Optical and Electrical Properties of the films of ALTiO2 prepared by Magnetron Sputtering

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Abstract. In the present work, ALTiO2 thin films were deposit on a glass substrate by using a DC magnetron sputtering at varying currents (170,180,200) mA. The thickness of ALTiO2 thin films was calculated using an optical interferometer system that used a He-Ne laser with a wavelength λ of (632.8)nm. The thickness of the thin films was (340,162,129) nm. UV-Vis spectroscopy was used to investigate optical properties. The wavelength spectrum between (300 -1000)nm was used to record the absorption and transmittance spectra of ALTiO2 thin films. With increasing thickness and currents, the optical band gap decreases from (3.2 to 1.9) ev. The electrical properties indicate that as the ALTiO2 film thickness increases (340,162,129) nm respectively (1.19 to 9.84) the resistivity decreases.

Key words: Optical properties, Titanium, Aluminide, Thin films, magnetron sputtering. Electrical properties.

1.Introduction

A large range of parameters, such as time, surface, thickness, and various substrates, can influence the electrical and structural properties of thin metal films. A composition of two or more thin metal film phases can improve the structural, electrical, and optical properties[1,2] Any attempts have been made to determine the structural and optical properties of Al203 [3]. For electronic device applications, aluminum thin films and Al alloys are commonly used [4]. Both experimentally and theoretically. Thanks to the rise in thrust-to-weight ratio, their low density and oxidation resistance at 1000 K TiAl-based materials have gained popularity in aerospace applications and automotive industries[5]. In the recent past, a variety of studies have been carried out on the preparation of titanium aluminides by reaction synthesis[6]. Crystalline TiAl films, however, are produced by sputtering from a stoichiometric target[7]. or by Multilayered coatings solid-state reaction[7,8] In a simple sputtering process, energetic ions bombard a target material to be deposited on the substrate, usually inert gas ions such as argon gas (Ar). The target atoms are removed by the strong collision of these inter gas ions on the target, which condenses on the substrate as a thin film of the same stoichiometry as the target substance[9]. Magnetron sputtering devices provide a strong magnetic field close to the target, allowing mobile electrons to spiral along magnetic flux lines. This structure keeps the plasma away from the target area, preventing contamination of the thin films being deposited on the substrate and maintaining thin film thickness uniformity during deposition [10]. The sputtering technique of DC
magnetron has the benefit of much higher efficiency than other methods of deposition, it is commonly used as mass processing processes[11]. DC magnetron sputtering route coatings have the advantage of uniform and homogeneous coatings over a wide field[12]. This process has many benefits, such as high deposition rate, high film purity and homogeneity, high adhesion and high accuracy of the thickness or grain size regulation of the films obtained[13].

2. Materials and Methods
A thin film of ALTiO2 was deposited: The 99 percent (5 cm) of the pure aluminum objective was cleaned with soft sanding and ethanol, and the cleaned substrate was put on the sample stage using ultrasonic with deionized water and ethanol 9 cm diameter at the center of the chamber 27x30 cm Close the chamber cover and the doorknob clockwise until tightly, the rotary vacuum began after the pressure has reached a value of 2.5X10-2 mbar. The distance between the target and the substrate was (2cm) we used the technique of magnetic field plasma sputtering AL2O3 compound precipitation was conducted on a group of vitreous samples to research the effect of increasing the atomization pressure on the sample thickness over time and current used. My agency: Three samples were deposited using a pressure (6X10-1) bar, and the sedimentation time was(15) min under different pressures.

2-Thin films thickness measurements
The thickness was measured using the optical interference method, where the rays that were reflected from the base and the thin film deposited on it interfere. He-Ne laser with a wavelength of (632.8)nm with an incidence angle of 45˚as shown schematically in figure(1) thin-film thickness (t) was determined using the following formula [14]

\[ t = \frac{\lambda}{2} \cdot \frac{Y}{X} \]  

Figure 1. The schematic diagram of the film thickness measurement

3. Results and Discussion
3.1. Optical properties
The prepared films were optically measured using a UV-Vis-NIR (300-1000 nm) Spectroscope, and the spectral dependence of the transmittance (T) and absorption (A) for all ALTiO2 films were calculated. the absorption spectra of ALTiO2 thin films as a function of wavelength ranging from(300-
1000)nm are shown in figure 2. As the current and thin film thickness are increased, the absorption will increase. This result accordsant to with research[14].

Figure 2. UV-Vis absorbance of ALTiO2 thin films, constant time = 14 minutes and for different currents and different thicknesses.

Figure 3 displays the transmittance spectra for the same wavelength range (300-1000)nm. We can see that transmittance has the opposite behavior as optical absorption; it reduces at short wavelengths when it reaches its lowest point, then begins to rise as the wavelength is increased, and also increases as the thickness and current are increased.

Figure 3. UV-Vis transmittance of ALTiO2 thin films, constant time = 14 minutes and for different currents and different thicknesses.
3.2. Calculation of reflectivity

The reflectivity spectrum is the ratio between the intensity of the reflected radiation to the intensity of the incident radiation and can be found depending on the absorption spectrum and the optical transmittance by using the following equation[15]

\[ R = 1 - A - T \] \hspace{1cm} (2)

Figure 4 displays the reflectivity film as a function of wavelength with and. We can see that the reflectivity values climb before they exceed their peak value at a short wavelength (300)nm, and begin to decrease as the wavelength increases at long wavelengths.

![Reflectivity spectrum of ALTiO2 thin films](image)

**Figure 4.** Reflectivity spectra of ALTiO2 thin films, constant time = 14 minutes and for different currents and different thicknesses

3.3. Calculation of absorption coefficient ($\alpha$)

The absorption coefficient of ALTiO2 films was calculated from the equation[16]:

\[ \alpha = 2.303 \frac{A}{t} \] \hspace{1cm} (3)

where:- $A$: absorption
$t$: thin-film thickness

Figure 5 shows absorption coefficient($\alpha$) as a function of wavelength for samples of varying current and thickness. The absorption coefficient rises at short wavelengths before reaching the maximum peak at (400), then declines as the wavelength is increased. Also, note that the absorption coefficient decreases steadily as thin-film thickness and current is increased in certain films.
3.4. Calculation of band energy gap

The Tauck relation [19] was used to measure the optical band energy gap of the films:

\[ \alpha \nu = B(\nu - E_g)^{1/2} \]  \hspace{1cm} (4)

where: (B) is constant, (\nu) is the photon energy, (E_g) is the optical energy gap and (\alpha) is the absorption coefficient.

The graphical relationship between (\alpha \nu)^2 vs. (\nu) was drawn by extending the best straight line whose extension crosses the axis of the photon energy \nu. The energy gap (E_g) value was determined from the point of intersection with the x-axis at which (\alpha \nu)^2 = 0, as shown in Figure (6) shows the relation between (\alpha \nu)^2 and \nu of ALTiO2 thin films prepared on glass substrates from the figure the energy gap was determined by the intercept of the linear part of the curve with X-axis and found to be (3.2, 2.7, 1.9) eV at different current (170, 180, 200)mA respectively with allowed direct transition. The value of the optical energy gap was found to be decreased by increases current and thickness. As a result of the formation of new levels in the bandgap, the transfer of electrons from the valence band to these local levels into the conduction band is facilitated, resulting in an increase in conductivity and a decrease in the bandgap. Table 1 summarizes the optical band gap values for ALTiO2 thin films.

| Thicknesses (nm) | The optical band energy gap (eV) |
|------------------|---------------------------------|
| 430              | 1.9                             |
| 162              | 2.7                             |
| 129              | 3.2                             |

Table 1. Optical bandgap for ALTiO2 thin films
3.5. Electrical properties

The electrical properties of ALTiO2 thin metal films of various thicknesses were determined using a two-point probe directly attached to an avometer, where the resistance between the two probes was measured and the electrical conductivity was estimated using the equation(5)[17]

\[ \rho = \frac{R \times A}{L} \]  
\[ \sigma = \frac{1}{\rho} \]  

Where \( R \) is resistance(\( \Omega \)), \( L \) distance between electrodes (cm)  
\( \rho \): is electrical resistivity \( \sigma \): is electrical conductivity.

The AL TiO2 film resistance is dependent on film thickness, as seen in Figure 7. As a result, as AL Ti film thickness increases to 300nm, the ALTiO2 thin film resistivity decreases, with the decreasing tendency due to the inverse linear dependency of film resistivity increase on grain size. This result accordant to with research[18]. As for the relationship of the electrical resistivity with the thickness of the prepared films, it is shown in Figure8, where the electrical resistivity(\( \rho \)) decreases with the increase in the thickness of the membrane, as it behaves in an opposite behavior to the electrical conductivity, which increases with the increase in thickness and as shown in the figure below. As for the electrical conductivity relationship (\( \sigma \)) with the thickness of the films prepared and deposited on glass bases, it is shown in Figure9, where the electrical conductivity increases with increasing thickness.

Figure 6. The band energy gap of ALTiO2 thin films constant time = 14 minutes and for different currents and different thicknesses
Figure 7. shows resistance as functions of increased thickness ALTiO2 films deposited on a glass substrate.

Figure 8. shows electrical resistivity as functions of increased thickness ALTiO2 films deposited on a glass substrate.
Figure 9. shows electrical conductivity, as functions of increases thickness ALTiO2 films deposited on a glass substrate

4. Conclusion
The optical and electrical properties for ALTiO2 thin films with different current were prepared by magnetron sputtering DC characteristic. The optical properties exhibited that the optical absorption spectra have different values according to the thickness of the deposited thin films, showed that the absorption coefficient increased with the increasing wavelength and the presence of absorption peaks above (300)nm, the bandgap decreased by increases current and thickness from (3.2 to 1.9) ev. The electrical findings indicate that as the thickness of thin films(t) increases, the resistance decreases, and the electrical conductivity increases.

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