PRODUCING ANTIBACTERIAL TEXTILE MATERIAL BY WEAVING PVB/CuO NANOCOMPOSITE FIBER COVERED YARN

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Abstract

Electrospinning is an efficient method for the production of polyvinyl butyral (PVB) nanofiber layers that are suitable for water filtration. Layered fabric systems with electrospun PVB/copper oxide (CuO) nanocomposite fiber covered yarn were developed to impart antibacterial functions to textile material. The motivation of this paper was preparation of antibacterial textile material. - The hybrid yarn should benefit from multi-functionality of nanofibers combined with tensile strength of the core yarn. Nanocomposite covered yarns were woven in weaving machine. It was found out that by adding CuO nanoparticles, antibacterial efficiency of nanofiber covered yarn was improved.

Keywords: PVB, CuO, antibacterial efficiency, nanofiber

1. INTRODUCTION

Global competition in textile market has led to the development of high-tech products with multifunctional properties such as filtration, UV protection, disinfection, or pollutant decomposing properties. Engineered polymers, nanofibers or additives are mostly used for multifunctionalization of textile materials.

Polyester yarns covered with PVB nanofibers containing CuO nanoparticles were successfully prepared. Due to its high temperature superconductivity, electron correlation effects and spin dynamics, CuO has been widely used as batteries, gas sensors, catalysis, high-temperature superconductors or solar energy conversion [1, 2]. Many research papers deal with PVB due to its easy process ability and an affordable price [3-6].

Due to possible antimicrobial activity of the CuO, the PVB nanofibers containing CuO nanoparticles exhibited excellent antibacterial properties. CuO is cheaper than silver nanoparticles, easily mixed with polymer solutions and relatively stable in terms of both chemical and physical properties [7]. Highly ionic nanoparticles CuO, could be particularly valuable as antimicrobial agents.

Here, we report on preparation of yarn covered with PVB/CuO nanofibers. Roller electrospinning system was used for this purpose. The working principle of roller electrospinning system was explained in previous work [8] with explanation of parameters which can play important role during processing [9, 10]. In this work, we optimized processing conditions for electrospinning process to prepare PVB nanofibers with incorporated CuO nanoparticles . Finally, antibacterial properties of the prepared nanofibers were tested to evaluate the possibility of using this textile material for economically viable applications in water purification technology or biotechnology. Yarns covered with nanofibers (pure PVB) and with PVB/CuO nanoparticle were woven and antimicrobial properties of CuO nanocomposite fibers and layered fabric systems were evaluated quantitatively. The priority of this work is that nanofiber-covered yarns were woven on industrial scale and antibacterial efficiency were was confirmed.

2. MATERIAL AND METHODS

2.1. Material

CuO was purchased from PENTA s.r.o. Prague. Polyvinyl butyral (Mowital PVB60H) with 60,000 Da. was obtained from Kuraray, Japan. Acetic acid and distilled water were used as solvents. Core yarn is black textured polyester multifilament yarn (dtex 167f 36x1x3).

A fixed amount of 9 % wt. PVB and 4% wt. distilled water was used for all solutions. One of the solutions was prepared as a blank sample without CuO (P0) and the second solution was mixed with 10% wt.CuO nanoparticles (P1). Bacteria Escherichia coli (E. coli) were purchased from Czech Collection of Microorganisms, Masaryk University. Incubation of bacteria was performed on a sterile agar with broth medium from company Oxoid Cz.

9% wt. PVB polymer solutions in acetic acid/distilled water were prepared. After complete dissolution, 10% wt. CuO nanoparticles were added to the polymer solution and stirred with ultrasonic stirrer.

Roller electrospinning system was used for producing PVB nanofibers as shown in Fig. 1. This technology was developed by Jirsak et al. [11].

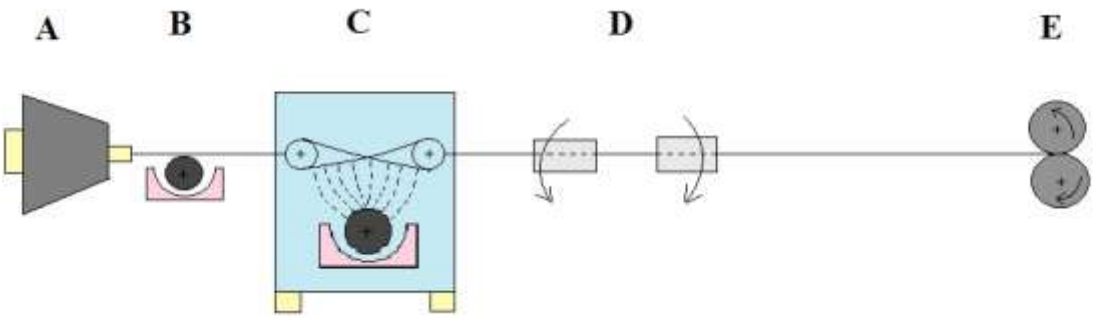


Fig. 1. Schematic diagram of a continuous production device A: base yarn, B: application of a conductive solution, C: nano spider, D: application of protective yarn(s), E: take-up mechanism.

External textured polyester yarn was used as a collector and after covering with nanofibers, yarns were collected into a basket in a desired meter and yarn speed. Spinning conditions are listed in Table 1.

Table 1 Spinning conditions of yarn covered by PVB nanofibers

Applied voltage	Distance between electrodes	Humidity /temperature	Speed of roller	Speed of yarn
60 kV	170 mm	18% / 24℃	11 rpm	80 m/min

2.2. Preparation of nanofiber-covered (hybrid) yarn and weaving

Textured polyester base yarn was transported to roller electrospinning and used as a collector. After covering by PVB nanofibers, yarn was transported into the basket. A protective polyamide yarn (11dtex) was used to cover the surface of nanofiber-covered-yarn to improve mechanical property and abrasion resistance of yarn and nanofibers on it as shown in Fig. 2.

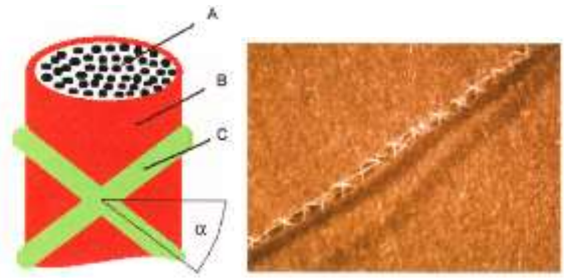


Fig. 2 Schematic diagram of a composite yarn, A: base yarn, B: nanofiber layer, C: protective yarn [11]

Scanning electron microscope (Tescan VEGA 3 SBU) was used to take image of hybrid yarns. Prepared yarns were delivered into the company VÚTS a.s. and plain woven as shown in Fig. 3.

Fig. 3 Woven fabric with nanofiber-covered yarn

2.3. Preparation of antibacterial test

The antimicrobial activities of the fabric systems were evaluated quantitatively in accordance with ASTM E 2149-01 (Standard test method for determining the antimicrobial activity of immobilized antimicrobial agents under dynamic contact conditions).

Firstly, samples were cut into 4.8x4.8 cm^2. The samples were sterilized in an oven for 60 min at 80°C. Sterilized specimen P0 was used as a blank sample. The antimicrobial activity of the nanoparticles is known to be a function of the surface area in contact with the microorganisms. The microorganisms E.coli were cultivated in sterilized tryptone soya broth and then incubated overnight at 37 °C in an incubator. Concentration of bacterial suspension was measured according to density of bacteria solution and colony forming unit (CFU) found as 10^8. The bacterial inoculum was diluted into 10^3 CFU/l for final tests. Specimens (blank and with CuO) were placed into inoculum E.Coli with 10^3 CFU/l. One test tube remained without sample as a ‘reference’ of purity the E. Coli inoculum. The test tubes with bacteria solutions and specimens were shaken all the time of test. Bacterial solutions were taken out from each test tube as a function of contact time (1 minute, 1 hour, 2 hours, 3 hours and 4 hours shaking) and cultured on agar plates, kept at 37 °C in incubator for 24 hours. Finally, the number of grown bacterial colonies was observed and counted.

The %reduction of test organisms after a specified contact time with the specimen was measured using the following Eqn. 1.

$$R\ (\%) = 100*(B-A)/B \qquad (1)$$

where R is reduction in percentage, A is the number of bacteria recovered from the inoculated treated test specimens in the test tube incubated over the desired contact period and B is the number of bacteria colonies in pure bacteria solution without any specimen (at “0” contact time).

3. RESULT AND DISCUSSION

Nanofibers were produced at stable conditions as listed in Table 1. Fibers were spun around a core textured yarn and form a core-shell. Then, nanofiber-covered yarn was covered with two supporting yarns from out surface to improve durability of yarn and nanofibers during weaving. Before weaving, image of hybrid yarns were taken by scanning electron microscope (SEM). The result of SEM is shown in Fig. 4.

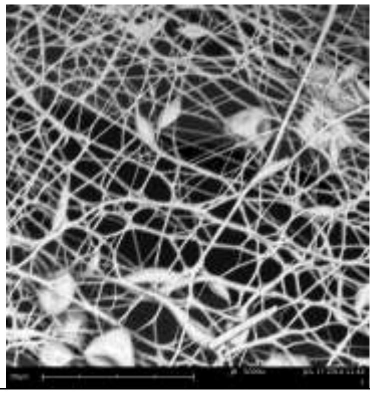
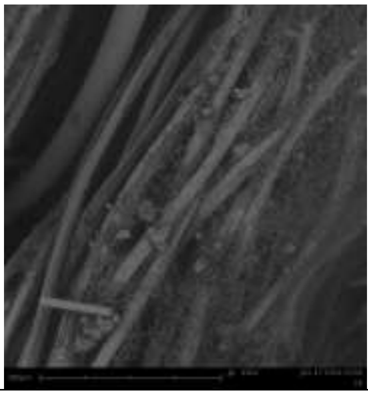
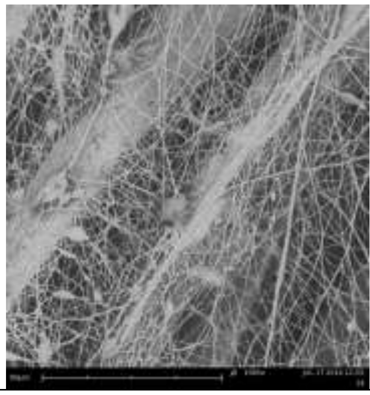
P0 (365 ± 92 nm)		
P1 (387 ± 74 nm)		

Fig. 4. SEM images of nanofiber-covered yarn

From Fig. 4 it seems that there are some droplets on the surface of nanofibers. However the aim of this work is producing antibacterial fabric. In this case effect of beads can be eliminated. The antibacterial efficiency were measured and shown in Fig. 5. The results showed that, at the first minute, the blank sample P0 did not have any antibacterial properties. On the other side, P1 shows a great inhibition effect (around 60%). When the contact time increase, P0 showed some efficiency around 40% . It could be due to rest of acetic acid in the sample which could be toxic for bacteria. The fabric with PVB containing 10% CuO shows great antibacterial properties. There were no bacteria grown on the agar plate after one hour contact of bacteria solution with specimen P1,

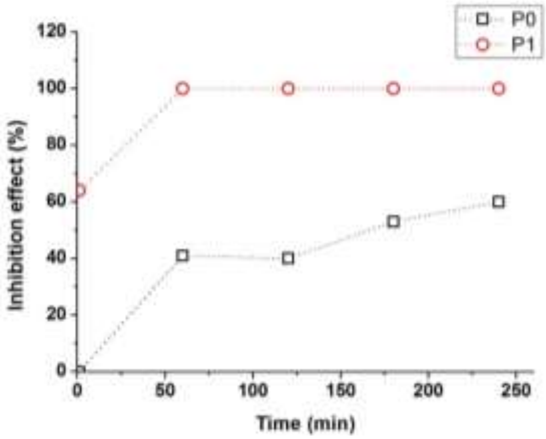


Fig. 5 Inhibition effect of bacteria at contact time with PVB/CuO and control PVB specimen

CONCLUSION

In this work, nanofiber-covered composite yarns were produced and woven successfully. Production speed of the composite nanofibrous yarns are suitable for the industrial scale application.. The antibacterial additive CuO incorporated to the nanofiber component of the fabric increased the added value by adding the antibacterial properties. According to the experimental results the nanofiber-covered yarns with CuO additive could be a good candidate for water cleaning applications.

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