ANTIBACTERIAL PROPERTIES OF CARBON FIBERS WITH LAYER DEPOSITED BY MAGNETRON TECHNIQUE

Roksana Kurpanik[1], Ewa Dzierzkowska[1], Maciej Gubernat[1], Marcin Kudzin[2], Maciej Boguń[2], Ewa Stodolak-Zych[1]*

[1] Faculty of Materials Science and Ceramics, Department of Biomaterials and Composites, AGH University of Science and Technology, Krakow, Poland
[2] Lukasiewicz Research Network- The Textile Research Institute, Lodz, Poland
*e-mail: stodolak@agh.edu.pl

[Engineering of Biomaterials 163 (2021) 103]

Introduction

A new look at carbon materials with a future in medicine is carbon nanofibers (CNF) or carbon fibers (CF) with controlled surface properties. Due to the fibrous form (nano)fibers can provide an attractive substrate to aid in the regeneration of many challenging tissues including neural and cartilage due to their microstructure that mimics the geometry of the extracellular matrix [1-2]. A well-known approach in the environmental protection is to use carbon fibers in the active form called activated carbon fibers (ACF) in which porous, highly absorbing surface exhibits bactericidal properties. These fibers are often subsidized with biocidal agents such as silver or zinc.

Carbon fibers with activated surface are the most promising absorbents (supports) characterized specific and selective capabilities for interacting with biologically active molecules and organisms. Fibers containing an ultra-dispersed metal phase represent a new type of absorbent which action is based on affinity for proteins and heavy-metal ions e.g.; Ag, Zn, Cu, Ni which induct special interaction with bacteria. In many instances, such fibers are called nanostructured composites [3].

In our research we propose to use classical low modulus carbon fibers, commonly used in medicine, as a carrier of active layer of bactericidal character. The carbon fibers (CF) were subjected to appropriate physicochemical treatment i.e. magnetron sputtering and covered with a layer of titanium, copper and zinc. A CF/Zn was used as a positive reference for CF/Ti and CF/Cu fibers investigated. Their antibacterial activity against Gram-positive and Gram-negative bacterial cultures was investigated.

Materials and Methods

A two-step thermal conversion process was used for the thermal treatment of polyacrylonitrile (PAN, Sigma-Aldrich) polymer fibers. The base material for this process was a polyacrylonitrile nonwoven with a surface density of 120 g/m^2. The first step of thermal conversion was oxidation (250^{o}C/air) and the second step was low-temperature carbonization (970^{o}C/nitrogen). Fiber morphology was observed using scanning electron microscope (Nova NanoSEM, FEI). The samples were modified using the DC magnetron sputtering system produced by P.P.H. Jolex s.c. (Czestochowa, Poland). The modifying metallic layers were deposited in a protective atmosphere using copper, titanium and zinc targets. The presence of the layer and its uniform distribution on the fiber surface were verified by SEM/EDS. The effect of the layer on physicochemical properties such as contact angle and surface free energy was evaluated with a 25 Kruss goniometer.

All materials were subjected to antimicrobial testing using the Kribby-Muller diffusion method. Morphology of Gram-positive and Gram-negative bacterial cultures contacted with fibrous substrate modified with a layer of copper, titanium and zinc was also examined.

Results and Discussion

The experimental results show that the process of thermal conversion of the polymer fiber with PAN to carbon fibers induces a fiber shrinkage of 6%. Thus, the diameter of the carbon fiber comparing to the diameter of the precursor polymer fiber decreases from 15 to 11 µm. The carbon fibers exhibit a significant decrease in wettability relative to that of the polymer nonwoven. Magnetron sputtering leads to a metallic layer on the source-exposed side of the nonwoven. The layer has a homogeneous character on the outer fibers. Its presence determines the increase of wettability from 30^o for carbon nonwoven to 50-62^o for carbon nonwoven with titanium and copper layer, respectively. All metallic layers show bacteriostatic effect and the nonwoven fabrics with copper layer also show bactericidal effect regardless of the type of strain used in the tests (FIG. 1).

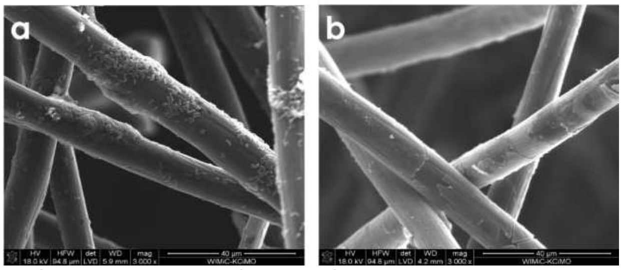

FIG. 1. Morphology of carbon fibers without copper layer (a) and with copper layer (b) after exposure to *E.coli.*

Conclusions

Carbon fibers formed by thermal conversion of PAN can be modified by magnetron sputtering. The resulting metallic layer is only external, and its thickness depends on the process conditions. The presence of the layer increases the contact angle and has an antibacterial activity.

Acknowledgments

The work was supported by the National Science Center – Poland: Project no: UMO-2018/31/B/ST8/02418

References

[1] Yong Liu, *et al.* New Carbon Materials, 35 (2020) 323-335.
[2] T. Weigel T, J. Brennecke *et al.,* Materials 14, (2021) 1378.
[3] E. V. Saklakova *et al.,* Fibre Chemistry. 47 (2015) 324-328.