

Planar photoelectrocatalytic (PEC) device based on free-standing TiO₂ nanotube membranes

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Titania TiO₂ is a cheap, non-toxic and stable semiconductor photocatalyst, which can break down most kinds of refractory organic pollutants, such as detergents, dyes, legionella, pneumophila, pesticides and herbicides etc. [1-4]. When the small titania photocatalyst particles are applied as suspensions in water or wastewater slurry-type reactors, the catalyst leaching, settling and the need for eventual catalyst separation by filtration have to be carried out. The cost of the separation might invalidate the claimed energy savings for the solar-induced decontamination process due to the small particle size of the used photocatalyst TiO₂ nanoparticles.

An alternative facile method to improve the PC activity is to apply an external bias voltage on the photocatalyst, in which the electric field can draw the photo-generated electrons away via the external circuit, leaving the holes for mineralization of organic pollutants [5]. Therefore, the probability of the rapid recombination of electron-hole pairs is largely reduced and the photo-degradation ability for the PEC can be enhanced furthermore.

In this paper, a large-size, crystallized and free-standing TiO₂ nanotube membrane was prepared through a two-step anodization technique [6-7]. The cross-section image of Scanning Electronics Microscope (SEM) of the membrane is present in Fig.1a. It can be seen that the membrane thickness is ~ 20 μm with the nanotube diameter equal to ~ 100 nm (the inset of fig1a). A prototype device based on the free-standing membrane is assembled to investigate the photoelectrocatalytic characteristics under ultra-violet (UV) illumination at room temperature. Figure 1b is a photograph of the packaged device, where the Au electrodes on the silicon substrates can be observed through the semi-transparency membrane underneath a quartz glass. Two openings (diameter = 0.8 mm) on the glass are exposed to let external organic substances interacting with the membranes and the schematic degradation setup is shown in Fig.2a. The PEC activity of the TiO₂ nanotube array membrane was evaluated by measuring the degradation rate of Methylene Blue (MB) dye (20 mg/l). In the dark environment, the spectra of visible light absorption of the solution show no variation during 180 minutes. Under UV illumination with applied voltage (0, 0.2, 0.5 V), the concentrations of MB (20 mg.L⁻¹) are linearly decreased to between 12 and 15 mg.L⁻¹. It can be observed in fig.2b that the optimized applied voltage is 0.2 V for the photoelectrocatalytic degradation of the MB solution and the MB concentration is decreased about 40% as compared with initial concentration after 180 minutes. The optimized result at 0.2 V might be due to the competition between the design of comb-drive electrode gap and the hole-electron separation.

In summary, we have experimentally demonstrated a novel photoelectrocatalytic (PEC) reactor with free-standing membrane titania nanotube arrays (TNAs) as photoelectrocatalytic electrode. The configuration of membrane reactor offers high degradation efficiency in comparison to the traditional bulk reactor. This technique provides a possible process route for large scale water remediation with excellent stability, reliability and

avoiding the photocatalyst filtration.

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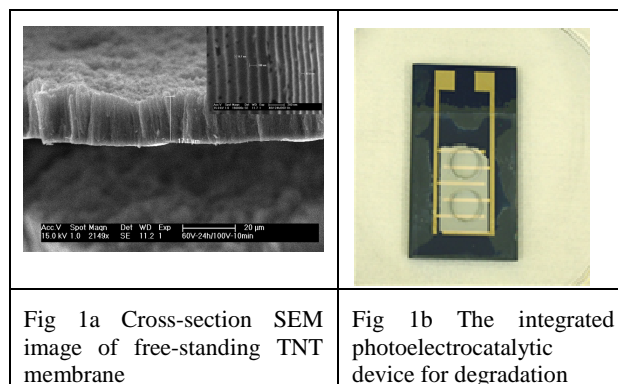


Fig 1a Cross-section SEM image of free-standing TNT membrane

Fig 1b The integrated photoelectrocatalytic device for degradation

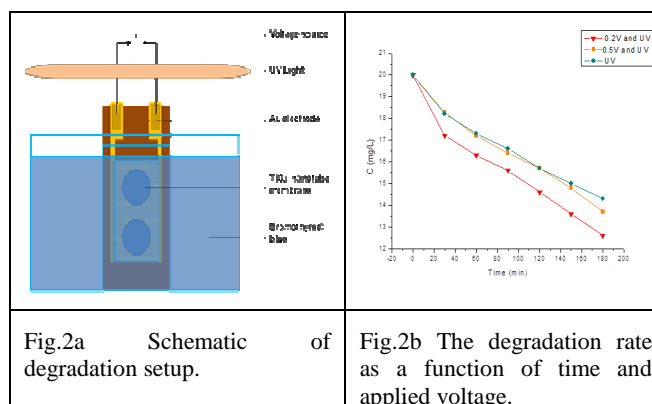


Fig.2a Schematic of degradation setup.

Fig.2b The degradation rate as a function of time and applied voltage.