

THE EFFECT OF TITANIUM DIOXIDE MODIFICATION ON THE COPPER POWDER BACTERICIDAL PROPERTIES

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Introduction

Copper is known as an important micronutrient required in very small amounts for survival of most aerobic organisms but at high concentrations can become toxic and inhibit microbial growth. Bogdanowicz et al. show that Cu NPs (diameter 5,3nm) were able to reduce more than 98% of all tested strains (include *E.coli* and *S.aureus*) after 2 hours of contact and Cu NPs has higher reduction rate for *E.coli* than *S.aureus* [2]. Argueta-Figueroa et al. also confirmed that Cu NPs has the antibacterial activity against *E.coli* and *S.aureus* (MIC - 1000µg/ml) and causes more membrane damages of the *E.coli* as compared to the *S.aureus* [1]. The results of the experiment with another Gram-negative bacteria (*Salmonella*) showed that under dry incubation conditions bacterial cells are extremely vulnerable to copper [6]. He X. et al. also show that CuO/TiO₂ coating has high antibacterial activity against *Staphylococcus aureus* in contrast to pure titanium and TiO₂ coating. It can be explained that the addition of copper is the crucial factor to endow copper/TiO₂ coating with the antibacterial effect against *S.aureus* [4]. The paper proposes modifications of copper powder with amorphous submicron titanium dioxide in order to increase biological activity. The modified powder can be used to create coatings by various methods including thermal methods. The work presents analysis of Cu and TiO₂ powders and results of bactericidal tests carried out on a Cu-TiO₂ composite powder.

Materials and Methods

A dendritic commercial copper powder with a particle size of 50-100 µm obtained by the electrolytic method was used for the tests. The powder was mixed with an amorphous submicron titanium dioxide powder produced by the sol gel method at the Department of Mechanics and Materials Engineering at the Wrocław University of Science and Technology [7]. The powders were mixed in a mechanical stirrer for 4 hours. Four different concentrations of Cu and TiO₂ powders were used. The experiment included *Escherichia coli* ATCC 11775 and *Staphylococcus aureus* ATCC 6538P, strains were used after 24 hours of incubation in 37°C to prepare the inoculum to a concentration of 10⁶cfu/ml. A suspension of *S. aureus* or and *E. coli* was sprayed over the total area of each Petri dish. Then paper discs (7mm diameter) soaked in solution of mixture of Cu-TiO₂ powders (10mg/l) were put on nutrient agar plates. After incubation in 35°C for 48 hours the diameter of inhibition zone was measured.

Results and Discussion

The analysis of the obtained results clearly shows the beneficial effect of the addition of the titanium dioxide fraction on the microbiological activity of the copper powder only against *S.aureus*. The results of zone inhibition method are shown on the Tab. 1 and Tab. 2. Copper NPs and Cu/10%TiO₂ powder show good inhibition zone against *E.coli*. The inhibition zone against *Staphylococcus aureus* was measured for mixed copper and TiO₂ powder, there was no inhibition zone for pure copper and for concentrations of titanium dioxide 10% and 25%. The inhibition zone of titanium dioxide concentration of 50% was noticed only against *S. aureus* (Gram positive bacteria). The tests confirm the results obtained for TiO₂-Cu coatings produced by magnetron sputtering method where the authors found that addition of copper into titania structure during sputtering process resulted in increasing antimicrobial activity for microorganisms (*Escherichia coli*, *Bacillus subtilis*, *Staphylococcus aureus*, *Enterococcus hirae* and *Candida albicans*) [8].

TABLE 1. Inhibition zone of Cu-TiO₂ powder against *E.coli*.

Powder composition	Diameter of inhibition zone, mm	
Cu NPs	<i>E. coli</i> ATCC 11775	10,5 (3,5)
Cu+10%TiO ₂ NPs		14 (7)
Cu+25%TiO ₂ NPs		7 (0)
Cu+50%TiO ₂ NPs		7 (0)

TABLE 2. Inhibition zone of Cu-TiO₂ powder against *S.aureus*.

Powder composition	Diameter of inhibition zone, mm	
Cu NPs	<i>S. aureus</i> ATCC 6538P	7 (0)
Cu+10%TiO ₂ NPs		7 (0)
Cu+25%TiO ₂ NPs		7 (0)
Cu+50%TiO ₂ NPs		15 (8)

Conclusions

The studies have shown a positive effect of the addition of TiO₂ on bactericidal properties only against *Staphylococcus aureus* (Gram positive bacteria). A significant increase in the inhibition zone is visible only at the highest tested proportion of the modifying phase of 50% TiO₂. Interestingly, no inhibition zone was found for this strain in pure copper powder tests. The inhibition zone was observed for pure copper powder against *Escherichia coli*. It seems reasonable to develop an optimal concentration of modifying TiO₂ fractions for individual bacterial strains. The modified copper powder can be used as a starting material for the production of coatings using, among others, the cold spray method.

References

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