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Synthesis, Characterization and Photocatalytic Activity of Electrospun Zinc and/or Titanium Oxide Nanofibers for Methylene Blue Degradation

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Abstract : Synthetic dyes dispersed in water cause environmental damage and have harmful effects on human health. Methylene blue (MB) is broadly used as a dye in the textile, pharmaceutical, printing, cosmetics, leather, and food industries. The complete removal of MB is difficult due to the presence of aromatic rings in its structure. The present study is focused on electrospun nanofibers (NFs) with engineered architecture and surface to be used as catalysts for the photodegradation of MB. Ti and/or Zn oxide NFs are produced by electrospinning precursor solutions with different Ti: Zn molar ratios (from 0:1 to 1:0). Subsequent calcination and cooling steps are operated at fast rates to generate porous NFs with capture centers to reduce the recombination rate of the photogenerated charges. The comparative evaluation of the NFs as photocatalysts for the removal of MB from an aqueous solution with a dye concentration of 15 µM under UV irradiation shows that the binary (wurtzite ZnO and anatase TiO_2) oxides exhibit higher catalytic activity compared to ternary ($ZnTiO_3$ and Zn_2TiO_4) oxides. The higher band gap and lower crystallinity of the ternary oxides are responsible for their lower photocatalytic activity. It has been found that the optimal load for the wurtzite ZnO is 0.66 mg mL^{-1}, obtaining a degradation rate of $7.94.10^{-2}$ min^{-1}. The optimal load for anatase TiO_2 is lower (0.33 mg mL^{-1}) and the corresponding rate constant (1.12×10^{-1} min^{-1}) is higher. This finding (higher activity with lower load) is of crucial importance for the scaling up of the process on an industrial scale. Indeed, the anatase NFs outperform even the commonly used P25-TiO_2 benchmark. Besides, they can be reused twice without any regeneration treatment, with 5.2% and 18.7% activity decrease after second and third use, respectively. Thanks to the scalability of the electrospinning technique, this laboratory-scale study provides a perspective towards the sustainable large-scale manufacture of photocatalysts for the treatment of industry effluents.

Keywords : anatase, capture centers, methylene blue dye, nanofibers, photodegradation, zinc oxide
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