Preparation of graphene—TiO₂ nanocomposite and photocatalytic degradation of Rhodamine-B under solar light irradiation

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ABSTRACT
GR—TiO₂ nanocomposite was prepared by simple chemical method using graphene oxide and titanium isopropoxide (Ti [OCH (CH₃)₂]₄) precursors. The crystalline nature of the composite was characterised by powder X-ray diffraction and the intercalation was explained by Raman spectroscopy. The morphology of the composite was analysed by field emission scanning electron microscopy. The elemental and quantitative measurement of the composite was determined by electron dispersive spectroscopy. The shape and size of the particle was measured by transmission electron spectroscopy and high resolution spectroscopy. The surface area and elemental composition of the composite was studied by using Brunauer—Emmett—Teller (BET) method and X-ray photoelectron spectroscopy. Photo-generated electrons were studied by photoluminescence spectra. The photocatalytic activity of nanocomposite was investigated by the degradation of Rhodamine-B (Rh-B) in an aqueous solution under solar light irradiation. The GR—TiO₂ demonstrates photocatalytic activity in the degradation with a removal rate of 98% under solar light irradiation as compared with pure TiO₂ (42%), graphite oxide (19%), and mechanical mixture GR + TiO₂ (60%) due to the increased light absorption intensity and reduction of electron—hole pair recombination with the intercalation of graphene and TiO₂. The results indicated that the GR—TiO₂ could be used as a catalyst to degrade Rh-B from coloured wastewater.

1. Introduction
Industries, such as textile, chemical, refineries, plastic, and food-processing plants produce wastewaters characterised by a perceptible content of organics. Because of increasing public concerns and more strict regulations on harmful dye wastewater, it is important to develop efficient technologies for the complete removal of dye pollutants from wastewater. Photocatalysis is gaining a lot of attention in the area of purification, such as degradation of organic pollutant, dyes in water with the use of solar light as the energy source, and atmospheric oxygen as an oxidant, which accelerates light-driven chemical reactions. Photocatalysts achieve their importance due to captivating properties, such as quantum confinement and enhanced reactivity. Titanium dioxide (TiO₂), as a photocatalyst,
has been widely investigated during the past decades because of its outstanding advantages such as low cost, nontoxicity, strong photo-oxidising power, and stability. TiO₂ exists in three crystallographic forms in nature such as brookite, anatase, and rutile. Anatase plays a dominant role in photocatalysis applications due to generally observed superior photocatalytic efficiency as well as facile synthesis.[1] However, TiO₂ can only degrade aromatic organics into CO₂ and H₂O under UV-illumination whereas it cannot absorb visible light with wavelength longer than 387 nm due to a large band gap of 3.2 eV. Thus, TiO₂ can only utilise 3%—5% of the solar energy that can reach onto the earth surface. Under irradiation of solar light, electron—hole pairs that are responsible for its photocatalytic activity can be generated in TiO₂. However, the photo-generated electron—hole pairs have a flash recombination time on the order of 10⁻⁹ s, while the time scale of chemical interactions of TiO₂ with the adsorbed dye or chemicals is in the slower range of 10⁻⁸—10⁻³ s.[2] This discrepancy between two time scales results in an unintended recombination of electron—hole pairs, leading to decreased efficiency in the photocatalytic activity of TiO₂. Therefore, besides its high band gap energy, another challenging issue in the photocatalytic utilisation of TiO₂ is overcoming the quick recombination of the photo-generated electrons and holes. A number of strategies have been proposed to challenge these limitations. One important approach is to employ metal ion or non-metal doping to the crystalline TiO₂. This strategy can decrease the electron—hole pair recombination rate, which substantially enhances the interfacial charge-transfer reaction rate.[3,4] Doped TiO₂ material is superior to that of UV-activated photocatalysis because of more sunlight can be used. In particular, the combination of TiO₂ nanoparticles with carbon nanomaterials, such as carbon nanotubes, graphite oxide, and graphene, has been proposed as a suitable method for increasing the photocatalytic activity.[5—9]

Graphene (GR) as a novel carbonaceous nanomaterial has attracted more and more interests due to its single layer of carbon atom, tightly stacking into a two-dimensional honeycomb sp² carbon lattice. It possesses a large surface area, chemical stability, and very high electron transfer, which make it a good candidate for catalyst carrier, carbon dopant, and photo-electron acceptor.[10—12] There are many reports on graphene doped/coupled TiO₂ compositions for organic/inorganic degradation with visible light.[13,14] In Graphene-TiO₂ nanocomposite, high interfacial contact between the graphene sheet and TiO₂ nanoparticles will be highly demand and this improves the photocatalytic activity. The unique structure will facilitate the charge separation and electron transfer from TiO₂ to graphene upon irradiation.[15] Several attempts in using GR for modification of TiO₂ for photocatalytic degradation of organics have been reported.[16,17] There have been several reports highlighting the improvements in photocatalytic activity of graphene—TiO₂ composites for the degradation of organic molecules. Discovered the two-dimensional interface of a titanatographene nanosheet composite for improved photocatalytic activity of Rhodamine-B (Rh-B), because huge surface area and interfacial contact between the graphene and titanate.[18] Facile fabrication of TiO₂-graphene composite with enhanced photocatalytic property of methyl orange due to morphology and surface area of the composite.[19] The combination of high surface area TiO₂ nanoparticle and graphene oxide may improve charge separation and stabilisation, which could heighten the photocatalytic activity.

In this paper, graphene—TiO₂ nanocomposite was prepared by facile chemical method of suspension with graphene oxide nanosheets and titanium isopropoxide and utilisation for photodegradation of Rh-B aqueous solution under solar light irradiation. Nanocomposite comparison with those of P25, TiO₂, and physically mechanical mixture and also studied the re-stability of the nanocomposite.

2. Materials and methods

2.1. Materials

Natural graphite powder was commercially obtained from Sigma-Aldrich. In addition, titanium isopropoxide (Ti [OCH (CH₃)₂]₄), hydrochloric acid (HCl), sulphuric acid (H₂SO₄), hydrogen peroxide (H₂O₂), potassium manganese oxide (KMnO₄), sodium nitrate (NaNO₃), and sodium hydroxide (NaOH), all these chemicals purchased from the Merck and used without further purification and
ethanol was supplied by Changshu Yangyuan chemical, China and throughout the experiment double distilled water was used.

### 2.2. Preparation of graphite oxide

Graphite oxide was prepared by the modified Hummers method.[20,21] In a typical procedure, as per stoichiometric ratio, about 5 g of graphite flakes was added to 115 mL of concentrated (98%) H₂SO₄ in an ice bath with stirring for 30 min. Fifteen grams of KMnO₄ added slowly to the above mixture with stirring and cooling for 30 min. Subsequently, 2.5 g of NaNO₃ was added with continuous stirring for 60 min so that the temperature of the mixture maintained below 15 °C during that time. The temperature of mixture then raised to 40 °C with water bath, and the mixture was continuously stirred for 30 min. After that, the mixture was diluted by 800–1000 mL of distilled water, the temperature of which then raised to 98 °C. The mixture was then added by H₂O₂ (30%) until gas evolution ceased followed by filtering. The colour of the dispersion turned from black to yellow. The product was washed repeatedly with 1 M HCl (5%) and distilled water until the pH value of the product arrived at near 7. Then the product was dried in an air oven at 60 °C to obtain graphite oxide.

### 2.3. Preparation of GR–TiO₂ nanocomposite

To prepare a colloidal suspension of GR, about 0.09 g of as-prepared graphite oxide was dispersed in 60 mL of ethanol by sonication for 60 min, after that 1.5 mL of titanium isopropoxide (Ti[OCH(CH₃)₂]₄) was added into the dispersion. The mixture was stirred at room temperature for 30 min. Then 15 mL of distilled water and 0.5 mL of HCl (1 M) was added drop wise and the reaction was stirred under N₂ atmosphere at room temperature for 24 h. The product was then centrifuged and washed with distilled water to remove any remaining organic residue. After that GR–TiO₂ dried at 80 °C in a hot air oven. A simple chemical route preparation of GR–TiO₂ nanocomposite was shown in Figure 1.

### 2.4. Characterisation

The resulting solids were characterised by various techniques including powder X-ray diffractometry (XRD) Bruker D8 using CuKα1 (1.5406 Å) and Kα2 (1.54439 Å) radiations. Raman spectra were recorded using a WiTec alpha 200 SNOM system. Morphologies of as-obtained products were studied by a field emission scanning electron microscope (FESEM) imaging with energy dispersive spectroscopy (EDS) using a Carl Zeiss Supra 55 operating at 5 and 20 kV. Structure analysis was conducted by a transmission electron microscope (TEM) measurements were performed on a JEOL 3010 at 200 Kv. Ultraviolet-visible (UV-Vis) absorption spectra were recorded using Shimadzu-1800. X-ray photoelectron spectroscopy (XPS) was recorded spectra on a KRATOS AXIC 165 equipped with Mg Kα radiation. All binding energies were referenced to C 1s at 284.8 eV. Nitrogen adsorption and desorption experiments were carried out on Micromeritics ASAP 2020 analyzer. The samples were outgassed at 150 °C for 12 h in a dynamic vacuum before physisorption measurements. The specific surface area was calculated using Brunauer—Emmette—Teller (BET) method. A photoluminescence (PL) spectrum was recorded by using JOBIN YVON Flurolog-3 spectrofluorometer with a YSOW Xenon lamp used as broad band source. The pH of the solution was measured by ELICO LI 617 pH meter. Solar light intensity was checked by TES 1332A Lux meter.

### 2.5. Photocatalytic experiments

The removal of organic pollutant was evaluated by the adsorption–degradation efficiency of Rh-B in dark and solar light irradiation. Organic dye solutions (30 mL and 5 × 10⁻⁵ mol/L) containing
0.030 g of samples were put in a sealed glass beaker and first ultra-sonicated for 5 min, and then stirred in dark for 30 min to ensure absorption—desorption equilibrium. After solar light illumination, 3 mL of samples was taken out at regular time intervals (60 min) and separated through centrifugation, which was recorded as base concentration $C_0$. The supernatants were analysed by recording variations of the absorption band maximum in the UV-Vis spectra of Rh-B by using a Shimadzu-1800 UV-Vis spectrometer to determine the concentration of Rh-B at optical absorption at 554 nm, which denoted as $C_t$. In the photocatalytic degradation test, the decomposition rate could be calculated using equation:

$$\ln\left(\frac{C}{C_0}\right) = k \times t$$

where $C_0$ is the pollutant concentration before sun light irradiation and $C_t$ is the pollutant concentration in the solution after the photodegradation, $k$ was the decomposition rate constant, and $t$ was the reaction time.[22]
3. Results and discussion

3.1. Spectral and morphological analysis

The powdered X-ray diffraction (P-XRD) spectroscopy pattern of the as-prepared GR–TiO₂, TiO₂, graphite oxide, and graphite is shown in Figure 2. For graphite, an intense crystalline peak around 26.46° was observed, which represents the characteristic peak of graphite. After oxidation, the peak shifts to 9.92°, which corresponds to graphite oxides. This significant change of peak location indicates the great expansion of d-spacing due to the introduction of oxygen functionalities (such as C–OH, C–O–C, C–OOH) of graphite oxide. Figure 2(d) was found that the peaks at 2θ values of 25.47°, 29.46°, 38.13°, 44.67°, 45.18°, 63.19°, and 69.96° can be indexed to (101), (004), (200), (105), (211), (204), and (116) from the GR–TiO₂ was relatively the same as that from crystal planes of anatase TiO₂ (Figure 2D70(c)) (JCPDS File No: 89-4921).[23] No characteristic diffraction peaks for GR are observed in the pattern because of the low amount and the relatively low diffraction intensity of GR. The presence of GR and TiO₂ is further supported by Raman spectroscopy.

Raman spectroscopy is a powerful apparatus to characterise the crystalline excellence of graphene oxide. The presence of both carbon and TiO₂ can be confirmed from the Raman spectra. Figure 3 shows the Raman spectra of graphite, graphite oxide, TiO₂, and GR–TiO₂ nanocomposites. From Figure 3(d) shows the Raman spectra of graphene-TiO₂, clearly seen vibration peaks at 397 cm⁻¹ (B₁g), 518 cm⁻¹ (A₁g), and 637 cm⁻¹ (E₂g) are characteristics of anatase TiO₂.[24] The D band is a common feature for sp³ defects in carbon, and the G band provides information on in-plane vibrations of sp²-bonded carbons. The intensity ratio of the D band to the G band usually reflects the order of defects in graphene.[25] Raman spectrum of GR–TiO₂ showed that the presence of D and G bands are 1364 and 1589 cm⁻¹, respectively, of graphene oxide indicating successful incorporation of the same into the TiO₂ (Figure 3(d)). In comparison to the GO (I_D/I_G = 0.99) and GR–TiO₂ (I_D/I_G = 1.02), the increased I_D/I_G peak intensity ratio in the GR–TiO₂ says the presence

![Figure 2](image_url)
of increased defects and disorders of graphene oxide introduced by the integration process demonstrating the strong interaction between the TiO$_2$ and GR.

The morphology and the structure of samples were characterised by FESEM. It can be seen in Figure 4 ((a) low magnification and (b) high magnification) that as-prepared GR–TiO$_2$ possesses sphere morphology. EDS proved the presence of carbon and TiO$_2$ in those materials. The EDS spectra of GR–TiO$_2$ composites were shown in Figure 4(c). These spectra indicate the TiO$_2$ with high purity had been successfully synthesised in this study. The C element should mainly originate from graphene sheets. The oxygen and Ti elements mainly come from the TiO$_2$. And the strong K$_a$ and K$_b$ peaks from Ti element appear at 4.51 and 4.92 keV, while a moderate K$_a$ peak of the element O appears at 0.52 keV. The elemental microanalyses (wt%) of the samples are listed in Figure 4(d).

TEM images of GR–TiO$_2$ nanocomposites with different magnification were shown in Figure 5. It can be observed that poly crystalline TiO$_2$ nanoparticles with average dimension of 3–6 nm are supported on the transparent GR sheets (Figure 5(a)–(c)). Hence, in this structure the GR sheets act as a template or scaffold for TiO$_2$ components. Figure 5(d) shows the lattice-resolved image and the selective area electron diffraction (SAED) pattern of the TiO$_2$ in the composite, indicating its poly crystalline anatase phase with the perfect lattice spacing of 3.5 Å. This is in agreement with the results of the XRD pattern shown in Figure 2(c). As shown in Figure 5(e) and 5(f), high resolution transmission electron microscopy (HRTEM) images clearly illustrate the crystalline nature of the GR–TiO$_2$ nanocomposite.

Figure 3. Raman spectrum of (a) graphite, (b) graphite oxide, (c) TiO$_2$, and (d) GR–TiO$_2$. 
XPS was utilised to analyse the surface chemical composition of the nanocomposite materials. The XPS survey spectrum of TiO$_2$–graphene clearly presents the photoelectron peaks of Ti, O, and C, confirming the existence of GR in the sample (Figure 6(a)) in graphene–TiO$_2$. From the Figure 6(b), it can be observed that 285 eV, which may be assigned to the elemental carbon, carbonates and Ti–O–C bond. The corresponding XPS spectrum, the two well resolved peaks observed at 461 and 467 eV from the Ti 2p core-level spectrum (Figure 6(c)), which can be assigned to Ti 2p1/2 and Ti 2p3/2 spin orbital components in TiO$_2$, respectively. For the O 1s electrons (as shown in Figure 6(d)), sample exhibits a strong peak at around 533.5 eV corresponding to the Ti–O bond.[26]

In fact, all the GR samples were obtained by chemically reducing GO, and the chemical reduction should not destroy the skeletons of GO nanosheets. After the chemical reduction treatment, a GO nanosheet would change to a GR nanosheet. GO is electrically insulator due to the presence of a large number of defect sites generated by the presence of epoxide, phenoxides, and carboxylic acids on its surface. Reduction of GO to remove these defects can generate GR with restored electrical properties. However, the electrical property of GR is significantly influenced by its reduction degree. To determine the reduction degree of GR, the oxygen-bound carbon content in GR was calculated based on the XPS results following the equation.
where $A_{C-C}$, $A_{C-O}$, and $A_{O-C=O}$ are the peak areas in the XPS spectra for the sp$^2$-hybridised (C–C) and O-bound (C–O and O–C=O) carbon, respectively. Figure 6 shows the XPS data of the C 1s electrons of the composite, which shows a dramatic decrease in the carbon-oxygen species in GR. (Figure 6(b)). The C:O ratio in GO and GR–TiO$_2$ determined by using the integrated areas under the C 1s peak are $\sim$1:1.28 and $\sim$1:0.29, respectively. This suggests that the chemical route synthesis significantly reduces C–O bondings, thereby converting GO to GR. The atomic ratio of C/O represents the degree of reduction.

In general, the surface area of the catalyst is the most important factor in influencing the catalytic activity. The specific surface area of the prepared GR–TiO$_2$ nanocomposites calculated by the multi-point BET method. Surface area of GR–TiO$_2$ (162.3 m$^2$ g$^{-1}$) was lower than that of GO (186 m$^2$ g$^{-1}$) due to the high density and low surface area of TiO$_2$ poly crystalline nanoparticles (Figure 7).

The PL emission spectra can be used to investigate the fate of photo-generated electrons and holes in a semiconductor, since PL emission results from the recombination of free carriers. PL emission spectrum is useful to disclose the efficiency of charge carrier trapping, immigration, and
transfer. The excitation wavelength for PL spectra was 325 nm. In the literature it was reported that PL spectrum of TiO₂ and 0.3% GR/TiO₂ composite was in the range of 350–550 nm [28] and the electron–hole recombination rate was lower for GR–TiO₂-based composites (Figure 8). This was due to the following fact that, first, the electrons were excited from the valence band to the conduction band (CB) and then migrated to GR sheet, which prevented the direct recombination of electrons and holes. Second, the multiple phase structures of GR–TiO₂ composite might act as rapid separation sites for the photo-generated electrons and holes due to the difference in the energy levels of their CBs and valence bands. Both factors resulted in the decrease of the PL intensity.

3.2. Photocatalytic activity of samples

The photocatalytic degradation of dye in aqueous under the solar light irradiation was carried out at regular time intervals and was shown in Figure 9(a). The absorption of these solutions decreased gradually with irradiation time. Experiments using solar light were carried out between 11.30 am and 1.30 pm in the summer season at Yogi Vemana University, Kadapa, Andhra Pradesh, India.
The intensity of the solar light was found to be around one lack flux for photocatalysis. The characteristic absorption of Rh-B almost disappeared after about 60 min, and the colour of Rh-B solution changed gradually from pink to colourless after irradiation for 60 min. It was observed that Rh-B cannot be reduced under the dark condition even in the presence of photocatalyst GR–TiO₂ composite. The concentration 5 × 10⁻⁵ M of Rh-B degradation is 98%, which shows that the GR–TiO₂ is a good catalyst. The TiO₂ shows that the degradation of Rh-B removal is 42%, graphite oxide removal is 19%, and mechanical mixing of GR + TiO₂ is 60%. The GR–TiO₂ composite material possesses much higher photocatalytic activity than pure TiO₂, GR, and mechanical mixture of GR + TiO₂.

Figure 7. A typical nitrogen adsorption–desorption isotherm of GR–TiO₂ nanocomposite.

Figure 8. PL spectra of as-prepared TiO₂ and 0.3% GR–TiO₂ solid powders.
Figure 9(b) displays the UV-Vis absorbance curves of degraded Rh-B solutions at different solar light irradiation times. Rh-B is a stable xanthene dye in aqueous solution and almost no dye molecules are decomposed by self-photolysis with the absence of GR-TiO$_2$.

The photocatalytic performance of TiO$_2$ and GR-TiO$_2$ composites was first evaluated by photocatalytic decolorisation of Rh-B aqueous solution (Figure 9(c)). It is clear that all the GR-TiO$_2$ nanocomposites exhibit a higher photocatalytic activity than the pure TiO$_2$ ($k = 0.0081$ min$^{-1}$). Especially, when the amount of GR is ca. 0.3 wt%, the resultant GR-TiO$_2$ nanocomposite shows the highest photocatalytic performance with a $k$ value of 0.0018 min$^{-1}$, which is larger than that of pure TiO$_2$ by a factor of 42%. The enhanced photocatalytic performance of the GR-TiO$_2$ nanocomposites was well known and can be attributed to the effective transfer and separation of photo-generated electrons by GR nanosheets.[29–34]

The cyclic properties of the catalyst were also measured in 30 mL Rh-B solution (20 mg/L) containing 0.03 g GR-TiO$_2$ using the similar method. Keeping the condition of photocatalytic degradation invariable, the identical catalyst is to be used one, two, and three times separately under the radiation of 60 min each time. From the results shown in Figure 9(d), changes of degradation rate were observed from the relationship between the number of times of reuse and the photo-
degradation rate. The experiments indicate that the composite of 0.3% GR–TiO₂ can still retain 94% activity for degradation of Rh-B after repeated uses of three times, indicating that it can be reused.

For photocatalysis process, four factors are crucially important, that is, the shape and size of the catalyst, the adsorption of the pollutant, the light absorption, and the electron–hole transportation and separation. A schematic illustration of the mechanism of enhanced photocatalytic performance of the GR–TiO₂ nanocomposites was shown in Figure 10. The major reaction steps in this mechanism under solar light irradiation were described in the following equations:

\[
\begin{align*}
\text{TiO}_2 & \rightarrow \text{hv} (e_{\text{CB}}^-) + (h_{\text{VB}}^+) \rightarrow \text{GR}(e^-) + h^+ \\
\text{TiO}_2(e_{\text{CB}}^-) + O_2 & \rightarrow \bullet O_2^- + \text{TiO}_2 \rightarrow \bullet OH + \text{TiO}_2 \\
\text{TiO}_2(h_{\text{VB}}^-) + OH^- & \rightarrow \bullet OH + \text{TiO}_2 \\
\text{GR}(e^-) + O_2 & \rightarrow O_2^- + \text{GR} \rightarrow \bullet OH + \text{GR} \\
\text{Rh-B} + \bullet OH & \rightarrow \text{CO}_2 + \text{H}_2\text{O}
\end{align*}
\]

When the as-prepared samples were irradiated by a photon of sufficient energy, equal or larger than band gap, the valence electrons (\(e^-\)) of anatase are excited to the CB and creating holes (\(h^+\)) in the valence band (VB). Normally, these charge carriers quickly recombine and only a fraction of electrons and holes participates in the photocatalytic reaction. However, when an optimal amount of GR was incorporated into the TiO₂, the CB of anatase TiO₂ is \(-0.24\) V (vs. SHE, standard hydrogen electrode), while the potential of GR is \(-0.08\) V (vs. SHE). Thus, the photo-induced electrons on the CB of TiO₂ can be smoothly transferred to GR sheets under sunlight irradiation, which effectively retards the recombination of photo-induced \(e^-\) and \(h^+\) the photo-generated \(h^+\) left in TiO₂.

![Figure 10. Proposed mechanism for the photodegradation of Rh-B by GR–TiO₂ composite under solar light irradiation.](image-url)
VB can react with adsorbed water molecules or surface hydroxyl groups to form hydroxyl radicals \( ^{\circ} \text{OH} \), and the excited \( e^{-} \) stored in GO are trapped by \( \text{O}_{2} \) molecules to form reactive superoxide radical ion \( ^{\circ} \text{O}_{2}^{-} \). Both \( ^{\circ} \text{O}_{2}^{-} \) and \( ^{\circ} \text{OH} \) are highly reactive towards Rh-B degradation. Owing to the high specific surface area and superior electron mobility of GR, an appropriate integration of GR and \( \text{TiO}_{2} \) would give rise to a hybrid nanocomposite to achieve high photodegradation activity. However, when the content of GR is further increased above its optimum value, the photocatalytic performance deteriorates.[36,37]

### 3.3. Role of adsorption capacity of GR–\( \text{TiO}_{2} \) nanocomposite

With the reduction degree of GO increased, the adsorption capacities of organic dyes were increased. This is attributed to the possible contributions from at least two aspects: (1) increased surface area and (2) increased \( \pi-\pi \) interaction. Graphene has strong adsorption affinity for aromatic compounds due to their \( \pi \)-electron rich property and flat conformation. It can interact with aromatic compounds through the \( \pi \)-electron coupling ability. Compared to graphene, GO contains much less \( \pi \)-electron and more O-containing groups on its surface. The oxygen-containing functional groups on the surfaces of GO may attract and localise \( \pi \)-electrons from the basal plane and GR, restraining the \( \pi-\pi \) interaction between the organic dye aromatic rings and the \( \pi \) orbital on GO and GR. The reduction of GO removed substantially the oxygen-containing functional groups on the surfaces of GO, leading to the increasing of the \( \pi-\pi \) interaction between GR and the adsorbate.[38]

### 4. Conclusion

Novel photocatalyst was prepared by simple chemical route for the degradation of Rh-B dye from aqueous solution under solar light irradiation, in which spherically \( \text{TiO}_{2} \) poly crystal’s average dimension was 3–6 nm. The as-prepared composite exhibited enhanced photocatalytic activity in degrading Rh-B organic dye compared with the graphite oxide (19%), mechanical mixture GR + \( \text{TiO}_{2} \) (62%), and \( \text{TiO}_{2} \) nanoparticles (42%), which can be attributed to enhance the electron–holes separation at the hetero-interface. GR–\( \text{TiO}_{2} \) composites also show a superior stability according to the cycling tests. Therefore, the GR–\( \text{TiO}_{2} \) composites are excellent candidates for applications in a number of environmental issues.

The morphology of the nanocrystals formed on the graphene can be tailored by the conditions including reaction time, and the method could be extended to synthesise a wide range of functional nanomaterials. The as-prepared GR–\( \text{TiO}_{2} \) nanocomposites can be used in water treatment, Li-ion battery, dye sensitised solar cells, and other optoelectronic applications.

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