

## ABSTRACT

Semiconductor mediated photocatalytic treatment of various industrial wastewater using photochemically active catalysts has attracted a significant interest in recent years because it offers the possibility of complete mineralization of harmful pollutants, resulting in  $\text{CO}_2$  and  $\text{H}_2\text{O}$  as final products. The ability of this advanced oxidation technology has been widely demonstrated to remove persistent organic compounds and microorganisms in water as a low-cost, environmental friendly and sustainable treatment technology.

Among the various semiconductor photocatalysts, titanium dioxide has proved itself to be the most suitable material for treating wastewater and industrial effluents because of its biological and chemical inertness, strong oxidizing power, non-toxicity, and long-term stability against photo and chemical corrosion. Yet there are few drawbacks in  $\text{TiO}_2$ , such as quick recombination of photoinduced electron-hole pairs and its low photo response towards visible light. These two inherent drawbacks make it an undesirable candidate for effective photocatalysis. Therefore numerous approaches were attempted to improve the charge transport in  $\text{TiO}_2$  based catalysts such as noble metal loading, metal ion doping, non-metal doping, dye sensitization and also addition of sacrificial reagents (electron donors or hole scavengers).

Another way of improving the photocatalytic activity of  $\text{TiO}_2$  is by incorporating conducting carbon materials especially with graphene or graphene based materials. Graphene oxide (GO) characterized by a layered structure with reactive oxygen functional groups bearing on the basal planes

and edges, is one of the most important derivatives of graphene. The presence of oxygen containing functional groups in GO and reduced GO (RGO) makes them an excellent support to anchor  $\text{TiO}_2$ . Based on the unique properties of graphene, considerable efforts have been made to incorporate graphene into  $\text{TiO}_2$  based composite materials.

A series of reduced graphene oxide supported  $\text{TiO}_2$  (RGOT) nanocomposites with different weight ratio of carbon content was prepared by a simple one pot solvothermal process using  $\text{TiO}_2$  nanoparticles (P-25) and GO as precursors. Physicochemical characterizations reveal that there is a strong chemical interaction between Ti and C through Ti-O-C bonds on the surface of the RGOT nanocomposites. The enhanced charge transfer/separation process resulting from the hybrid RGOT nanocomposite is due to the charge transfer interaction between  $\text{TiO}_2$  and RGO and it is well supported by the PL and EIS spectra.

The photocatalytic activity of RGOT nanocomposites were assessed towards the degradation of the model dye pollutant Rhodamine B in aqueous phase under UV light using an immersion well batch photoreactor. The photodegradation efficiency of the RGOT nanocomposites with different ratio of RGO reveals that  $\text{TiO}_2$  loaded with 20wt % of RGO was most efficient under UV light. About 94% degradation of RhB occurred in 150 min with RGOT-20 under UV light, whereas bare  $\text{TiO}_2$  showed only 62% efficiency after 180 min. The RGOT composites effectively reduced the electron-hole recombination rate compared to bare  $\text{TiO}_2$  which lead to enhanced photocatalytic activity. Also the enhanced activity can be attributed to the large surface area made available by the RGO. It was found that control over the RGO composition in the composite leads to an efficient photogenerated charge carrier separation owing to electron injection from conduction band of  $\text{TiO}_2$  to RGO sheets.

The photocatalytic degradation experiment was optimized in order to achieve maximum efficiency under four applied constraints namely, minimum use of catalyst, maximum possible degradation, lesser irradiation time and near natural pH of the dye solution. The optimal values of the experimental parameters under the related constraint conditions were found using response surface methodology. The regression analysis indicated a good agreement between the experimental and the predicted values which have been discussed in elaborate in the thesis. The photocatalytic degradation of the dye over nanocomposite was found to follow pseudo-first order kinetics. Studies on the influence of electron acceptor such as  $\text{H}_2\text{O}_2$  and  $\text{K}_2\text{S}_2\text{O}_8$  and inhibitors such as  $\text{NaCl}$ ,  $\text{Na}_2\text{CO}_3$  and ethanol on the degradation were also investigated under optimized conditions. Addition a small amount of electron scavengers such as  $\text{H}_2\text{O}_2$  and  $\text{K}_2\text{S}_2\text{O}_8$  along with RGOT-20 showed beneficial effects up to a certain level of concentration on the degradation of RhB. The percentage degradation of RhB was affected in the presence of trace amounts of inhibitors such as  $\text{NaCl}$ ,  $\text{Na}_2\text{CO}_3$  and ethanol. Reusability studies revealed that the RGOT nanocomposite is stable, easily separable and could be reused without loss of efficiency up to four cycles.

Furthermore, the antibacterial activity of RGOT-20 nanocomposite was studied and found to be higher in comparison to bare  $\text{TiO}_2$  photocatalyst against the bacterial model *E.coli* and *P.aeruginosa* under visible light. Coupling  $\text{TiO}_2$  with RGO resulted in a higher photocurrent density and more charge carriers to form reactive species ( $^{\circ}\text{OH}$ ,  $\text{O}_2^{\circ-}$ ) promoting the photo-damaging of the cell membrane of the bacteria. Studies on the influence of inorganic ions such as  $\text{HCO}_3^-$ ,  $\text{Cl}^-$ ,  $\text{SO}_4^{2-}$  and  $\text{NO}_3^-$  were also investigated on the antibacterial property of the nanocomposite.