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Study of the effect of base temperature and base type on some optical properties of titanium oxide (TiO_2) nanofilms

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Abstract

Titanium oxide films were fabricated using thermal chemical spray technique on two types of substrates (Glass-quartz) at temperatures (300,400) ^{0}C. The optical properties were studied using UV-Vis spectroscopy within the wavelength range (300-1100 nm) to calculate values of (transmittance, absorbance, energy gap, absorption coefficient). The $E_g$values for glass were (3.57 eV) and for quartz (3.822 eV). The results also showed that the transmittance for quartz substrates was more than 55%, while for glass substrates it was more than 35% at 400°C.
As for its value at a base temperature of 300 degrees Celsius for glass, it was 3.014 ev and for quartz bases, its value was 3.028 ev'. As for the results panel, the transmittance of quartz bases is more than 55% and for glass bases is more than 35% at a base temperature of 400 degrees Celsius, while its value at a base temperature of 300 degrees Celsius for quartz is more than 50% and for glass is 30%. Through the spectral analysis of the energy dispersion EDX, the appearance of transition elements (TiO_2) that make up of the prepared films was.

Introduction

Deposition methods for materials, both metallic and ceramic, have diversified to encompass a wide range of electronic applications [1]. Film deposition is an effective method for assessing the optical properties of a large number of materials [2]. Plating methods were prominent in ancient times, with the Romans applying gold and silver to special substrates or walls. During the Middle Ages, techniques evolved to include the deposition of metals using electrical and chemical methods. In the nineteenth century, plating techniques evolved to include coatings to protect against corrosion and increase the durability and strength of plating substrates. In the twentieth century, there was significant development in chemical and physical techniques, with the emergence of chemical thermal deposition and physical vapor deposition [3]. These methods have developed samples for use in semiconductor films, electronics, and solar cells. In the modern era, the widespread use of nanomaterials has improved the manufacture of thin films with advanced applications in sensors, optoelectronic applications, and anti-reflective coatings, particularly in solar cell applications [4]. The chemical-thermal deposition method is characterized by the preparation of thin films of metals or their oxides by disintegrating the molecules at high temperatures into thin layers with a specific thickness that depends on the operating conditions, number of sprays, and time[5]. The films produced by this method typically have distinctive structural and optical properties that contribute to their suitability for solar cells or gas sensor applications. Solid-state electronics applications are diverse and varied, but the best methods are used to produce materials at a low cost and high productivity [6]. Therefore, chemical-thermal deposition is used because of its high efficiency in forming thin layers of metal oxides, which have applications in solar cells with unique applications. Among these applications, nanomaterials with a diameter of approximately 50 nm are used [7]. By varying the spraying surface, we find a perfect match with high and medium wavelengths, as well as minimizing reflection as much as possible, resulting in films suitable and effective for leading applications in solar cell production [8].

In 2020, Oosthuizen et al. studied gas sensors for cerium oxide nanosheets using the chemical deposition method. Various ethanol concentrations, ranging from 10 to 50 ml, were used, and several characterization methods were employed, including structural, optical, and electrical. The structural results showed that the particle size ranged from 6 to 8 nm, and the defect concentration was less than 10%. Ethanol concentrations of 40 ml produced a slightly higher response than the others. The results indicated that selective detection of substance levels remains a challenging issue [9]. In 2023, researcher Maudud Ahmed and others studied the preparation of nanoscale cadmium oxides based on defect properties using chemical deposition. The material was sprayed and the grain size of the resulting layer was calculated, which found that its grain sizes were in the range of 16 to 30 nanometers at temperatures ranging from 400 to 800 degrees Celsius. X-ray diffraction results indicated the absence of new or mixed phases in the deposited material. Transmission electron microscopy (TEM) structural properties revealed the gradual regularity and symmetry of the external grains. Optical properties revealed that the energy gap ranged from 2.32 eV to 2.38 eV [10]. In 2024, researcher Hayat and others studied the properties of a memory-based resistive switch based on zinc and iron oxides. If ferromagnetic nanoparticles of ZnO were synthesized using chemical precipitation techniques, X-ray diffraction results revealed a regular distribution of the sprayed films, and the nanoparticles exhibit ferromagnetic behavior at temperatures below 400 K[11]. The current paper aims to improve the structural and optical properties of titanium oxide nanofilms by varying the coating temperatures and substrates. Applications in solar cells and gas sensors require encouraging results from the deposited films in terms of reflectivity, absorbance, band gap, and EDX performance.

The experimental section

German-made Microscope Slides glass and quartz substrates were used, as well as 50nm nano-titanium oxide (TiO_2) produced by CDH, also from Germany. The glass and quartz substrates were placed in the middle of the electric heater after ensuring that the solution falls perpendicularly on all parts of the substrates. Nano-sized TiO2 films, prepared in the form of a prepared solution (1g of titanium was dissolved in 100ml of distilled water), were deposited at a nanoscale size of 50nm and a molar concentration of 0.01% on different glass and quartz substrates. The technique used was thermochemical spraying, as explained in the technology section above. The number of sprays was 30, with a spray time of 2 seconds, and the distance between the nozzle and the substrate was 30cm. The resulting samples were then annealed on the glass and quartz substrates. It is also necessary to leave the substrates on the electric heater for an hour after the spraying process is completed to allow the prepared films to complete the oxidation and crystal growth process. The annealing effect varies from one material to another depending on several factors, such as the nature of the material, temperature, ambient gas type, and annealing time. In this study, the annealing process of the films was carried out using a Korean-made Muffle electric furnace equipped with a digital control system. The heat treatment was carried out at temperatures of 300, 400, and 500°C for two hours, and the final substrates were then annealed at 100°C for two hours. Figure 1 show thermal chemical spray system.

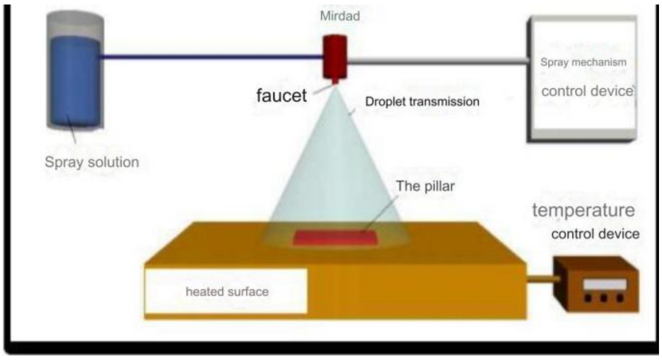

Fig. 1 *Thermal chemical spray system*

Results and Discussion

The optical properties of the films prepared by thermal chemical spray were evaluated using UV-Vis spectrophotometer, and the absorption coefficient was calculated using the equation [12]. Where, $\propto$ = 2.303 A/t, $\propto$: The absorption coefficient, A :absorption, t :Film thickness. It was observed that there are direct transitions between the conduction and valence bands, and the generation of energy levels within the energy gap and the conduction band was the reason for the increase in A value with the increase in wavelength [13]. Figures 2 show the energy gap (Eg) values for films deposited on both glass and quartz, with values of 3.822 eV for quartz and 3.575 eV for glass at a base temperature of 400°C [14].

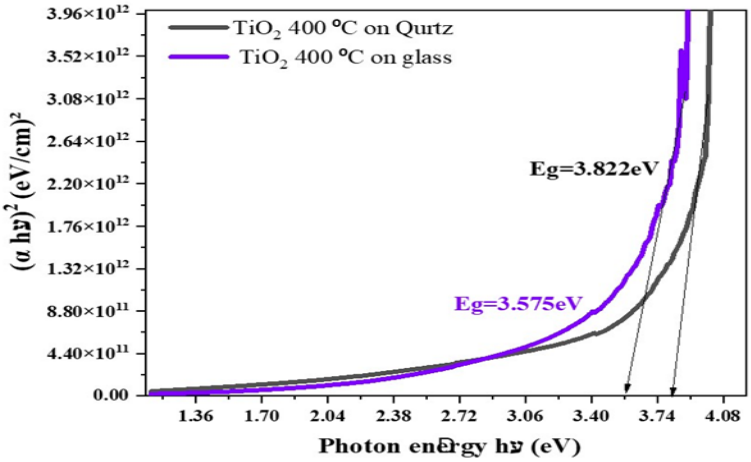

Fig. 2 *The energy gap (Eg) values for films deposited on both glass and quartz of 400˚C.*

Figures 3 show the energy gap values at a base temperature of 300°C, with values of 3.014 eV for glass substrates and 3.208 eV for quartz substrates.

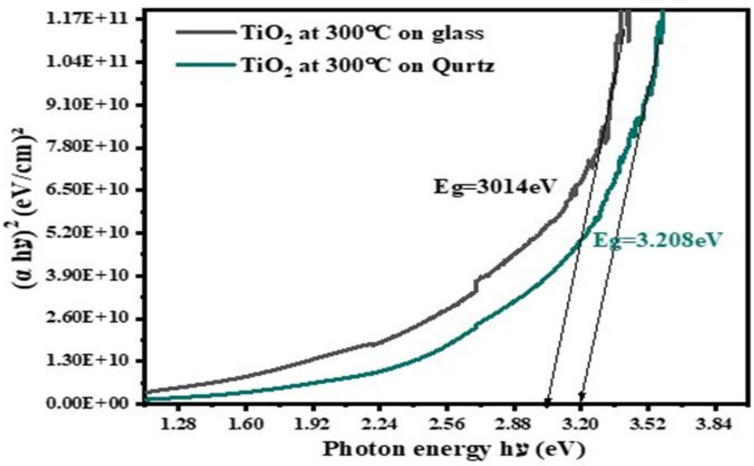

Fig. 3 *The energy gap values at a base temperature of 300°C.*

Figure 4, it is observed that the transmittance values for quartz are greater than for glass, with transmittance for quartz films being more than 60% and for glass more than 45.5% at a base temperature of 400°C. At a base temperature of 300°C,

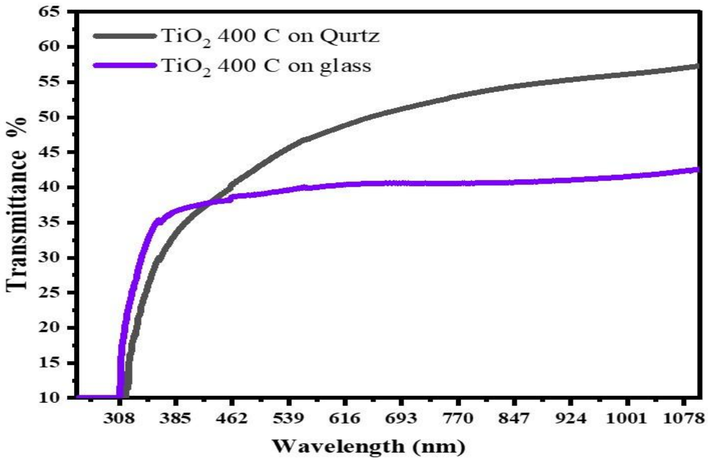

Fig. 4 *The transmittance values for quartz are greater than for glass of 400°C.*

as shown in figures 5, the transmittance values for films deposited on glass were more than 40% and for films deposited on quartz more than 50%.

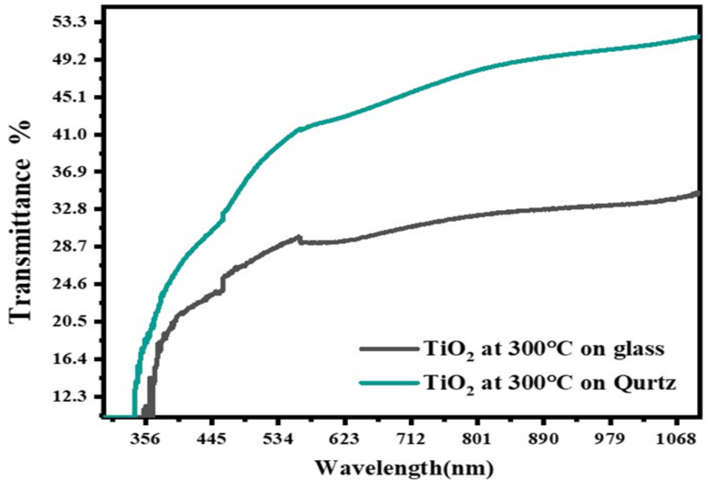

Fig. 5 *The transmittance values for films deposited on glass of 300°C.*

Figures 6 show the absorption coefficient for both glass and quartz substrates for films prepared at a temperature of 300°C.

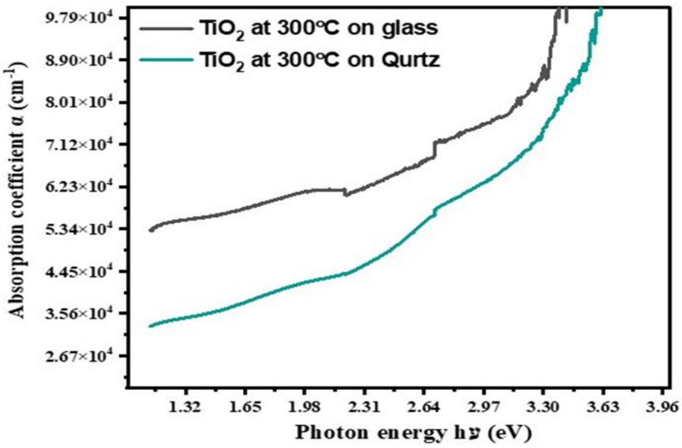

Fig. 6 *The absorption coefficient for both glass and quartz substrates at 300°C.*

And figures 7and 8 represents the absorption coefficient and absorption at a base temperature of 400°C, indicating that the electronic transitions are direct since the values are greater than 10^4.

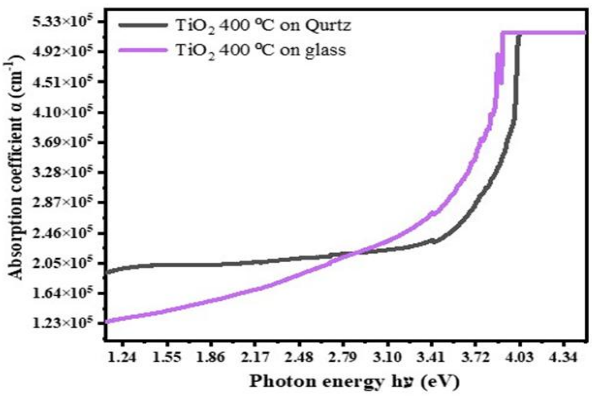

Fig. 7 *The absorption coefficient for both glass and quartz substrates at 400°C.*

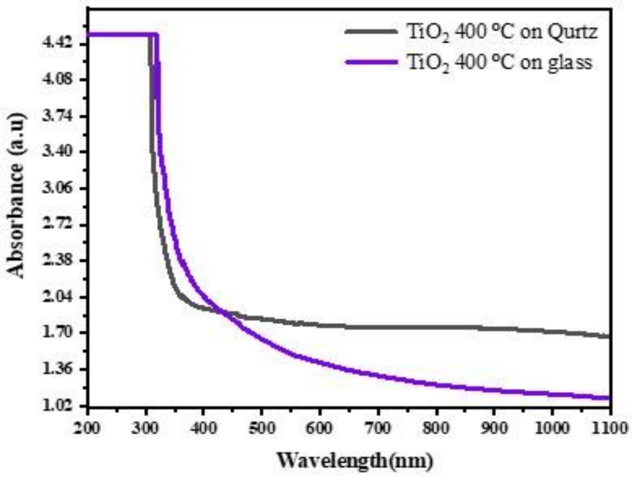

Fig. 8 *The absorption for both glass and quartz substrates at 400°C.*

Figures 9 represent the absorbance at the base temperature and the type of substrates for both glass and quartz at temperatures of 300°C.

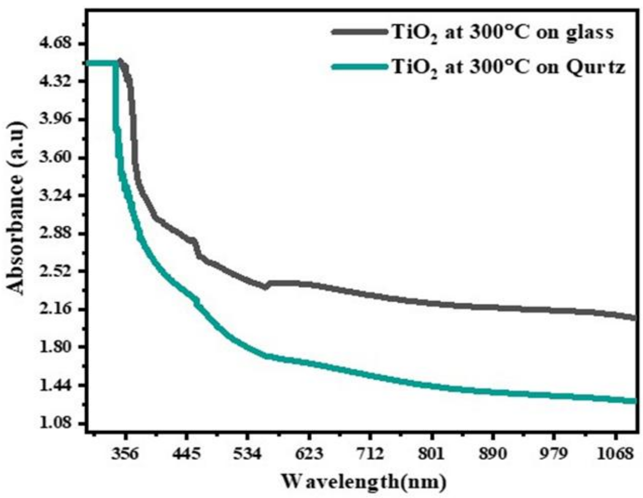

Fig. 9 *The absorption for both glass and quartz substrates at 300°C.*

Figure 10 represents the EDX spectra of titanium dioxide nanoparticles for the sample (A-glass and B-quartz). The EDX analysis confirmed the atomic composition of the prepared sample. The results show that the spectra consist of high-intensity peaks of titanium (Ti) and oxygen (O), indicating the successful synthesis of pure titanium dioxide nanoparticles. The EDX analysis found the elemental ratios of Ti to be (30.53%) and oxygen (69.48%) [15-18].

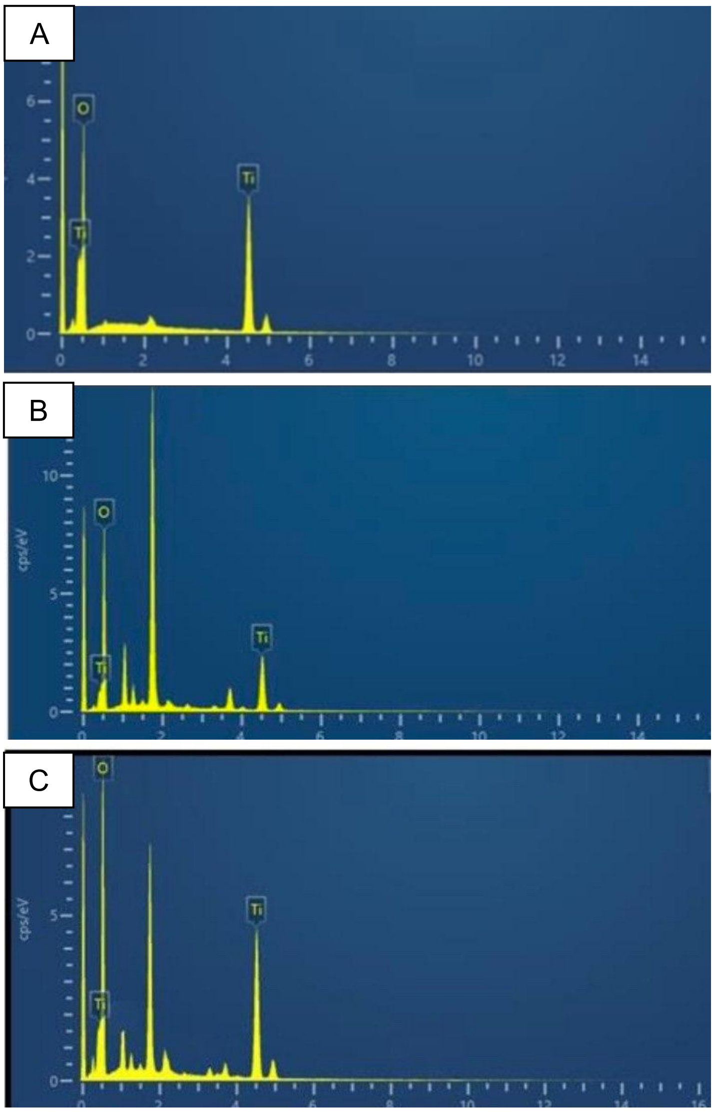

Fig. 9 *The EDX spectra of titanium dioxide nanoparticles for the sample (A-glass and B-quartz) at 400 ̊C, and C-at 300°C.*

Conclusions

The energy band gap values increasing with increasing temperature, the energy band gap values of the substrates prepared on quartz substrates are larger than those prepared on glass substrates, the films prepared on quartz substrates have higher Transmission values than the films prepared on glass substrates, which makes them possible to apply in the manufacture. All the electronic transitions of the films are direct type because they have an absorption coefficient greater than 10^4.

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دراسة تأثير درجة حرارة القاعدة ونوع القاعدة على بعض الخصائص البصرية لأغشية أوكسيد التيتانيوم النانوية(TiO2)

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الكلمات المفتاحية:
الاغشية الرقيقة، اوكسيد التيتانيوم، الخصائص البصرية ،طيف EDX و طيف UV.

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الخلاصة:

تم تصنيع أغشية أكسيد التيتانيوم باستخدام تقنية الرش الكيميائي الحراري على نوعين من الركائز (الزجاج-الكوارتز) عند درجات حرارة (300،400 درجة مئوية). دُرست الخصائص البصرية باستخدام مطيافية الأشعة فوق البنفسجية-المرئية ضمن نطاق الطول الموجي (300-1100 نانومتر) لحساب قيم (النفاذية، الامتصاصية، فجوة الطاقة، معامل الامتصاص). كانت قيم Eg للزجاج (3.57 إلكترون فولت) وللكوارتز (3.822 إلكترون فولت). كما أظهرت النتائج أن نفاذية ركائز الكوارتز كانت أكثر من 55%، بينما كانت لركائز الزجاج أكثر من 35% عند درجة حرارة 400 درجة مئوية. أما بالنسبة لقيمتها عند درجة حرارة أساسية 300 درجة مئوية للزجاج، فقد كانت 3.014 إلكترون فولت، ولقواعد الكوارتز، فقد كانت قيمتها 3.028 إلكترون فولت'. أما بالنسبة للوحة النتائج، فإن نفاذية قواعد الكوارتز تزيد عن 55%، وللقواعد الزجاجية تزيد عن 35% عند درجة حرارة 400 درجة مئوية، بينما تزيد قيمتها عند درجة حرارة 300 درجة مئوية للكوارتز عن 50%، وللزجاج 30%، ومن خلال التحليل الطيفي لتشتت الطاقة EDX، ظهر وجود عناصر انتقالية (TiO2) في الأغشية المحضرة.