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NATALIIA DUDCHENKO, GALINA AMIRIAN,
ILANA PERELSHTEIN
Bar-Ilan Institute of Nanotechnology & Advanced Materials
(BINA), Bar Ilan University, Israel

ONE-POT PREPARATION OF COPPER/ZINC OXIDE NANOPARTICLE-COATED ANTIBACTERIAL TEXTILE

Purpose. *In-situ synthesis and coating of CuO/ZnO nanoparticles on cotton fabrics using ultrasound irradiation with further investigation of their antibacterial properties.*

Keywords*: CuO/ZnO nanoparticles, antibacterial textiles, one-pot synthesis, ultrasound irradiation.*

Objectives. In recent years, antibacterial textiles have gained significant attention due to the rising demand for materials that can inhibit bacterial growth, particularly in sectors like healthcare, sportswear, and everyday clothing. Copper and zinc oxide nanoparticles are particularly well-suited for antibacterial applications due to their distinct biological properties. CuO has long been recognized for its antimicrobial efficacy. In nanoparticle form, it can generate reactive oxygen species (ROS), disrupt bacterial cell membranes, and cause cellular damage, leading to bacterial death. ZnO nanoparticles are non-toxic, UV-absorbing, and possess strong antimicrobial properties. They can induce oxidative stress in bacterial cells and promote the release of zinc ions, inhibiting bacterial growth. One of the most efficient and sustainable methods for integrating these nanoparticles into textiles is the one-pot synthesis with ultrasound irradiation, which allows for the direct, in-situ formation of nanoparticles on the fabric surface. This method holds potential for applications in medical textiles, sportswear, and protective clothing where hygiene and bacterial resistance are critical.

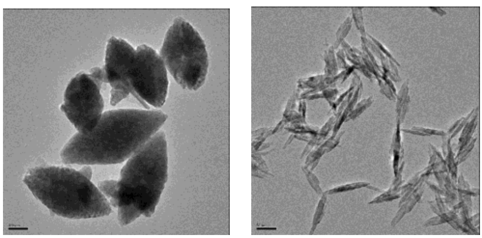
Methodology. All chemical reagents were purchased from Aldrich and used without further purification. The procedure of in-situ nanoparticles' synthesis and incorporation is as follows. 0.005 M and 0.01 M $Zn(Ac)\cdot 2H_2O$ or $Cu(Ac)_2$ (Ac = acetate) is dissolved in 100 mL of water. The pH is adjusted to 8–9 by the addition of NH3·H2O. The reaction mixture is irradiated for 30 min with a high-intensity ultrasonic horn (Ti-horn, 20 kHz, 750 W). The sonication flask is placed in a cooling bath maintained at a constant temperature of 30 °C. The product is first washed thoroughly with water to remove traces of ammonia, then with ethanol, and dried under vacuum. The coating of textiles is carried out in the presence of fabric using the above reaction conditions.

The powders' crystal phase and structural crystallinity were analyzed using X-ray Diffraction (XRD) with a Bruker D8 diffractometer using Cu K-alpha radiation. The morphologies and particle sizes of the metal oxide nanoparticles were observed using High-Resolution Transmission Electron Microscopy (HR-TEM) with a JEOL 2100, operating at an accelerating voltage of 200 kV. The prepared textiles were examined using Scanning Electron Microscopy (SEM) with a FEI QUANTA 200F to confirm the even distribution of nanoparticles on the textiles. The weight percentages of the coated metal oxides were analyzed using Ion-Coupled Plasma (ICP) with an ULTIMA 2 instrument.

The CuO/ZnO-coated textiles were tested for antibacterial efficacy using the Colony Forming Unit (CFU) method against common bacterial strains such as *Escherichia coli* (E. coli) and *Staphylococcus aureus* (S. aureus), which are often used in lab tests due to their relevance in medical and industrial settings.

Research results. The diffractograms of the synthesized nanoparticles indicate the presence of one main phase, either ZnO or CuO. In both patterns, the peaks are sharp, indicating a good crystalline structure.

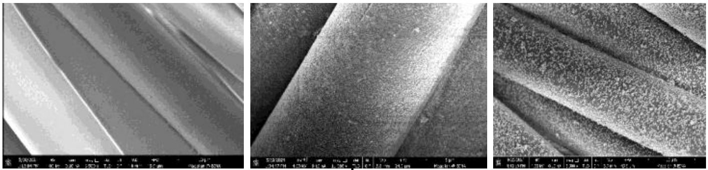
A detailed analysis of the HR-TEM images reveals that the ZnO nanoparticles have a rugby ball shape with an average length of approximately 200 nm and a width of about 90 nm (Fig. 1a). Needle-shaped structures were observed for the CuO nanoparticles (Fig. 1b) with an average length and width of approximately 70 nm and 10 nm, respectively.



(a) (b)

Fig. 1. **HR-TEM images of synthesized ZnO (a) and CuO (b) nanoparticles**

CuO/ZnO nanoparticle-coated textiles were compared with pristine textiles using SEM. The coated textiles showed homogenous and dense coatings of metal oxides, in contrast to the smooth surface of the pristine textiles (Figure 2). According to ICP analysis, the concentration of metal oxide nanoparticles on the textile surface is approximately 1 wt%.



a b c

Fig. 2. **SEM images of pristine (a), CuO- (b), and ZnO- (c) coating of textiles**

The study evaluated the effectiveness of CuO/ZnO nanoparticle-coated textiles against both planktonic and biofilm forms of Escherichia coli (E. coli) and Staphylococcus aureus (S. aureus). It was shown, that after overnight treatment with CuO- and ZnO-coated textiles, the number of both planktonic and biofilm bacteria decreased by 99%. The reported findings are the average of at least 3 independent experiments, and untreated (non-coated) textiles were used as a control.

The potential applications of CuO/ZnO nanoparticle-coated textiles are extensive. In the medical field, they can be used for bandages, hospital gowns, and surgical masks with antibacterial properties, reducing the risk of infection and contamination. These textiles can also be utilized in sportswear and outdoor clothing due to their ability to prevent the growth of odor-causing bacteria, keeping clothes fresh for longer periods. Additionally, they can be used in home furnishings such as antimicrobial curtains, bed linens, and towels, offering added protection in household settings and promoting hygiene and cleanliness.

Conclusion. The one-pot preparation of copper and zinc oxide nanoparticle-coated textiles offers a highly efficient, cost-effective, and sustainable method for producing antibacterial fabrics. With the growing need for hygienic and protective materials, this technique has the potential to revolutionize industries ranging from healthcare to everyday apparel. As research continues to advance, further optimization of this method could lead to even more versatile and multifunctional textile products.