Synthesis of Bio-inspired Mg-HA-MWCNT Porous Composite by Spark Plasma Sintering

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Abstract

In the present research work, an attempt has been made to utilize the potential of spark plasma sintering technique to develop porous Mg-HA-MWCNT composite for scaffold applications. The alloying of HA and MWCNT was carried out using ball mill and sintering was carried out using SPS technique. Morphology, mechanical properties was investigated by FE-SEM and nano-indentation technique. From the SEM, micrograph, the relative density of the synthesized composite was obtained in the range of 85-95%. The results showed that porous Mg-10HA-MWCNT possessed not only low elastic modulus of 20 GPa (close to that of human bone) but also high compressive strength (35 MPa). Excellent corrosion resistance and bioactivity has been found.

Introduction

In recent years, the demand of magnesium (Mg) alloys for the fabrication of temporary bone fixation devices has increased not only of being biodegradable, but Mg is an osteoconductive material that accelerates bone growth. However, Mg and its alloys are susceptible to excessive degradation rate in physiological environment, which causes failure of the implant before the new bone tissues have completely replaced it [1-6]. This phenomenon limits the utility of these materials. The alloy factor has been admitted to testing the Mg alloy deterioration rate near to the current bone regeneration rate. Spark plasma sintering (SPS), a potential strategy for metal-processed alloyed metal consolidation, has arisen [7-11]. The present paper aims to research Mg-HA-MWCNT composites produced via the PLC process for synthesis, characterization, corrosion, and cellular reaction.

Materials and Methods

The high purity (~99.9 percent) powder (PP) particles such as Mg, MWCNT, and HA were produced. In Wt% of Mg, MWCNT and HA, the PP was mixed as: 100:1:20. Next, the ultrasound was ultrasonically treated with deionized water and combined for 1 hour with ultrasound. The powder blend is then homogenized by the magnetic punching unit. The homogenized mixture was dried before solidification and consolidation was performed using spark plasma sintering method (SPS-5000) at 400 K sintering temperature and 40 MPa pressure at the heating speed of 50 k / min (holding time 5 min) was applied under vacuum environment. Fig.1 shows the mechanism for the same.

There was a sturdy lightweight with a thickness with approx. 20 mm or 4 cm. FE-SEM (JEOL 7600F) fitted with EDS and XRD techniques described the asfabricated nano-composite. The elastic modulus has been calculated using the Oliver-Pharr process by nanoindentation (Hystron TI-950 indentation system). The resistance to corrosion of the asythesized comspite has been tested using a potentiodynamic electrochemical workstation (DC potentiostat / galvanostate configuration, Auto Lab PGSTAT30.). For 3, 7 and 14 days, immersion experiments were carried out in SBF solution for the breakdown rate of as-fabricated Mg-composites. In addition, in-vitro cell culture studies on human osteoblast MG-63 cell lines have been reported for bioactivity.
Results and Discussions

Fig. 2 shows the image of as-synthesized porous Mg-HA-MWCNT bio-inspired composite. High degree of interconnected structural porosities of pore size of 2-5 μm can be clearly seen. High magnification (50000×) shows the formation of flower-shape HA layer. HA decomposed and formed flake-like structure, which enhanced the bioactivity and mechanical properties. The black and yellow arrows indicated the reinforcement of MWCNT and formation of HA-layer, respectively.

The EDS spectrum confirms the presence of Mg, Ca, P, O, and C elementals in the as-fabricated nano-composite. High content of carbon confirms the presence of MWCNT and HA decomposed in Ca, P, and O. Various bioceramic oxides and carbides were formed during sintering process due to high heat generation. XRD confirms the formation of biomimetic phases, which enhanced the corrosion and bioactivity of the composite. The relative density of the synthesized composite was obtained in the range of 85-95%. The results showed that porous Mg-10HA-MWCNT possessed not only low elastic modulus of 20 GPa (close to that of human bone) but also high compressive strength (35 MPa). Corrosion behavior of the synthesized composite investigated by potentiodynamic polarization test shows a reduction in the inter-laminar corrosion with the alloying of HA and best corrosion resistance was found for Mg-10HA-MWCNT composite. The sintered porous Mg-HA-MWCNT composite, while partly decomposed and secondary, had excellent bioactivity and a channel / interface to the MG-63 cells for binding, multiplication and differentiation is seen in Fig. 3.
Conclusions

All in all, the findings indicate that the combination of interlinked pores, low elastic modulus, a strong compressiveness and enhanced biological activity may render a promising candidate for hard tissue implants for the preparation of porous Mg-10HA-MWCNT composite by SPS.

References