Journal of Environmental Chemical Engineering 4 (2016) 319–327

Contents lists available at ScienceDirect

Journal of Environmental Chemical Engineering

journal homepage: www.elsevier.com/locate/jece

Facile photocatalytic reactor development using nano-TiO_2 immobilized mosquito net and energy efficient UVLED for industrial dyes effluent treatment

Wan-Kuen Jo[a], Rajesh J. Tayade[a,b,*]

[a] Department of Environmental Engineering, Kyungpook National University, 80 Daehek-Ro, Bukgu, Daegu 702-701, Republic of Korea
[b] Discipline of Inorganic Materials and Catalysis, Central Salt and Marine Chemicals Research Institute, Council of Scientific and Industrial Research (CSMCRI-CSIR), G. B. Marg, Bhavnagar, 364002 Gujarat, India

A R T I C L E I N F O

Article history:
Received 21 August 2015
Received in revised form 30 October 2015
Accepted 16 November 2015
Available online 30 November 2015

Keywords:
TiO_2-coated mosquito net
Photocatalysis
Ultraviolet light emitting diode (UVLED)
Photocatalytic reactor
Dyes

A B S T R A C T

The degradation of dyes present in water has been widely studied using well established photocatalytic process using various nanosized photocatalysts in the past. After the treatment of water the release of nanoparticles in the environment could cause adverse effects on the human health and ecosystem. The present study focuses on the facile development of highly adhered, TiO_2 immobilized photocatalytic surface using low cost support materials such as mosquito net to avoid adverse effect of nanosize photocatalyst released after water treatment. A simple photocatalytic reactor using TiO_2 coated mosquito net and ultraviolet light emitting diodes (UVLEDs) was fabricated and used to study photocatalytic degradation of dyes (methylene blue (MB), malachite green (MG), direct blue-15 (DB), and amaranth (AM)). The photocatalytic degradation of methylene blue, malachite green, direct blue-15 and amaranth dye was obtained 93%, 88%, 94% and 85% respectively using the TiO_2 coated mosquito net under irradiation of ultraviolet light for 4 h. Furthermore, the effects of the initial concentration, number of UVLEDs used, and addition of H_2O_2 on the degradation of MB were also studied to optimize the experimental conditions.

1. Introduction

Photocatalysis using semiconductive materials is widely applied in environmental purification and energy science [1]. There are different semiconductive materials such as zinc oxide, tin oxide, zinc sulfate, cadmium sulfide, tungsten trioxide, and titanium dioxide [2–5]. Among these, titanium dioxide is the most promising photocatalyst, mainly for photocatalytic degradation of contaminants present in air and water [6–8]. In the last few decades, extensive research has been carried out to explore the photocatalytic degradation of various pollutants present in air and water using TiO_2 as a photocatalyst [6–8]. The focus on TiO_2 is because of its specific properties such as powerful oxidation strength, chemical stability, non-toxicity, low cost, and availability in large amounts. Also, TiO_2 has higher photocatalytic degradation efficiency than other photocatalysts. However, the use of TiO_2 particles in photocatalytic pollutant degradation applications is not feasible because of the high cost of the filtration facilities required for separating and recovering the catalyst after the degradation of pollutants and the risk of releasing TiO_2 particles into the atmosphere.

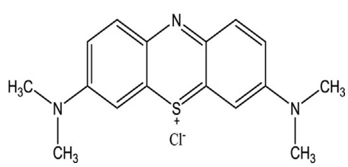
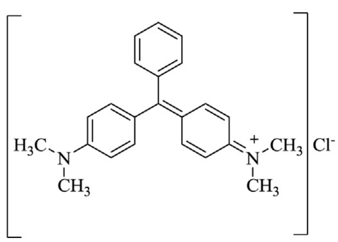
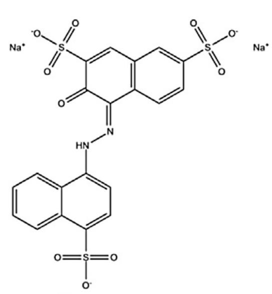
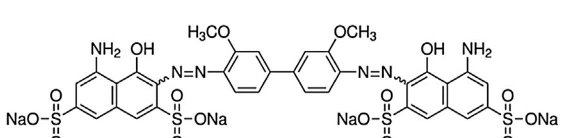
Photocatalytic reactors for the aqueous phase photocatalytic degradation of pollutants are typically based on a catalyst-suspended slurry system [6,9–12]. These include annular reactors and immersion well reactors. The advantages of these reactors are their simple design; moreover, the suspended catalyst provides a higher surface area for the adsorption and degradation of pollutants [11,12]. However, this type of reactor has the drawback of low energy utilization, and it is difficult to attain uniform irradiance of the total catalyst surface and to separate or recover the photocatalyst after the reaction. As the particle size of the TiO_2 is on the nanometer scale, these TiO_2 particles have an adverse of on the human and ecological health when released into the environment. To avoid the separation of the photocatalyst particles from the reaction mixture, efforts have been made to immobilize the TiO_2 photocatalyst on an inert support to overcome the disadvantage of the suspended catalyst-based slurry system for

* Corresponding author at. Present address: Discipline of Inorganic Materials and Catalysis, Central Salt and Marine Chemicals Research Institute, Council of Scientific and Industrial Research (CSMCRI-CSIR), G. B. Marg, Bhavnagar, 364002 Gujarat, India.
E-mail addresses: rtayade@gmail.com, tayade@csmcri.org (R.J. Tayade).

http://dx.doi.org/10.1016/j.jece.2015.11.024
2213-3437/

safe and practical applications. Because of their interesting chemical, electrical, and optical properties, these films have been studied extensively. These films have been synthesized using various chemical methods such as hydrothermal, sol–gel, chemical vapor deposition, metal organic vapor deposition, liquid phase deposition, and deposition, and physical methods such as physical vapor deposition, electrophoretic deposition, RF sputtering, and spin-coating [13–22]. It is very important for the thin film to have an appropriate thickness and phase composition to obtain photocatalytic activity at the surface of the thin film. Also, the adherence of the coated TiO_2 needs to be high so that it can be used repeatedly. TiO_2-coated thin films have been used for the photocatalytic degradation/decolorization of various dyes such as reactive black, malachite green (MG), methylene blue (MB), indanthrene golden orange dye, methyl orange, and rhodamine B using various sources of irradiation such as a solar simulator or conventional ultraviolet mercury lamp; recently, a few reports utilized ultraviolet light-emitting diodes (UVLEDs) [23–25].

Table 1
Molecular structures and dye properties.

Dye name and molecular structure	Chemical properties of dye	
Methylene Blue 	Chemical formula	$C_{16}H_{18}ClN_3S$
	Molecular weight	319.85 g/mol
	Maximum absorption	664 nm
	Class	Thiazin dyes
	Solubility	Soluble
Malachite Green 	Chemical formula	$C_{23}H_{25}ClN_2$
	Molecular weight	364.91 g/mol
	Maximum absorption	628 nm
	Class	Triarylmethane
	Solubility	Soluble
Amaranth 	Chemical formula	$C_{20}H_{11}N_2Na_3O_{10}S_3$
	Molecular weight	604.47 g/mol
	Maximum absorption	520 nm
	Class	Azo
	Solubility	Soluble
Direct Blue 15 	Chemical formula	$C_{34}H_{24}N_6O_{16}S_4Na_4$
	Maximum absorption	992.8 g/mol
	Absorption maximum	610 nm
	Class	Azo
	Solubility	Soluble