Study of electrical and gas sensing characteristics of 
(TiO$_2$/rGO) nanocomposite to NH$_3$ sensor application

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Abstract. TiO$_2$/rGO nanocomposite is synthesized by using pulsed laser ablation in liquid method, the UV–VIS absorption spectra and Scanning electron microscopy (SEM) TiO$_2$/rGO nanocomposites reveal absorption spectra in ultraviolet region and that the particles were in an aggregated state shrubbery, showed AFM image the size of each image showed that the membrane materials and through the two-dimensional and three-dimensional examines are homogeneous, noting that there are no spaces in the surface. Electrical properties of the nanocomposite improved markedly with bare TiO$_2$NPs, without significantly changing the morphology of the TiO2NPs. Ammonia-sensing acts for (TiO$_2$/rGO) layered film tackled. Sensing behavior of the (TiO$_2$/rGO) nanocomposites examined under the 100 ppm of NH$_3$ environment. The (TiO$_2$/rGO-1) nanocomposite clarified a high reaction to NH$_3$ gas (48 %) in room temperature.

Keywords. Laser ablation, reduced graphene oxide (RGO), Ammonia, Nano composite Room-temperature sensor.

1. Introduction
Titanium dioxide TiO$_2$ or titania is the largest semiconductor in the world. It is an n-type semiconductor. Band gap energy are up to the phase of TiO$_2$ (anatase phase of 3.2 eV and rutile phase of 3.0 eV) [1]. TiO2 nanostructures are involved in different employments such as photo catalytic or solar cells, and gas sensors [2-3]. TiO2 discovered to advance chemical gas sensors depend on the resistance diverse to obtain various gas kind. Originally, TiO2 requests heated up to (200-500°C) to get a perfect performance to hydrogen and various volatile organic vapors [4–5]. The kind of sensor depend on catalytic oxidation of aimed gas vapors at which the pre-adsorbed ionized oxygen kinds like O$_2$ are used freed the trapped electrons on the surface back to the oxide bulk and so lead to the resistance change (i.e, sensor response) [4–6]. Graphene expected to be promising sense platform according to its huge specific surface area and sensitive transverse Hall resistance to the changes in action focus [7]. Yet, weak adsorption merit towards analysys gas molecules are a forward [8]. Hence obstacle, functionalization with TiO2 with graphene could exceed the restriction of both substance with their synergistic results and show better sense features. TiO$_2$/rGO reported of the first time by Williams et al [9]. The diminutive graphene oxide (rGO) functionalized by oxygen-including type like OH and OOH group sat shows desirable properties for gas sensors like the ultra-low noise and low detection confine relation to graphene [10, 11]. During UV support photo catalytic decrease technique. Hence, different routes of ways are being pressed to
synthesize such substances of advantage at multiple implementation viz. photo catalysis, hydrogen generation, Li-ion batteries, dye decay, solar energy transformation, chemiresistive gas sensing sensors [12]. The current study, TiO2/rGO nanocomposite synthesized by using pulsed laser ablation. Also, the hybrid composites depend resistive-kind sensors explained suitable sensibility and eclectic to NH3 in temperature of the room.

![Graph for forming of two kinds of microstructure in (TiO2 rGO)](image)

**Figure 1.** Graph for forming of two kinds of microstructure in (TiO2 rGO)

2. EXPERIMENT
Titanium Dioxide TiO2 NPs is resulted by laser ablation of high pureness Ti targeted dived in double-distilled water (DDDW) in room temperature. Ti target was positioned in the bottom of quartz vessel filled with 4mL from liquid and applied with Q-switched Nd: YAG laser turned on at a wavelength of (532) nm, 7ns pulse duration, and recurrence frequency of 6Hz. The laser energy was used to ablate Titanium target was 300mJ/pulse and 600 pulse. The laser beam focused on (Ti) target using a focusing lens of 100mm focal length. TiO2 NPs, synthesized by the above step (by PLAL), were mixed with (1mL) (2mL) of GO (< 450 nm, Cheap Tubes) (0, 00625g each 1mL deionized water). The first concentration will be denoted by (TiO2– rGO-1) ,The second concentration (TiO2 -rGO-2). This suspension was irradiated (1000 pulse) with the same laser parameters. Through this method, GO gets decreased and becomes rGO and simultaneously, the nanostructured TiO2 NPs anchor on the rGO sheets to form (TiO2-rGO) nanocomposite.

3. NH3 gas sensing
The (TiO2/rGO) Nano composites were dropped cast on to coated glass substrate (ITO). The substrate positioned in gas sensing room. Electric connections constant. The input voltage of 1V was given, and consequent resistance data provided by sensor was obtained by utilizing indigenously made resistance guage unit. NH3 gas was pushed to the chamber with a various quantities of 100 ppm. The consequent resistance different information were obtained and plotted according to the period. The whole work was done in a room temperature. Thus Sensitivity (S) of the materials to NH3 was found by the following equation [13].

\[ S = \frac{R_g - R_a}{R_a} \]

Whereas
Ra : the resistance in air
Rg : the resistance in NH3 gas

4. Results and discussion
4.1. aSEM and AFM analyses
Figures (2) (3) show SEM symbols of (TiO2/rGO) Nano composites prepared by using pulsed laser ablation method at wavelength (532)nm. TiO2 can be seen decorated on reduced graphene oxide flakes with considerable integrated structure. The surface morphology of the (TiO2/rGO) Nano composite shows many aggregates or chunks distributed of TiO2 nanoparticles on the top surface of rGO sheets and the particles were in an aggregated mention shrubbery, The study show the density to TiO2 Nano crystals wrapped reduced graphene oxide controlled by the feed ratio for (TiO₂/rGO) reducing as quantity of GO raised.

![Figure 2. SEM images for (TiO₂/rGO-1) Nano composite.](image)

![Figure 3. SEM pictures for (TiO₂/rGO-2) Nano composite.](image)

Figures (4),(5) clarifies the surface morphology of the TiO2-rGO Nano composites film, show utilizing tapping-mode AFM. The size of every pictures were 24.8 μm × 24.8μm. The results showed that the membrane materials and through the two-dimensional and three-dimensional exams are homogeneous to certain extent and homogeneous vertically heights, noting that there are no spaces in the surface of the material. The TiO₂/rGO-1 Nano composite film had a rougher surface and grain sizes greater than did the TiO₂/rGO-2 Nano composite film.
Figure 4. AFM photo in 2D, 3D of TiO$_2$/rGO-1 nanocomposite.

Figure 5. AFM photo in 2D, 3D of TiO$_2$/rGO-2 nanocomposite.

4.2. Optical properties
Figure (6) shows the absorption spectrum of (TiO$_2$/rGO) Nano composites as a sign of the wavelength of the incident light. The figure that the absorbance of Nano composites basses a high value at a wavelength in the near of the basic absorption edge (310nm), then the absorbance reduces with the increasing of wavelength. It is clear that the sample (TiO$_2$/rGO-2) has higher absorption than the sample (TiO$_2$/rGO-1).

Figure 6. The absorbance spectra as a function of wavelength for (TiO$_2$/rGO) nanocomposites.
4.3. Electrical Properties

4.3.1. Current – Voltage (I – V) properties
Figure (7) clarifies the I–V conductivity plots at room temperature of TiO$_2$ NPs and (TiO$_2$/rGO) nanocomposites prepared by using laser ablation method at wavelength (532) nm, where Indium Tin Oxide (ITO)-coated glass substrate was used of measuring (I-V) characteristics. the relationship between current and voltages is linear and indicating ohmic behaviour. So the resistance can be calculated by Ohm's law where it's almost constant, TiO$_2$/rGO nanocomposites showed increased conductivity relative to TiO$_2$.

![Figure 7. I-V characteristics of TiO$_2$ and TiO$_2$/rGO Nano composites.](image)

4.3.2. Gas sensing characteristics of (TiO$_2$rGO) Nano composite films
Figures (8) (9) show sensitivity (S) of NH$_3$ gas sensors depend on (TiO$_2$rGO) nanocomposite that prepared by using pulsed laser ablation in DDDW at wavelength (532) nm to 100 ppm NH$_3$ gas in room-temperature. So that to obtain a measurement of sensitivity of the sample produced in this work, electrical resistance of nanocomposites was measured in the air and presence of gas in room temperature. The resistive of gas sensors are called as the relative change in resistance or conductivity for the nanocomposite. A known quantity of intended gas introduced after the ohmic strength of the sensor matter gets stability. The recovery features (as the target gas is withdrawn) are also controlled as a function of time. Sensitivity (S) is calculated from equation (1). The sensitivity of TiO$_2$/rGO-1 and TiO$_2$/r GO-2 nanocomposites are (48) (25), respectively. The sensitivity of the (TiO$_2$/rGO-1) nanocomposite for ammonia gas higher than that of (TiO$_2$/rGO-2) nanocomposite because the sensitivity depends on grain size and grain boundary. When the distance between the grains are small rising the interaction between oxygen absorbed and gases is rising, also the grain boundary will increase interaction and increase sensitivity, response and recovery time is due to the first definition under exposure to NH$_3$ at room temperature. It is fundamental that, both responses time and remedy time relied on gas focus and the temperature at which the sensor performed, in this work The operating temperature is constant(RT) and gas concentration is also constant and is estimated at about 100 ppm, When exposed nanocomposites (TiO$_2$/rGO) to NH$_3$ gas, the resistance of the nanocomposite decreased thus make the sensor performance in room temperature, where Ammonia is an electron supplier and might assist electrons to the (TiO$_2$rGO) sensing matters at the sensation actions. Semiconductor gas sensors are generally employed at the pressure in the atmosphere. So atmospheric oxygen on the surface adsorbs electrons from the conduction band of n-type (TiO$_2$rGO) nanocomposite film, forming O$_2$-and
an electron-depleted layer at the surface of the film. The current research as NH3 gas was adsorbed, and electrons freed into the conduction band due to Equation below [14], decreasing resistance.

\[4\text{NH}_3(g) + 3\text{O}_2(\text{ads}) \rightarrow 2\text{N}_2 + 6\text{H}_2\text{O} + 6e^-\]

Figure 8. Repetitive response curves of (TiO$_2$/rGO-1) Nano composite exposed to 100 ppm NH3.

Figure 9. Repetitive response curves of (TiO$_2$/rGO-2) nanocomposite exposed to 100 ppm NH3.

5. Conclusions

(TiO$_2$rGO) nanocomposite synthesized by laser ablation way at wavelength 532nm and 300mj. The SEM symbols of (TiO$_2$rGO) nanocomposites disclose that the particles were in an aggregated state shrubbery, The UV–VIS absorption spectra in the ultraviolet region. The optical, electrical and gas sensing features of (TiO$_2$rGO) Nanocomposites were also investigated systematically with a view toward gaining insight into how to GO impacts the properties of TiO$_2$NPs. The results suggested that GO addition is an effective method for improving the electrical and sensing performance of TiO$_2$NPs. The TiO$_2$/rGO-1 nanocomposite showed a high reaction to NH3 gas (48 %) in room temperature.

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