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Photodecolorization of direct yellow 86 (2-Solamine) by using zinc oxide nanosized deposited on glass beads

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Abstract

In this research, photocatalyticdecolorization of Direct yellow 86(2-Solamine) in water in alkaline and neutral media under external UV light irradiation by zinc oxide nano-sized catalysts on granule glass as a semiconductor photocatalyst is described. The photodecomposition rates have been found to be different by applying the different atmospheres through degradation process. The effect of four type atmospheres including air, nitrogen, oxygen and argon was investigated. Kinetics of decolorizaton was investigated and pseudo-first order kinetic was found under oxygen and argon atmosphere. Finally it was found that photodecomposition using ZnOnano-sized layered on glass is a new alternative route for efficient wastewater treatment.

Keywords: Nano-sized zinc oxide, photodecomposition, photocatalyst, sol-gel.

Introduction

Textile industries produce large amount of colored dye effluents which are toxic that induce a lot of damage to the environment. Various chemical and physical methods such as precipitation, adsorption, air stripping, flocculation, reverse osmosis and ultrafiltration can be used for removal of these waste waters. Semiconductor photocatalysis is a promising technique, for photodegradation of various hazardous chemicals that are encountered in waste waters. The major advantage of this technique is that, it can degrade (detoxify) various complex organic chemicals, which has not been affected by some other methods. The general classes of compounds that have been degraded by semiconductor photocatalysis include: alkanes, haloalkanes, aliphatic alcohols, carboxylic acids, alkenes, aromatics, halo aromatics, polymers, surfactants, herbicides, pesticides and dyes. Heterogeneous photocatalytic oxidation (PCO) is an effective method to remove low concentrations of organic contaminants (Lakshmi *et al.,* 1997; Mills *et al.,* 1997; Coutoe*t al*., 2002; Habibi*et al*., 2005, 2006; Ebrahimi 2008). In a waste treatment application of photocatalyst it would be more suitable if the catalyst was immobilized, so the material would not have to be separated from solution. Thin films are one of the most important materials due to technological applications (Blount *et al.,* 2001). It has also been reported that ZnO exhibited higher activity than TiO_2 in the photocatalytic degradation of specific dyes (Gouvêa*et al.,* 2000; Kansal*et al.,* 2007; Sobana*et al.,* 2007; Barreca*et al*., 2009). Thin film photocatalysts with their high photocatalytic ability, high stability, and convenientreuse;have received more and more attention (Habibi*et al.,* 2010a, 2010b, 2009a, 2009b, 2008; 2011a, 2011b, 2011c, 2011d). As part of our goal to produce zinc oxide thin film on granule glass by sol-gel coating method, in this paper, a commercial granule glass was successfully used as substrate to prepare nano-sized zinc oxide thin film. The binary zinc oxide /Glass films have been employed in photocatalyticdecolorization of direct yellow 86 in aqueous solutions. Decolorization of dye is measured by spectrophotometer (Perkin Elmer, Lambda25).

Experimental

General

All the chemicals were analytic grade reagents without further purification and purchased for Merck Company ($Zn(CH_3COO)_2.2H_2O$ 99.5% , HCl 37% , NaOH 98%). The dye (C.I. Direct yellow 86) was obtained from Youhao (China). The coating substrate (granule glass) was pre-heated at 275°C for 10 min in air after each coating. The sol-gel coating was made usually a day after the sol solution was prepared.

Film deposition: Nanosized zinc oxide thin film was supported on glass beads (diameter 3mm) by the method as follows. Glass beads were pretreated with dilute hydrofluoric acid (5% v/v) for 24 h and washed thoroughly with distilled water, making a rough surface for better contact of zinc oxide thin film on it. Zinc oxide binary sol was added to the glass beads placed in a funnel and the excess of it was removed. They were subsequently placed in the furnace and pre-heated at 275°C for 10 min and then post-heated at 450°C for 1 hour. The deposition was repeated for 5 times to obtain films with different thickness (Ebrahimi, 2008).

Photocatalytic measurement

The photocatalyticdecolorization experiments were carried out in a simple oxidation reactor, placed in a 25°C water bath. 5 g of granule glass with 5-layer that placed in 25 mL 25 ppm dyes solution and was irradiated with four 8W lamp (Philips; 365nm) placed 5 cm above the solutions. For pH adjustment 0.01 M NaOH and HCl solution was used to reach desired pH. Concentration was measured by spectrophotometer (Perkin Elmer, Lambda25). In all experiments 25 mL of 25 ppm dyes solution were used with stirring during the irradiation.

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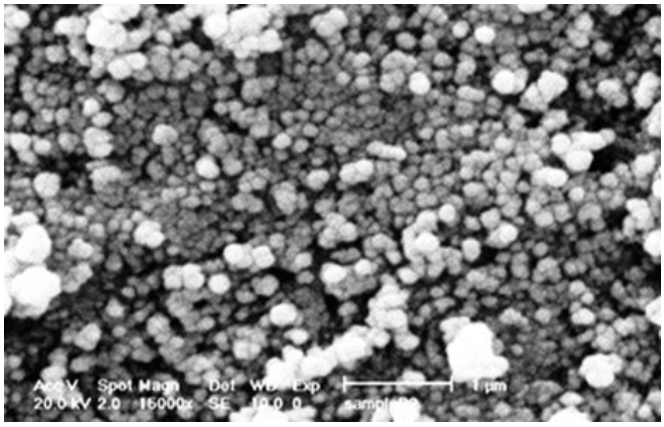
Results and discussion

Characterization techniques for thin films

The structure and crystalline size were determined by XRD diffraction (Bruker D8 advanced X-ray diffractometer: Cu kα radiation). X-ray diffraction shows zinc oxide structure with c-axis orientation (002) (Ebrahimi, 2008). The surface of the films was observed by scanning electron microscopy (SEM) with a Philips XL30 (Fig.1).

Fig. 1. SEM of Nano-sized zinc oxide thin film Supported on glass beads.



Photocatalytic activity

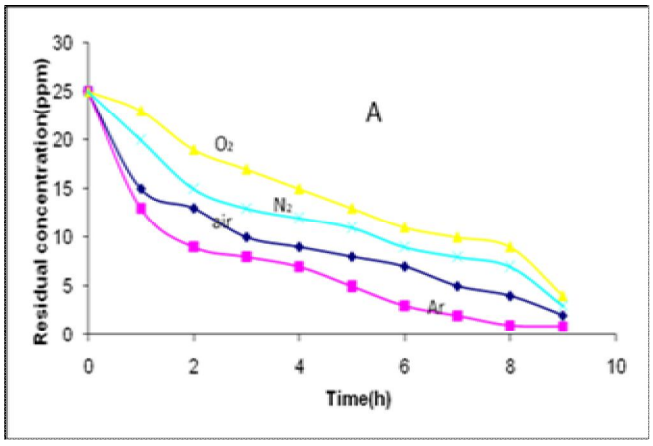
Evaluation of the granule glass coated with nano-sized zinc oxide as potential photocatalyst for water pollutant purification was based on the decolorization of a dye. Fig.2 show the decolorization of Direct Yellow 86 dye (25 ppm) under UV irradiation (365nm) on granule glass coated with nano-sized zinc oxide with 5-layers at alkaline(Fig.2 A) and neutral pH(Fig.2 B) respectively.

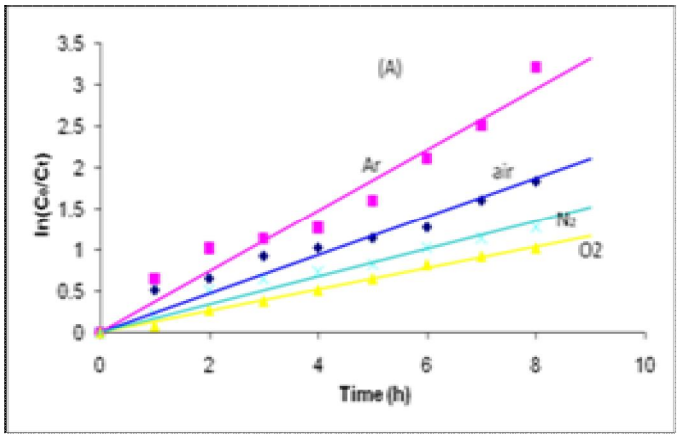
As shown in Fig.2 in alkaline pH(A), the decolorization rate is decreased in order of Ar, air, N_2 and O_2 respectively while in neutral pH(B), the order of decolorization rates is O_2, air, Ar and N_2 respectively. For evaluation of decolorization rate constant, the $\ln(C_0/C_t)$ versus time were sketched as seen in Fig.3A and 3B.

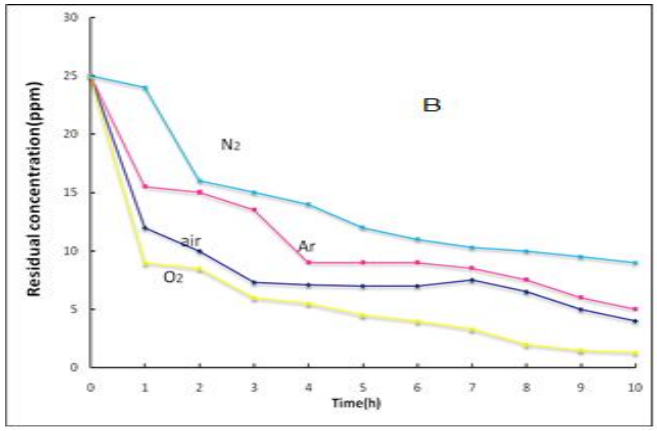
As depicted in figures of 3A and 3B, both in alkaline and in neutral medium, the plots are relatively linear and therefore fitted by pseudo-first order kinetics under O_2 and N_2 atmosphere. For other atmosphere pseudo-first order kinetics is not fitted for dye decomposition. The rate

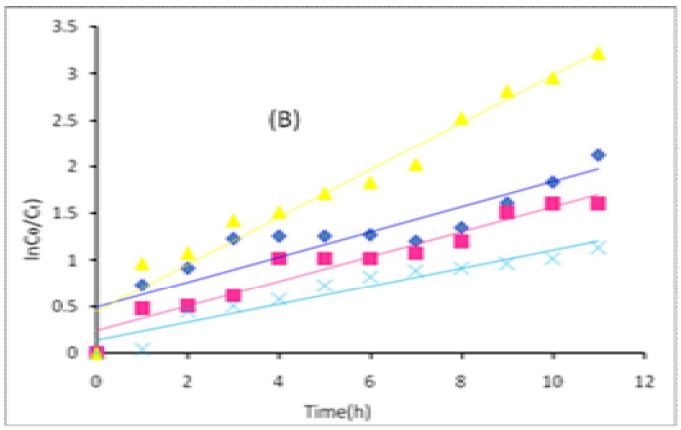
Fig. 2. Residual concentration of Direct Yellow 86 dye (25ppm), in de-ionized water after photocatalytic decolorization under UV irradiation in alkaline medium(pH=10)(A) and neutral pH(B) under various atmosphere.

Fig.3.ln(C_0/C_t) versus time(h) for photocatalytic decolorization under UV irradiation in alkaline medium(pH=10)(A) and neutral pH(B) under various atmosphere.









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constants in alkaline and neutral media under O_2 and N_2 are 0.13 h^{-1}, 0169 h^{-1} and 0.253 h^{-1}, 0.098 h^{-1}respectively.

Conclusion

In this work, we reported preparation of nano-sized zinc oxide thin film on glass beads. The deposition was repeated for 5 times to obtain films with different thickness. Then photocatalytic activity of it, at various atmospheres: air, nitrogen, oxygen and argon, was investigated. The titled dye was decolorized efficiently by use of this photocatalytic system. Among considered atmospheres, orders of kinetics were found that to be pseudo first order at nitrogen and oxygen. Kinetics of decolorizaton was investigated and pseudo-first order kinetic was found under O_2 and N_2 atmosphere. Easily preparation, handling and separation of photocatalyst from solution are some advantages of this system. Improvement of photocatalytic activity of this system by doping of some metal on catalyst surface is under investigation in our library.

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