Enhancement effect of O_3 on the antifungal efficacy of nano-metals supported TiO_2 on resistant mold spores

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Increasingly tremendous rainfall events due to climatic changes have caused serious water damages and extensive dampness in indoor environments, which lead to molds growth. For example, the indoor fungal concentration in remediated houses can reach as high as 2×10^5 spores/m^3 several weeks after the flood (Hsu *et al.*, 2011). Exposure to home dampness and molds is a risk factor for irritation, allergy, infection and respiratory diseases. To remediate microbial pollution, antimicrobial efficacy of nano-metals has been extensively studied (Sondi and Salopek-Sondi, 2004; Morones *et al.*, 2005; Egger *et al.*, 2009). However, most of the relative studies focused on the bactericidal efficacy. Molds, especially their spores, are more resistant than bacteria. Therefore, an expansively evaluation of the antifungal efficacy of this technique is necessary.

In this study, the nano-metals (Ag, Cu and Ni) supported catalysts were successfully prepared by the simple and low-cost incipient wetness impregnation method, while the titanium dioxide (Degussa (Evonik) P25) nanoparticle was served as the support (Fig 1). The prepared catalysts were denominated as 0.5wt%Ag/P25, 5wt%Ag/P25, 2wt%Cu/P25 and 5wt%Ni/P25, respectively, according to the species and the amount of loaded metals.

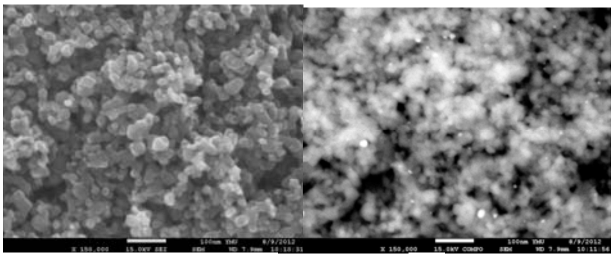

Fig.1. SEM images of 0.5wt%Ag/P25 (a), SEI (secondary Electron Image) (b) COMBO mode (SEI and Back Scatted Electron Image) Bright spots in the COMBO mode are Ag particles

The antifungal experiments of *Aspergillus niger* spores were conducted on two surfaces (quartz and putty) in the darkness with and without ozone exposure. The critical Ag concentration to inhibit the germination and growth of *Aspergillus niger* spores of 5wt% nano Ag catalyst was 65 mg/mL, which was lower than several cases reported in previous studies (Egger *et al.*, 2009).

The antifungal kinetics fitted the Chick-Watson model:

$$SR = \exp(-kt) \qquad (1)$$

in which SR is the survival ratio of *Aspergillus niger* spores; k is the inactivation rate constant; t is the elapsed time. The inactivation rate constants of *Aspergillus niger* spores on nano-metals (Ag, Cu and Ni) supported catalysts in the presence of ozone (Fig.2(b) k=0.475~0.966 h^{-1}) were much higher than those in the absence of ozone (Fig.2(a) k= 0.001~0.268 h^{-1}). However, on the surface of TiO_2 particles, no antifungal effect was observed until 6-hour exposure to ozone. Consequently, ozone has a synergetic effect on nano-metal antifungal effectiveness.

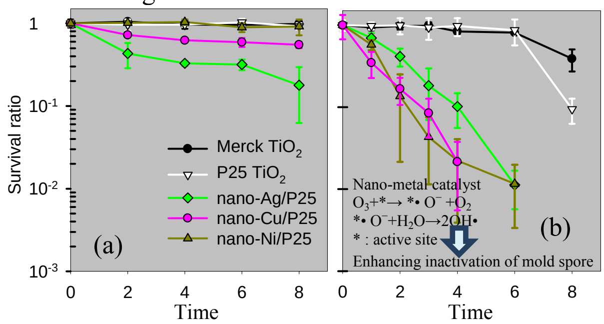

Fig. 1 Time profiles of the survival ratio of *Aspergillus niger* spore on the surface of catalysts and quartz chip (a) in the darkness (Dark); (b) exposed to 5-ppm ozone

Antifungal experimental result of the catalysts on putty was shown in Fig. 3. Nano-Ag and -Cu catalysts did inactivate the *Aspergillus niger* spores when being applied on putty, but the inactivation rate constants were lower than those applied on the quartz chips. This may result from the fact that the Ag and Cu ions could form complexes with the alkalinity of the putty which reduced the diffusivity of the nano-Ag and Cu.

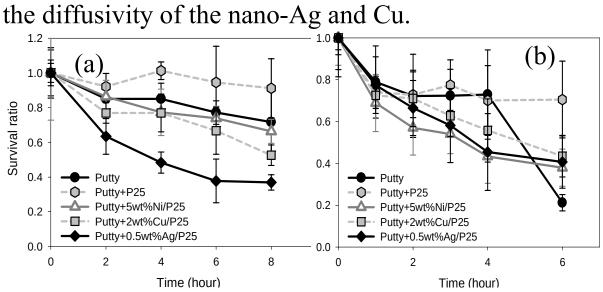

Fig.3. The antifungal kinetics of the 0.5wt%Ag/P25, 2wt%Cu/P25 and 5wt%Ni/P25 catalysts against *Aspergillus niger* spore when being applied on the putty (a) in the darkness (Dark); (b) exposed to 5-ppm ozone

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