Gas sensitivity properties of TiO$_2$/Ag nanocomposite films prepared by pulse laser deposition

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Abstract

In this study, a double frequency Q-switching Nd:YAG laser beam (1064 nm and $\lambda = 532$ nm, repetition rate 6 Hz and the pulse duration 10ns) have been used, to deposit TiO$_2$ pure and nanocomposites thin films with noble metal (Ag) at various concentration ratios of (0, 10, 20, 30, 40 and 50 wt.%) on glass and p-Si wafer (111) substrates using Pulse Laser Deposition (PLD) technique. Many growth parameters have been considered to specify the optimum condition, namely substrate temperature (300$^\circ$C), oxygen pressure (2.8×10$^{-4}$ mbar), laser energy (700) mJ and the number of laser shots was 400 pulses with thickness of about 170 nm. The surface morphology of the thin films has been studied by using atomic force microscopes (AFM). The Root Mean Square (RMS) value of thin films surface roughness increased with increasing of Ag contents, while the crystallite size was found to decrease with increase in different silver content. The sensitivity toward NO$_2$ and NH$_3$ gas has been measured under different ppm concentrations. TiO$_2$ with noble metal has a sensitivity higher than pure TiO$_2$ where as TiO$_2$ with Ag metal deposited on glass substrate has maximum sensitivity to NO$_2$ gas with a value of ~50% at the nanocomposite 90% TiO$_2$/10% Ag films with best operation temperature at 200 $^\circ$C. In addition, noble metal like Ag to the titanium dioxide materials makes them sensitive to NO$_2$ gas.

Keywords

Titanium oxide, morphology and sensitivity properties, PLD technique.

Article info

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خصائص المتحسس الغازي للغشاء المتراكب النانوي TiO$_2$/Ag المحضر بطريقة الليزر النبضي

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الخلاصة

تم في هذه الدراسة استخدام حزمة ليزر النديموم-ياك ذات التردد المضاعف بتقنية المنشفة Q, ذات الطول الموجي 1064 نانومتر و ذات الطول الموجي 532 نانومتر و بمعدل تكرار 6 هرتز، و زمن نقطة مداره 10 نانو ثانية، لترسيب الغشاء للمتراكب النانوي TiO$_2$Ag النقي و المخولتو مع العنصر النبيل TiO$_2$ بنسب تراكيز مختلفة 10, 20, 30, 40 و 50% wt. باستخدام تقنية الترسيب (PLD) بالليزر النبضي. عدة معاملات اخذت بنظر الاعتبار لتحديد الشروط المثلى للتحديد درجة حرارة
Introduction

The market for resistive-type gas sensors is dominated by materials developed on the base of thin or thick layers composed of polycrystalline metal oxides. The nanostructures of different forms, i.e., nanowires, nanotubes, nanoflowers, have been shown to display better gas selectivity and sensitivity [1-3]. Additionally, open nanostructures facilitate the penetration of gas, and as a consequence, reduces the response time. Titanium dioxide (TiO$_2$) is effectively used in environmental and energy production applications such as dye-sensitized solar cells, photocatalytic water purification, and hydrogen generation by water splitting [4-6]. In sensor technology this n-type semiconductor is frequently considered as a promising material for gas detection applications [7]. In addition, Noble metals like Pt, Pd, Au, and Ag have been utilized to reduce the operation temperatures through effective improvements of the interaction between TiO$_2$ surface and the gas molecules [8-11]. Other studies addressed some limitations of the gas sensors by improving the structure and morphology of the gas sensor films. Sonker et al. [12] successfully prepared a nano-petal like NO$_2$ sensor through a cheap and easy chemical route. Plecenik et al. [13] constructed a highly-sensitive room-temperature semiconductor gas sensor based on nanoscale Pt-TiO$_2$-Pt sandwich.

In this study, we have prepared pure TiO$_2$ and its composite, which mixed with Ag, by PLD technique to produce high-quality TiO$_2$/Ag nanocomposite thin films. Special attention was paid to the influence of the processing parameters, such as mixing concentration on the morphology and Sensitivity properties of the films during the deposition.

Experimental

Titanium dioxide with a purity of 99.99% and silver with purity of 99.99% were mixed together at different concentration of $x=0, 10, 20, 30, 40$ and $50$ wt. % using agate mortar then the mixture was pressed, using hydraulic manually type (SPECAC), under pressure of 6 tons for (5) minutes to form a pellets of (2.8 cm) in diameter and (0.3 cm) thick. The pellets were sintered in air at temperature of (400 ºC) for 3 h. The TiO$_2$/Ag films were deposited on glass slides substrates of (1.5×1.5 cm$^2$). The substrate was cleaned with dilated water using ultrasonic process for 15 minute to deposit the films at 300 ºC. PLD technique was used to deposit the films under vacuum of (2.8×10$^{-4}$ mbar) using Nd:YAG with ($\lambda= 1064$ nm) SHG Q-switching laser beam at 700 mJ, repetition frequency (6Hz) for 400 laser pulse is incident on the target surface making an angle of 45° with it. The distance between the target and the substrate was (2.5 cm). The substrate was heated under temperature (300 ºC).

Atomic Force Microscopy (AFM) is a widely used technique for investigating the surface
microstructure and quantifies surface topography. The grain size and surface roughness are investigated with a NanoScope atomic force microscope in tapping mode. In this study, the morphological features of the various films are investigate with Angstrom Advanced AA3000 Scanning Probe Microscope (SPM), which manufacture in USA.

Gas sensor system

The process of determination the sensitivity parameter is mainly comprised in the response time and recovery time of the fabricated TiO₂/Ag gas sensor detector, for which a suitable setup is prepared for this purpose. Fig. 1, displays the system of gas sensor testing, which consists of a cylindrical stainless steel test chamber of diameter 30cm with a height of 35cm. The effective volume of the chamber is (6594) cc; it has an inlet for allowing the tested gas to flow in and an air admittance valve to allow the flow of atmospheric air after evacuation. At the base of the chamber, a multi-pin feed through allows the electrical connections to be established to the heater sensor electrodes, and K-type thermocouple.

![Gas sensor testing system](image)

Fig. 1: A photograph of gas sensor testing system.

The heater consists of a K-type thermocouple and a hot plate inside the chamber in order to make a control on their operating temperature of the sensor as shown in the Fig. 2. A UNI-T UT81B PC-interfaced digital multimeter, and Laptop PC, is used to register the variation of the sensor current when exposed to air-NO₂ gas mixing ratio. The gas mixing is fed through a tube over the sensor inside the test chamber to give the real sensitivity.

Sensitivity, $S$, is defined as the ratio of change of resistance in test gas $\Delta R = R_a - R_g$, to the value of resistance in air $R_a$ where $R_g$ is the sensor resistance in the presence of the test gas [14]:

$$S = \frac{\Delta R}{R_a} = \frac{R_a - R_g}{R_a}$$  \hspace{1cm} (1)

where $R_g$ is the electrical resistance of gas sensors and $R_a$ is the electrical resistance of gas sensors in the air.
Results and discussion

Fig. 3 shows the Atomic force microscopy images of TiO$_2$/Ag nanocomposite films deposited on glass substrate at (300 °C) temperature. Figure show the surface topography (in two and three dimensional). As can be noticed from these, the films have high degree of homogeneity and consisted of small nanocrystalline grains, the surface morphology of TiO$_2$/Ag nanocomposite as observed from the Atomic force microscopy micrographs proves that the grains are uniformly distributed with individual grains extending as shown in Fig. 3. The surface roughness value and the root mean square, as in Table 1, observed surface roughness had random variation where it is increase at concentration ratio of Ag 10 % wt. while decrease at ratio (20 and 30)% wt. and then increase at ratio (40)% wt. and decrease at (50)%wt.. However, the roughness variation among these values may be considered random, and a specific contribution of Ag mixing to the roughness cannot be defined. The average grain size of nanocomposite pure TiO$_2$ thin film is calculated from AFM studies found to be equal to (55.26) nm and decreases with increasing of Ag concentration ratio.

Table 1: AFM characteristics of the TiO$_2$ films deposited at different Ag mixing ratio.

| Samples         | RMS (nm) | RS (nm) | Ten point height (nm) | Average G.S (nm) |
|-----------------|----------|---------|-----------------------|------------------|
| TiO$_2$ - Pure  | 1.41     | 1.21    | 2.63                  | 55.26            |
| 90% TiO$_2$:Ag 10% | 3.86     | 3.30    | 8.04                  | 49.01            |
| 80% TiO$_2$: Ag 20% | 2.39     | 2.07    | 4.12                  | 46.97            |
| 70% TiO$_2$: Ag 30% | 1.19     | 1.01    | 4.96                  | 42.86            |
| 60% TiO$_2$: Ag 40% | 4.46     | 3.85    | 15.9                  | 39.06            |
| 50% TiO$_2$: Ag 50% | 2.00     | 1.64    | 10.9                  | 36.78            |
Gas sensing measurement
Sensitivity with operation temperature

The film is initially tested to confirm its semiconducting behavior. The sensor is placed on a heater base and its resistance is measured as the temperature rises up from (25-300) °C in the dry air atmosphere. Figs. 4 and 5 show the variation of sensitivity as a function operation temperature in the range (25-300 °C) of the TiO₂ films with variance concentration ratios of Ag. The sensing test was done using 3% NO₂: air and 10%NH₃: air mixed ratio and bias voltage (6 V) were applied to the electrodes of all samples.

Fig. 4 is an illustration the sensitivity of TiO₂ composite sensor, as thin films, to 60 ppm of NO₂. The maximum sensitivity to NO₂ by pure TiO₂ sensor is about 7.55% at around (300) °C, [15, 16] but the (TiO₂)₉₀%(Ag)₁₀% sensor displays a great enhancement of sensitivity to NO₂, especially at (200) °C where the sensitivity to 60 ppm of NO₂ reaches as high as (49.79%), more than 11 times more sensitive than that of pure TiO₂ sensor. It should also be noted that the optimum sensing temperature required for the maximum sensitivity is at around 200 °C for TiO₂ sensor [16] which is lower than that of pure TiO₂ sensor (~300 °C). Table 2 show the relation of sensitivity with temperature and concentration ratios of Ag in a pure TiO₂ and (TiO₂)ₓ₋ₓ(Ag)ₓ nanocomposite thin films gas sensor with NO₂ test gas.
Fig. 4: The variation of sensitivity with the operating temperature for different Ag concentration in a pure TiO$_2$ and (TiO$_2$)$_{1-x}$(Ag)$_x$ nanocomposite thin films gas sensor with NO$_2$ test gas.

Table 2: The values of sensitivity of a pure TiO$_2$ and nanocomposite (TiO$_2$)$_{1-x}$(Ag)$_x$ thin films gas sensor with NO$_2$ test gas as a function of operation temperature and concentration ratios of Ag.

| Temp. (°C) | 0% | 10% | 20% | 30% | 40% | 50% |
|------------|-----|-----|-----|-----|-----|-----|
| 30         | 2.3162 | 6.5610 | 4.41915864 | 2.1848450 | 4.34899 | 13.261872 |
| 100        | 4.73037 | 16.5957 | 5.06306306 | 1.9581395 | 8.46161 | 18.742966 |
| 200        | 5.1648 | 49.015 | 10.3162393 | 29.664363 | 9.1848 | 17.768759 |
| 300        | 7.5558 | 16.5610 | 12.4191586 | 31.0137169 | 33.0679 | 21.02841918 |

Fig. 5 shows NH$_3$ is used as the probing gas, similar results are obtained: the maximum sensitivity of 70%TiO$_2$/30%Ag composite sensor to 200 ppm of NH$_3$ can reach 20%, which is about 13 times higher than the sensitivity of pure TiO$_2$ sensor, and the optimum sensing temperature of TiO$_2$ composite sensor is at around (300) °C. Table 3 shows the relation of sensitivity with temperature and concentration ratios of Ag in a pure TiO$_2$ and (TiO$_2$)$_{1-x}$(Ag)$_x$ nanocomposite thin films gas sensor with NH$_3$ test gas.
Fig. 5: The variation of sensitivity with the operating temperature for different Ag concentration in a pure TiO$_2$ and nanocomposite TiO$_2$/Ag thin films gas sensor with NH$_3$ test gas.

Table 3: The values of sensitivity of a pure TiO$_2$ and nanocomposite (TiO$_2$)$_{1-x}$(Ag)$_x$ thin films gas sensor with NH$_3$ test gas as a function of operation temperature and concentration ratios of Ag.

| Temp. ºC | 0% | 10% | 20% | 30% | 40% | 50% |
|----------|----|-----|-----|-----|-----|-----|
| 25       | 1.03573 | 4.07239 | 2.00364 | 3.13725 | 4.01837 | 21.0127 |
| 100      | 1.21089 | 2.32919 | 1.59798 | 5.85885 | 5.09554 | 9.84848 |
| 200      | 1.63551 | 21.3612 | 7.75254 | 7.10696 | 4.86656 | 3.38189 |
| 300      | 1.68855 | 13.5319 | 8.78926 | 20.0328 | 36.9365 | 26.4029 |

All the above results have shown that the sensitivities of TiO$_2$ thin films as gas sensors to the oxidizing and reducing gases have been greatly enhanced.

AFM results have shown that, in the presence work, the (TiO$_2$)$_{1-x}$(Ag)$_x$ thin films has different cluster sizes. When the particle size of TiO$_2$ is small enough, especially the grain size is comparable to the depth of the sub-surface depletion layers, the whole resistance and sensitivity of the TiO$_2$ sensor are controlled by the grains themselves, inducing an inverse relationship between particle size and gas sensitivity [17, 18], with the smaller particle producing higher sensitivity.

Furthermore, it is well known that the conductivity of a semiconductor gas sensor is mainly determined by the presence of singly-charged oxygen vacancies [19] and the surface adsorbed oxygen species plays an important role during the sensing process [20]. The higher sensitivity may be attributed to the optimum surface roughness, porosity, large surface area and large rate of oxidation [21]. The maximum sensitivity of the TiO$_2$ with 10%Ag films to NO$_2$ gas is found to be 49% at 200 ºC as showing in Fig. 4.

Figs. 6 and 7 show the dependence of the sensor’s sensitivity to the
content of Ag in TiO$_2$ thin films sensors. These figures show the sensitivities of pure TiO$_2$ sensor and different (TiO$_2$)$_{1-x}$(Ag)$_x$ sensors to 60 ppm of NO$_2$ in the temperature range (25 °C-300) °C. The maximum sensitivity of the pure TiO$_2$ sensor to 60 ppm of NO$_2$ is 4.55 % at (300) °C [22]. However, (TiO$_2$)$_{90}$(Ag)$_{10}$ sensor displays a great enhancement of sensitivity to NO$_2$: the maximum sensitivity can be achieved up to 49%, and the optimum temperature where the sensitivity is the maximum is at around (200) °C, which is lower than that of the pure TiO$_2$ sensor.

![Fig. 6: The variation of sensitivity with different Ag concentration in a pure TiO$_2$ and (TiO$_2$)$_{1-x}$(Ag)$_x$ nanocomposite thin films gas sensor with NO$_2$ test gas.]

![Fig. 7: The variation of sensitivity with different Ag concentration in a pure TiO$_2$ and (TiO$_2$)$_{1-x}$(Ag)$_x$ nanocomposite thin films gas sensor with NH$_3$ test gas.]

**Response time and recovery time**

The response time and recovery time of the pure TiO$_2$ towards 3% NO$_2$ and 10% NH$_3$ :Air gas mixing ratios has been explored. The successive tests are performed at a bias voltage of 6V and a 300 °C operating temperature. The results are shown in Figs. 8, and 9.

Fig. 8 indicates here both the response and recovery times of the TiO$_2$ gas sensor with (0, 10, 20, 30, 40 and 50) % Ag concentration ratios. The response and recovery time decreases with increasing Ag concentration to a minimum value at 40% Ag concentration and increased after that.
Fig. 8: The variation of response time and recovery time Ag concentration ratios in TiO$_2$ at optimum operating temperature (300 ºC) for NO$_2$ testing gas.

Fig. 9 shows the relation between the response and recovery time with Ag concentration ratio (deposition ratio of preparing sample) of optimum operating temperature of 10% NH$_3$:Air mixed ratio (test gas). The response and recovery time were decreased with increasing Ag content to 30% Ag and increase after that.

Gas sensing mechanism of TiO$_2$ pure and (TiO$_2$)$_{1-x}$(Ag)$_x$ thin films

Gas sensing mechanism depends on the surface reaction between chemisorbed oxygen, oxidant and reducing gases. The adsorption of oxygen on the film surface has two forms: physisorption and chemisorption. At elevated temperature, chemisorption is dominant. The transition from physisorption to chemisorption needs activation energy, which can be accomplished by increasing operating temperature. It has been reported that the amount of oxygen adsorbed on the sensor surface goes on increasing with an increase in temperature [23, 24].
Molecular oxygen and atomic oxygen have a dominant influence on the electrophysical and gas sensing characteristics of TiO$_2$ films in the temperature ranges of (25–300) °C, where the oxygen is adsorbed at the surface of the metal oxide that enables an electron trapping. Hence the charge carrier density is reduced which leads to an increase in the resistance of the TiO$_2$ Pure and (TiO$_2$)$_{1-x}$(Ag)$_x$ nanocomposite. This reaction can be expressed as follows [24]:

$$O_2^{(atm)} + 2e^- (cond \ band) \rightarrow 2O^- (ads)$$

where $O_2$ is the adsorbed oxygen molecules, $O^-$ is the chemisorbed oxygen and $e^-$ are the trapped electrons from the TiO$_2$ Pure and (TiO$_2$)$_{1-x}$(Ag)$_x$ nanocomposite surface.

$O^-$ Species on the surface, act as electron acceptors, and lead to the formation of depletion layer extending to the particles as well as surface barrier. This surface states and surface barrier play an important role for sensors, since it controls the electron transfer between particles, test gas and the sensing material, affecting the overall resistance. Exposure to NO$_2$ and NH$_3$ gases, with an elevated temperature, the reabsorbed oxygen species ($O^-_{surf}$).

It results in the rising coverage of oxygen, binding more electrons to the conduction band of TiO$_2$, raising the barrier. This phenomenon increases the depletion region reducing the conductivity or enhancing the resistance [25].

Figs. 10 and 11 show the variation of resistance with time of TiO$_2$ Pure and nanocomposite TiO$_2$/Ag thin films as exposed to 3%(60l/h) NO$_2$ and 10%(200l/h) NH$_3$ in the air ambient injected into testing chamber and bias voltage is keeping at (6 V), at optimal operating temperature of each sample. The resistance is measured directly with time and the sensor resistance initially reaches the steady state before gas opening, in this time we open the gas to allow mixing with air inside the chamber. The resistance increases abruptly to reach a steady state then we switch the gas off. Then current returned to initial case. The ability of a sensor to sense the presence of gas depends on the nature of the interaction between the gas molecules and the surface atoms of the sensing film. The reactivity of the surface is critically dependent on its mixing and the defect structure.

Fig. 10 shows a rapid increase of the resistance with time for pure TiO$_2$ to reach a saturation state when the gas on, this may be due to a saturation of adsorption of a NO$_2$ gas on the surface. The resistance returns to the initial state when the gas off, the sensitivity of pure is (4.5%) calculate while the response and recovery time is (39.6 s), (63.9 s) are observed.

The maximum resistance that obtained (49 %) and achieved for (10% concentration ratio of Ag) with response and recovery time is (33.3 s), (51.3 s) respectively. We can conclude that the mixing of TiO$_2$ with Ag leads an unstable surface to the formation of bridging oxygen vacancies, the concentration of these bridging oxygen sites are the most energy favorable for NO$_2$ gas adsorption. The mixing Ag with TiO$_2$ structures is a possible way of gas adsorption by filling the bridging vacancy site with the gas atom. The binding energy (E.B) of the adsorbed gas atoms with the Ag mixed TiO$_2$ slab displays a maximum at a low concentration ratio of Ag and will cause strongly interaction with the surface and gas molecules that provide a robust change in sensor resistivity [26].
Fig. 10: The variation of resistance with a time of pure TiO$_2$ and (10, 20, 30, 40, and 50) concentration ratios of Ag as exposed to 3% mixing ratio NO$_2$: air and bias voltage of (6) V at optimum temperature (300) °C.

Fig. 11 shows that the low resistance (1.688%) for pure TiO$_2$ with fast response and recovery time (24.3 s), (37.8 s) respectively, while Fig. 7 exhibits the maximum resistance (36.9 %) and response and recovery time (9 s), (34.2 s) for 40% from mixing ratio of Ag with TiO$_2$. Decrease in sensitivity due to decrease in binding energy favorable between gas atoms with bridging oxygen sites.
Fig. 11: The variation of resistance with time of pure TiO$_2$ and variance concentration ratio of Ag as exposed to 10% mixing ratio NH$_3$: air at optimum temperature (300) °C.

The influence of gas concentration on sensitivity

The TiO$_2$ sensing samples are prepared at different conditions. Fig. 12 exhibit the transient response as a function of NO$_2$ gas concentration for the TiO$_2$ sensing element at (300) °C. The sensitivity of the TiO$_2$ gas sensor increases as the NO$_2$ gas concentration is increased from 20 to 60 liter/hour and it drops relatively rapidly when the NO$_2$ gas is removed, indicating that the gas sensor has a good response for different NO$_2$ concentrations. Besides, it takes almost the same time for the sensor to reach the maximum sensitivity for different NO$_2$ concentrations. This result is consistent with the conclusion for the dominance of operation temperature for the response time [22]. Both response and recovery time of the
sensor have the same behavior as the NO$_2$ target gas concentration increases. Both of them were decreased with increasing NO$_2$ concentration up to 60 l/h at which the lowest response and recovery times of (15 s) and (51 s) are observed. As it is apparent from the figure, the sensor sensitivity to NO$_2$ gas increased linearly with NO$_2$ test gas mixing ratio up to 60l/h. The maximum sensitivity record (36%) for the sample prepared.

![Fig. 12: The variation of sensitivity with time for different concentration with NO$_2$: air mixing ratio of nanocomposite TiO$_2$/Ag thin films at a bias voltage of (6 V) and operating temperature (300 °C).](image)

Figs. 13 and 14 represent the variation of sensitivity and a grain size with silver (Ag) mixing with titanium dioxide (TiO$_2$) of optimum operating temperature (300 °C). NH$_3$ reducing gas and NO$_2$ oxidant gas used as testing gases where mixing with air during test. Fig. 13 shows as NO$_2$ used as testing gas, the grain size was decreased with Ag mixing concentration from 0% concentration to 20%, from 20% Ag to 40% the grain size not high stall with small variation, after that from 40% Ag to 50% grain size increased. The sensitivity increased as grain size decreased, where the maximum sensitivity shows with grain size (42.86, 39.06 nm) at (30%, 40% concentration ratio of Ag) as shown in Fig.13.

Fig.14 shows as NH$_3$ used as testing gas, the sensitivity was increased with concentration ratio of Ag increased in (0-10)% and from (20-40)% while the sensitivity was decreased at concentration ratio of Ag in tow regain, first regain beyond 10% to 20% and second regain between (40-50) % wt. This figure, also, show that the grain size decreased with increased Ag mixing where, the sensitivity increased as grain size decreased, where the maximum sensitivity shows with grain size (39.06 nm) at (40% mixing) as shown in Fig. 14.
The reduction in the grain size allows the space charge to cover large volume of the grain and the large number of grain boundaries providing large area for adsorption oxygen. Hence large variation in the barrier and resistance can enhance the reactivity at optimum mixing ratio. Also, the density of surface states increases with reduction in the particle size hence, the density of surface states can help in higher sensitivity. The relationship of sensitivity of NO$_2$ and NH$_3$ with Concentration ratio of Ag and grain size were showed in Table 4.
Table 4: The effect of Ag concentration ratio into both sensitivity and grain size.

| Concentration ratio of Ag (%) | Sensitivity for NO₂ (%) | Sensitivity for NH₃ (%) | G.S (nm) |
|-----------------------------|-------------------------|------------------------|---------|
| 10                          | 4.555809                | 1.688555               | 55.26   |
| 20                          | 16.56104                | 13.53191               | 46.97   |
| 30                          | 12.41916                | 1.789264               | 39.06   |
| 40                          | 32.01372                | 20.03284               | 42.86   |
| 50                          | 33.06796                | 37.9365                | 36.78   |

Conclusions

Nanocomposites TiO₂/Ag films prepared by using pulsed laser deposition techniques on the glass and p-Si wafer (111) substrate exhibits a uniform growth of nanocrystalline films. The surface topography characteristics of all films studied by the Atomic Force Microscope (AFM) show that there is a decreasing in average grain size while the average surface roughness increased with increasing of the Ag contents in TiO₂. Nanocomposites TiO₂/Ag films sensors demonstrated high sensitivity and relatively fast to NO₂ Oxidized gas. Thus, they exhibit decrease in the conductance for exposure to NO₂ gas of different concentrations for (ppm) and operating temperatures, showing excellent sensitivity. It is found that the sensing of NO₂ and NH₃ gas in noble metal Ag sensors is related to the enhancement of adsorption of atmospheric oxygen. The variation of the operating temperature of the films leads to a significant change in the sensitivity of the sensor with an ideal operating temperature of about 200 °C was 49.79% a for NO₂ gas with 10%Ag films, while highest response obtained for NH₃ gas (36.93%) was at a concentration ratio 40% Ag at an operation temperature of 300 °C after which sensor sensitivity decreases. The fast response and recovery time at this point are coming from at 40% Ag concentration at time 15s and 23.4s with NO₂ gas, while fast response time (7s) and recovery time of (12s) with NH₃ gas at 40% Ag concentration comparing to other samples.

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