

**Enhanced ultraviolet-visible photocatalysis of RGO/equiaxial geometry TiO<sub>2</sub> composites on degradation of organic dyes in water**

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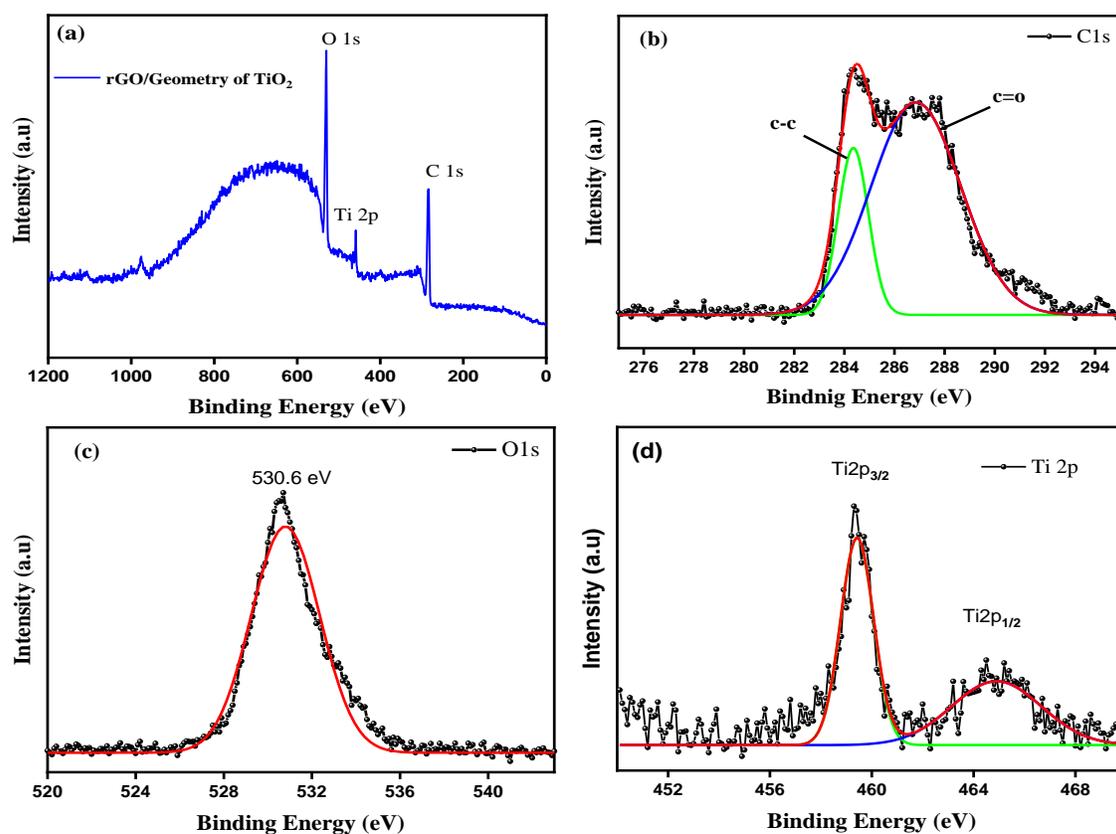
## Preparation of graphene oxide (GO)

Preoxidation: Graphene oxide (GO) was typically synthesized according to Hummers modified. In a three-necked flask, 1 g of graphite powder, 1.25 g of  $K_2S_2O_8$ , 6 mL of concentrated  $H_2SO_4$  and 1.25 g of  $P_2O_5$  were added and stirred at  $80^\circ C$  for 24 h in a water bath at room temperature. After this, the mixture was slowly dispersed in 250 mL of distilled water in a 0.5 L of a beaker, filtered and washed five times with deionized water, and oven-dried at  $60^\circ C$  for 24 h.

Peroxidation: Concentrated  $H_2SO_4$  (60 mL) and  $NaNO_3$  (1 g) were first added to the peroxidised graphite powder, then 7.5 g of  $KMnO_4$  was added to the mixture under continuous stirring (roughly 1.5-2 h) in an ice bath at  $< 20^\circ C$  to obtain a dark green colour. The mixture was continued to stir at room temperature for 96 h. After that 0.5 L of distilled water was slowly added to the prepared mixture and placed for 2 h. The suspension was further treated with 20 mL of 30%  $H_2O_2$  aqueous solution was slowly added to form a golden yellow solution with foaming, followed by 200 mL of 10% HCl solution was added to remove metal ions. Washed with distilled water until getting the pH is close to 7. The precipitate was centrifuged to get a brown viscous liquid, while the water was evaporator through rotatory to obtain a viscous, jelly-like GO. Finally, lyophilization was carried out to obtain a brown GO solid.

## The XPS analysis

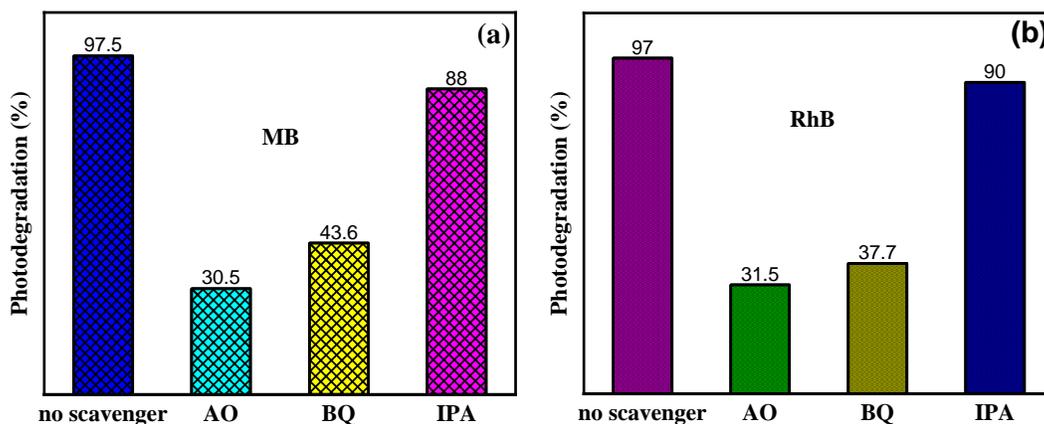
X-ray photoelectron spectroscopy (XPS) is an effective technique to determine surface elemental compositions and chemical states in as-synthesized rGO/equaixial geometry  $TiO_2$  catalysts. The survey spectrum (XPS) as shown in **Figure S1** (a) shows the binding energy (BE) of chemicals located at 288.78, 459.42, and 530.60 eV are attributed to elements of carbon, titanium, and oxygen, respectively. In **Figure S1**(b) the deconvoluted peaks at the BE of 284.06, and 288.88 eV scribed to unique bonds such as C-O and O=C-OH, respectively[1]. Also, the BE peak at about 530.6 eV can be ascribed to the curve fit of O 1s spectra of rGO/equaixial geometry  $TiO_2$  as shown in **Figure S1** (c). In addition, the XPS of Ti 2p reveals two characteristics (BE) peaks situated at 459.4 and 464.9 eV, linked to Ti ( $2p_{3/2}$ ) and Ti ( $2p_{1/2}$ ) in the  $Ti^{4+}$  chemical state [2] as shown in **Figure S1**(d).



**Figure S1.** X-ray photoelectron spectroscopy (XPS) spectra of as-synthesized rGO/equaixial geometry TiO<sub>2</sub> catalysts

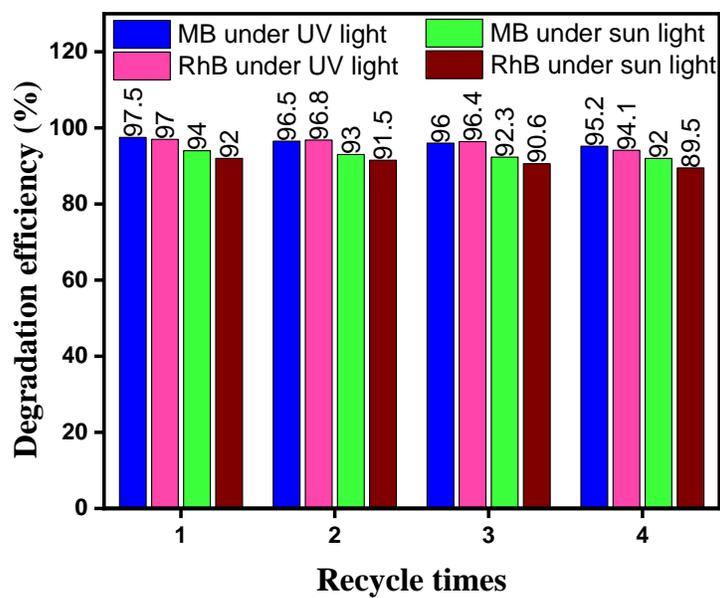
To support the mechanism of photocatalytic degradation, into the role of reactive species involved in the degradation of MB and RhB, active species trapping experiments were conducted. Ammonium oxalate (AO), benzoquinone (BQ), and isopropyl alcohol (IPA) for the quenching of the hole ( $h^+$ ), superoxide radical ( $O_2^{\bullet-}$ ), and hydroxyl radical scavenger ( $\bullet OH$ ), respectively [3]. The photocatalytic degradation of organic dyes with the rGO/equaixial geometry TiO<sub>2</sub> composite was carried out under UV light and sunlight irradiation in the presence of these scavengers and monitored with the help of UV-visible spectroscopy, as shown in **Figure** (S2 a, b). After the addition of AO and BQ in the reaction system, significant inhibition phenomena for the photocatalytic reaction are observed on MB dye that decreased to 51.5 and 49.7% and RhB dye decreased to 46.3 and 43.8% after the addition of the scavenger AO and BQ, respectively. However,

the addition of IPA, suggesting that the dominant reactive species regulating the photocatalytic degradation of MB and RhB are hydroxyl radicals ( $\bullet\text{OH}$ ). It can be found that the photocatalytic degradation of MB and RhB was not affected by the addition of IPA (a quencher of  $\bullet\text{OH}$ ). Therefore, it can be concluded that holes ( $\text{h}^+$ ) and  $\text{O}_2^{\bullet-}$  are the main active species of rGO/equaixial geometry  $\text{TiO}_2$  for MB degradation under UV light and RhB degradation under visible light irradiation.



**Figure S2.** The influence of the scavengers of various active species for rGO/equaixial geometry  $\text{TiO}_2$  composite, MB dye under UV light irradiation (a) and MO dye under sunlight irradiation (b)

For the functional use of the adsorbents, stability and recyclability are essential considerations. The recycling experiment was performed using the composite rGO/equaixial geometry  $\text{TiO}_2$  to assess the composites' stability. The results shown in **Figure S3** presented MB and RhB degradation rates with the rGO/equaixial geometry  $\text{TiO}_2$ , which were 97% and 97.5% after four recycling runs they became 94.1 and 95.2, respectively under UV light. The strong photocatalytic efficiency of rGO/equaixial geometry  $\text{TiO}_2$  was retained, suggesting that under UV light irradiation, rGO/equaixial geometry  $\text{TiO}_2$  was extremely stable. These findings show that when the organic dyes are photodegraded, rGO/equaixial geometry  $\text{TiO}_2$  is very stable.



**Figure S3.** Cycling runs for MB and RhB degradation in the presence of rGO/equaixial geometry Catalyst under UV and sun light.

## References

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3. Yu, H., et al., *Facile construction of novel direct solid-state Z-scheme AgI/BiOBr photocatalysts for highly effective removal of ciprofloxacin under visible light exposure: mineralization efficiency and mechanisms*. J. Colloid Interface Sci., 2018. **522**: p. 82-94.