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The Antibacterial Activities of Ag/Nano-TiO_2 Modified Silicone Elastomer

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We studied the ability of Ag/nano-TiO_2 to inhibit *Staphylococcus aureus* growth on silicone elastomer material. Ag/nano-TiO_2 silicone elastomer was prepared with different concentrations of 0%, 2%, 4%, 6%, 8%, 10%. The antibacterial efficacy of Ag/nano-TiO_2 silicone elastomer was determined by the inhibition zone method and the impregnated culture method. The antibacterial timeliness of Ag/nano-TiO_2 silicone elastomer was tested by direct contact method. The samples were kept through thermal aging process in an accelerated aging chamber. The effect of concentrations of Ag/nano-TiO_2 was insignificant ($P < 0.05$). There was significant difference between the Ag/nano-TiO_2 silicone elastomer and the blank silicone elastomer ($P < 0.5$). There was also significant difference among specimen groups whose aging periods were 50 °C, 100 °C, 150 °C, 200 °C for 87 h ($P < 0.5$). The silicone elastomer with different concentrations of Ag/nano-TiO_2 effectively inhibits *Staphylococcus aureus* growth.

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1. Introduction

The nano-TiO_2 have attracted more attention in recent years, as photocatalysts show sustaining antibacterial capability, biocompatibility and self-cleaning functionality. Some scholars will try to add different types of antibacterial agent in materials. Nano-TiO_2 are stable, unlike other antibacterial agents with the dissolution, the effect gradually decreased [1]. But the antibacterial effect of nano-TiO_2 which is of low utilization in visible light must be in the UV radiation. It is generally believed that silver particles can activate nano-TiO_2. Many scholars have tried to prepare higher efficiency nano-TiO_2 based catalyst by Ag to improve its visible light response [2].

Due to its mechanical properties, silicone elastomer material was used in a very wide range of application. However, the anti-aging properties and the color stability of the materials that can reduce its service life [3]. Furthermore, this material has lack of antibacterial properties that can limit its usefulness in some applications. Therefore, this study aimed to determine the ability of Ag/nano-TiO_2 to inhibit *Staphylococcus aureus* growth on silicone elastomer material.

2. Material and methods

Ag/nano-TiO_2 (80 nm, China), silicone elastomer (Dow corning, USA), LB Broth Medium (Lennox, USA). Silicone elastomer samples (0%, 2%, 4%, 6%, 8%, 10%) were prepared by pouring a mixture of Ag/nano-TiO_2 and silicone elastomer matrix into a teflon mold and cutting into disc shape ($d = 6$ mm).

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The antibacterial properties of samples were tested by inhibition zone method. 0.5 MFC (McFarland turbidity) of *Staphylococcus aureus* suspension was evenly smeared on nutrient agar Petri dish. The different concentrations of circular samples were posted on the Petri dish that was incubated at 37 °C for 24 h. The antibacterial properties of samples were tested by impregnated culture method. Samples were soaked in 5 ml bacteria solution whose McNamara turbidity is 0.5 M CF with 20 ml broth. After culturing at 37 °C for 24 h, the optical density (OD) value of bacterial suspension was measured with microplate reader (SpectraMax-M5, USA).

Antibacterial timeliness was tested using the direct contact method. The 30 wells were covered with an equal amount of tested materials, a total of 6 groups with 5 wells. A 10 μl bacterial suspension of *Staphylococcus aureus* and 200 μl broth was mixed with the test material. The negative control group covered with the test material including fresh medium. The plates were incubated at 37 °C for 24 h. The OD value of the outgrowth in each well was recorded for 16 h at 650 nm by using a microplate reader. The OD values of the negative control wells were considered as the baseline.

Long acting antibacterial properties — the samples were exposed to accelerated aging environment, using the high temperature chamber (YLCD-8000P, KELONG, China), basing on ISO188:2007 standard. After accelerated aging temperature of 50 °C, 100 °C, 150 °C, 200 °C for 87 h, the samples were submitted to the antibacterial properties measurements process by impregnated culture method.

The specimens were observed by a scanning electron microscope (HITACHI, S-3700N, Japan).

The data were analyzed using one-way ANOVA. Newman–Keuls was performed to identify groups that did not differ significantly from each other ($P < 0.05$).

3. Results

A representative SEM photomicrograph of the Ag/nano-TiO_2 silicone elastomer and the blank silicone elastomer is shown in Fig. 1. The Ag/nano-TiO_2 was uniformly dispersed in the silicone matrix (Fig. 1).

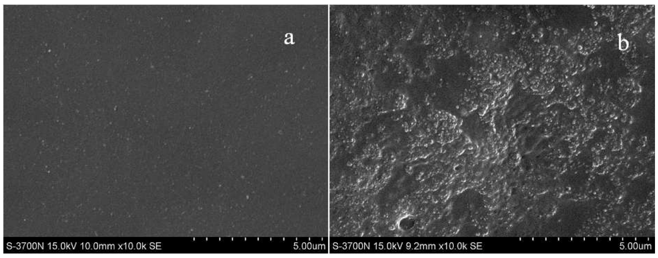

Fig. 1. Representative SEM photomicrograph of fracture surface of silicone elastomer filled with Ag/TiO_2 nanoparticles: (a) 0%w/w, (b) 10%w/w (10000×).

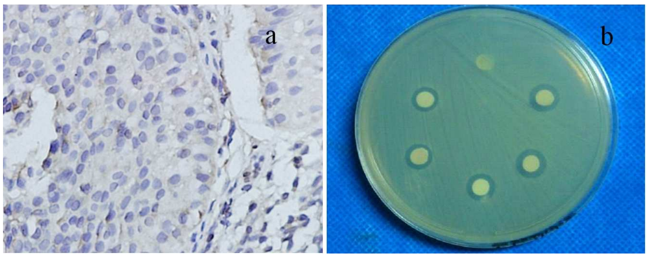

Fig. 2. Representative optical photomicrograph of the *Staphylococcus aureus* (a) and the experimental results of inhibition zone of Ag/nano-TiO_2 (b).

Data for inhibition zone diameter showed a significant difference for the each concentration experimental group ($P < 0.05$).With the improvement of concentration of Ag/TiO_2, the inhibition zone diameter increased except for 10% group (Fig. 2a, 3a). Data for OD values showed significant decrease for the experimental group with the concentration decrease ($P < 0.05$). The OD value of 6% group reached the minimum value (Fig. 3b).

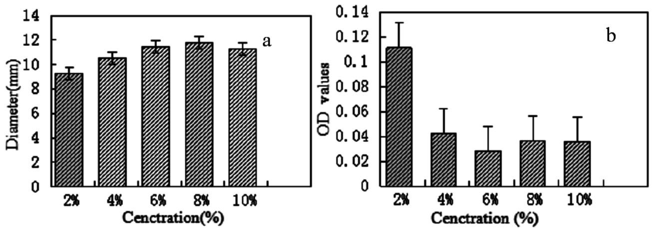

Fig. 3. Antibacterial properties — inhibition zone diameter versus concentration (a) and OD values versus concentration (b).

Antibacterial timeliness test showed that bacterial growth was significantly inhibited when compared with the control group from the incubation period of 4 h to 16 h ($P < 0.05$) (Fig. 4).

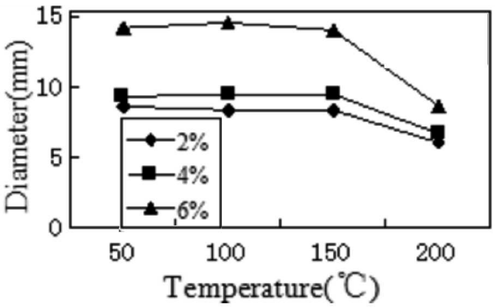

Fig. 5. Inhibition zone diameter versus aging temperature.

There were significant differences in the inhibition zone diameter of silicone elastomer diaphragm containing Ag/nano-TiO_2 at different temperature ($P < 0.05$) (Fig. 5).

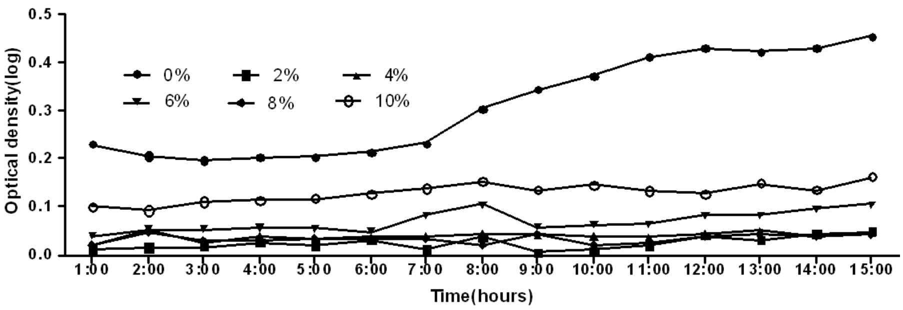

Fig. 4. Direct contact test of freshly mixed experimental silicone elastomer materials.

4. Discussion

Ag/nano-TiO_2 is photocatalyst that has long-lasting antibacterial efficacy [4]. Antibacterial property of materials has been evaluated in a variety of ways. The inhibition zone method and the impregnated culture method are good indicator of bacterial inhibition rate [5]. In this study, the antibacterial property of silicone elastomer is determined by inhibition zone method and impregnated culture method, which found that with the Ag/nano--TiO_2 increase, the antibacterial rate is improving. When the concentration of nano-TiO_2 is within the range of

6%–8%(w/w), the antibacterial ability is up to the maximum. So we can indicate that the antibacterial ability is associated with the amount of Ag/nano-TiO_2 in the silicone elastomer.

For unmodified silicone elastomer, the specimens had no inhibitory effect. This finding is in accordance with Zhou et al. [6]. On the other hand, silicone elastomer containing different concentrations of Ag/nano-TiO_2 were effective in inhibiting bacterial growth of the incubation period from 1 h to 16 h. It can be found that lower concentration TiO_2 particles produce good inhibitory effect.

Another important factor, which should be taken into consideration, is the exposure method used for samples aging. Some authors have suggested using chamber for an artificial time of 87 h to simulate situations in which facial prostheses are used for a period of one year. The time of use of prosthesis varies on an average from three months to 1 year, resulting in elastomer degradation and antibacterial ratio instability [7]. We utilized accelerated aging chambers in this study, a method that is most commonly used as reported in the published literature. The results showed that the materials can maintain a good long term antibacterial property. However, the antibacterial properties sharply decrease at the temperature of 200 °C, the reason may be that the high temperature damages the structure of Ag/TiO_2, thereby, affecting the performance of it. The results provide a reference for use of silicone elastomer.

Acknowledgments

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