https://doi.org/10.2352/ISSN.2169-4451.2017.32.429

Fabrication of ZrO_2-SiO_2 binary oxide Scaffold for Bone Tissue Engineering applications

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Abstract

Musculoskeletal disorders and bone defects have been established as one of the most important diseases affecting human health. The occurrence of bone defects due to the growing number of traffic accidents and osteoporosis have led to demand for mass numbers of bone implants. ZrO_2-SiO_2 binary oxide as a potential candidate with the features of mechanical strength and biocompatibility that precisely mimic the host bone has been synthesized using so-gel technique (1). Fabrication of ZrO_2-SiO_2 binary oxides into 3D porous scaffold is essential for structural stability of the bone implant enables them as a substrate for cells, growth factors and waste removal through their interconnected pores. Stereo lithography (SL) is one the most efficient Rapid Prototyping (RP) technique that has been adopted to fabricate 3D ceramic scaffolds with controlled architecture of desired shape, pore size and interconnectivity (2). The printed scaffold has been analysed for its surface morphology, porosity and interconnectivity through Scanning Electron Microscopy. The mechanical stability of the scaffold has been assessed using compression and bending strength tests.

Introduction

Musculoskeletal disorders and bone defects have been established as one of the most important diseases affecting human health. The occurrence of bone defects due to the growing number of traffic accidents and osteoporosis have led to demand for mass numbers of bone implants. Development of synthetic biomaterial as a perfect alternative to the natural bone with the features of mechanical strength, biocompatibility and successful performance under *in vivo* conditions is still under investigation. ZrO_2 and Al_2O_3 bio inert ceramics have been explored well owing to their superior mechanical properties but restricted by their poor bioactive features (3). Calcium phosphate based bioactive ceramics and SiO_2 based bioactive glasses as an alternative have also been attempted with minimum success due to their drawbacks of poor mechanical features (4). In an attempt for a possible alternative, ZrO_2-SiO_2 binary oxide as a ceramic-glass composite with features of mechanical strength and bioactive nature was reported by the authors (1).

In addition to the material development, fabrication of implant into three dimensional (3D) porous scaffolds is essential for mechanical support, cellular activity and serves as a template for cell attachment and stimulates bone tissue formation *in vivo*. Also, the 3D scaffold should serve as a carrier for cells, growth factors and waste removal through their interconnected pores. Rapid Prototyping (RP) or Solid Free Form (SFF) fabrication is one of the efficient ways to produce 3D ceramic scaffolds with desired porosity and internal architecture. The commercially available RP techniques are 3-D Printing, Stereolithogrphy (SL), Selective Laser sintering (SLS) and Fused Deposition Modeling (FDM). Among these RP techniques, SL is the most suitable manufacturing tool for fabrication of 3D scaffolds owing to the precise control on internal architecture (5).

Hence, the present investigation reports on fabrication of ZrO_2-SiO_2 binary oxide scaffold by indirect stereolithography. The printed scaffold is evaluated for its morphology, mechanical strength and biocompatibility.

Material and Methods

ZrO_2-SiO_2 binary oxide has been synthesized by using sol-gel technique. For this purpose, analytical grade $ZrOCl_2{\cdot}8H_2O$ and $(C_2H_5)_4OSi$ (TEOS), were taken as precursors for ZrO_2 and SiO_2 respectively and molar ratio of 1:1 has been utilized during the synthesis. The dried powders heat treated at 1100 °C and ball milled into submicron size for ceramic slurry preparation. The scaffold fabrication involving various steps has been explained through **Fig. 1**.

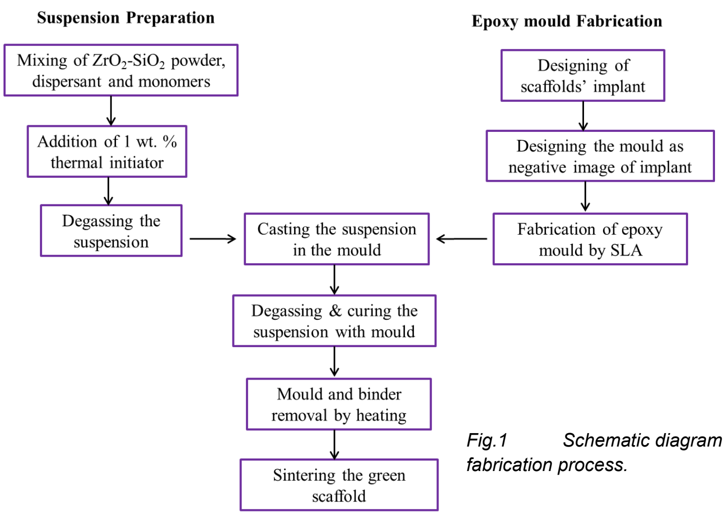

Fig.1 Schematic diagram representing the scaffold fabrication process.

Results

The scanning electron (SE) micrographs presented in **Fig.2** display surface morphology of the scaffold fabricated by Indirect Streolithography. The micrographs clearly indicate the morphology of pores and struts and the presence of cracks are also witnessed. The influence of pore size and internal architecture on mechanical and biological behaviour will be discussed in detail.

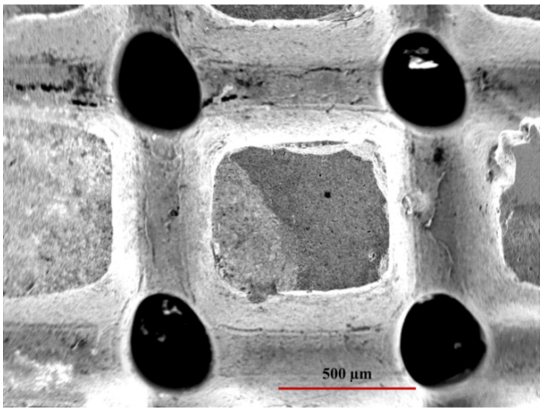

Fig.2 SE micrograph representing the scaffold morphology.

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Biography

Vasanthavel Subramaniyan is graduated in B.Tech-InIndustrial Biotechnology from Anna University, India, in the year of 2006. He has completed his postrgraduation in M.Tech–Nanoscience and Technology in Pondicherry University, India inthe year of 2013. He is currently doing his PhD under the supervision of Dr. S. Kannan in the same University and he visited the University of Manchester,UK through Commonwealth Split-site PhD programme for fabrication of bioceramics by 3D printing under the supervision of Prof. Brian Derby. His research is focused on development and fabrication of bioceramic scaffolds for bone tissue engineering applications.