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Bismuth tungstate coating on polyester fabric modified with dopamine for photocatalytic property under visible light irradiation

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ABSTRACT

Bi_2WO_6 particles were grown onto the polyester fabric modified with dopamine through a facile dip-coating method. The chemical composition, surface morphology and crystal structure of the Bi_2WO_6 coated polyester fabric modified with dopamine were characterized by X-ray photoelectron spectroscopy (XPS), scanning electron microscopy (SEM) and X-ray diffraction (XRD). The photocatalytic activity was evaluated by the degradation of methylene blue (MB) and acid orange 7 (AO7) under visible light irradiation. The influences of dopamine concentrations on the degradation efficiency of MB and AO7 were investigated. Optical absorptions of the Bi_2WO_6 coated polyester fabric modified with dopamine before and after degrading the dyes were studied. Adhesive strength between the Bi_2WO_6 coating and the polyester fabric modified with dopamine was evaluated. The tensile strength of the Bi_2WO_6 coated polyester fabric modified with dopamine was also examined. The results show that the Bi_2WO_6 particles are uniformly coated on the surface of the polyester fabric modified with dopamine. The Bi_2WO_6 coated polyester fabric modified with dopamine exhibits excellent photocatalytic activity with degradation efficiency of 97.7% of MB and 96.8% of AO7, respectively. The largest degradation efficiency is obtained when concentration of dopamine is 3 g/L. In addition, the Bi_2WO_6 coating and the polyester fabrics modified with dopamine not only improve the adhesive strength but also improve the breaking strength.

1. Introduction

Semiconductor photocatalytic oxidation technique has been a promising and green method in wastewater treatment containing organic pollutants [1]. Recently, the semiconductor photocatalysts such as TiO_2 and ZnO, have been widely investigated due to their excellent photocatalytic activity, photochemical stability, nontoxicity and low-cost. Unfortunately, these photocatalysts exhibit photoactivity only under ultraviolet light excitation because of their wide bandgap, which means that only about 3–5% solar energy arriving at the Earth's surface can be utilized [2]. Bismuth tungstate (Bi_2WO_6), as one of the simplest members of the Aurivillius oxide group constructed by alternating $(Bi_2O_2)^{2+}$ layers and perovskite-like $(WO_4)^{2-}$ layers and with a narrow band gap, was discovered to possess higher visible-light-driven photocatalytic activity on water treatment [3]. Nowadays, Bi_2WO_6 photocatalysts have been prepared and a great progress has been achieved [4]. Various methods have been used to prepare Bi_2WO_6 photocatalysts, such as microwave-solvothermal method [5], electrospinning [6], hydrothermal methods [7] and solid state reactions [8].

However, Bi_2WO_6 photocatalysts are also easily agglomerated and it is difficult for Bi_2WO_6 photocatalysts to be separated and collected from reaction system. Therefore, it is promising to immobilize the photocatalysts on a stationary and solid support. Accordingly, Bi_2WO_6 photocatalysts have been coated on the supporting materials such as soda-lime and indium-tin oxide (ITO) glass [9] and reticular stainless steel [10]. Textiles possess excellent properties such as the flexibility, relative stability, good resilience and low-cost. Therefore, textiles have been widely used as substrates for TiO_2 and ZnO catalysts to provide photocatalytic activity [11–13]. However, it has not been reported that Bi_2WO_6 are coated on textiles for photocatalytic application.

In addition, the adhesion strength between the coating and the textiles has a vital role for their stability. The coating may easily fall off the textiles if the adhesion strength between the coating and the textiles is relatively weak. Thus, it is very important to study the adhesion strength between the coating and the textiles to ensure the stability of the coating.

It has been reported that polydopamine films could be formed on the surface of materials by self-polymerization of dopamine to achieve the surface modification of the materials. Dopamine comprises alkylamine and catechol functionalities, can self-polymerize at slightly basic pH to form polydopamine (PDA) which is prone to adhere on almost all types of surfaces easily [14]. Up to date, dopamine has been

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used to modify the surface of various materials to improve the adhesion of the coating on substrates [15,16].

To the best of our knowledge, there are no reports on the modification of textile with dopamine prior to Bi_2WO_6 deposition on textiles. In this study, Bi_2WO_6 particles were coated on polyester fabric after being pretreated with dopamine by a simple dip-coating method. The Bi_2WO_6 coated polyester fabrics modified with dopamine were characterized by XPS, SEM and XRD. The photocatalytic activity of the Bi_2WO_6 coated polyester fabric modified with dopamine was performed for the degradation of methylene blue (MB) and Acid orange 7 (AO7) under visible light irradiation. In addition, the influences of dopamine concentrations on the degradation efficiency of MB and AO7 were investigated. Optical absorptions of the Bi_2WO_6 coated polyester fabric modified with dopamine before and after degrading the dyes were also studied. The washing fastness of the Bi_2WO_6 coated polyester fabric modified with dopamine was examined. Furthermore, the breaking strength and elongation at break of the Bi_2WO_6 coated polyester fabric with dopamine modification were carried out.

2. Experimental

2.1. Materials and reagents

Plain weave 100% polyester fabric (warp density of 50 threads/cm and weft density of 34 threads/cm, 75 g/m^2) in white color was used as the substrate. $Bi(NO_3)_3\cdot 5H_2O$, $Na_2WO_4\cdot 2H_2O$, NaOH, HNO_3 and methylene blue (MB) were purchased from Kelong chemical reagent factory, China. Acid orange 7 (AO7) was obtained from Shanghai Titan Scientific Co., Ltd. Fig. 1 shows the chemical structures of MB and AO7. Dopamine was purchased from Xiya Reagent Co., Ltd. All the chemicals were of analytical grade without further purification.

2.2. Modification of polyester fabric with dopamine

Polyester fabric (5 cm × 5 cm) was cleaned with the solution containing ethanol and acetone ($V_{ethanol}$: $V_{acetone}$ = 1:1) at 50 °C for 30 min under ultrasonic stirring and then dried at 80 °C. Dopamine (0.01–0.9 g) was dissolved in the Tris buffer solution (100 mL). The pH value of the solution was adjusted to 8.5. Polyester fabrics were then dipped into the solution of dopamine and the mixture was kept at ambient temperature for 24 h. After that, the polyester fabrics were taken out and rinsed with deionized water for several times.

2.3. Bi_2WO_6 particles coating on polyester fabric modified with dopamine

0.2 g self-made-prepared Bi_2WO_6 in our laboratory was dissolved in 50 mL deionized water. Subsequently, the polyester fabrics with dopamine modification were immersed into Bi_2WO_6 suspension and then shaked in the shaker at room temperature for 2 h. Finally, the obtained fabrics were washed with deionized water and then dried in oven at 80 °C. For comparison, Bi_2WO_6 particles were also coated on the polyester fabric without pretreatment of dopamine. In detail, Bi_2WO_6 particles were synthesized by the following procedures. 2.4250 g $Bi(NO_3)_3\cdot 5H_2O$ was dissolved in 20 mL HNO_3 (4.0 M) solution and 0.8250 g $Na_2WO_4\cdot 2H_2O$ was dissolved in 30 mL NaOH (2.0 M) solution. After that, the solution of Na_2WO_4 was dropwise added into the solution of $Bi(NO_3)_3$ and then the mixed solution of $Bi(NO_3)_3$ and Na_2WO_4 was stirred under magnetic stirring for 30 min. Subsequently, pH value of the suspension was adjusted to 6 with 5% aqueous ammonia and the suspension was stirred for 1 h. The precursor suspension was then added to a 250 mL Teflon-lined autoclave up to 80% of the total volume. The autoclave was sealed and maintained at 160 °C for 24 h.

2.4. Characterization

XPS measurement was carried out on a Kratos XSAM800 spectrometer with an Al Kα X-ray source (1486.6 eV photons). Binding energies were calibrated using the containment carbon (C 1s = 284.8 eV). Surface morphologies of the Bi_2WO_6 coated polyester fibers without and with dopamine modification were investigated using a JEOL JSM-6700F field emission scanning electron microscope (SEM). The crystal structure of the Bi_2WO_6 particles, and the Bi_2WO_6 coated polyester fabrics without and with dopamine modification were recorded on X' Pert PRO diffractometer in the 2θ range 10° to 80°. The accelerating voltage and the applied current were 40 kV and 40 mA, respectively. The UV–vis spectra of the coated polyester fabrics were evaluated in the range of 200–800 nm with a UV-2700 spectrophotometer (Shimadzu).

2.5. Photocatalytic degradation

In order to evaluate photocatalytic activity of the Bi_2WO_6 coated polyester fabrics modified with different concentrations of dopamine, photocatalytic degradation of MB and AO7 were performed under visible light (λ > 420 nm) using 500 W Xe lamp (GXZ500, Shanghai, China). The Bi_2WO_6 coated polyester fabrics modified with different concentrations of dopamine were placed in 50 mL solution of MB and AO7 (initial concentration: 10 mg/L), respectively. The absorbance of MB at the wavelength of 664 nm and the absorbance of AO7 at the wavelength of 484 nm were recorded. Absorbance ratio (A_t/A_0) of MB and AO7 were selected to evaluate the photocatalytic degradation. The degradation efficiency of MB and AO7 (D_{MB} and D_{AO7}) and the value of k was calculated according to the following Eqs. (1) and (2) [17,18]:

$$D_{MB}(D_{AO7}) = (A_0 - A_t)/A_0 \times 100\% \quad (1)$$

$$-\ln\frac{A_t}{A_0} = kt \quad (2)$$

where A_0 is the initial absorbance of MB and AO7; A_t is the absorbance of MB and AO7 after being irradiated by light for a time period of t, respectively; k is the catalysis rate constant and t is the irradiation time. In addition, the absorbance changes of MB and AO7 aqueous solution during the photodegradation process were measured using a 4802 double-beam UV–vis spectrophotometer for every 30 min.

In addition, the influence of the initial concentration of MB (10 mg/L, 15 mg/L and 20 mg/L) on the degradation efficiency of MB was also investigated.

Washing fastness of the Bi_2WO_6 coated polyester fabrics was carried out to examine the adhesion of the Bi_2WO_6 coating on the polyester

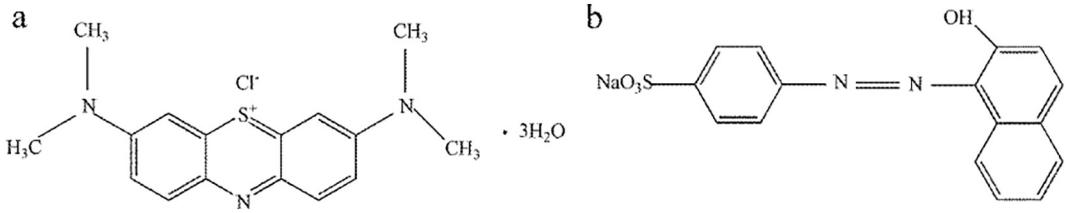

Fig. 1. The chemical structures of (a) methylene blue (MB) and (b) acid orange 7 (AO7).