PHYSICAL CHEMISTRY 2014

12th International Conference
on Fundamental and Applied Aspects of
Physical Chemistry

The Conference is dedicated to the
25. Anniversary of the Society of Physical Chemists of Serbia

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September 22-26, 2014
Belgrade, Serbia

ISBN 978-86-82475-30-9

Title: PHYSICAL CHEMISTRY 2014 (Proceedings)
Editors: Ž. Čupić and S. Anić
Published by: Society of Physical Chemists of Serbia, Studenski trg 12-16, 11158, Belgrade, Serbia
Publisher: Society of Physical Chemists of Serbia
For Publisher: S. Anić, President of Society of Physical Chemists of Serbia
Printed by: "Jovan" Priting and Publishing Company; 200 Copies;
Number of pages: 6+ 441; **Format**: B5; Printing finished in September 2014.

Text an Layout: "Jovan"

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12th International Conference on
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Organized by
The Society of Physical Chemists of
Serbia

in co-operation
with

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Boreskov Institute of Catalysis of Siberian Branch of the Russian Academy of Sciences

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THE ANTIMICROBIAL ACTIVITY OF TRIANGULAR SILVER NANOPLATES ON COTTON FABRIC PRETREATED WITH CHITOZAN

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ABSTRACT

Triangular silver nanoplates are a type of most-studied noble-metal nanostructures over the past decade, owing to their special structural architecture, outstanding plasmonic features across both visible and IR regions, and catalytic properties for a wide range of applications. Herein, we used these nanoparticles to deposit on cotton (Co) fabric pretreated with biopolymer chitosan (CHT) and investigated their antimicrobial activity. The antimicrobial efficiency of the coated fabrics was evaluated toward Gram-negative bacteria *E. coli*, Gram-positive bacteria *S. aureus* and fungus *C. albicans*. It was found that deposited silver nanoparticles imparted excellent antimicrobial properties to Co fabric.

INTRODUCTION

Silver nanoparticles (AgNPs) are one of the well-known antibacterial substances with multimode level of antimicrobial action, which could be used industrially for several purposes, including amendments to textiles and cosmetics, food processing, water treatment, etc.[1,2]. Their antimicrobial activity depends on size, shape, functional surface coverage and stability in the growth medium. On the other hand, textile materials, in particular cotton under certain conditions, can support the growth of different microbes [1].One promising innovation is to impart these textiles with antimicrobial properties. Since the chitosan has been exploited in textile finishing, with great metal-complexing capacity due to a free amino and hidroxy groups, we explored its characteristic to enhance deposition of triangular Ag

nanoplates on the Co fabric. Besides, we used low concentration of CHT to avoid its antimicrobial activity, providing possibility to solely investigate antimicrobial effect of triangular Ag nanoplates.

EXPERIMENTAL

Triangular Ag nanoplates were obtained by one step seedless route [3,4]. Aqueous solutions of $AgNO_3$ (0.1 mM, 25 mL), $Na_3C_6H_5O_7$ (30 mM, 1.5 mL), H_2O_2 (30 wt%, 60 μL) and PVP (0.7 mM, 1.5 mL) were mixed with 150 μL (0.1 M) of $NaBH_4$ under vigorous stirring. The solution immediately turned pale yellow, then orange and pink, and finally blue and at the end of the reaction, indicating a finished growth process of nanoplates. The final content of the AgNPs in the colloid solution determined by atomic absorption spectrometer was 11 mg/l.

The optical properties of the AgNPs were studied by Thermo Evolution 600 UV–Vis spectrophotometer, while the morphology and their size were analyzed with a JEM-2100 LaB6 transmission electron microscope (TEM) operated at 200 kV.

Co fabric was first treated with 0.3% CHT solution (solution-to-fabric ratio 30:1), then washed with distilled water, squeezed at pressure of 2 kg/cm^2 and dried at room temperature. Then, 1g of Co fabric or CHT-treated Co fabric was immersed in 25 mL of colloid of triangular AgNPs for 30 min and dried at room temperature.

The antimicrobial activity of Co fabrics loaded with AgNPs was tested against *E. coli* (ATCC 25922), *S. aureus* (ATCC 25923), and *C. albicans* (ATCC 10259) using the standard test method ASTME 2149-01 [5]. Microbial inoculums was prepared in tryptone soy broth, supplemented with 0.6% yeast extract, and left overnight in thermostat at 37°C. One gram of sterile fabric cut into small pieces was placed in flask with 50 mL of sterile sodium hydrogen phosphate buffer solution (pH = 7.2), which was then inoculated with 500 μL of microbial inoculums and shaken for 2 h at 37°C. A 100 μL volume of aliquots from the inoculums previously subjected to decimal dilution with sterile physiological saline solution were placed in sterile Petri dishes, covered with tryptone soy agar, and incubated for 24h at 37°C. After incubation period, the colony forming units (CFU) of each plate were determined. The percentage of microbe growth reduction (R, %) was calculated using the equation $R = \frac{C_0 - C}{C_0} 100$, where Co is the number of CFU on the control fabric (untreated Co fabric without AgNPs) and C is the number of CFU after deposition of AgNPs on either untreated or CHT-treated Co fabrics.

RESULTS AND DISCUSSION

The morphology study of the initial solution of AgNPs by TEM measurements clearly reveals the presence of triangular and truncated-triangular NPs with edge length between 40-60 nm and thickness of about 5 nm (Figure 1a). Absorption spectrum of AgNPs dispersion contains three distinctive peaks, which indicates the presence of fine triangular AgNPs, Figure 1b. The observed peaks at 332, 466 and 754 nm are assigned to the out-of-plane quadrupole resonance, in-plane quadrupole resonance and in-plane dipole plasmon resonance, respectively [6].

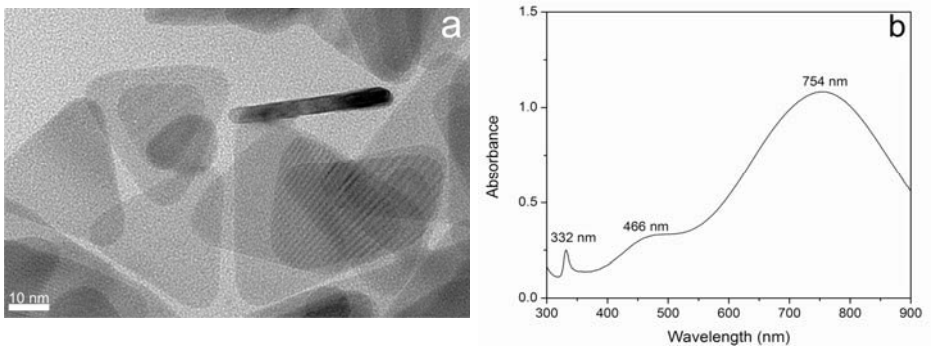

Figure 1. a) TEM image of triangular Ag nanoplates, and b) Absorption spectrum of their colloid dispersion.

Besides, the third peak is very sensitive to the sharpness of the tips on the triangles and for truncated triangles it could be blue-shifted in comparison to the position of resonance band for the perfect prism (λ = 770 nm), without influence on other resonances. For this reason, the observed blue-shift of third peak (λ = 754 nm) can be explained by higher yield of truncated prisms with blunt edges in comparison to the perfect prisms.

Antimicrobial activity of untreated and CHT-treated Co fabric impregnated with Ag nanoplates was tested after applied sterilization procedure and compared with CHT-treated Co fabric. It was found that CHT-treated Co fabric impregnated with AgNPs reached maximum microbial reduction in the case of *E. coli* and *C. albicans* (R = 99.9%) and this reduction was R = 99.6% in the case of *S. aureus*. On the other hand, the values of microbial reduction of untreated Co fabric impregnated with AgNPs were R = 99.9%, 56.9% and 28.4% against *E. coli*, *S. aureus* and *C. albicans*, respectively. Besides, control CHT-treated Co fabric without AgNPs did not show any antimicrobial activity due to low content of CHT on the surface of Co fabric. The results of these antimicrobial tests, clearly indicated that binding

of AgNPs to free amino and hydroxy groups of CHT impregnated Co fabric, induced larger content of deposited AgNPs on the Co fabric compared to untreated fabric, and therefore, higher levels of antimicrobial activity. Furthermore, the encouraging results obtained can be related to the shape of NPs, namely truncated triangular Ag nanoplates, which provide crystalline facets of higher reactivity (high atom densities) and, presumably, a higher rate of ions release from their tips and edges compared to other shapes of NPs.

CONCLUSION

The presented results demonstrated advantage of using CHT-treated Co fabric impregnated with AgNPs instead of untreated Co fabric in order to enhance the antimicrobial activity of coated textiles. Furthermore, this study showed that triangular Ag nanoplates have excellent antimicrobial activity against *E. coli*, *S. aureus* and *C. albicans* strains and could be used to prepare antimicrobial fabrics.

ACKNOWLEDGEMENT

This work was financially supported by the Ministry of Education and Science of Republic of Serbia (research project numbers: 172056 and 45020).

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