Tenth Annual Conference of the Yugoslav Materials Research Society
YUCOMAT
Herceg Novi, Montenegro
September 8-12, 2008

ULTRASONIC DEAGGLOMERATION AND PARTICLE SIZE REDUCTION OF HYDROXYAPATITE BY COATING WITH POLY(D,L-LACTIDE-CO-GLYCOLIDE)

Marija Jevtić[a], Miodrag Mitrić[b], Srečo Škapin[c], Ines Bračko[c], Nenad Ignjatović[a], Dragan Uskoković[a]

[a]*Institute of Technical Sciences of the Serbian Academy of Sciences and Arts, Belgrade, Serbia*
[b]*Institute of Nuclear Sciences "Vinča", Belgrade, Serbia*
[c]*"Jožef Stefan" Institute, Ljubljana, Slovenia*

INTRODUCTION

The bone mineral, a calcium phosphate complex dominated by hydroxyapatite, is deposited on the organic matrix, 90% of which is collagen.[1] Plate- and rod-like particles are the chief feature of the morphology of natural hydroxyapatite. In some parts of bone tissue, these structures are parallelly oriented and laterally connected. Such structure is maintained due to polymeric, proteinous matrix within which it is enclosed.[2] Rod-like particles of hydroxyapatite enclosed within the polymeric matrix are 8-15 nm thick, 20-40 nm wide and 200-400 nm long. These dimensions are functionally related to the part of the skeleton, but they are always in nanometer scale.[3] The main goal of bioengineering process is to develop biomaterials with characteristics similar to natural ones.[4] Synthetic hydroxyapatite (HAp) is a biomaterial obtained in the biomimetic process. This bioceramic is meant to be chemically and morphologically similar to the mineral component of mammals' hard tissue.
Application of ultrasonic field in the process of synthesis and deagglomeration is a very effective method for obtaining nano-sized particles.[5],[6]
In this study, plate-like particles of hydroxyapatite, obtained by sonochemical homogeneous precipitation, were deagglomerated in a high-intensity ultrasonic field and a small volume of inert medium. The so-formed HAp particles were coated with poly(d,l-lactide-co-glycolide) in order to obtain rod-like structures with nanometer dimensions.

RESULTS and DISCUSSION

Identification of hydroxyapatite and PLGA/HAp composite was performed by XRD method (Figs. 1a and 1b, respectively). FESEM micrographs of the as-obtained HAp and HAp additionally processed in the field of ultrasound for 10, 15 and 20 min (represented in Figs. 2a, 2b, 2c and 2d, respectively) show deagglomeration and reduction of the size of rod-like particles induced by ultrasonic processing. The relationship between the duration of the ultrasonic processing and the particle size is summarized in Table 1. The as-obtained rod-like particle (Fig. 2e) within plate-like structures, represented in Fig. 2a,[9] are significantly larger in size than rod-like particles inside PLGA/HAp (Fig.2f), indicating that the formation of formation of HAp nano-rods is the most effectively prevented by ultrasonic deagglomeration, after the particles are coated by polymer. The regular morphology of sphere-like particles of PLGA/HAp composite material is represented in Fig. 2g.

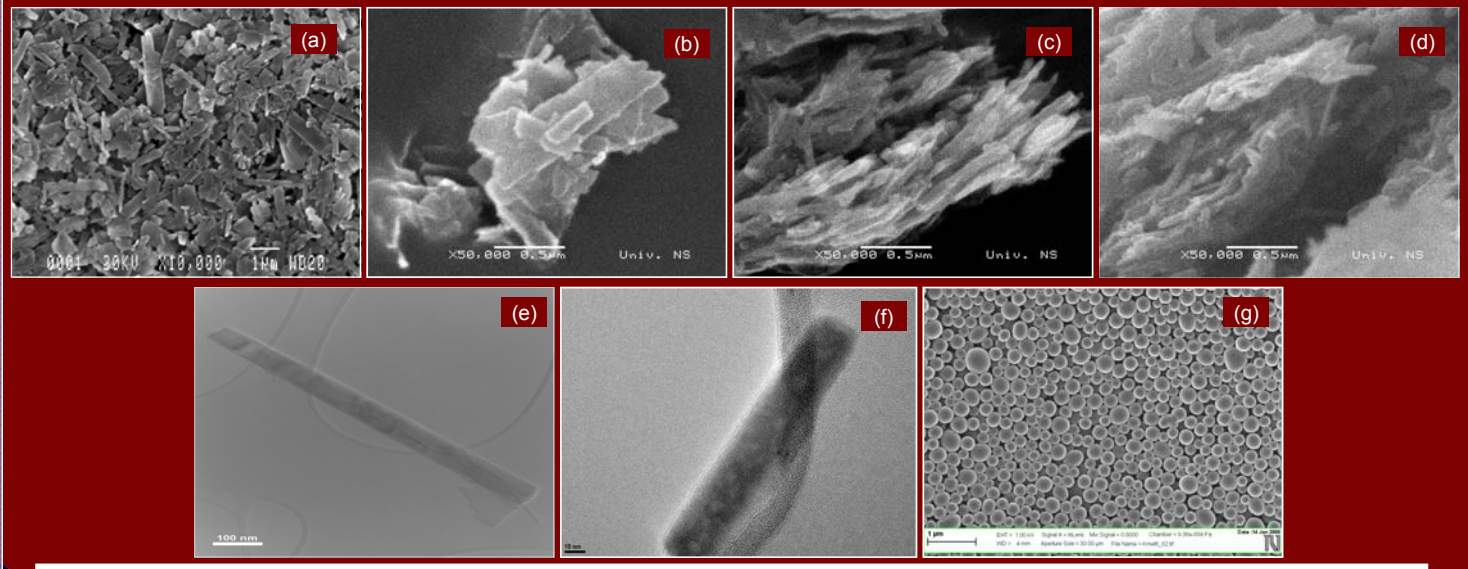

Figure 2: SEM micrographs of hydroxyapatite- sonochemically synthesized (a)[9] and additionaly processed in the field of ultrasound during 10 min (b), 15 min (c) and 20 min (d). TEM images of HAp after sonochemical synthesis (e)[9] and within composite (f). FESEM micrograph of PLGA/HAp composite material (g).

Table 1: Dimensions and shape of HAp particles obtained according to SEM images in Figs. 1a-1d

Sample	Particles shape	Lengt (nm)	Wight (nm)
HAp (sonochemically synthesized)	plate-like	1000-1500	100-800
HAp (processed by ultrasound during 10 min)	plate-like	400-600	200-400
HAp (processed by ultrasound during 15 min)	Rod-like	350-550	50-100
HAp (processed by ultrasound during 20 min)	Needle-like	150-300	~50

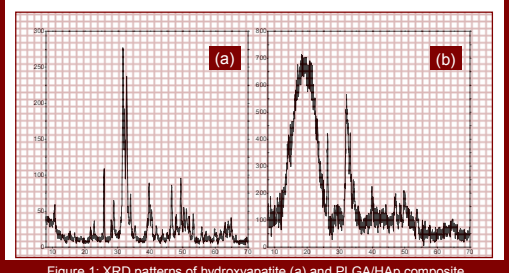

Figure 1: XRD patterns of hydroxyapatite (a) and PLGA/HAp composite

MATERIALS and METHODS

Hydroxyapatite was synthesized by homogeneous sonochemical precipitation method (detailed in [7]). So obtained pellet was additionaly treated by high-intensity ultrasonic field in a small volume of inert medium (ethanol) in order to deagglomerate the particles of HAp. The applied parameters of ultrasound were: t=10, 15 and 20 min, on:off=02:01, ultrasonic field power P=600 W; inert medium volume V=15 ml. Additionally, in one sample after the process of deagglomeration had been completed, HAp particles were coated by poly(d,l-lactide-co-glycolide) with the assistance of ultrasound (according to procedure described in [8]). The process of synthesis was carried out by ultrasonic processor for high-volume applications (VCX 750, Newtown, Connecticut, USA). The identification of materials was performed by X-ray diffraction method (XRD), while morphological changes were analyzed by scanning and transmission electron microscopy (SEM and TEM).

CONCLUSION

In this study, morphological properties of hydroxyapatite rod-like particles obtained after processing in a high-intensity ultrasonic field and a small volume of inert medium were analyzed. The presented results show that the interaction between shock waves, obtained during ultrasonic wave motion propagation throughout liquid, and solid HAp particles cause deagglomeration and reduction of particles size. Coating of these nano-rods with poly(lactide-co-glycolide), as a polymeric matrix, enables the most efficient prevention of repeated agglomeration of the particles. Dimensions of the obtained HAp nano-rod within polymeric matrix are very similar to the dimensions of HAp particles within collagen in natural bone tissue. Having in mind the similarity of the morphological properties of the synthetic biomaterial and natural one, very good interaction between synthetic HAp and live surroundings can be expected which, is very important for biomedical applications of this material.

REFERENCES

[1] T. D. Price, M. J. Schoeninger, G. J. Armelagos, J. Human Evol., 14 (1985) 419-447.
[2] W. L. Murphy, D. J. Mooney, Nature Biotechn., 20 (2002), 30-31.
[3] X. Su, K. Sun, F. Z. Cui, W. J. Landis, Bone, 32 (2003) 150-162.
[4] M. J. Olszta, X. Cheng, S. S. Jee, R. Kumar, Y. Y. Kim, M. J. Kaufman, E. P. Douglas, L. B. Gower, Mater. Sci. Eng., R58 (2007) 77-116.
[5] A. Gedanken, Encyclopedia Mater.: Sci Techn., (2008) 9450-9456.
[6] M. D. Lique de Castro, F. Priego-Capote, Ultrasonics Sonochem., 14 (2007) p.p. 717-724.
[7] M. Jevtić, D. Uskoković, Mater. Sci. Forum, 555 (2007) 285-290.
[8] M. Jevtić, M. Mitrić, N. Ignjatović, D. Uskoković, Acta Biomater., (2008), doi: 10.1016/j.actbio.2008.07.026.
[9] M. Jevtić, M. Mitrić, S. Škapin, B. Jančar, N. Ignjatović, D. Uskoković, Cryst. Growth Des., 8 (2008) 2217-2222.