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Featured Letter

A novel manufacturing route for the fabrication of topologically-ordered open-cell porous iron scaffold

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ABSTRACT

Pure iron is gaining significance in the field of bone tissue engineering owing to its excellent mechanical and biodegradable properties. However, its degradation rate is too slow which needs to be accelerated. The solution to this problem is the preparation of porous iron scaffolds. However, methods for preparing porous iron have received the least attention and till date, no manufacturing methodology for fabrication of topologically-ordered porous iron structures has been developed. Hence, the present work aims to develop a manufacturing methodology using 3D printing and pressureless microwave sintering for the fabrication of topologically-ordered open cell porous iron scaffold. Two different types of unit cell structures were fabricated, and investigation into the accuracy of fabricated iron scaffolds has been reported. The dimensional deviation varying from 5 to 15% was obtained with the porosity varying within the range of 80–86%. Also, XRD results revealed that no contamination of mould material as well as oxide formation was observed in the fabricated iron scaffolds. Compression tests were performed on the fabricated iron scaffolds. The maximum value of plateau stress, compressive modulus of elasticity and compressive strength were found to be 6.94 *MPa*, 316 *MPa* and 16.67 *MPa* respectively.

1. Introduction

The demand for Topologically Ordered Porous Structures (TOPS) is growing in the field of bone tissue engineering owing to their improved mechanical and biological properties. However, these structures involve complex design and hence demands specific fabrication needs. These needs include the control on the fabrication of pore architecture, flexibility in the type of unit cell structure and capability to include customization in design. The most commonly used techniques for the fabrication of biocompatible metal based TOPS are direct solid freeform fabrication [1] and indirect solid freeform fabrication in combination with casting [2] as well as powder metallurgy [3]. These structures are used successfully in the biodegradable scaffold applications [2]. The most studied biodegradable metals are magnesium, iron, and zinc [4]. Out of these metals, iron possesses better mechanical properties but it's too slow degradation rate hinders its application in bone tissue engineering. One of the solutions to the aforesaid problem is the fabrication of porous iron scaffold [4].

Several research attempts have been reported related to the fabrication of porous iron scaffolds. Polyurethane foam impregnation method [5]; powder metallurgy using ammonium bicarbonate as space holder particles [6] and inkjet 3D printing [7] have been the commonly used fabrication technique for preparing porous iron scaffold. However, these techniques are associated with the problems such as the formation of toxic compounds, irregular pore shape, and size [8]. Moreover, it is difficult to achieve the control over the porosity and pore architecture of the scaffold structure. Indirect solid freeform in combination with casting was used successfully for fabricating magnesium based TOPS [2]. However, iron based TOPS are difficult to fabricate using this method owing to its high melting temperature. Though many studies have been performed on the preparation of porous iron, but to the best of our knowledge, none of these studies has addressed fabrication of Topologically Ordered Porous Iron Scaffold (TOPIS). Hence, there exists a need to develop a manufacturing methodology to fabricate TOPIS.

The present work thus aims to develop a manufacturing methodology to fabricate TOPIS using 3D printing and pressureless microwave sintering process. The novelty of the proposed methodology is the methodization of 3D printing in combination with pressureless microwave sintering for fabricating TOPIS. Microwave

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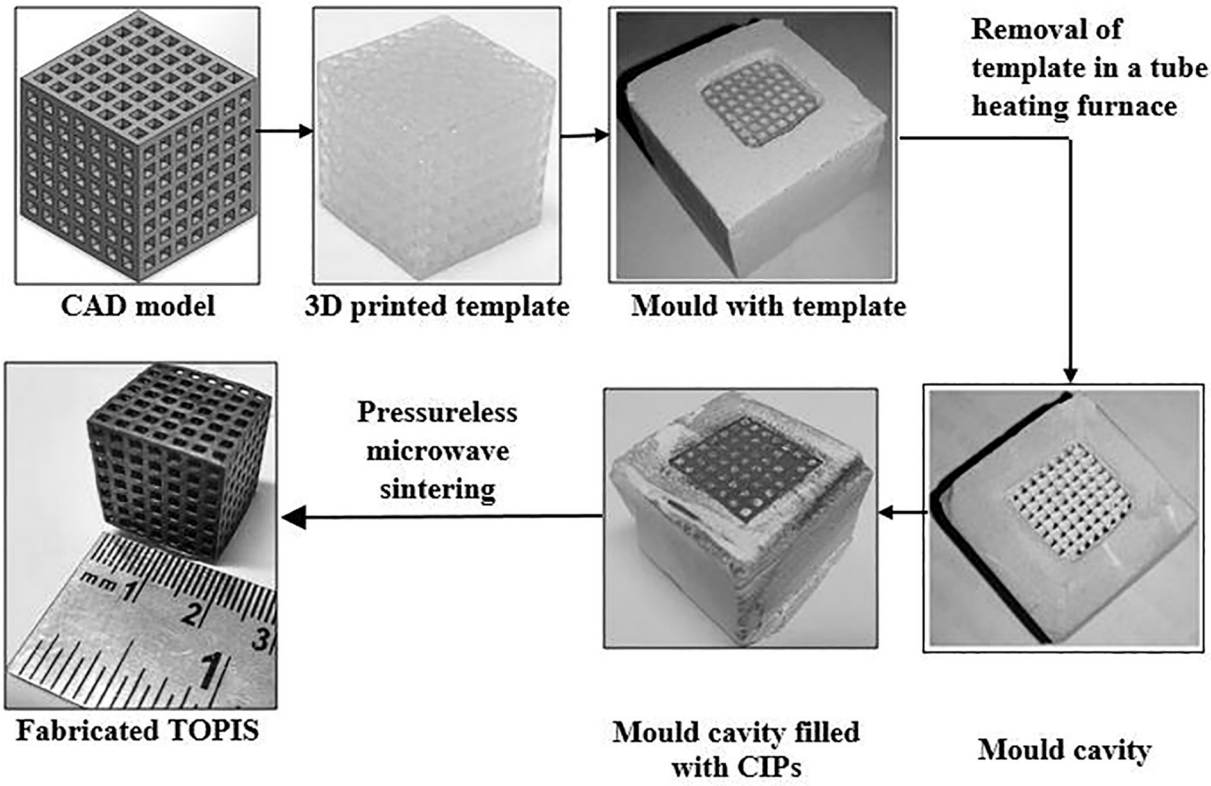
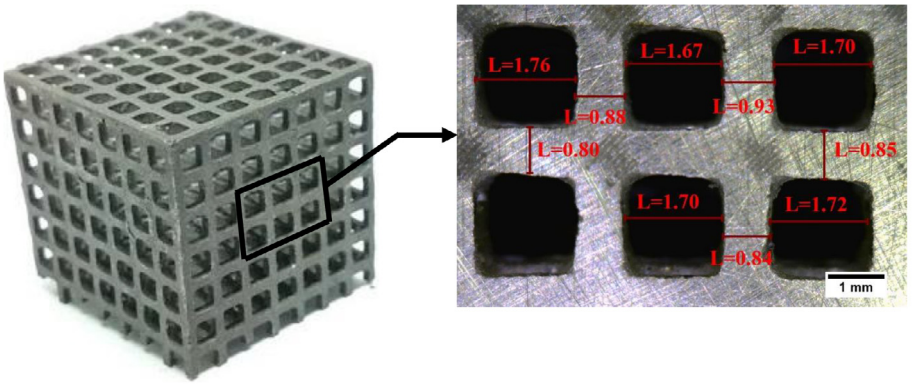
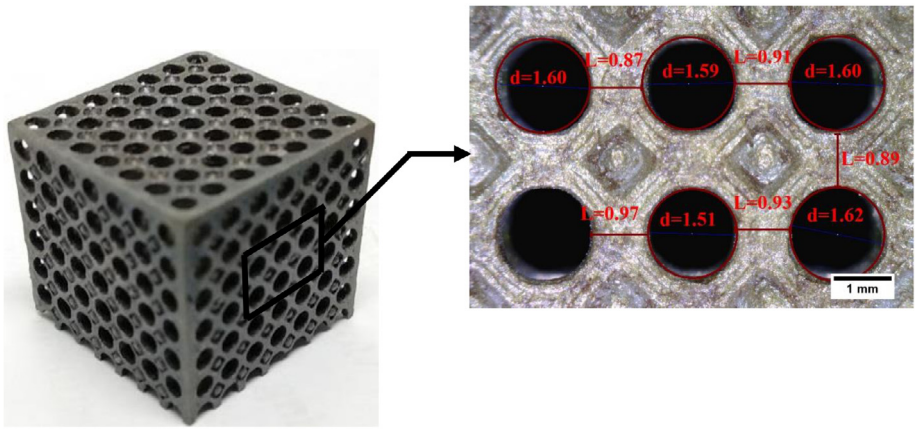


Fig. 1. Illustration of developed seven step methodology for the fabrication of TOPIS.



(a)



(b)

Fig. 2. Fabricated TOPIS along with measured dimensions (mm) (a) cubic unit cell based; (b) truncated octahedron unit cell based.