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In vitro study of the bioactivity of sol-gel glass 60S doped with Y

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Introduction / Objectives / Aims

The high biocompatibility of of sol-gel glass is due to the ability to form a layer of hydroxyapatite (HA) on the surface in contact with biological fluids and the peculiarity of sol-gel synthesis allows the introduction of various biologically active components.

In this work, the synthesized and investigated in vitro bioactivity nanostructured samples of sol-gel glass (60S) doped with Y - 60% SiO_2, 32% CaO, 4% P_2O_5, 4% Y_2O_3. The ability of the prepared glass to form apatite in vitro, after immersion in simulated body fluid (SBF), was assessed by Fourier Transform Infrared Spectroscopy (FTIR) and X-ray dispersion analysis (EDX). Changes in specific surface area, change in zeta potential and dispersion stability of nanoparticles were evaluated. The establishment of negative zeta potential, in vitro biological activity and nanometric particle size, make glass 60S doped with Y possible candidate for bone engineering.

Metods

- The obtained samples were characterized by a scanning electron microscope MIRA 3 FE-SEM microscope (TESCAN, CR) equipped with an Energy-dispersive X-ray detector (EDX, UK).
- EDX spectra and SEM micrographs of the prepared samples before and after immersion in SBF on days 7, 14, 21, and 28 were used to study changes in the morphology and elemental composition of the sample surface.
- SSA determined by the method of nitrogen thermal desorption using KELVIN 1042 Sorptometer.
- Infrared spectra were recorded on an FTIR (Fourier-transform infrared spectroscopy) Spectrometer Tensor 27 (Bruker Optik GmbH) in the range 4000–400 cm−1 using KBr pellets.

Synthesis of sol-gel glass 60S

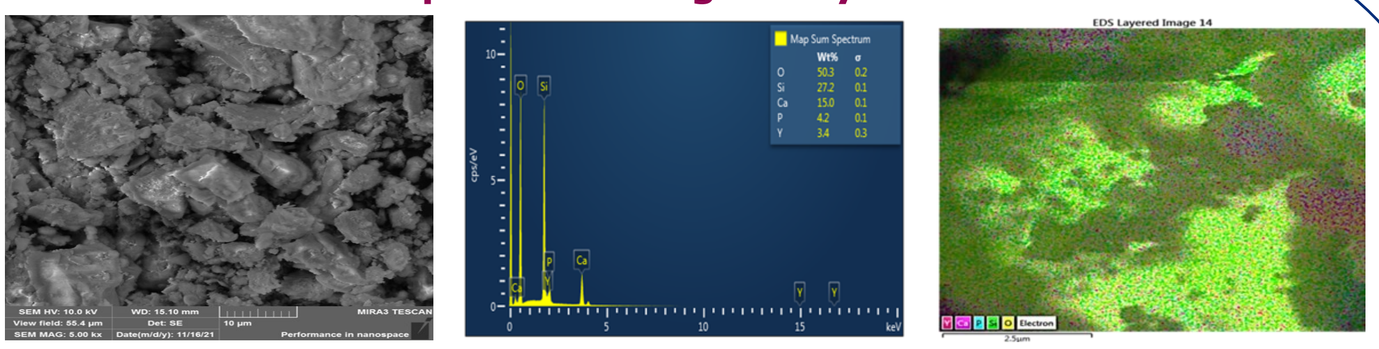
- 60S glass has a composition (mol%) of 60% SiO_2, 36% CaO, 4% P_2O_5.
- The synthesis was carried out by sol-gel method using: thyl orthosilicate (TEOS) $(C_2H_5O)_4Si$, triethyl phosphate (TEP) $(C_2H_5O)_3PO$, ethanol C_2H_5OH, calcium nitrate tetrahydrate $(Ca(NO_3)_2 .4H_2O)$, 59 % solution of nitric acid (HNO_3). Mass ratios of precursors for the synthesis of 60S glass were: $(C_2H_5O)_4Si$,: $(C_2H_5O)_3PO$: $(Ca(NO_3)_2{\cdot}4H_2O)$: H_2O : C_2H_5OH = 8,59 : 1: 5,85 : 9 : 3.
- For the synthesis of doped Y sol-gel glass the solution of calcium nitrate was replaced by solution containing mixture of Ca $(NO_3)_2.4H_2O$ and $Y(NO_3)_3.6H_2O$ in the above mentioned ratio.

The sol-gel glass 60S and in vitro apatite forming ability

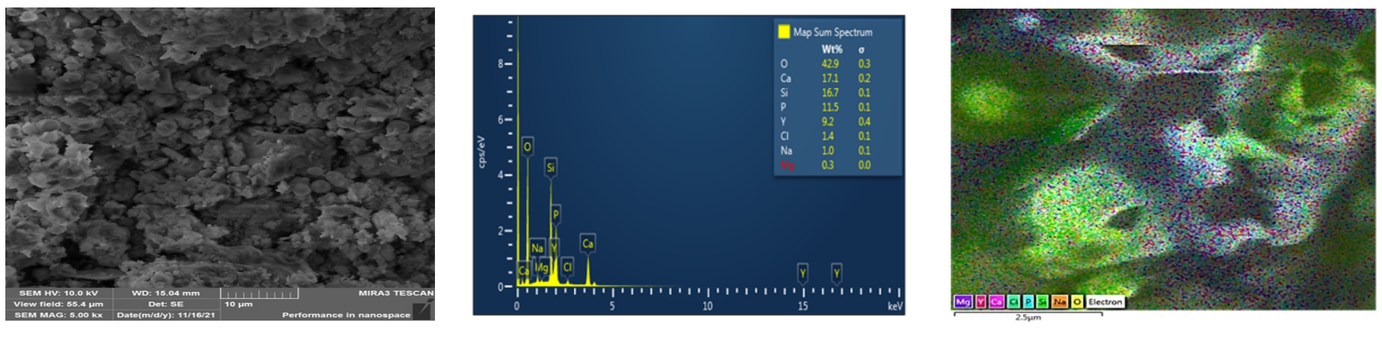
EDX analysis confirmed the presence of Si, Ca, P and Y . According to research EDX method, the elemental composition of the surface changes significantly, after 7 days of immersion in SBF. This indicates the passage of active ion exchange processes, which is consistent with the theory of dissolution of bioactive glass in physiological fluids. The increase of concentration of Ca and P in the elemental composition of the sample is due to the active processes of adsorption of Ca^{2+} and HPO_4^{2-} ions on the surface.

The amorphous apatite layer aggregates and almost completely covers the glass surface for up to 21 days immersion in SBF solution, which leads to low detection of Si by EDX.

Evaluation of the bioactivity of the synthesized materials was performed by on the ability to form, as a result of active ion exchange, a layer of hydroxyapatite (HA) which promotes the formation of effective connections with bone and soft tissues.



EDX spectrum and micrograph of sol-gel glass 60S doped Y before immersion in SBF; on the insert the elemental mapping of a samples



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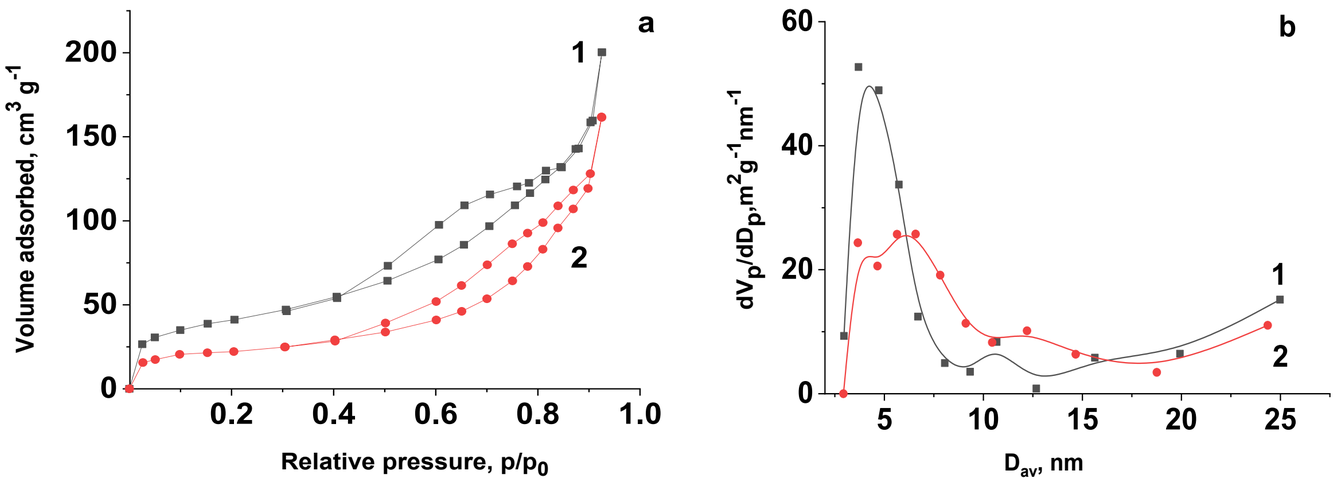
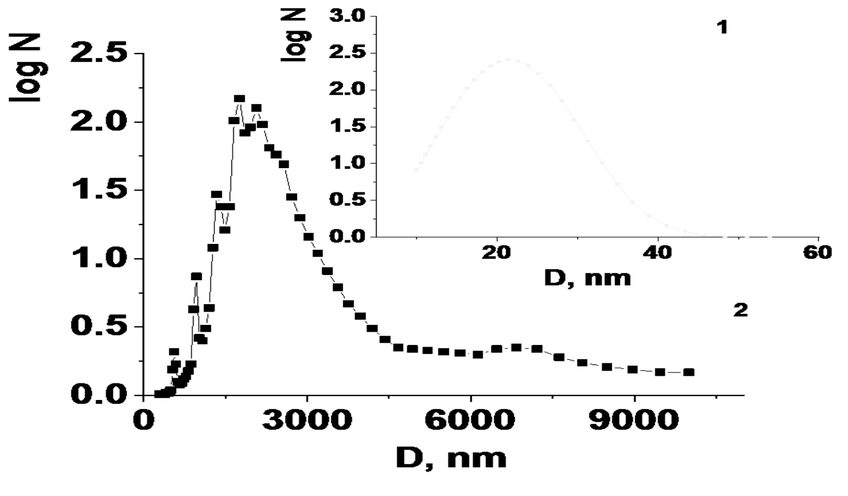


Adsorption/desorption isotherms (a) and pore distribution (b) of samples sol-gel glass 60S doped Y before (1) and after 7 days immersion in SBF (2)



Size distribution of sol-gel glass 60S doped Y particles after 1 hour (1) and after 24 hours (2) immersion in SBF