POLYACRYLONITRILE PRECURSOR FIBRES CONTAINING BIOGLASS

Grzegorz Szparaga, Paulina Król, Maciej Boguń*

Department of Man-Made Fibres
Technical University of Lodz, Poland
MAILTO: maciek.bogun@wp.pl

[Engineering of Biomaterials, 99-101, (2010), 121-122]

Introduction

One of the directions in which biomaterials engineering and regenerative medicine are developing today is the discovery of ever newer implant materials which would considerably shorten the body's regeneration time, and thus reduce the costs of hospitalization and rehabilitation of patients.

An alternative solution to the implants currently used in orthopaedics and traumatic surgery might be the use of composites produced with carbon fibres obtained using a new generation of polyacrylonitrile precursor fibres. The introduction of bioglass into the precursor fibres as a nanoadditive will make it possible to obtain carbon fibres or unwoven fabric whose structure contains an inorganic, biologically active compound. A convincing argument for the use of a nanoadditive of this type could be the fact that it is one of the most widely used bioceramic materials in orthopaedics [1-5]. The carbon fibres are also required, in addition to the basic biological properties, to demonstrate high strength in combination with higher porosity. Both of these parameters are directly dependent on the structure and properties of the precursor fibres. The formation of PAN fibres wet from solution makes it possible to control the process parameters suitably so as to obtain the desired properties [6-8]. Carbon fibres or unwoven fabrics obtained in this way can be used to produce composite materials also containing other biodegradable polymers, such as aliphatic polyesters. The composites so obtained will be characterized by differentiated biodegradation times, anisotropy of properties (due to the presence of fibres) and extensive possibilities in designing their porosity. Porosity, and also the nature of the surface of the ready implant, are parameters which determine how well the material introduced into the body interacts with the surrounding tissues.

The objective of the research reported here was the production of a new generation of precursor PAN fibres containing bioglass nanoadditive, and fulfilling the condition of good processability into unwoven fabric. These fabrics will be a starting product for obtaining a new type of carbon-polymer composites intended for bone tissue regeneration. This work constitutes part of a series of research on the selection of appropriate conditions for the formation of precursor PAN fibres containing bioglass nanoadditive.

Formation of PAN fibres and methods

Fibers were spun by the wet process from solution using a laboratory spinning machine that made it possible to stabilize required technological parameters under a constant control. A spinneret with 240 orifices, 0.08 mm in diameter each, was used. Fibers were solidified in a bath containing an aqueous solution of DMF with a concentration adapted to the given spinning series under investigation. The fiber drawing process was carried out in two stages: in a plasticizing bath and under superheated steam. After rinsing the fibers were dried at 20-40°C under isothermic conditions.

Moisture content measurements at 100% RH were carried out in accordance with the Polish standard PN-71/P-04635.

Water retention (WVR) was measured by relating the weight of retained water after centrifuging a sample for 10 min at an acceleration of 10000 $m \cdot s^{-2}$ to the weight of a dry sample. Prior to centrifuging, fibers were immersed in water containing 1% of Rokafenol NX-3 (a surface-active agent) for 24 h.

Fiber tenacity at break was measured according to the Polish standard PN-85/P-04761/04, using an Instron tensile testing machine.

Results

The objective of the work was to obtain precursor fibres with good strength properties, enabling the processing of the fibres into unwoven fabric, which will then undergo a process of carbonization. Conditions of forming were taken as in our previous work [..], making it possible to obtain precursor fibres with the increased porosity that is advantageous for the medical application of carbon fibres. The obtained precursor PAN fibres have a tenacity in the range 34–41 cN/tex, where the highest value of this parameter was obtained for fibres formed at a value of pull-out at the as-spun draw ratio of –40%. These fibres also gave the highest value for total draw, at 912%.

The lowest specific tenacity value was obtained in the case of fibres whose total draw was 737%. In spite of the large differences in specific strength, the fibres obtained have similar elongation at brake, at a level of 10–11%. Both the specific strength and elongation at brake values are at levels which make it possible to process these fibres into unwoven fabric.

Tests of sorption properties show that all the types of fibres obtained have similar moisture sorption at 65% RH, amounting to around 2%, and moisture sorption at 100% RH, in the range of 6.3–7.4%.

TABLE 1. Properties of PAN fibres containing bioglass.

Sample symbol	As-spun draw ratio [%]	Total draw ratio [%]	Moisture sorption at 65% RH [%]	Moisture sorption at 100% RH [%]	Tenacity [cN/tex]	Elongation at brake [%]
P B1	10	817.48	2.20	6.45	37.83	11.48
P B1A	10	737.85	2.04	6.30	34.27	10.38
P B2	-40	912.58	2.04	7.39	41.02	11.81

Summary

The tests carried out demonstrated the possibility of obtaining PAN fibres containing bioglass with a tenacity of more than 30 cN/tex and elongation at brake of around 10%. Both of these parameter values are such as to allow the conclusion that the fibres obtained will offer good processability into unwoven fabric. The results of tests of the properties of the fabrics obtained, and of the process of their carbonization, will be the subject of subsequent work.

Acknowledgement

Research financed by the Minister of Science and Higher Education in 2010-2013 as project No. N508 487638.

References

[1]. Hench, L.L. J Am Ceram Soc 74, 1991, 1487
[2]. Hench, L.L. J Am Ceram Soc 81, 1998, 1705
[3]. Yilmaz, S.; Efouglu, E.; Kilic, A.R. J Clin Periodontol 25, 1998, 832
[4]. Yoshi, S.; Oka, M.; Yamamuro, T.; Ikeda, K.; Murakami, H. Acta Orthop Scand 71, 200, 580
[5]. Yukna, R.A.; Evans, G.H.; Aichelman-Reidy, H.B.; Meyer, E.T. J Periodontol 72, 2001, 125
[6]. I.Smitzis, Colloid Polym. Sci. 255, 1977, 948
[7]. S.P.Papkow, Chim. Wołok. 4,1981, 13
[8]. T.Mikołajczyk, I.Krucińska, K.Kamecka-Jędrzejczak, Textile Res. J. 59, 1989, 557
[9]. M.Boguń, T.Mikołajczyk, S.Rabiej Journal of Applied Polymer Science 114, 2009, 70
[10[. M.Boguń, T.Mikołajczyk, G.Szparaga, A.Kurzak, M.Wójcik Fibres&Textiles East Eur. 5, 2008, 48
[11]. T.Mikołajczyk, M.Boguń, M.Błażewicz, I.Piekarczyk J. Appl. Polym. Sci. 100, 2006, 2881

ENHANCED CELL INTEGRATION TO TITANIUM-GRAFIT COMPOSITE

Elżbieta Menaszek[1,2], Anna Ścisłowska-Czarnecka[3], Piotr Deptuła[4], Jan R. Dąbrowski[4]

[1]AGH University of Science and Technology,
Department of Biomaterials,
30 Mickiewicza ASve., 30-059 Cracow, Poland
[2]Jagiellonian University, Collegium Medicum,
Department of Cytobiology,
9 Medyczna Str., 30-688 Cracow, Poland
[3]Academy of Physical Education, Department of Anatomy,
38 Jana Pawła II Ave., Cracow, Poland,
[4]Bialystok University of Technology,
Department of Materials and Biomedical Engineering,
45C Wiejska Str.,15-351 Bialystok, Poland

[Engineering of Biomaterials, 99-101, (2010), 122]

Introduction

Titanium based materials are widely used owing to desirable properties that include light weight, high strength and durability. Titanium based materials are also biocompatibile, making them ideal for medical replacement structures such as orthopedic and dental implants.

Nevertheless, because of poor wear resistance, titanium materials are still facing clinical challenges such as implant loosening over time. The addition of graphite to lower the friction coefficient and increase wear resistance could produce a composite material that overcomes these disadvantages. Furthermore, the addition of graphite could improve the cell/material surface interaction and influence the cell capacity to proliferate and differentiate.

In our study the ability to promote cell proliferation and adhesion of titanium and titanium-grafit composite was compared by assessing the attachment of human normal osteoblasts in vitro.

Materials and methods

Materials

Specimens were fabricated by means of powder metallurgy method. Commercially available pure titanium in volume 80% and graphite in volume 20% were used as the component powders. The particle size of the pure titanium powder was below 150 μm, graphite powder had a mean particle size of 100 μm. Both components were mixed, cold compacted under pressure of 500 MPa and sintered for three hours in vacuum at the temperature of 1230^{0}C.

Cell culture

The autoclaved titanium or titanium-graphite composite round compacts were placed in 48-well plates, one in each well. 1 ml of cell suspension containing 1,5x10^4 NHOst cells (Lonza, USA) was added on the surface of each specimen. Cells seeded on tissue culture plates (TCPS) at the same density, were used as positive controls. The biocompatibility of the sintered titanium-graphite composite was determined by the cytotoxicity studies (ToxiLight assay, Lonza, USA), adherence (crystal violet absorbance test) and proliferation rate (ViaLight assay, Lonza, USA) of cells seeded on materials. The morphology of the adherent cells was studied by fluorescence microscopy.

Results

Obtained results indicate that the presence of graphite have an impact on cellular adhesion, but not significantly on cellular proliferation. The cells seeded on the surfaces of the titanium-graphite composites have slightly lower proliferation, as compared to those cells seeded on the pure titanium and TCPS surfaces. However, it was observed that the human osteoblasts adhered well onto the surface of titanium-graphite compacts and exhibit proper phenotype (FIG.1).

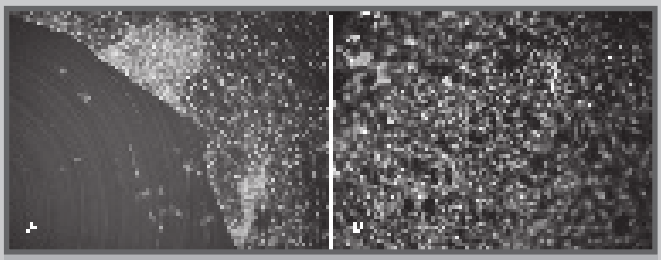

FIG.1 The cell adherence to titanium (A) and titanium-graphite composite (B). Cells well proliferated on the surface of titanium can be very easily detached from it. Micrographs obtained through fluorescence microscopy. Objective magnification 10x.