SHORT CALCIUM PHOSPHATE WHISKERS AS REINFORCEMENT OF POLYMER COMPOSITES FOR BONE TISSUE REGENERATION

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Introduction

The necessity of replacing autogenous grafts with synthetic implants forces the development of new, improved materials that meet different requirements depending on the given need [1].

The worst bone injuries include heavy fractures as well as large bone defects caused by infections or cancers. In the case of the former, the promising biomaterials supporting regeneration may be solid composites for implants stabilizing the fractures (plates, screws, nails), characterized by very high mechanical strength, stiffness and degradability. However, injuries associated with the occurrence of bone defects require the use of filling materials that, apart from biocompatibility, resorbability and strength, will have an appropriate microstructure and optimal pore size that will allow good cell penetration, ingrowth of tissue, rapid vascularization and ease of nutrient delivery [2].

Meeting of such diverse requirements is expected primarily from polymer-ceramic composite materials. A well-known method of strengthening of these composites is the use of fillers with various morphology, especially thin fibers (whiskers). Apatite whiskers that exhibit biotolerance in the tissue environment, controlled resorption and the possibility of creating a permanent and strong connection to the bone are particularly widely considered. The whisker reinforcement effect can be explained by a shear lag analysis in which the whiskers can be loaded up to their fracture strength [3].

The aim of the work was verifying if the short Ca-P whiskers are proper to reinforcing porous and solid polymer composites. In the work we checked how the addition of short Ca-P whiskers affects the strength properties of porous composites and we compared the results with previously obtained results for solid composites [4]. As the polymer matrix in the composites a biodegradable polylactide was used which is widely used in orthopedic surgery as well as in tissue engineering scaffolds. The work shows also the research results on the effect of the whiskers on morphology, density and porosity of composites.

Materials and Methods

Ca-P whiskers used in this work were prepared in accordance with our previous work [5] and modified with lauric acid or γ-aminopropyltriethoxysilane (Sigma-Aldrich) to improve surface chemical compatibility between whiskers and the polymer matrix.

Solid composites were prepared by hot-pressing of casted and evaporated suspensions of Ca-P whiskers in solution of polylactide (Evonik) in dichloromethane (Avantor). The composites with 10 wt.%, 20 wt.% or 30 wt.% of Ca-P whiskers were prepared.

Porous composites were prepared by lyophilization of frozen suspensions of Ca-P whiskers in solution of polylactide in 1,4-dioksane (Avantor). The whiskers content in composites was in the range of 10-30 wt.%.

The morphology of whiskers and composites was evaluated by scanning electron microscopy (SEM). A Fourier transform infrared spectrometer was used to identifying the chemical functional groups. Density and porosity were determined by the liquid displacement method. Mechanical properties of the composites were evaluated by tensile or compressive tests.

Results and Discussion

The obtained results indicate that with the addition of whiskers to composites, the compressive strength of the porous composites may increase significantly (from 0,13 MPa up to 0,26 MPa for composites based on 4% polylactide solutions), while the tensile strength of the solid composites slightly decreases. The composites based on modified whiskers show higher compressive and tensile strengths than the composites with unmodified whiskers.

SEM observations show that short Ca-P whiskers are embedded in thin walls of the porous scaffolds providing them with reinforcement. The modified whiskers are better covered with the polymer than the unmodified whiskers and they're distributed more homogenously in the polymer matrix. That confirms better surface chemical compatibility between modified whiskers and the polymer matrix (FIG. 1).

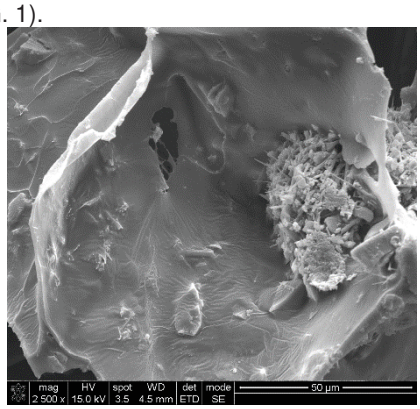

FIG. 1. SEM image of porous composite with the addition of modified Ca-P whiskers.

By manipulating of solutions concentrations and the content of whiskers, porous scaffolds with different densities and a wide pore size range (2-360µm) can be obtained – suitable for the growth of new bone tissue.

Conclusions

The addition of Ca-P whiskers affects the mechanical strength and morphology of as well porous composites as solid composites. The whiskers are proper to reinforcing the composites. The surface modification of whiskers allows for a better interfacial connection between these whiskers and the polymer matrix.

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