Chemically and physically functionalized carbon composites – a prospective material for tissue treatment

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Introduction

Many structural materials have been placed in the human body in attempt to aid the body in repairing processes of diseased hard and soft tissues. By far, the predominantly used materials in the treatment of soft and hard tissue have been and still are metals and pure polymers. The engineering of living tissue in vivo requires new concept in technology of materials used as the implants for repairing and the development of tissues.

Hard and soft tissues reveal complex structure, thus their physical and mechanical properties are often strongly anisotropic resulting from the presence of fibrous components in organic or inorganic matrix. Various forms of fibrous implants in the form of tissue, braids, mesh, woven and unwoven fabrics, three dimensional fibrous matrices have been tested in medicine for several years [1,2,3,4,5,6]. Synthetic resorbable polymers in the form of the scaffolds used alone or seeded with cells to support the regeneration of the body organs and tissues were also extensively investigated [7].

The use of fibrous scaffolds seems to be especially attractive in tissue engineering. The concept of tissue repair with the use of synthetic fibrous material is the autologous growth or regeneration of original tissue within the biomimetic microstructure. Such types of materials allow uniform seeding, geometric features controlled on the micrometric and nanometric scale and shaping of the supporting material into three-dimensional shapes. Moreover, by chemical and/or physical modification of surface biomaterial, the cell attachment and growth can be optimized in term of surface features and geometry. The composites having such fibrous components open new possibilities in design and modeling biomaterial properties.
Carbon fibers and carbon fibers – based composites are also investigated as potential constituents of medical devices for structural fixation of bone fragments, bone substitutes and support for cellular growth in tissue engineering [8,9].

The research group from the Faculty of Materials Science and Ceramics from Cracow (Poland) has developed various forms of composite biomaterials based on specific carbon fibers. Depending on the method of preparation, the type of matrix and selecting fibrous carbon precursors, surface modifications, there have been elaborated various composites in forms of braids, fabrics, cloths, CF-based composites [10].
The table 1 gathers the types of carbon fibrous materials, their basic properties and area of possible applications.

Table 1 Types of possible carbon fibrous implants

No	Type of fibrous material	Features	Possible applications
1	MD unwoven fabric/pyrolytic carbon coating	LTI–type carbon - coatings, basic surface groups	Scaffolds for bone defect filling, without load bearing
2	MD unwoven fabric, chemically modified	Surface acidic groups	Scaffolds for joint cartilage defects filling, reinforcement of polymer matrix for trachea and larynx implants
3	1D braids, chemically modified	Low-crystalline CF[1], surface acidic groups, High strain to failure of CF	Replacement and reconstructions of ligaments and tendons
4	1D,2D roving, tissue, surface modified	Basic and acidic groups	Reinforcements of polymers, carbon, and ceramic matrices, for load bearing devices and mini- devices
5	Porous carbon fibers	Small size pores in whole volume of CF	Tailored scaffolds for cartilage, cancellous bone, directionally–dependent tissue conductors

)[1] CF- carbon fibers

The work illustrates selected examples of carbon fibers and carbon fibers based composites (PTFE/PVDF/PP polymer) in vitro and in vivo study.

Experimental

PTFE/PVDF/PP polymer containing tetrafluoroethylene, vinylidene fluoride and propylene unitshas been used to prepare the composite samples. To modify this polymer two types of fibers differing in surface acidic groups were used:

- non- treated carbon fibers - [surface acidic groups-$4.51*10^{-5}$ mol/g]
- chemically treated carbon fibers –[surface acidic groups -$10.55*10^{-4}$]

Also two type of fibrous scaffolds made of porous (PAN) and non-porous carbon fibers (PAN P) were compared in vivo conditions. An open porosity of porous fibers was about 6%, with mean pore of 10 nm. Viability of the cells contacted with the materials was studied by MTT method. The cells originated from fibroblasts and osteoblasts human line. Human cells lines called hFOB 1.19 and HS 5 were used. Viability of the cells was determined after a 7 day period. At the same time the amount of collagen type I produced by the cells was analyzed using the ELISA test. Amount of collagen I in the vicinity of implant site was determined in vivo test.

Results and discussion

Results of vitality studies and the amount of collagen were expressed in percentages, assuming that the number of the control cells surviving at the same time as well as the amount of collagen produced by these cells were equal to 100%. Results of the *in vitro* studies are presented in Fig. 1, 2 and 3.

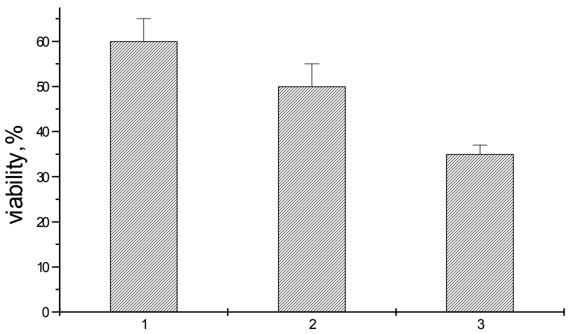

Fig. 1 Viability of fibroblast cells (human line HS5) in contact with the surface of : 1- pure polymer, 2- carbon fibers – based polymer, 3- chemically modified carbon – fibers – based composite

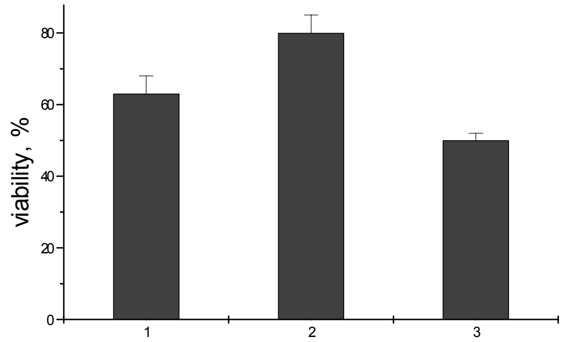

Fig. 2 Viability of osteoblast (human line hFOB) in contact with the surface of: 1- pure polymer, 2- carbon fibers- based composite, 3- chemically modified carbon fibers-based composite

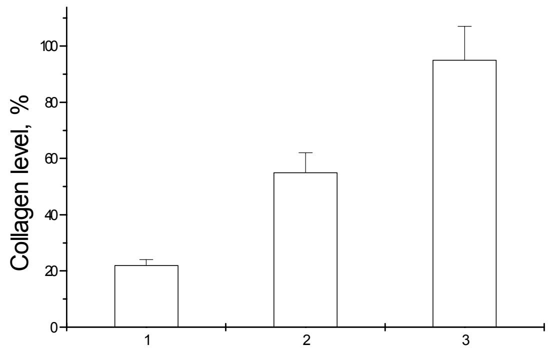

Fig.3 Collagen I level produced by osteoblasts on the surface of :1- pure polymer, 2- carbon fibers- based composite, 3- chemically modified carbon fibers – based composite

Figure 4 compares the amounts of collagen I (in percentages) determined in vicinity of porous and non- porous implant with reference to surface unit of implant site.

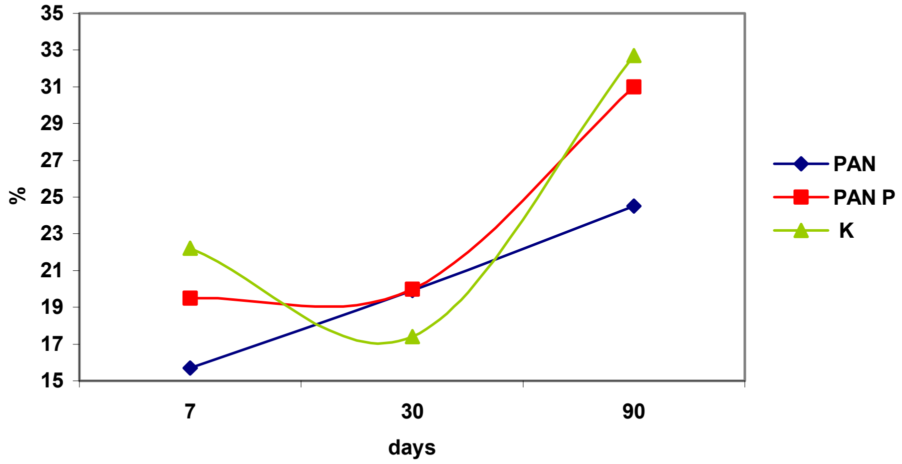

Fig.4 Percentage of collagen I in implant site (per mm^2) after implantation of non-porous carbon fibers (PAN), porous fibers (PAN P), control sample - K

Conclusions

Dispersion of carbon fibers in polymer matrix changes cell response to implant in comparison to pure polymer.

Carbon fibers with nanometer dimension elements (pores) can enhance cells adhesion, multiplication, and function. They can play significant role in biomaterials engineering and tissue engineering.

Different techniques of carbon fibers modification allow preparation of optimal biomaterials for definitive medical use.

Acknowledgments:
This work was supported by Polish State Committee for Scientific Research, project no. PBZ/KBN-082-T08/2002

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