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Preparation of polyurethane/CuO coating film and the study of antifungal activity

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ABSTRACT

In this study, the effect of CuO nanoparticles on antifungal activity of polyurethane/CuO coating film was studied. CuO nanoparticles with concentrations of 1%, 2% and 5% w/v were prepared. Characterisation of nanoparticles and the coated surface were carried out using UV–vis Spectroscopy, DLS, XRD and TEM. The images of TEM were used to study the dispersion of nanoparticles in the coating film. The best nanoparticle size distribution was obtained in a coating with 2 wt% of nanoparticles, in which by further increasing the concentration up to 5 wt%, the nanoparticles dispersion was diminished and rather accumulation was observed in the coating film. The antifungal activity of polyurethane /CuO coating film against one type of fungus (penicillium) was measured by disc-diffusion method and the optimum conditions were determined.

1. Introduction

Nanotechnology involves tailoring of materials at the atomic level to achieve unique properties, which can be suitably manipulated for some desired applications. Recently, metal and metal-oxide nanoparticles have been attractive as novel platforms for biomedicine and bio- nanotechnology [1,2]. Metal and metal-oxide nanoparticles provide solutions to scientific and ecological challenges in diverse areas, such as, medicine, electronics, energy, coatings, packaging, and cosmetics. Several physical and chemical methods have been used to synthesize the nanoparticles, and these include techniques involving aerosol technologies, lithography, laser ablation, and UV irradiation. In addition, microbial cells, such as, algae, bacteria, and fungi, are known to produce metal and metal-oxide nanoparticles intracellularly or extracellularly [3,4]. Suspended and supported Cu and CuO nanoparticles, for antibacterial applications, have been studied extensively, not only concerning their synthesis methodologies and bactericidal behaviors, but also for the possible toxicological impacts on the environment and human health. Factors affecting their antibacterial capacity include the size, shape, accessibility, dispersion, support and etc. [5].

Sow et al. examined the effect of alumina and silica nanoparticles on properties of water-based polyurethane coatings, which showed that the addition of silica nanoparticles is caused a significant increase in coating adhesion to its substrate, but Nano-alumina hasn't a significant effect on improvement of the property. They also stated that the difference between silica and alumina nanoparticles is directly related to the distribution of these nanoparticles. They studied the Enhancement of Nano-base coating properties of cellulosic crystals. They stated that these nanoparticles can significantly improve wear and scratch resistance but do not have a significant effect on the adhesion strength of coating and the apparent change in coating quality [6]. In general, different nanoparticles have been studied by researchers in coatings, and among them zin oxide particles (Cuo) have been studied widely [7]. One of the areas where many studies have focused on is the effect of metal-oxide nanoparticles on the transparent protective properties of folds against ultraviolet waves of the sun. As these studies have shown, the use of copper oxide nanoparticles in polyurethane resin coatings, acrylics, polyurethane / acrylic water bases, alkaline silicone water base and other transparent coatings, significantly improved the resistance of these coatings against the UV waves and prevent the damage and color changes of these coatings dramatically [8,9]. Also, many studies have focused on the effect of increasing the copper oxide nanoparticles on transparency of folds on the mechanical and abrasive properties of these coatings and have achieved significant results. In this regard, a study on the effect of silica-bonded titanium dioxide and

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oxide ion nanoparticles suggests that the use of these nanoparticles at 1% weight significantly improves wear resistance, the Young's modulus and hardness in water based commercial Acrylic coatings [10]. In terms of abrasion coefficient and also wear and tear of the single-element polyurethane coatings with copper oxide nanoparticles, Song et al suggested that adding of these nanoparticles to a certain level improves the coating properties. However, further increment of these nanoparticles does not have any other positive impact on the evaluated properties due to the high surface energy of copper oxide nanoparticles. Dhoke et al. studied the effect of copper-oxide nanoparticles on the properties of alkali water base coatings and they suggested that applying of these nanoparticles significantly improved resistance to Scratches, wear and corrosion in the coatings due to the strong interaction between copper oxide nanoparticles and polymer [11].

As mentioned above, chemical reduction method is used to synthesize metal oxide nanoparticles. In this study, CuO nanoparticles were synthesized by precipitation process using Copper (II) acetate, sodium hydroxide and absolute ethanol. The main goal of this work is the preparation of polyurethane /CuO coating film using corona discharge and the study of its antifungal effects against fungus penicillium. CuO nanoparticles and polyurethane /CuO coating film was analysed using UV-Spectroscopy, XRD and TEM. The disc-diffusion method was used to study antifungal activity.

2. Materials and method

Polyurethane film (thickness of 25 μm) was purchased from Merck Co. Ltd. (Germany). The CuO nanoparticles were synthesized by precipitation process using Copper (II) acetate, sodium hydroxide and absolute ethanol. Tryptic Soy Broth (TSB) and Müller-Hinton agar powders as growth media, were purchased from Sigma-Aldrich (Germany). Epoxy resin (Epon 826) was used to coat on polyurethane film.

2.1. Preparation of the coating solution

In a typical synthesis, 2.0 g copper acetate was dissolved in 80 mL absolute ethanol, and the mixture was stirred for 30 min, followed by addition of 0.8 g sodium hydroxide. Then the whole solution was transferred into a Teflon lined stainless steel autoclave, sealed, and maintained at 120 °C for 2 h. After cooling down to the room temperature, a black product was separated by centrifugation and washed several times with absolute ethanol and pure water. Finally, the product was dried at 60 °C in air for 6 h. The precipitated CuO nanoparticles were washed with distilled water and then prepared in three concentrations of 1%, 2% and 5% w/v in distilled water.

2.2. Improving **of polyurethane surface using corona discharge**

The surface of polyurethane film was polarised by corona discharge. To polarise the polyurethane surface, the polyurethane film was placed between the two electrodes. This work was carried out for three different time slots of 1, 3 and 5 min and for each time period with three different powers of 100, 5000 and 10,000 W. The films were coated using the prepared solutions with different concentrations and left to dry out at environmental temperature. Antifungal tests were carried out on all 9 cases of Taguchi design method and the optimum conditions were determined.

2.3. Antifungal **activity**

The anti-fungal activity was studied by disc-diffusion method. Penicillium fungus was used in this study [12]. This pathogenic microorganism was cultured in tryptic soy broth (TSB) at 37 °C on rotary shaker at 200 rpm. Wells of size 5 mm were prepared on Müller-Hinton agar plates using a cork borer, and each strain was spread uniformly on individual plates using a sterile cotton swab and coating films was placed in each well according with Table 1. After incubation at 37°C for 48 h, test strain susceptibility was assayed by measuring diameter of inhibition zones near the wells.

Table 1
Experimental design by Taguchi method. A: concentration (1%, 2%, and 5%), B: Power (100 W, 5000 W, and 10,000 W), C: times (1 min, 3 min, and 5 min).

Test Number	Factors		
	A	B	C
1	1	1	1
2	1	2	2
3	1	3	3
4	2	1	2
5	2	2	3
6	2	3	1
7	3	1	3
8	3	2	1
9	3	3	2

3. Results and discussions

3.1. UV–vis spectroscopy

The formation of CuO nanoparticles was confirmed by UV–vis spectral analysis, which is useful for analyzing nanoparticles. In UV–Vis spectrum (Fig. 1) exhibited a strong, broad peak at 280 nm, which is the characteristic of CuO nanoparticles and caused by SPR of the electrons in the metal. According to Mie's theory, only a single SPR band is expected in the absorption spectra of spherical CuO nanoparticles, whereas anisotropic particles can give rise to two or more SPR bands depending on particle shapes [13]. CuO nanoparticles solution in different concentration (1%, 2% and 5%) was monitored by UV–vis spectral in the range of 200-600. It shows the surface plasmon resonance of CuO nanoparticles peaks at 280 nm (Fig. 1), considering the fact that light absorption of CuO nanoparticles happens in the range of 250–300 nm. The peaks were at 275 and 278 nm for concentrations of 1% and 5%, respectively (not reported here).

3.2. Dynamic light scattering

Particle size and distribution are important properties of nanoparticles because they control other properties, such as dissolution rate, solubility at saturation, physical stability and even biological activities [4]. Particles size was determined by size distribution analysis in aqueous solution using dynamic light scattering (DLS). As shown in Fig. 2, the sizes of CuO nanoparticles ranged from 50 to 100 nm with an

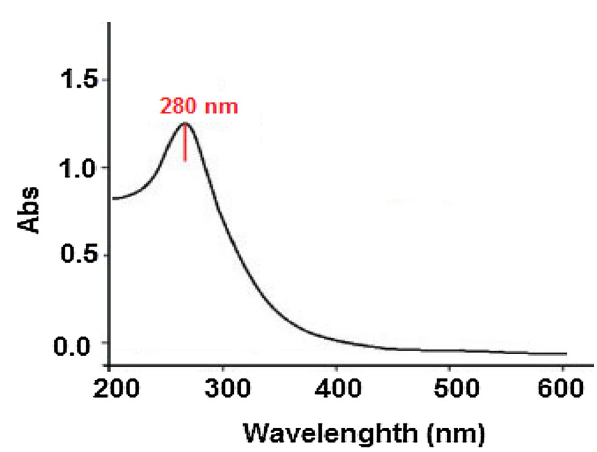

Fig. 1. Absorption spectra of CuO nanoparticle solutions (2%).