Synthesis and Characterization of a Novel Porous Bioactive SiC Tissue Engineering Scaffold

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Statement of Purpose: SiC is an inert material with excellent biocompatibility properties. Nevertheless, the use of SiC as a medical device has been limited due to difficulties in manufacturing including high temperatures (>2000ºC) and high pressures[1]. In the present study, we report on a new synthesis method of a porous SiC scaffold at low temperature and without the use of compact pressure. Furthermore, we report on the induction of bioactivity properties of SiC as demonstrated by the deposition of a hydroxyapatite (HA) layer on the material surface. Preliminary cell culture studies demonstrated cell adhesion and spreading inside the porous structure of the scaffold.

Methods: The SiC surface was activated by solution chemistry using alkaline solution at different pH values (12.10, 12.40, 12.57, 12.88, 13.00). To create porous discs, the SiC particles were mixed with polyethylene glycol (PEG) in a ratio of 60/40, pressed at 0.1 MPa into discs (10mm dia x 2mm) and heat treated at 900ºC/2hr. To induce bioactivity, the discs were subjected to dual immersion treatments (i) in NaOH/10 hr. (ii) and simulated body fluid (SBF)/48 hr. The mechanical properties of the discs were measured in compression mode using an Instron Machine (Model 5582) at a loading speed 0.0200 in/min. The surface chemistry of the material before and after immersion treatments was analyzed by Fourier transform infrared spectroscopy (FTIR) in the diffuse reflectance mode. The surface charge was quantified by measuring the zeta potential in phosphate buffered saline (PBS). The surface morphology was analyzed using scanning electron microscopy (SEM) and the percent atomic composition was analyzed by energy dispersive X-ray analysis (EDX). HeLa cells were seeded on the surface of activated SiC porous discs and cell adhesion and spreading were analyzed using SEM and image analysis technique.

Results: FTIR analysis showed formation of silica (SiO_2) on the materials surface. The area under the peak corresponding to SiO_2 increased by 75% as the pH of the treating solution increased from pH 12.40 to pH 13.00. In conjunction with the increase in the silica gel layer, the zeta potential of SiC increased from -16.9+/-1.8 to -31.2 +/-3.3 mV. SEM analyses showed the growth of the silica crystals on the material surface. After immersion in SBF, FTIR analyses showed the characteristic peaks of hydroxyapatite (a doublet at 575 and 611 cm^{-1}, 880 cm^{-1}, 1100 cm^{-1}) characteristic of HA. The compression strength of the material increased from 23.02+/-2.42 MPa to 61.22±8.08 MPa as the presence of silica created on the material surface increased. EDX showed a significant increase in the atomic percent

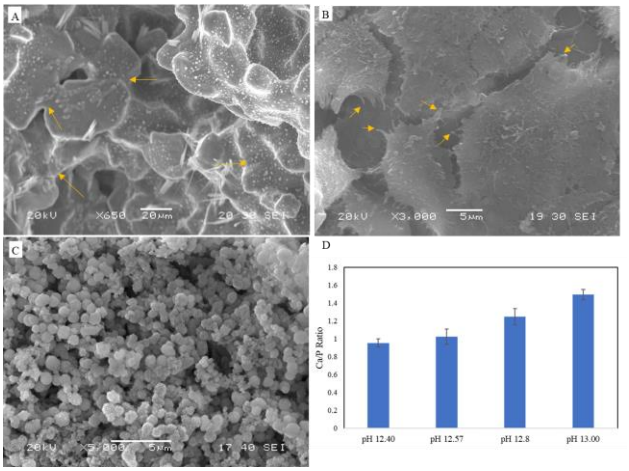

Figure 1. (A) The silica gel layer connects adjacent SiC particles. Arrows points at fused particles (B) HeLa cells are adhered to and spread on the surface. The arrows point to the focal contacts with the material (C) Hydroxyapatite crystals deposited from the SBF onto the SiC surface. (D) The average ratio +/- SD of Ca/P on the materials surface as measured by EDX for SiC treated with solutions of different pH.

of calcium on the materials surface as the silica gel layer increased. A calcium/phosphorous ratio of 1.50 was measured for the surface of the SiC treated with 13.00 pH solution, indicating calcium deficient HA. SEM analyses showed cells seeded on the porous SiC scaffold attached and fully spread. Focal contact areas were seen at the interface between the cells and the material. Fracture surface analysis showed cell adhesion and spreading on the walls of the pores.

Conclusions: We successfully synthesized a porous bioactive SiC tissue engineering scaffold employing low temperature and without appreciable compact pressure. The mechanical properties and bioactivity of the porous SiC discs increased as the silica gel layer created on the material surface increased. In conjunction with the increase in the silica gel layer, the surface negativity of the SiC increased as well. This led to an increased Ca uptake from the SBF solution. The attachment and spreading of the HeLa cells on and within the porous SiC scaffold indicates the suitability of SiC as a carrier for cells. Ongoing work involves the use of mesenchymal stem cells to measure cell differentiation and bone matrix formation.

References:

[1] She JH, Deng ZY, Daniel-Doni J, Ohji T. Journal of Materials Science. 2002;37(17):3615-22