

Visible light driven mineralization of phenol using FeO co-doped TiO₂ immobilized fibrous carbon from aquatic waste

Monika¹, Pinku Nath¹, Ajit Kumar Sharma^{1*}

¹Department of Chemical Engineering and Physical Sciences, Lovely Professional University, Jalandhar, Punjab, India

Abstract

In the present study, FeO doped TiO₂ photo-catalysts were immobilized onto fibrous carbon fiber (ACFs) via a sol gel method followed by hydrothermal process. The catalytic behavior of TiO₂/FeO-ACF exhibited the highest photo-degradation rate for phenol as compared with pure TiO₂, ACFs and TiO₂/FeO under the visible radiation of light. The Fe (III) atom has been substituted by some of the Ti atoms during the sol-gel process at the in the TiO₂ lattice causing a change in optical absorption. Furthermore, support for ACF has observed with reduction of photo-generated holes and electron recombination, promoting the photocatalytic operation of FeO's loaded TiO₂. The produced ACF as a sorbent has shown very good performance for removing phenol from industrial aquatic waste. For photo-degradation and for sorption sensitivity by combined process with photo-degradation, the maximum extraction of phenol (100 mg / L) was 89.4 and 127.8 mg / g, respectively, at the value of 4 pH with illumination of solar light within 90 Minutes. The photo-degradation efficiency of phenol was 96.1% and 62.4% and 79.5% respectively was achieved to reduce chemical oxygen (COD) with addition of total organic carbon (TOC) and market demand under visible irradiation of light with TiO₂/FeO-ACF, the photo induced hole and electron recombination is possibly restricted and high efficiency in light harvesting due to red shift.

Keywords: visible light; photo-degradation; sorption; phenol; activated carbon fiber;

1. Introduction

A significant group of wastewater pollutants produced by the chemical, petrochemical, paint, clothing, pesticide and food processing industries contains phenol compounds. Regrettably, other conventional methods, such as membrane division, physiochemical or biological approaches and process of photo oxidation and reduction cycle, which considered for incapable for reduction and deactivate ecological damage of aquatic phenol¹. Recently the removal of phenol has been a very interesting and promising option, due to its high preservation ability, simple handling and the high efficiency of phenol deletion by combining sorption and catalytic oxidation-reduction procedures². The aqueous phase photocatalytic degradation through Titanium

dioxide (TiO_2) of phenolic compounds considered as comparatively leisurely method through industrial based application constraints. It includes protection concern, the powdery products with large no of utilization and large energetic caused by ultra-violet radiation. In specific industrial applications, adsorbents and chemical catalyst as a powdery materials resources as a source of problem in industrial waste water drainage. On the other side, powder catalysts are considered to be hard to recycle and can contribute to secondary contamination. TiO_2 or co-doped metal oxide TiO_2 photo-catalyst deposited on high-surface support materials is attractive. The activated carbon fiber (ACF) is a newly developed supporting material with a large surface area. The current study modifies the ACF surface by doping TiO_2/FeO in order to improve their sorption sensitivity and their photo-catalytic properties against aquatic phenol sorption-oxidation.

2. Experimental

The TiO_2 -ACF and TiO_2/FeO -ACF catalytic filters have been developed in the in-situ metal doping process, using a modified sol gel system. During the sol-gel process used for TiO_2/FeO -ACF preparation, Iron nitrate ($\text{Fe}(\text{NO}_3)_2 \cdot 6 \text{H}_2\text{O}$) was filled with the titanium Tetraisopropoxide (TIP) solution addition ACF. In addition to the 80 mL of ethanol for hydroxylation, GAA as weak acid in the amount of 12.38 mL was mix in the titanium solution source at the amount of 6.99 mL TIP solution. For complete hydrolysis, a mixture stimulated for 0.4 h with the temperature of 30°C . In the above-mentioned TIP solution, the mixture sample 75 mL of $\text{Fe}(\text{NO}_3)_2 \cdot 6 \text{H}_2\text{O}$ (0.25 weight percent) and addition of deionized H_2O mix to it. Subsequently, the ACF felt was used as a substrate to deposit TiO_2/FeO nanoparticles in the range of 3 cm x 3 cm. Then fibrous carbon was mix in above homogeneous mixture for immobilization of nano-composite of FeO/TiO_2 . Subsequent to sonicating with 0.4 h, the ACF substrate be drained and clean with the help of EtOH to surplus of TIP source of titanium dioxide linking with fibrous carbon which was dry in the temperature of 80°C for 12 h. The immobilized TiO_2/FeO ACF was calcinated at 500°C for 2 hour in the nitrogen atmosphere and the TiO_2/FeO -ACF sample was collected with improve crystallinity structure of metal oxides onto fibrous carbon.

The synthesis of titanium dioxide nano particles and NPs of TiO_2/FeO nanocomposites was done by the above process, except that no ACF element was added².

3. Result and Discussion

3.1.1. The absorption of optical properties

Figure.1a The synthesized optical amalgamation of ACF, TiO_2 -ACF and TiO_2/FeO -ACF complex shows a spectrum at the series of 200-800 wave length (nm). The spectrum of ultra -violet for ACF reveals to carbon-based ACF were entirely absorb illumination of visible light and rays of UV radation². On the other hand, the TiO_2 doped ACF (TiO_2 -ACF) had increased absorption at 375–440 nm and showed improvement of

photocatalytic property at the illumination of solar radiation region compare with the titanium dioxide. This knows how to be accredited to the movement for the transition of charge and excited reduction with energy of photon, which outcome in less energy gap between VB and CB as compared with titanium dioxide. The synthesized $\text{TiO}_2/\text{FeO-ACF}$ absorption of optical spectra show an increase in the absorption of the wavelengths between 405 and 585 nm. The major increase in absorption of optical spectrum inside the visible region of $\text{TiO}_2/\text{FeO-ACF}$ resulted from the involvement of the iron particles ' a resonance of plasmon spread on the TiO_2 surface². The resonance of plasmon at iron particles animated the electrons for TiO_2 with the valence band of TiO_2 and stimulated them the excited electrons from the valence band to the conduction band of TiO_2 ^{1, 2}. The development of $\text{TiO}_2/\text{FeO-ACF}$ light absorption be also appropriate to the function of the included FeO which bonded to TiO_2 throughout Fe-O-Ti bonding most important to oxygen vacancies and to Ti^{3+} arrangement in the TiO_2 lattice². Consequently, the designed Ti^{3+} similarly represented as an transitional component to develop the transfer of electrons from the valence band to the conduction band of TiO_2 , causative to the improvement for $\text{TiO}_2/\text{FeO-ACF}$ in the optical characteristic properties.

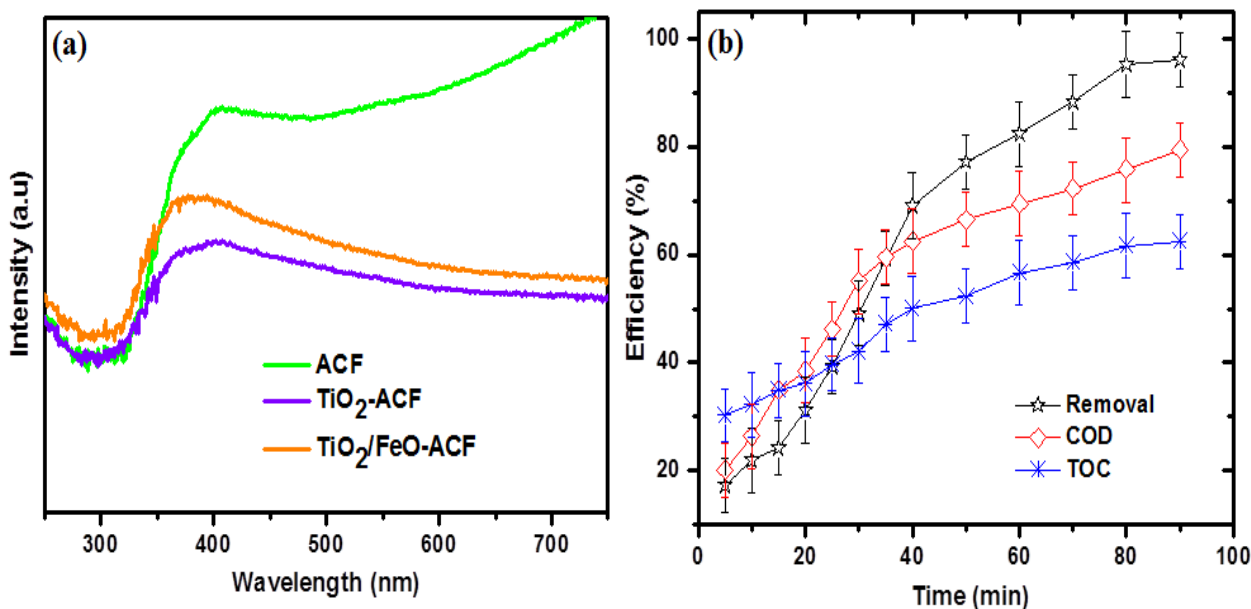


Figure 1 Spectrum of ultra-violet for composites (1a) with Variation of TOC, COD and phenol elimination recital through various time periods of radiation with $\text{TiO}_2/\text{FeO-ACF}$ at pH 4 under visible light irradiation.

3.1.2. Removal efficiency and degree of mineralization

The use of TiO₂/FeO-ACF in visible light radiation with variations in phenol removal quality in terms of TOC and COD resulted in a high level of phenol mineralization (**Fig. 1b**). After only 90 min of visible light irradiation, the efficiency of phenol photo-degradation was achieved 96.1%, where the maximum COD and TOC reduction were around 79.5 and 62.4 %, respectively. This result shows that ACF immobilized with TiO₂/FeO has made an important photo-catalytic contribution for the mineralization of phenol to the adsorptive elimination. As mentioned earlier, phenol can be removed with TiO₂/FeO-ACF effectively and cost-effectively.

4. Conclusion

A visible light driven photo-catalytic filter was fabricated by immobilization with TiO₂/FeO nanoparticles onto ACF via a sol gel method followed by hydrothermal process. The sorption affinity of phenol on the surface of TiO₂/FeO-ACF is completely depending on two types of interactions by electrostatic and dispersive phenomena. The improved photo-degradation of phenol under visible light irradiation had been attributed to the dispersion of TiO₂/FeO particles on the surface of the ACF, which increased the electron-hole pair separation efficiency of TiO₂/FeO-ACF. The novel photo-catalytic filter TiO₂/FeO-ACF reveals that, after a 90 min visible light radiation at an initial pH of 4, it has a maximum phenol removal efficiency of 96.1%, decreases TOC and COD by 62.4% and 79.5% respectively.

References

- [1] E.O. Igbinosa, E.E. Odjadjare, V.N. Chigor, I.H. Igbinosa, A.O. Emoghene, F.O. Ekhaise, N.O. Igiehon, O.G. Idemudia, *The Scientific World Journal*, 460215 (2013) 1-11.
- [2] A. Karci, *Chemosphere* 99 (2014) 1–18.
- [3] X. Li, S. Chen, X. Fan, X. Quan, F. Tan, Y. Zhang, J. Gao, *J. Colloid Interface Sci.* 447 (2015) 120-127.
- [4] K.Ji, H. Dai, J. Deng, H. Zang, H. Arandiyani, S. Xie, H. Yang, *Appl. Catal. B Environ.* 168-169 (2015) 274–282.
- [5] J. Liu, Z. Zhao, P. Shao, F. Cui, *Chem. Eng. J.* 262 (2015) 854–861.
- [6] J. Tian, Z. Zhao, A. Kumar, R.I. Boughton, H. Liu, *Chem. Soc. Rev.* 43 (2014) 6920-6937.

- [7] J. Chen, F. Qiu, W. Xu, S. Cao, H. Zhu, Appl. Catal. A Gen. 495 (2015) 131–140.
- [8] M. Dahl, Y. Liu, Y. Yin, Chem. Rev. 114 (2014) 9853-9889.
- [9] A.T. Raji, E.B. Lombardi, Physica B 464 (2015) 28–37.
- [10] Y. Miao, Z. Zhai, L. Jiang, Y. Shi, Z. Yan, D. Duan, K. Zhen, J. Wang, Powder Technol. 266 (2014) 365–371.

