INFLUENCE OF CHEMICAL COMPOSITIONS ON THE STRUCTURE AND THE BIOACTIVE PROPERTIES OF SiO_2-CaO AND SiO_2-CaO-P_2O_5 BIOACTIVE GLASSES

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Introduction

Bioactive glasses are the materials known for their ability to create a bond with a bone tissue through the layer of carbonated apatite. They are also known for their biocompatibility, osteoconductive and even in some cases osteinductive properties [1]. The bioactivity of glasses is very complexed issue and depends on many different factors such as chemical composition, texture or surface properties. Aim of that study was to evaluate the influence of materials chemical composition on the structure and bioactivity, described as an ability of creating a layer of apatite on materials surface in contact with simulated body fluid *in vitro.* There were two main compositional variables considered: first of all value of CaO/SiO_2 ratio and also presence of phosphorus in materials composition.

Materials and Methods

Bioactive glasses from the binary SiO_2 - CaO and ternary SiO_2 - CaO - P_2O_5 systems were obtained by the sol-gel process. CaO/SiO_2 molar ratio in obtained materials varied between 0.2 to 1.5. Dried gels were heat treated in the temperatures 600ºC (binary glasses) and 700ºC (ternary glasses) for 20h. All of the obtained powders were subjected to the structural analyses. XRD analysis was performed in order to evaluate degree of crystallinity of glassed. Moreover, FTIR analysis has been made due to characterization of the structure of obtained glasses.
The local structure of silicon and phosphorus (ternary glass system) in obtained materials were examined with magic angle spinning nuclear resonance (MAS-NMR). Moreover, the optical basicity parameter was calculated according to the NMR data. Bioactivity of powders was assessed during the incubation in simulated body fluid (SBF) test. After 7 days of incubation powders were analyzed with XRD and FTIR to qualify changes in materials structure occurred in the contact with incubation fluid.
In order to quantify the concentrations of calcium, phosphorus and silica that dissolve from glass powders during the incubation, ICP-OES spectroscopy was performed. Glass powders of the particles size < 45um were closed into biodegradable, polymer (PLGA) matrix. The weight ratio of glass particles to the polymer was 1:1. The experiment was conducted in SBF and particular ions concentrations were measured after 3, 7 and 14 days.
What is more, measurements of ion dissolution form samples pre-covered with apatite were conducted. At first, samples were incubated for 3 or 7 days in SBF solution and then were immersed in α-MEM cell culture medium supplemented with Fetal Bovine Serum (FBS). Medium was collected and tested after 24h, 48h, 4 and 7 days respectively.

Results and Discussion

XRD analysis revealed the beginning of crystallization in majority of glasses. The intensity of that process increased with the increase in CaO/SiO_2 ratio. Crystallized phases were calcium silicates (binary and ternary glasses) and hydroxyapatite (ternary glasses). FTIR spectra showed changes in the materials structure depending on the CaO/SiO_2 ratio. It has been proven that with the increasing CaO/SiO_2 ratio the number of bridging oxygens significantly decrease. That can suggest that higher content of modifier, such as calcium, in the glass structure causes a decrease in glass network polymerization.

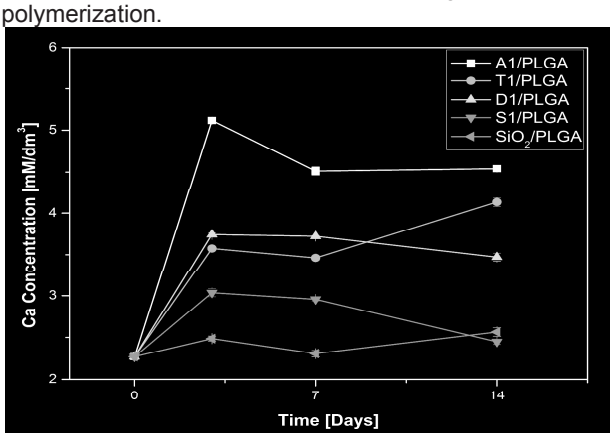

FIG. 1. Changes in calcium concentrations in SBF solution after 3, 7 and 14 days of samples incubation.

The ^{29}Si MAS-NMR spectra revealed that silicon was present in Q^2, Q^3 and Q^4 structural units. Moreover, ^{31}P MAS-NMR indicated that phosphorus exist mainly as a monophosphate complex. It has been also shown that the presence of phosphorus in the structure induct the process of silica network repolymerization. Optical basicity was increasing with a rise of CaO/SiO_2 ratio [2].
Changes in powders structure after incubation in SBF have been indicated. XRD analysis revealed carbonate apatite and calcite crystallization. These results were confirmed by FTIR analysis. What is more, main phase crystallized in the binary system glasses was calcite otherwise, main phase appeared in ternary glasses was carbonated apatite.
ICP-OES analysis revealed that particular ions concentrations in SBF had been changing in time (FIG. 1). The character of changes depended strongly on the glass composition. Analysis of concentrations of ions released to immersion fluid from materials pre-covered by HCA layer indicated different dynamics of release in comparison with not pre-covered materials.

Conclusions

Our study has confirmed that chemical composition of bioglasses affects the glass structure as well as the process of bioactivity. We have proven that it is possible to modulate the chemical properties of this kind of composites depending on desires application.

Acknowledgments

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References

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