The effects of CaO/SrO substitution in bioactive glasses: a combined structural and bioactivity study

Margit Fabian[1], Istvan Tolnai[2], Zsolt Kovacs[3], Anukanana Lyuu[4], Viktoria Kovacsne Kis[5]

[1]Centre for Energy Research, Environmental Physics [2]Centre for Energy Research, [3]Eötvös Loránd University, [4]Eötvös Loránd University, [5]Centre for Energy Research

fabian.margit@ek-cer.hu

Bioactive glasses are widely used in biomedical applications due to their ability to bind to bone tissue and even to soft tissues, first discovered in the Na2O-CaO-SiO2-P2O5 system [1]. Most of the glasses studied and clinically used today have compositions similar to that of commercial Bioglass© 45S5 (SiO2 content of 45 mol%). Still, a minor change in the composition may deeply alter the bioactivity and the ability of binding to the bone tissue, for example, the introduction of Sr ions into the bone-implant structure results in a significant reduction of bone fracture risk due to the enhanced osteoblast activity and inhibition of the osteoclast function [2].

Our research aims at the characterization of the local structure and bioactivity of Sr-containing bioactive glasses by performing a series of thermal analysis, neutron- and X-ray diffraction, spectroscopic experiments in the presence of a controlled SrO/CaO substitution. The main question here is how the presence of Sr atoms affects the short- and the intermediate-range order and how this modification of the network structure influences durability, biocompatibility and fracture toughness of the glass.

The studied system: 45SiO2-28Na2O-(25-x)CaO-2P2O5-xSrO, were the x=0, 12.5 and 25 were prepared by melt-quench technique. The differential thermal analysis (DTA) data showed that the glass transition temperature and the melting temperature decreased with increasing SrO content and with the increase of SrO, the latent heat value of the bioactive glass decreases. For the study of the short- and intermediate range order neutron (ND) and X-ray diffraction experiments were performed. ND measurements were carried out at the 10 MW Budapest research reactor using the PSD diffractometer [3] and analyzed by the Reverse Monte Carlo simulation [4]. The results show well-defined first- and second neighbour distances. It was found that the basic network structure consists of tetrahedral SiO4 and PO4 units. The Raman spectroscopy revealed information about the connectivity of silicate and phosphate units and about the changes in local connectivity induced by the replacement of CaO with SrO.

In vitro experiments comprise soaking of the test material in simulated body fluid (SBF) under physiological conditions (37°C, p(CO2) = 0.05 atm (5%)) for different timespans typically ranging from few days up to 3 weeks [5]. Bioactive layer formation initiates by formation of a transient amorphous Ca-phosphate phase and followed by crystallization of nanocrystalline hydroxylapatite, which, under in vivo conditions, triggers bonding to bone tissue. SEM-EDS measurements performed on the surface of the samples provide qualitative information on the compositional variation as function of the morphological elements. Details of the structural characteristics will be presented.

References

[1] L. L. Hench J. Mater. Sci: Mater. Med. 17 (2006) 967

[2] S. Kargozar, M. Montazerian, E. Fiume, F. Baino Front. Bioeng. Biotech. 7 (2019) 161

[3] E. Svab, Gy. Meszaros, F. Deak Mater. Sci. Forum 228 (1996) 247

[4] O. Gereben, P. Jovari, L. Temleitner, L. Pusztai J. Optoelect. Adv. Mat. 9 (2007) 3021

[5] T. Kokubo, H. Takadama Biomaterials 27 (2006) 2907