and density of the deposited $SiO_2$ thin film were known, it is often called weight difference method [16],

$$t = \frac{m}{A\rho} \qquad (6)$$

Where, t is the thickness, m is the weight of the thin film in gm, A is the area of the film in $cm^2$, and ρ is the materials density of the coated film in gm $cm^{-3}$. The film thickness has been calculated 192 nm.

The absorption coefficient (α) was calculated using the Lambert law as shown in below [17]:

$$\alpha = 2.303\,\frac{A}{t} \qquad (7)$$

Where (A) is the absorbance and (t) is known above for $SiO_2$ thin film, respectively, and the band gap of the deposited $SiO_2$ thin film was evaluated using Eq. 8 [18]:

$$\alpha h\nu = A(h\nu - Eg)^{1/2} \quad (8)$$

This formula for direct transitions, where, A is proportionality constant, and Eg is the energy band gap. The energy gap of the deposited $SiO_2$ can be suggested as it is shown in the Figure 7, which was found to be (3.25 eV), While the energy gap of the bulk silica is (11 eV) [17]. This value of band gap makes the synthesized silica applicable for substrates of computer chips, electronic industries, and solar cells [19].

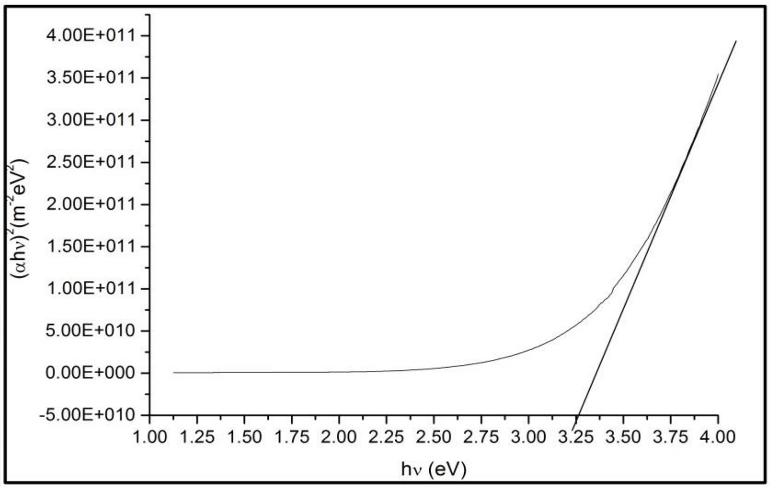

**Figure 7:** Energy band gap of the deposited $SiO_2$

## Conclusion

Silicon dioxide thin coatings on glass substrates were prepared by thermal evaporation at pressure of $10^{-5}$ mbar. Particle size of $SiO_2$ film can be estimated form SEM and it was found to be 90 nm and the energy gap of this oxide was calculated to be 3.25 eV, with high transmittance and low absorbance and reflactance.

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