Synthesis of core/shell nanorod of bismuth doped hydroxyapatite with improved antimicrobial characteristics: a facile approach

M.Selvakumar[1], Saravana Kumar Jaganathan[2], Golok B. Nando[1] and Santanu Chattopadhyay[1]
[1]Indian Institute of Technology, Rubber Technology Centre, Kharagpur 721302, India.
[2]IJN-UTM Cardiovascular Engineering Centre, Faculty of Bioscience and Medical Engineering, Universiti Teknologi Malaysia, Johor Bahru 81310, Malaysia

Introduction: Core/shell nanoparticles are gradually attracting more and more attention in various biomedical applications such as drug delivery, scaffolds, tissue engineering and so on. Hydroxyapatite (HA) is one of the most utilized ceramic materials for bone tissue engineering applications as its composition and structures closely resemble the natural bone mineral[1]. This work holds a new facile approach to synthesize the core-shell nanorod of bismuth(Bi) doped hydroxyapatite with high aspect ratio at room temperature without any template for the first time. Furthermore, we developed this nanoparticle with improved antimicrobial characteristics by doping bismuth for the first time without compromising their biocompatibility. We thoroughly characterized the formation of core/shell structure by using various tools and studied antimicrobial and biocompatibility test or proofing their potential biomedical application.

Methods: Bismuth (III) nitrate petntahydrate, calcium nitrate tetrahydrate and diammonium hydrogen phosphate were used as a precursors for synthesizing Bi doped HA nanorod and procured from MERCK, India.

Bi doped hydroxyapatite nanorods of high aspect ratios were prepared without using any templates at room temperature in normal atmospheric conditions. In a beaker, 0.2 (M) each of Ca(NO3)2.4H2O and (NH4)2HPO4 in 500ml of double distilled water was prepared so that the Ca:P molar ratio was maintained at approximately 1.67. The pH of both solutions was maintained at ~4 with the addition of the required amount of diluted HCL. We followed the in-situ technique for the doping Bi on nHA rods; 5 wt% (with respect to Calcium and Phosphate precursors) of bismuth (III) nitrate petntahydrate was added to the solution of calcium nitrate. DHAP was then added drop-wise to the mixture of Ca(NO3)2.4H2O and bismuth (III) nitrate petntahydrate solution. The whole suspension had a milky aspect, and was vigorously stirred at room temperature using a mechanical stirrer (2500 rpm). This process was continued for 4 hrs.

The resulting white gelatinous precipitate was filtered by using a centrifugal filtration process (3500 rpm for 10 minutes), washed thoroughly five times with double distilled water (until neutral, pH=7), and dried at 90 °C for 15 hrs and calcined at 400 °C for 6 hrs.

Results: The FTIR spectrum confirms the presence of functional group of the Bi doped HA. Bands at 3571 and 631 cm−1 are assigned to stretching mode (υS) and liberation mode (υL), respectively, of the -OH group. The peak at 1040 cm−1 is the triply degenerated vibration; υ3 946 cm−1 is the non-degenerated symmetric stretching mode, υ1, of the P–O bond of the phosphate group. Moreover, the two moderately sharp peaks at 633 and 3570 cm−1 are attributed to vibrational –OH and structural -OH, respectively, highlighting the high crystallinity of the product as a result of heat treatment (calcinations). The X-ray diffraction (XRD) patterns confirms the hexagonal closed pack crystal structure of Bi doped HA and it further indexed according to the standard data (JCPDS No. 09–0432). The characteristic peaks at 2θ regions of 26, 32, 33 and 40 are attributed to the (002), (211), (300) and (310) planes, respectively, and they indicate the crystalline nature of Bi doped hydroxyapatite thus formed. By contrast, using the full width at half maximum of peaks corresponding to these planes, and by using Scherrer's equation, the crystallite sizes for Bi doped HA were determined. This clearly suggests that there are no significant changes observed in the crystallite size of the Bi doped HA crystal compared to the existed HA in the literature. HRTEM photomicrograph images (Figure 1) demonstrate that the prepared Bi dopped hydroxyapatite results in the formation of a well-defined core/shell morphology (rod-like and nano-sized) with a aspect ratio of ~8.5. EDAX confirms the Bi has been successfully coated (Core morphology) on the surface of HA. Antimicrobial ratio was calculated from the number of colonies after 24 h (for bacteria) and 48 h of incubation periods against E. coli and bi doped HA shows excellent antimicrobial activity (> 80%) with all the microbes. MTT assay of osteoblast-like MG63 cells also shows excellent biocompatibility for the bi doped HA samples.

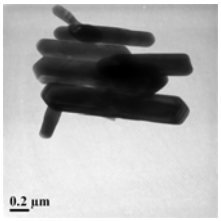

Figure 1. HRTEM image of Bi dopped HA

Conclusions: We successfully synthesized novel high aspect ratio of bi doped hydroxyapatite nanorod without any template at room temperature. This has been successfully characterized by various tools. Bi doped HA shows excellent antimicrobial activity as well as biocompatibility. It can be concluded that the synthesized novel bi doped HA have great potential for applications in artificial vascular prostheses, cardiovascular devices, scaffolds, bone implants and soft tissue applications.

References: M. Selvakumar, Saravana Kumar Jaganathan, Golok B. Nando and Santanu Chattopadhyay. Synthesis and Characterization of novel polycarbonate based polyurethane/polymer wrapped hydroxyapatite nanocomposites: mechanical properties, osteoconductivity and biocompatibility. Journal of Biomedical Nanotechnology. 2015, Vol. 11, 291-305. DOI:10.1166/jbn.2014.1975.