POLYACRYLONITRILE NONWOVENS FOR THE PRODUCTION OF CARBON MATERIALS SUPPORTING THE REGENERATION OF BONE AND CARTILAGE TISSUES

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ABSTRACT

The influence of the change in surface weight on the physical properties of oxidized polyacrylonitrile precursor nonwovens intended for the production of carbon materials used in tissue engineering was studied. Thermal insulation properties of the nonwovens and their behavior during incubation in phosphate buffered saline (PBS) were investigated. Initial carbonization tests showed that from the point of view of carbonization and further application of carbon materials, the most effective was the use of a surface weight of about 120 g/m^2. At the same time, for the research conducted on the incubation of nonwovens in PBS, no significant change in the pH of the solution was found.

KEYWORDS

Polyacrylonitrile fibers; Nonwovens; PBS incubation; Thermal insulation properties.

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INTRODUCTION

One of directions in the development of contemporary medicine is the search for new materials that will support the process of tissue regeneration. Among these types of materials, carbon fibers, carbon nanostructures and composites with their participation are of particular importance. They have been used in many solutions in modern medicine [1-5]. In this case, it is important to properly select both the carbon fiber precursor and the carbonization process itself so that the produced carbon structure and its properties are appropriate for the intended purpose [6,7]. When thermal insulation properties of precursor nonwovens are known, it possible to select the most favorable conditions for the carbonization process in order to obtain a carbon nonwoven fabric with the same chemical structure in the entire bulk. This is extremely important from the point of view of medical application of carbon nonwovens, which will constitute the scaffolding of hybrid carbon-polymer biomaterials. At the same time, knowledge of the impact of the carbonization process on the liquid absorption capacity, changes in pH and conductivity of the incubated medium allows us to shape the behavior of the biomaterial in vitro and in vivo.

The aim of this study was to examine thermal insulation properties of the produced precursor nonwovens with two surface weights and to investigate the incubation of the nonwovens in a phosphate-buffered saline (PBS) solution.

EXPERIMENTAL

Materials

Oxidized polyacrylonitrile fibers from Toray (Hungary) were used for the production of nonwovens. Figure 1 shows a cross-section and longitudinal view of the fibers used. Medical grade phosphate-buffered saline solution (PBS) was used for incubation tests.

Methods

The nonwovens were produced using a mechanical fleece forming system with a laboratory carding machine. Then, the obtained fleece was subjected to the needling process on a HEUER type ROM 30LP/120/11/900 needle punching machine.

Measurements of the surface topography (SEM analysis) of the materials were carried out on a VEGA3 TESCAN (Tescan Osay Holding, Brno, Czech Republic).

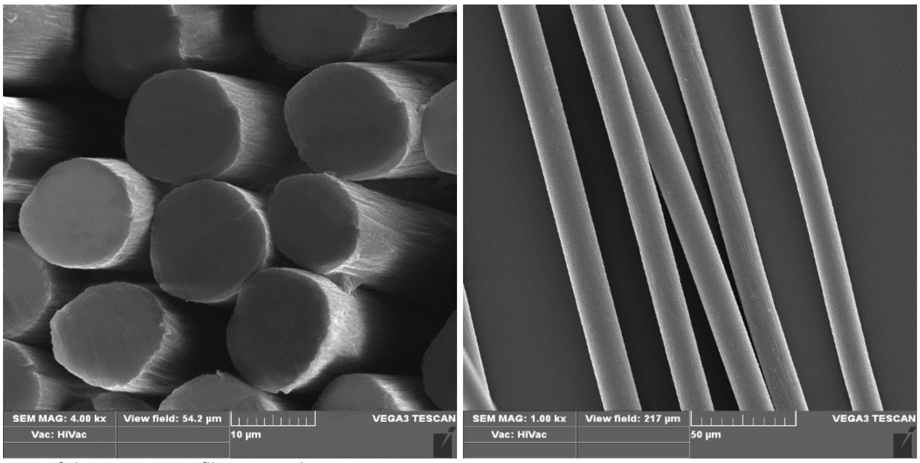

Figure 1. SEM pictures of the precursor fibers used.

Table 1. Thermal insulation parameters for precursor nonwovens.

Sample	λ $Wm^{-1}K^{-1}$	a m^2s^{-1}	b $Wm^{-2}s^{1/2}K^{-1}$	r Km^2W^{-1}	h mm	p -	q_{max} Wm^{-2}
OPAN 120	0,0368 ±0,0006	6,61E-07 ±1,04E-07	45,6 ±3,1	0,0712 ±0,0006	2,62 ±0,04	3,70 ±0,32	0,531 ±0,046
OPAN 600	0,0475 ±0,0019	4,37E-07 ±1,19E-07	73,1 ±8,3	0,1302 ±0,0066	6,17 ±0,16	5,86 ±0,78	0,528 ±0,065

where: λ – thermal conductivity; a – thermal diffusivity; b – thermal absorption; r – thermal resistance; h – thickness; p – the quotient of the maximum and stationary heat flow; q_{max} – maximum heat flow.

To test the thermal insulation properties, the Alambeta device (Sensora, Czech Republic) was used, by means of which thermal conductivity, thermal diffusivity, thermal absorption, thermal resistance, quotient of the maximum and stationary heat flow density were measured.

The incubation of the nonwovens in PBS was examined at specific intervals. The pH and conductivity of the incubated medium was determined with an immersion probe.

RESULTS AND DISCUSSION

The study of thermal insulation properties shows that an increase of the surface weight from 120 g/m^2 to 600 g/m^2 causes an increase in thermal insulation parameters. This is typical because of a similar structure of the material used and differences in its thickness. There are significant differences in all tested thermal insulation parameters. The exception is heat flow density, which is at a similar level for both surface weights (Table 1). When analyzing results of the test and carrying out the process of carbonization of nonwovens, it should be stated that the increase of the surface weight results in quality deterioration of the produced carbon materials. It should be noted, however, that in the case of medical use of this type of biomaterial, the carbonization process is carried out to a temperature 1200°C. At the same time, as part of the work, research was carried out on the incubation of the produced nonwovens in the PBS medium at various intervals. Figures 2 and 3 show the results of changes in pH and conductivity of the incubated medium after keeping the nonwovens in it for various periods.

The conducted research shows that the surface weight is of no great importance for the pH of the medium. In both cases, the change of pH ranges from 6 to 7. On the other hand, in the case of conductivity, the influence of the surface weight of the nonwoven on changes of this parameter is visible. The incubation medium in which the nonwovens with a lower surface weight were kept shows an increase in conductivity over time, unlike the medium in which the nonwovens with a surface weight of 600 g/m^2 were incubated.

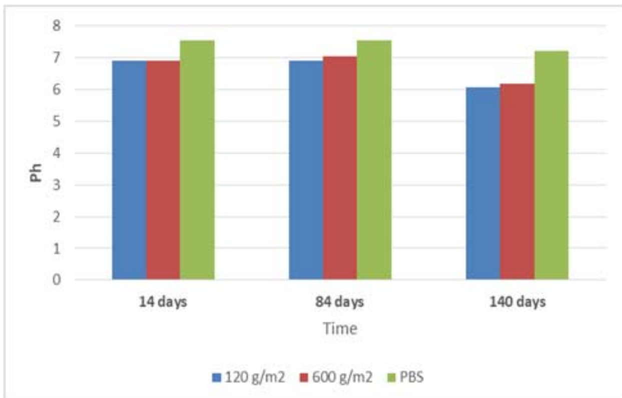

Figure 2. Changes in the pH of the incubation medium over time.

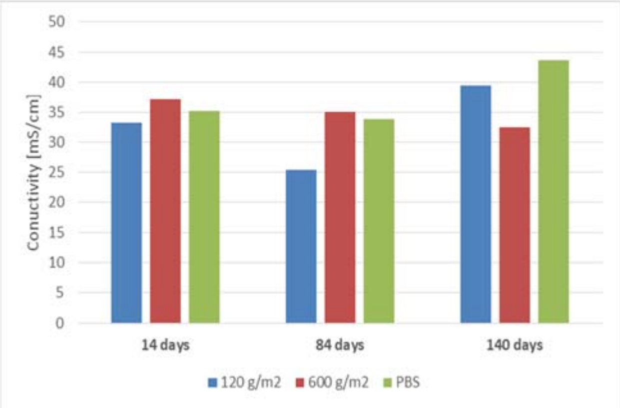

Figure 3. Changes in the conductivity of the incubation medium over time.

CONCLUSIONS

It follows from the research on thermal insulation properties that the surface weight of nonwovens can have a significant influence on the carbonization effectiveness. This may result in differences in the properties of the carbon material in the entire bulk. In the case of medical use of carbon structures, it is important that the carbon structure produced during the carbonization process is homogeneous. In this case, the lack of homogeneity in the chemical structure may result in the formation of inflammations in vivo. Research on the incubation of nonwovens with different surface weights in the assumed time intervals showed differences in the parameters tested. Therefore, it is important to reconcile many opposing interdependencies in the design of biomaterials, so that the material constructed in this case, being a type of GBR membrane (guide bone regeneration), contributes to the effective process of tissue regeneration.

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