

NEW APPROACH TO ANTIBACTERIAL ACTIVITY AND SAFETY EVALUATION OF NANOSIEZED SILICON-SUBSTITUTED HYDROXYAPATITE CO-DOPED WITH Zn²⁺ AND Sr²⁺ IONS

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Nanotechnology is the most intensively developing a multidisciplinary field of research combining various disciplines of science achievement. Nanomaterials show unexpected and interesting chemical and physical properties different from those of the original in the micro-sized scale.

Hydroxyapatite(Ca₁₀(PO₄)₆(OH)₂ (HAp)) naturally occurs in human body as a component of teeth and bones. The HAp can be synthesized and structurally modified as the product that is similar to natural one. Moreover, calcium hydroxyapatite is considered non-toxic for human cells (*in vitro* and *in vivo*) and is being used as bone substitute as well as in implant coatings, dermal fillers and drug delivery systems.

The hexagonal structure in apatites belongs to *P6₃/m* space group and allows the cations to localize in the 4(f) and 6(h) positions and are able to accommodate a variety of cations as substituents. Furthermore, metals like silver, gold or zinc are well-known for their antimicrobial effects therefore the metal-doped hydroxyapatites could be used in a bacterial infection prevention, in particular as concerns implant insertion procedure.

Zinc and strontium ions co-doped silicon-substituted hydroxyapatite were synthesized using a hydrothermal method. The concentrations of Zn²⁺ and Sr²⁺ ions were set on 2, 5 and 10 mol% in a ratio to entire calcium ions molar content (please see Table 1).

Table 1 Formulas of tested hydroxyapatites

Dopants	Hydroxyapatite formula
5 mol% Sr ²⁺	Ca _{9,5} Sr _{0,5} (PO ₄) ₂ (SiO ₄) ₄ (OH) ₂
5 mol% Sr ²⁺ , 2 mol% Zn ²⁺	Ca _{9,3} Sr _{0,5} Zn _{0,2} (PO ₄) ₂ (SiO ₄) ₄ (OH) ₂
5 mol% Sr ²⁺ , 5 mol% Zn ²⁺	Ca _{9,0} Sr _{0,5} Zn _{0,5} (PO ₄) ₂ (SiO ₄) ₄ (OH) ₂
5 mol% Sr ²⁺ , 10 mol% Zn ²⁺	Ca _{8,5} Sr _{0,5} Zn _{1,0} (PO ₄) ₂ (SiO ₄) ₄ (OH) ₂

XRD (X-ray diffraction) was performed in order to confirm their apatite structure. Their antibacterial activity was checked in the spot test using Gram-negative bacteria: *Pseudomonas aeruginosa*, *Klebsiella pneumoniae* and *Escherichia coli* strains. Moreover some safety tests were performed: cytotoxicity test (MTT), Ames test (to check mutagenic potential) and hemolysis (to check their effect on erythrocytes extracted from blood samples).

The obtained results suggest that tested compounds are potentially non-harmful for human, moreover these doped with strontium and 5-10% of zinc have antimicrobial activity against *K. pneumoniae* and *E. coli* cells. Pure strontium-doped hydroxyapatite (with no zinc additive) promoted the growth of these strains. Regarding *P. aeruginosa* strain no antimicrobial activity was observed for tested materials.