Ultrasound Synthesis of Poly-DL-lactide-co-glycolide/Hydroxyapatite Core-shell Nano-spheres

Dragan Uskokovic,[1] Marija Jevtic, [1] Marijana Petkovic, [1] Nenad Ignjatovic, [1] Miodrag Mitric[2]
[1]Institute of Technical Sciences of the Serbian Academy of Sciences and Arts, Belgrade, Serbia
[2]Institute of Nuclear Sciences "Vinca", Belgrade, Serbia

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Introduction: Composite materials made from hydroxyapatite (in further text HAp) and a polymer – natural or synthetic – are highly applicable for bone tissue recovery, i.e. as implants where they work by accelerating bone reconstitution induced by various injuries. However, it is of the best interest to produce composite materials that will be used as implants in bone recovery that are deep in the nanometer range since they have increased active surface and increased potential to form different implant shapes with controlled porosity. The aim of this work was to further develop and simplify the method for the processing of the core-shell particles with HAp as a core and poly-DL-lactide-co-glycolide (DLPLG) as a shell of composite structures, and to test the applicability of ultrasound for the preparation of DLPLG/HAp composite.

Materials and Methods: In the first step, HAp was synthesized by homogeneous precipitation method in the field of ultrasound. Briefly, Ca $(NO_3)_2$ x $5H_20$ and $NH_4H_2PO_4$ were dissolved in distilled water (molar ratio Ca: P was 2). This solution was placed into reaction vessel and heated at 88 °C. Urea (10 mL of 12% urea) solution in water was added to a reaction mixture and the solution was treated with ultrasound (Ultrasonic Processor for High Volume Applications VCX 750, Newtown, Connecticut, USA) with following parameters: T_{max}= 90°C, t = 2 h, amplitude = 80 %. So treated apatite was than mixed and dispersed in polymer solution, DLPLG (2% DLPLG in acetone) in ultrasonic field with following parameters: T = 25 °C, t = 2 min., amplitude = 20 %. Precipitation started by adding ethanol drop wise to the reaction vessel with this dispersion cooled using ice at T = 8 °C in the field of ultrasound. Ratio DLPLG: HAp was either 90:10 wt% or 75:25 wt %. Sonochemical treatment was continued until all ethanol, as insolvent, was added. When precipitation was finished, obtained colloid was mixed with PVP (100 mL 2mmol/L) as surfactant solution. Reaction mixture was shortly centrifuged to spin down the pellet that was air dried afterwards.
Samples were shape and size analyzed using scanning electron microscopy (SEM, JEOL JSM-5300) and phases identified by X-Ray diffraction and infrared spectroscopy. Infrared spectroscopy (IR) was performed with Michelson interferometer with resolution 32-0.5 cm^{-1}, spectra range (for KBr) 7.8-400 cm^{-1} and accuracy lower that 0.01 cm^{-1}. Each spectrum was the average of 64 scans.

Results and Discussion: In the case of higher DLPLG content (90wt%) almost perfect spheres are much smaller, more uniform in size in the range of under 150 up to 320 nm. Obviously, sample with lower HAp content is agglomeration free with regular space arrangement of spheres in contrast to sample with higher ceramic content.
IR and XRD spectra finally confirm the presence of both DLPLG and HAp in both DLPLG/HAp composite materials. If one assumes that each HAp particle is coated with DLPLG polymer and with taking the mass ratio of 90:10 DLPLG:HAp, one could roughly estimate that the size of HAp within a sphere is about 20-40 nm.

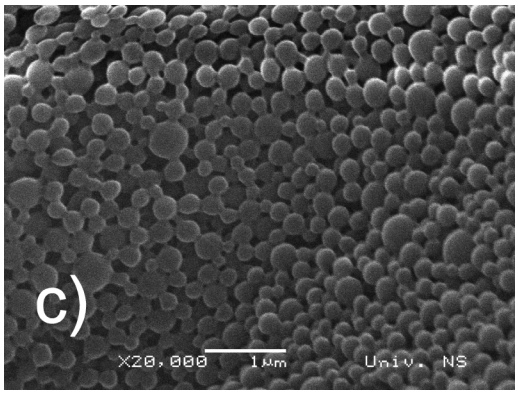

Figure 1. Scanning electron micrographs of DLPLG/ HAp nano-particles (90:10 wt%) prepared in the field of ultrasound.

Conclusions: A simple procedure for preparation of core-shell, nano-sized and regularly spherical DLPLG/HAp composite particles is presented. In addition, the applicability of ultrasound in all steps of the composite preparation – synthesis of HAp and coating of the HAp crystals with DLPLG – was demonstrated. Size of DLPLG/HAp composite particles obtained by presented method was about 150 -320 nm and particles are highly uniform and perfectly spherical in shape in addition.