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Water-Stable Electrospun PVA Nanofibers via Vapor Crosslinking and Controlled In Situ Silver Nanoparticle Incorporation for Antimicrobial Applications

Felipe Cordova Lozano (felipe.cordova@udlap.mx) *[1] Mexico, Luis Emilio Toxqui Martínez (ltoxqui@cideteq.mx)[2] Mexico, Ana Karen Cordova Estrada (ana.cordova@udlap.mx)[3] Mexico, Ivanna Gisell Vazquez Casillas (ivanna.vazquezcs@udlap.mx)[4] Mexico, Regina Alexa Gualito Cervantes (regina.gualitocs@udlap.mx)[4] Mexico

1 Chemical and Biological Department, Science School, Universidad de las Américas Puebla. Ex hacienda Sta. Catarina Mártir S/N. San Andrés Cholula, Puebla. ZIP 72810. Mexico, 2 Centro de Investigación y Desarrollo Tecnológico en Electroquímica, Parque Tecnológico Querétaro, s/n, San Fandila, ZIP 76703, Pedro Escobedo, Querétaro, Mexico, 3 Departament of Civil and Engineering, Universidad de las Américas Puebla UDLAP, San Andrés Cholula, Puebla, México, ZIP 72810, 4 Department of Chemical Engineering, Universidad de las Américas Puebla UDLAP, San Andrés Cholula, Puebla, México, ZIP 72810

INTRODUCTION

Polyvinyl alcohol (PVA) nanofibers produced by electrospinning are attractive for biomedical and antimicrobial applications due to their biocompatibility, high surface-area-to-volume ratio, and ease of processing in aqueous systems [1-3]. However, their inherent water solubility and lack of intrinsic antimicrobial activity limit their practical use in humid or physiological environments. This study reports the fabrication of water-stable electrospun PVA nanofibers via glutaraldehyde (GA) vapor crosslinking methodology, followed by the in situ incorporation of silver nanoparticles (Ag NPs) to enhance antimicrobial functionality. Such materials have potential applications as wound dressings, tissue engineering scaffolds, antimicrobial coatings for medical devices, drug delivery systems, and filtration membranes for water purification [4-5]. In particular, their porous nanofibrous structure can promote cell adhesion and gas exchange while simultaneously inhibiting the growth of pathogenic microorganisms, by improving their performance in healthcare and environmental applications.

METHOD

A 10 weight % PVA solution was prepared and electrospun under controlled parameters (10 kV, 0.27 mL/h, 7.0 cm tip-to-collector distance, and 70 % of relative humidity). Due to the nature of the polymer, these nanofibers exhibited complete solubility in water.
Crosslinking was performed using a (1:1) 0.5 M Glutaraldehyde/0.01 M HCl vapor treatment for 17 h, using a vacuum chamber. It was turned on the vacuum pump during 3 h and turned off to leave the vapor capsule chamber closed during 14 h.
After this process, Ag NPs were deposited onto crosslinked PVA nanofibers (cPVA) through chemical reduction using a solution of 0.001 M $AgNO_3$ as a precursor and a solution of 0.02 M $NaBH_4$ as a reductant agent. The sample was stirred in the $AgNO_3$ solution for 1 h under light protection. The solution was removed, and the vial was cooled in an ice bath before adding the pre-cooled $NaBH_4$ solution. It was stirred for 30 min. Finally, the nanofibers were washed three times with deionized water and dried at 40 °C.

RESULTS

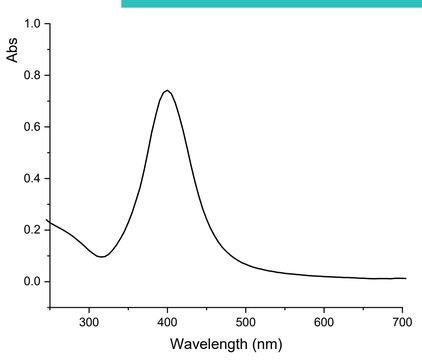


Figure 3. UV–Vis spectrum of the Ag NPs solution

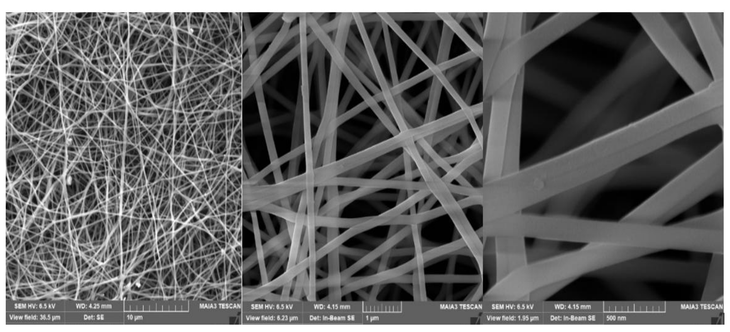
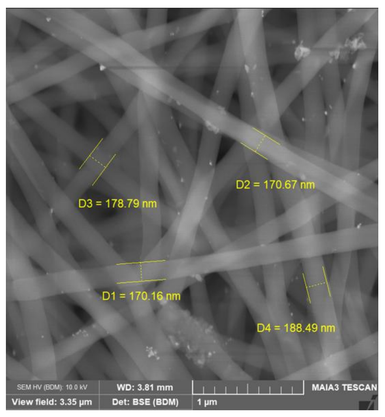
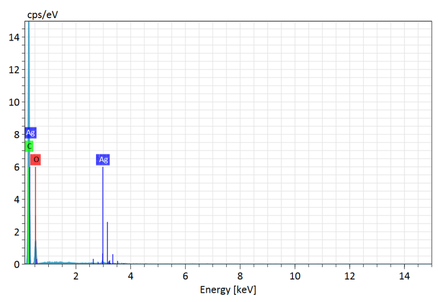


Figure 4. SEM image of crosslinked electrospun PVA nanofibers.

Figure 1. Electrospinning system

Figure 2. Vacuum chamber for crosslinking process





The weight percentage of C, O and Ag were 77.42%, 21.24% and 1.34%, respectively.

Figure 5. Morphology and EDS spectra of electrospun PVA nanofibers loaded with Ag NPs.

Figure 6. Antimicrobial activity against *E. coli* (*Escherichia coli*)

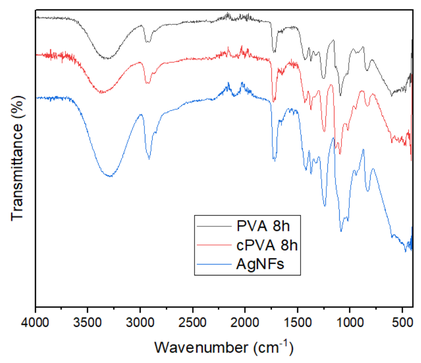


Figure 7. FTIR of PVA NFs, cPVA NFs and cPVA NFs-Ag NPs.

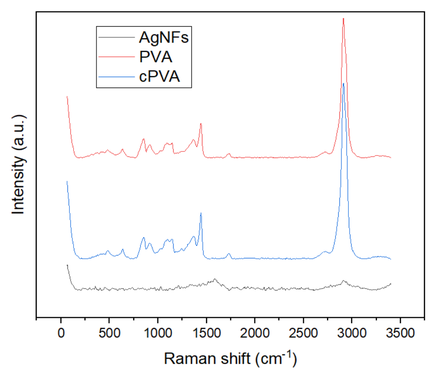


Figure 8. Raman spectra of PVA NFs, cPVA NFs and cPVA NFs-Ag NPs.

UV-Vis spectrum of the Ag NP solution showed a characteristic absorption peak at approximately 410 nm, which is commonly associated with silver. SEM images revealed a homogeneous network of randomly oriented nanofibers with diameters ranging from approximately 70 to 205 nm. Additionally, small bright spots were observed distributed along the surface of the fibers, which can be attributed to the presence of silver nanoparticles embedded in the nanofibers. FTIR spectra showed the characteristic absorption bands of PVA, confirming the preservation of its chemical structure after Ag NP's incorporation, Finally, an antimicrobial test against *E. Coli* confirmed that the silver NP's in the NF's exhibited significant antimicrobial activity.

CONCLUSIONS

The modified nanofibers demonstrated structural stability in water and surface chemical interactions between silver nanoparticucles and acetal groups. In this manner, GA vapor crosslinking effectively rendered PVA nanofibers water-insoluble while preserving morphology. Controlled in situ reduction enabled uniform Ag NPs incorporation, producing nanofibrous composites with potential for antimicrobial biomedical applications..

FUTURE WORK/ REFERENCES/ACKNOWLEDGMENT

FUTURE WORK

In this work we propose to continue working on:

- Evaluate the long-term stability of Ag NP-loaded nanofibers under physiological and environmental conditions.
- Investigate the release kinetics of silver ions from the nanofibrous mats.
- Expand antimicrobial studies against additional microorganisms, including *Staphylococcus aureus*, *Pseudomonas aeruginosa*, and fungal pathogens.
- Assess cytocompatibility and cell proliferation using mammalian cell lines to determine suitability for biomedical applications.
- Explore the incorporation of bioactive compounds and antibiotics to develop multifunctional wound dressing materials.

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