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Photocatalytic deactivation of airborne microbial cells by the stainless steel sieves with surface coated TiO_2 thin films

Yu-Jie Chang [a,*], Jyh-Wei Lee [b,c], Ching-Hsing Lin [d], Chen-Yu Chang [e], Yao-Chuan Lee [d], Mei-Yin Hwa [d]

[a] Graduate School of Environmental Education and Resources, Taipei Municipal University of Education, Taiwan
[b] Department of Materials Engineering, Mingchi University of Technology, Taiwan
[c] Center for Thin Film Technologies and Applications, Mingchi University of Technology, Taiwan
[d] Department of Safety Health and Environmental Engineering, Tungnan University, Taiwan
[e] Center of General Education, National Taitung Junior College, Taiwan

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ABSTRACT

Stainless steel (SS) 304 sieves are characterized by their high permeability and high surface area, which can be flexibly used in different photochemical reactor designs. In this work, low pressure plasma cleaning methods in Ar or N_2 atmospheres were adopted to clean the surfaces of sieves prior to the deposition of TiO_2 coatings by sol–gel and dipping methods. Heat treating at 200 °C was employed after the deposition process. The surface morphologies, crystalline structures and chemical compositions of TiO_2 coated sieves were further analyzed. The antibacterial properties of sieves were also evaluated, using the bioaerosol residual test. It was obvious that all TiO_2 coated sieves exhibited adequate bactericidal efficiency, destroying over 98% of bacteria. For TiO_2 coated #100 and #300 mesh sieves without plasma cleaning, good TiO_2 adhesion and at least 98% bactericidal efficiency were observed. The bactericidal efficiency of sieves also increased with increasing Ti content of coatings. In addition, the surface morphologies and chemical compositions of Ar plasma pre-cleaned and TiO_2 coated sieves were unchanged even after being sterilized 5 times, which is very useful in the rapid temperature change environments. It is concluded that the Ar plasma pre-cleaned and TiO_2 coated SS 304 sieve is a simple, economic and flexible coating method, which is easy for technical transferring and promising in the application of environmental protection fields.

1. Introduction

Many researchers have devoted lots of efforts to the investigation and development of photocatalytic TiO_2 since Fujishima and Honda reported the photo-induced and electrochemically assisted decomposition of water in 1972 [1]. Photocatalytic TiO_2 has been widely applied in the pollution removal and environmental protection fields [2,3]. The photokilling of bacteria by exposure to photocatalytic TiO_2 has also drawn lots of attention [4–6]. For example, TiO_2 nanoparticles were first used to kill bacterial cells in an aqueous environment [4]. In addition, the utilization of TiO_2 nanotubes to kill cancer cell created a possible application in anticancer treatment [6]. Several fabrication methods including chemical vapor deposition, impregnation, anodizing, sputtering and sol–gel were developed to produce TiO_2 thin films. In general, the sol–gel method is usually used to deposit TiO_2 film on substrates in order to eliminate bioaerosols by photocatalyst reactions. In the literature, synthetic fibers [7] and molecular sieves [8] have been used as substrates to control bioaerosols, due to the possibility of killing microorganisms with a lower pressure drop [9]. On the other hand, stainless steel (SS) sieves are characterized by their high permeability and high flexibility. The corrosion resistance of SS sieve is retained when sieves are coated with TiO_2 [10,11]. The antibacterial properties of TiO_2 coated SS sieves have been investigated by several researchers [12,13]. However, the fabricating process for TiO_2 coated SS sieves and their effectiveness against bioaerosols have not yet been reported. Low pressure plasma cleaning is one of the common alternatives for industrial cleaning, since the banning of chlorofluorocarbons (CFCs) in industry. Good cleaning results have been reported on metallic surfaces using the plasma cleaning process [14,15]. In this work, the low pressure plasma cleaning of SS sieves in Ar or N_2 atmospheres prior to TiO_2 coating, using the sol–gel method was performed. The bactericidal ability of sieves against bioaerosols and the durability tests of TiO_2 coated SS sieves in rapid change temperature environments were adopted to evaluate the effect of plasma cleaning on the performance of SS sieves.

2. Experimental procedures

Several SS sieves with #100 and #300 meshes were ultrasonically cleaned in acetone and ethyl alcohol followed by a deionized water rinse. Surfaces of sieves were then cleaned and activated by a low

* Corresponding author. Fax: +886 2 23815125.
E-mail address: yujchang@gmail.com (Y.-J. Chang).

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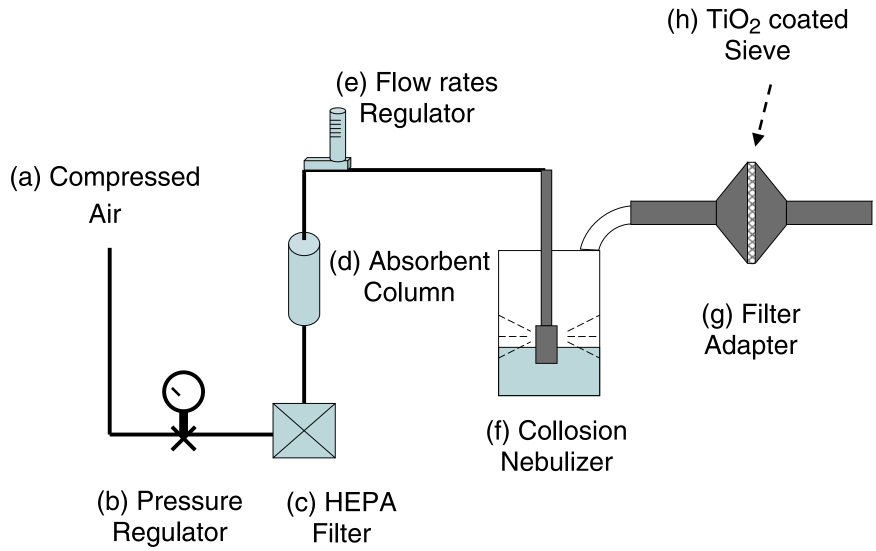

Fig. 1. The setup of bioaerosol generation system.

pressure plasma system (Femto, diener electronic, Germany) at 40 kHz/100 W using Ar or N_2 gas supply for 5 mins. The deposition of TiO_2 films on two groups of sieves, plasma pre-cleaned and untreated SS304 sieves were accomplished by sol–gel and dipping techniques at room temperature, respectively. These films were prepared by dissolving the titanium alkoxide precursor (titanium isopropoxide, $Ti(OC_3H_7)_4$) in isopropanol (IPA, C_3H_7OH). Acetic acid (CH_3COOH) was used to avoid the early precipitation of the oxides. After the addition of the acetic acid, the solution was stirred vigorously for up to 24 h with a magnetic stirrer until gel formed. Then, the gel was placed in an airtight beaker to stop further reaction. Then, 95% ethanol solution was added to the gel to form the final

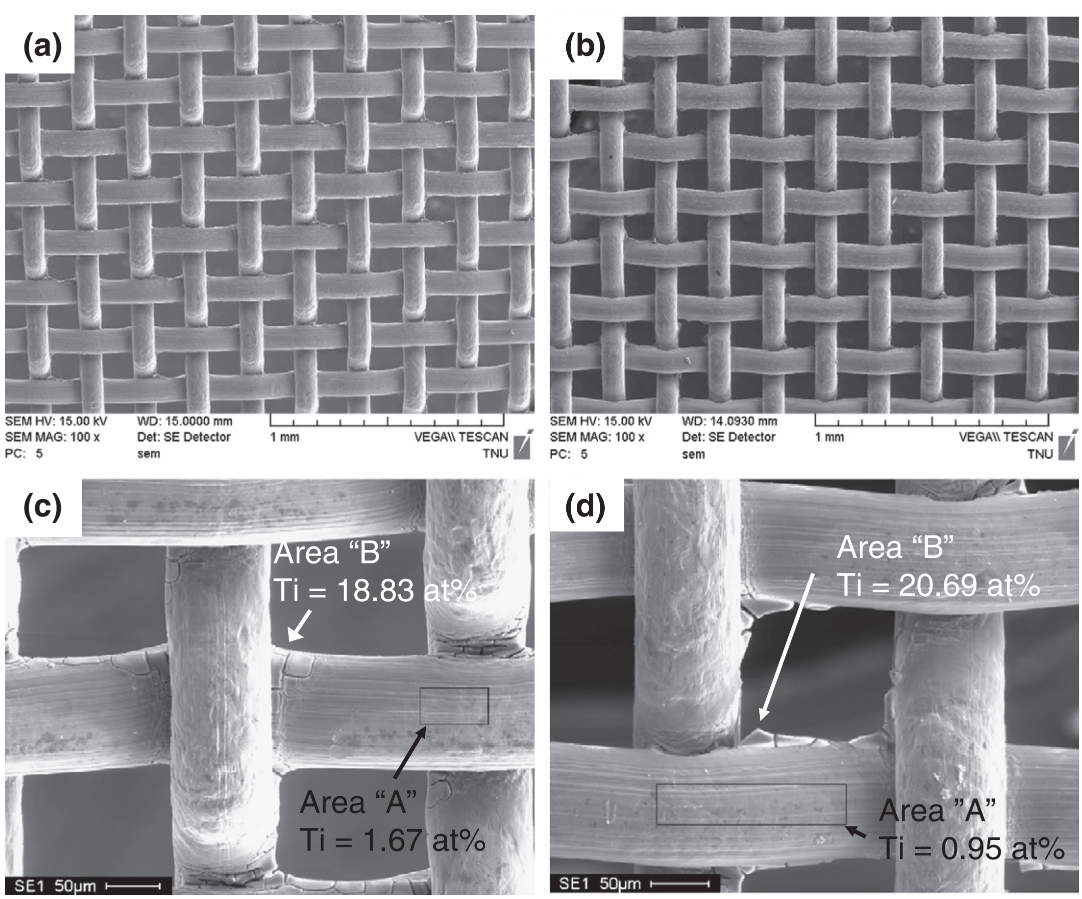

Fig. 2. The micrographs and EDS results of TiO_2 coated SS sieves (a) without plasma cleaning, (b) with N_2 plasma pre-cleaning, and (c) higher magnification of (a), and (d) higher magnification of (b).