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Investigation the effect of doping concentration in Ruthenium-doped TiO$_2$ thin films for solar cells and sensors applications

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Abstract

Thin films of Ru doped TiO$_2$ have been deposited on glass substrates at different doping concentration (0.05, 0.07, 0.09, 0.11 mol l$^{-1}$) by the sol gel method. The prepared thin films were studied: their structural, morphological, optical and photocatlytic properties. The XRD spectra confirm that all the samples have anatase phase with preferential orientation along (101) plane. The position of (101) peaks shift to higher angles with increase doping concentration and 0.07 mol l$^{-1}$ sample have a sharp and high intensity diffraction peak. Due to condensation and agglomeration effect. The thickness of the thin films increases from 110 nm to 255 nm with the increment of Ru concentrations. AFM images show that the films had good quality and pyramidal shape was distributed over their entire surface. Transmittance and absorbance spectra of the un-doped and Ru doped TiO$_2$ thin films were recorded by UV–vis spectrometer. The optical band gap of the thin films increases from 3.66 eV to 3.85 eV as the Ru amount increases; this is due to the Moss-Burstein effect. Calculated results show that both the excitation coefficient ($k$) and refractive index ($n$) decreases with wavelength at all Ru concentration. Optical conductivity can improve after doping which can be a suitable material for use in sensor and solar cell applications. The photocatalytic activity was investigated by monitoring the degradation of methylene blue (MB) under visible and sun light. The results revealed that the photocatalytic activity under sun light was higher comparing to UV light for all films. Ru doped TiO$_2$ thin films enhance the efficiency of its photocatalytic activity. It was found that the percentage of degradation was higher in 0.11 mol l$^{-1}$ Ru doped TiO$_2$ when compared with other films.

Introduction

Metal oxides made when metal ions form coordination bonds with oxides, giving rise to a closely packed structure. Metal oxides are mostly attractive candidates due to extraordinary physical and chemical properties [1]. The great variety of structures and physical properties of metal oxide made them a promising material in technological applications such as medical science, gas sensing, energy storage, and surface coatings. Thin films of oxide materials are generating increasing interest from the scientific community and from industry. Among these films ZnO, SnO$_2$, CdO, ZnO, TiO$_2$, etc have been investigated during last years. For example, Wang et al [2] modified ZnO film by NH$_4$Cl in CsPbI$_2$ Br$_2$ perovskite solar cells. They reported that improvement in open-circuit voltage ($V_{oc}$) from 1.08 to 1.27 V and the power conversion efficiency was 10.16% which is the highest value reported at low temperature. (Cu$_2$O/rGO) nanocomposites were synthesized via a facile wet-reduced method to enhancement of photoresponse from the light-controlled [3]. The device show hopeful applications in memory storage and logic circuits. Enhancement of power conversion efficiency (PCE) for ZnO/Cu$_2$O solar cells with well oriented and micrometer grain sized of Cu$_2$O films was study by Zang [4]. He reported that the (PCE) of the solar cells improve from 3.18%, to 60.6%. Roughened and microhole arrays of ZnO used to enhancement InGaN light-emitting diodes (LEDs) [5]. ZnO was fabricated using an Ar and H$_2$ plasma treatment then pre-coated on a p-GaN layer followed by a femtosecond laser direct writing technique. It found that LEDs fabricated with roughened ZnO had similar current–voltage (I–V) characteristics to those of conventional LEDs.
On the other hand, many research efforts have been made in recent years for developing highly oriented and transparent TiO₂ thin films, because of their important application in pigment, solar cell, sensors, self-cleaning glass, smart windows and water splitting technology. In addition, the rapid increase in research involving TiO₂ is based on the wide band gap 3.2 eV, high thermal stability, high refractive index, good photocatalytic properties and efficient transmittance in the visible and near-infrared wavelength region [6, 7]. There are four different crystalline phases of TiO₂ occurring in nature: rutile, anatase, brookite and TiO₂ (B) (monoclinic).

Semiconductor doping simply means the purposeful introduction of impurities or dopant into an extremely pure semiconductor. The challenge has always been with materials with a wide band gap. This is because as the band gap of a material increases it becomes difficult to dope them in regular (p-type and n-type) semiconductors. Doping in metal oxide semiconductors is highly used as gas sensors. Literature has shown that the doping of TiO₂ with transition metal, rare earth and noble metal ion [8]. Recently, many studies have been focused on donor materials into TiO₂ due to their outstanding optical and photocatalytic properties. Due to the light collecting capability of donor-acceptor systems [9]. It will know photocatalytic activity of TiO₂ depends on microstructure, grain size, preparative route, foreign ions and doping concentration. Among n-type doping of TiO₂ Ru (Ruthenium) doped TiO₂ as the best choice for its excellent solar cells and sensors applications. The atomic radius of Ru (0.056 nm) is close to that of Ti (0.060 nm) so it’s suitable material for doping of TiO₂ film [10]. Ruthenium-doped TiO₂ thin films have been seldom reported.

There are some researches work on Ru doped TiO₂. Matsunagaa et al [11] denoted the photocatalytic activity of Ru doped TiO₂ powder as a rutile phase. They recorded a reduction on the reflectivity of 20%–80% in the range of 420–750 nm for Ru-doped TiO₂ powder (rutile). Thin films form of TiO₂ is better than powder form during the reaction and the separation of catalyst after the operation. Using incipient wet impregnation method (0.2, 0.4, 0.6 and 0.8 w%) Ru were doped with TiO₂ [12]. They observed that enhancement of photocatalytic degradation of 2-chlorophenol under visible light with doping concentration. The incorporation of Ru in TiO₂ led to the formation of more electron capture traps, which contribute to high separation efficiency of photogenerated carriers. Erol et al [13] study degradation of contaminated industrial waste water using Ru-TiO₂ thick films prepared by sol gel method. The molar ratio of Ru/Ti was 0.05 and the films annealed at 600 °C. They reported that Ru doped TiO₂ exhibited high photocatalytic efficiency to decompose organic species in contaminated waters.

Various methods are used to prepare of TiO₂ and doped-TiO₂ thin films such as thermal oxidation of titanium, ion sputtering, spray pyrolysis, sol-gel method, etc [14]. Sol gel technique is one of the most applicable method because it has low fabrication cost and it is fast method, in addition it can achieve high quality thin film in large area substrates. The present work aimed to investigate the change of doped TiO₂ thin films properties (structural, morphology, optical, and photocatalytic) as a result of a change in molarity of Ru (0.05, 0.07, 0.09, 0.11).

**Experimental technique**

Ru doped TiO₂ films were prepared using the sol–gel method. The sol was prepared using titanium (IV) isopropoxide (Ti(OC₃H₇)₄) [98%], isopropanol, Methanol, Acetonitrile, Ethanol, Acetic acid (CH₃COOH). First, 1.6 ml titanium (IV) isopropoxide dissolving with 0.64 ml of isopropanol. Then stirred at 60 °C for 10 min, followed by dropwise adding of 0.71 ml of acetic acid (CH₃COOH) and stirred for 15 min. Then 1.65 ml methanol added and stirred for one hour at 60° to yield a clear homogeneous solution. At the same time, Ruthenium (III) acetylacetone were dissolved in 3 ml of the same solvent isopropanol and glacial acetic acid and stirred for 15 min at room temperature. The concentration of Ru for doping taken as zero, 0.05, 0.07, 0.09, and 0.11 g. Then the doped solution was mixed with pure solution. The resulting mixture solution was stirred for 1 h at 60 °C and then it cooled to room temperature. The dimensions of the glass substrates were 2.5 cm × 3.5 cm. The substrates ultrasonically cleaned with distilled water, acetone and ethanol after that they dried using a dryer. The films were prepared using (KW-4A) spin-coating unit which at 500 rpm for 10 s and 3000 rpm for 30 s. All samples were drying at 100 °C for one hour to get rid the solvent and any organic residuals. Finally, the doped films were annealed in air at 400 °C for 3 h. The crystal structure of the films was characterized using an x-ray diffractometer model PW3710 with Cu Ka radiation (λ = 0.154 nm). The thin-film thickness of the samples was measured by the spectroscopic ellipsometer (PHE-103 The ellipsometer operates in the spectral range 250–1100 nm (white light). The layer stack imparts a change in the state of polarization to the light that is reflected back to the analyzer and into the detector. There will be variable reflection angles from 20°–90° that depend on rotating polarizer method. Thickness value determined from values of psi and delta for each wavelength.
The UV–vis–NIR spectrophotometer was used to measure the transmittance and absorption of un-doped and Ru doped TiO$_2$ films deposited in different concentration. The band gap ($E_g$) is obtained by extrapolation of the linear portion to the photon energy axis at $(\alpha h\nu)^2 = 0$.

The photocatalytic performance of the un-doped and Ru doped TiO$_2$ thin films was reported from the photobleaching of methylene blue (MB) solution upon exposure of the film/substrate to UV light and sun light the degradation at an incident wavelength of 665 nm. The MB solutions were prepared by 100 ml deionized water spiked with 2.5 ml ($200$ ppm $5$ ppm concentration added, $180$ min run time, at every $30$ min $5$ ml sample taken, centrifuged ($4000$ rpm, $3$ min) then analyzed on UV spectrophotometer.

**Results and discussion**

**Structural study**

Figure 1 show the XRD patterns of un-doped and Ru doped TiO$_2$ thin films at different doping concentration ($0.05, 0.07, 0.09$ and $0.11$ mol l$^{-1}$). It is observed that the pure TiO$_2$ thin film has the anatase phase crystal plane with (101) reflection while Ru doped TiO$_2$ thin film also undergoes characteristic peaks of anatase crystal plane (101). The absence of the other phases may propose the possible incorporation of Ru$^{+3}$ within the host TiO$_2$ lattice. The figures show that with increased doping concentration, the position of (101) peaks shift to higher angles (see table 1) which indicates the expansion of the lattice parameters. However, it can see from the figures that the characteristic peaks appear different degree wider and the intensity of diffraction peaks first increase with increased of Ru content. Analysis suggests that Ru$^{+3}$ radius is ($0.68$ Å) similar to the Ti$^{4+}$ radius is ($0.61$ Å) so the Ru$^{+3}$ can enter into the TiO$_2$ lattice and replace part of Ti$^{4+}$ which effected on lattice crystallinity $0.07$ mol l$^{-1}$ sample have a sharp and high intensity diffraction peak compared with other samples. It is noted that the crystallite size of $0.07$ sample is large $66$ nm (see table 1).

The x-ray diffraction peaks of crystal plane (101) in anatase are chosen to determine the lattice parameter of the films. The lattice constants ‘a’ and ‘c’ calculated using Bragg’s law (1) & (2) given below [15]:

![Figure 1. XRD patterns of un-doped and Ru doped TiO$_2$ thin films at different doping concentration ($0.05, 0.07, 0.09$ and $0.11$ mol l$^{-1}$).](image)
Table 1. Structure parameter of un-doped and Ru doped TiO₂ thin films at different doping concentration (0.05, 0.07, 0.09 and 0.11 mol l⁻¹).

| Sample      | Interplanar distance (d) (Å) | FWHM (degree) | \(\theta\) (degree) | \(a = b (\lambda)\) | \(c (\lambda)\) | \(c/b\) | Cell volume (nm³) | Crystallite size (nm) |
|-------------|-----------------------------|----------------|---------------------|---------------------|----------------|-------|-------------------|---------------------|
| un-doped    | 2.952                       | 0.240          | 32.19               | 3.748               | 9.370          | 2.50  | 114.71            | 71                  |
| 0.05        | 2.750                       | 0.152          | 32.43               | 3.780               | 9.510          | 2.52  | 135.88            | 60.5                |
| 0.07        | 2.752                       | 0.139          | 32.52               | 3.784               | 9.515          | 3.05  | 135.9             | 66                  |
| 0.09        | 2.753                       | 0.180          | 32.53               | 3.786               | 9.515          | 2.51  | 136.25            | 51                  |
| 0.11        | 2.759                       | 0.188          | 32.69               | 3.791               | 9.526          | 2.51  | 148.69            | 50                  |

\[
d_{\text{hkl}}^2 = \frac{\lambda}{2 \sin \theta}
\]

\[
d_{\text{hkl}}^2 = h^2a^2 + k^2b^2 + l^2c^2
\]

Where \(\theta\) is the Bragg angle, \(d_{\text{hkl}}\) is the distance between crystal planes of (hkl), \(\lambda\) is the x-ray wavelength and \(a\), \(b\), and \(c\) are lattice parameters (in anatase form, \(a = b = c\)). The lattice parameters generally increase as Ru³⁺ content increases according to table 1, which indicates that the Ru³⁺ ions are successfully interstitial in the TiO₂ lattice. The change in doping concentration causes change in cell volume. This may be because there are a large number of vacancies and lattice disorders present at the interface, which leads to the rise in the volume of the unit cell with doping (see table 1).

The crystallite size estimate using Scherrer equation [16]:

\[
D = \frac{\kappa \lambda}{\beta \cos \theta}
\]

Where \(D\) is the crystallite size, 0.9 is a constant, and \(\beta\) is the full width at half maximum of diffraction peak. It can be observed from the table that, the highest crystallite size value for the un-doped sample reduced when Ru atom was introduced in the film, which can be attributed to the production of more lattice defects and lattice strains in the thin films after doping.

Variation of the film thicknesses with doping concentration

Thickness of the obtained films was recorded as a function of the doping concentration between 0 to 0.11 mol l⁻¹. The relation between film thickness and dopant concentration illustrated in figure 2. It was found that the film thickness increases as consequent to increment in the doping concentration. The value of film thickness reaches its maximum value (255 nm) at high doping concentration due to condensation and agglomeration effect. The agglomeration depends on the doping additive concentration. It is necessary to note that dense agglomerates influence the sensor response because of control the diffusion of oxygen and target gas inside dense agglomerates particles [17]. This behavior indicate that increment of doping concentration is the main reason for enhance the sensor response and recovery time for Ru-doped TiO₂ thin films.

Surface morphological study

The surface morphology of Ru doped TiO₂ thin films at different doping concentration was analyzed using atomic force microscope (AFM). Figure 3 shows two and three dimensions AFM images of the Ru doped TiO₂ films at different doping concentration (0.05, 0.07, 0.09, 0.11 mol l⁻¹).

It was observed that the films show good quality and pyramidal shape were distributed over the entire surface. The increment in pyramidal shape indicates that crystallinity and surface roughness was improved with the increase in doping concentration. The root mean square (RMS) values found to be increase from 13.4 to 52.9 nm with doping enhancement and average roughness was 4.74 nm. However, the surface skewness of the Ru doped TiO₂ films is positive, which approves the presence of numerous bumps. Surface roughness is an important parameter for improving the photocatalytic degradation properties for solar cells and photo detectors [18].

Optical study

The optical transmittance spectra of un-doped and Ru doped TiO₂ thin films deposited on glass substrate by sol gel technique was measured by UV–vis spectrophotometer. Figure 4 shows the optical transmittance spectra of un-doped and Ru doped TiO₂ thin films at different doping concentration (0.05, 0.07, 0.09, 0.11 mol l⁻¹). As shown in figure, a gradual increment in transmittance was observed from 350 nm to 700 nm. The films were highly transparent and the transmittance decreases when Ru doping increases. This may be due to the thickness
increment and the doping effect similar result was found by Wang et al \cite{19} when they doped vanadium with ZnO thin films. The film doped with 0.07 mol l\(^{-1}\) Ru shows low transmittance due to highest crystallite size.

Figure 5 displays absorbance spectra of un-doped and Ru doped TiO\(_2\) thin films at different doping concentration. The absorption edge of the films shifts to lower wavelength from (305 to 278 nm) with increasing of Ru concentration associate with an increase of the carrier concentration in conduction band according to Burstein-Moss effect \cite{20}. This indicates the rise in Fermi level in the conduction band due to enlarged charge carriers, which effect the optical band gap values.

The direct energy gap \(E_g\) of the un-doped and Ru doped TiO\(_2\) thin films was obtained by plotting \((\alpha h\nu)^2\) versus \((h\nu)\) figure 6. Then extrapolating the straight-line part of the plot to the photon energy axis. The relationship between the absorption coefficients \(\alpha\) and the incident photon energy \(h\nu\) is given by \cite{21}:

\[
(\alpha h\gamma) = A(h\gamma - E_g)^n
\]

Where \(h\gamma\) is the photon energy, and \(n\) is the constant, which varies with the probability of transitions, it takes values as 1/2 in this study and \(\alpha\) is the absorption coefficient, which expressed as \cite{22}:

\[
\alpha = \frac{1}{d} \ln \left( \frac{1 - R^2}{T} \right)
\]

Where \(d\) is film thickness and \(R\) is reflectance. From figure 6 it is noted that the band gap (\(E_g\)) increased with an increase in Ru doping concentration. The value of band gap of pure film is about 3.66 eV raised to 3.85 eV for 0.11 mol l\(^{-1}\) Ru doped TiO\(_2\) thin film. Presence of Ru elements in the films effect in position and concentration of carrier, which lead to broadening in optical band gap as we mentioned before.

The optical constants, the extinction coefficient \((k)\) and refractive index \((n)\) of Ru doped TiO\(_2\) thin films at different concentration was calculated in this study. Extinction coefficient \((k)\) was calculated from the following equation \cite{23}:

\[
K = \frac{\alpha \lambda}{4\pi}
\]

The following relation \cite{24} can determine the refractive index \((n)\):

\[
n = \frac{1 + R}{1 - R} \left( \frac{4R}{(1 - R)^2} - K^2 \right)^{\frac{1}{2}}
\]

The variation of the extinction coefficient \((k)\) and refractive index \((n)\), with wavelength for the Ru doped TiO\(_2\) thin films at different Ru concentrations (0.05, 0.07, 0.09, 0.11 mol l\(^{-1}\)) is shown in figures 7 and 8, respectively. It is apparent that both the extinction coefficient \((k)\) and the refractive index decrease with increasing the incident wavelength in the visible range of frequency due to normal dispersion of the films.

\[
\text{Figure 2. The variation of film thickness with doping concentration of un-doped and Ru doped TiO}_2\text{ thin films at different doping concentration (0.05, 0.07, 0.09 and 0.11 mol l}^{-1}).
\]
Furthermore, the values of extinction coefficient ($k$) for all films are close to zero, which agree with the fact that TiO$_2$ thin film is transparent in the visible region. From figure 8, we can see the refractive index of the pure films found to be lower than other films this may related to the film crystallinity, lattice point defect and film porosity similar result it found by Sava et al [25] when they study boron doped TiO$_2$ thin films. However, decrease the extinction coefficient ($k$) and the refractive ($n$) radibly with wavelength for different Ru doping concentration could be correlated to an increase of the carrier content after doping and creation of the scattering centers by Ru.
atoms. Similar behavior was found by Vishwas [23] in AL doped TiO$_2$ thin films prepared by thermal evaporation technique.

The dielectric constant $\varepsilon$, was calculated from the relation [26]:

$$\varepsilon = \varepsilon_\infty - \left( \frac{\varepsilon^2}{4\pi\varepsilon_0 c^2} \right) \left( \frac{N}{m^*} \right) \lambda^2$$  \hspace{1cm} (8)

Where $e$ is the elementary charge, $c$ is the velocity of the light, $\varepsilon_\infty$ the permittivity of free space ($8.854 \times 10^{-12}$ F m$^{-1}$), $N$ is the free carrier concentration and $m^*$ the effective mass of the charge carriers. The variation of the dielectric constant with wavelength for Ru doped TiO$_2$ thin films at different doping concentration is notify in figure 9. From the figure we can observed that the dielectric constant for all sample was decreases with wavelength increment. This may be due to the polarization reductions when the electron reach the grain boundary. Additionally, the ruthenium doping concentration effect the dielectric constant values this

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**Figure 4.** Transmittance spectra of un-doped and Ru-doped TiO$_2$ thin films at different doping concentration (0.05, 0.07, 0.09 and 0.11 mol l$^{-1}$).

**Figure 5.** Absorbance spectra of un-doped and Ru doped TiO$_2$ thin films at different doping concentration (0.05, 0.07, 0.09 and 0.11 mol l$^{-1}$).

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behavior indicate Ru$^+$ interstitial in the TiO$_2$ lattice which lead to change the number of oxygen vacancy and unit cell volume. Usually, during the doping process in the TiO$_2$ crystal lattice, replacement of host anions and/or cations occurs, which leads to an increase delocalized and localized impurity states will be created within the band gap of TiO$_2$ along the crystal field splitting of metal 3d orbitals [27]. The dielectric constant decreases due to the space charge polarization of the dopant materials [28]. The small dielectric polarizability of Ru ions compared to titanium ions resultant decreasing the dielectric polarization, which in turn to decrease the dielectric constant.

For obtaining, the optical conductivity the following equation was used [29]:

$$\sigma = \frac{\alpha n \epsilon c}{4\pi}$$ (9)

The variation of optical conductivity with energy of Ru doped TiO$_2$ with different doping concentration is shown in figure 10. The result show that the optical conductivity rises with doping concentration due to the increment in carrier concentration known as Burstein-Moss effect [20].
The high optical conductivity indicate that the films have good optical response that means Ru doped TiO₂ thin films are good candidate for sensor and solar cell applications [30].

**Photocatalytic study**

The photocatalytic activity of un-doped and Ru doped TiO₂ thin films was shown by degrading a methylene blue solution (MB) with concentrations of 0.5, 1.0, 3.0, 5.0, 7.0, 10.0, 15.0, and 20.0 mg l⁻¹ prepared in volumetric flasks; the absorbance of each of the standard MB solutions recorded at the maximum absorption wavelength of 665 nm. Photocatalytic performance was investigated from these measurements by analyzing the percentage of dye degradation when the films were used as a catalyst. Photo degradation percentage (D) of Methylene blue solution, which was evaluate by the following relation [31]:

\[
D = \frac{[A]_0 - [A]_t}{[A]_0} \times 100\%
\]
Degradation efficiency (D) = \( \left( C_0 - C_i / C_0 \right) \times 100\% \) \hspace{1cm} (10)

Where \( C_0 \) initial concentration, \( C_i \) sample concentration. Figure 11 shows degradation efficiency of un-doped and Ru doped TiO\(_2\) thin films at different doping concentration (0.05, 0.07, 0.09 and 0.11 mol l\(^{-1}\)) under UV and sun light.

On the other hand, several factors influenced the photoactivity of TiO\(_2\) photocatalyst including crystal size, surface morphology and surface area [33]. Moreover, the MB photo degradation improve after doping. The films doped with 0.11 mol l\(^{-1}\) shows the highest photocatalytic activity and smallest crystallite size. Also The enhancement of photocatalytic degradation of MB can be explained by the modification of films surface morphology, the film doped with Ru at 0.11 mol l\(^{-1}\) shows high roughness (Rms = 52.9 nm). Furthermore, Ru doped TiO\(_2\) thin films caused a significant formation e\(^-\)/h\(^+\) pair with carriers transfer on surface which

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Figure 10. Variation of optical conductivity with energy for un-doped and Ru-doped TiO\(_2\) thin films at different doping concentration (0.05, 0.07, 0.09 and 0.11 mol l\(^{-1}\)).

Figure 11. Degradation efficiency of un-doped and Ru doped TiO\(_2\) thin films at different doping concentration (0.05, 0.07, 0.09 and 0.11 mol l\(^{-1}\)) under UV and sun light.
effected photo degradation activity. These results show a good agreement with the findings of Masae et al.\textsuperscript{[34]} when they doped Na with TiO\textsubscript{2} thin films by sol gel method. It was found that the photocatalytic activity of Na doped TiO\textsubscript{2} exhibit the highest performance at about 90.0\% for the degradation of an MB solution. Moreover, similar behavior that observed by Sangpour et al.\textsuperscript{[35]} for Au: TiO\textsubscript{2} and Cu: TiO\textsubscript{2} thin films. Which have higher photocatalytic activity, due to presence of metallic nanoparticles that prevent the charge carrier recombination by electron capture subsequent created holes leading to increase in the rate MB photodegradation reaction under UV and visible light. Also Rajendran et al.\textsuperscript{[36]} reported that the highest percentage of degradation (92\%) for 0.05 mol\% Cu doped TiO\textsubscript{2} thin films than that of pure TiO\textsubscript{2} (68\%). Finally, the photocatalytic activity of Ru doped TiO\textsubscript{2} thin films strongly dependent on the amount of Ru.

**Conclusion**

From the present work, it can be summarize that:

- The un-doped and Ru doped TiO\textsubscript{2} thin film has the anatase phase has confirmed by XRD analysis. Ru\textsuperscript{3+} ions are successfully interstitial in the TiO\textsubscript{2} lattice causes change in cell volume and the crystallite size were decrease with doping concentration for all thin films.
- The increment of doping concentration lead to increase the film thickness due to condensation and agglomeration effect.
- AFM analysis indicated that the addition of Ru into TiO\textsubscript{2} thin films enhance the average surface roughness.
- The transmittance spectra, band gap and optical constant of the un-doped and Ru doped TiO\textsubscript{2} thin films has obtained from UV--vis spectroscopy. The optical analysis showed that all the films had high transmittance in the visible region. With the increment of Ru doping content the absorption edge of the films goes to lower wavelength. The optical band gap of the un-doped film is lower than that of the Ru doped TiO\textsubscript{2} due to enlarged charge carriers according to Burstein-Moss effect.
- The extinction coefficient (k) and the refractive index values for all the films decrease rapidly for all doping concentration. This may be due to change in film crystallinity and film porosity. The dielectric constant was decrease with the increment of wavelength due to polarization reductions.
- The films have high optical conductivity which makes the Ru doped TiO\textsubscript{2} films a promising material in sensor and solar cell applications.
- The photocatalytic activity under sun light was higher comparing to UV light for all films. The 0.11 mol\textsuperscript{-1} sample of Ru doped TiO\textsubscript{2} thin films seem to exhibit the optimum photocatalytic activity.
- As a conclusion, the structural, morphological, optical and photocatalytic properties of the TiO\textsubscript{2} thin films could be varied by Ru concentration.

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