Post processing of SLM surfaces in lattice structures

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Abstract

Medical additive manufacturing meets patient specific needs with tailor-made implants that often possess an unique design not achievable through conventional machining. Examples are titanium lattice structures produced via Selective Laser Melting (SLM) used as bone-scaffolds for craniomaxillofacial applications. Due to the fabrication characteristic, the implant surface is process-decorated with micro-particles of the starting powder possessing a d50 diameter of about 60 µm. Aim of this study is to identify the most suitable post-processing method for removing these adhering particles. Finally, a thin bone-like coating is uniformly applied on the whole 3-dimensional implant surface to accelerate and improve osseointegration.

Titanium cube samples were fabricated via SLM using a ReaLizer 250HL. The cubes possess an open-porous lattice structure composed by 125 rhombic dodecahedron unit cells, with a designed porosity of 80% and strut diameter of 500 µm.
Three different post-processing methods for removing surface particles were compared:
1) Vibratory Grinding using abrasive Al_2O_3 particles (corundum) of size 150-212 µm.
2) Ultrasonic Cleaning. The samples were immersed in a 1.6 kW ultrasonic bath filled with water containing 0.8 µm abrasive SiC particles.
3) Acid-Etching. The samples were kept in an aqueous solution of acid combination (H_2SO_4 and HCl).
The Acid-Etched cubes were modified with a <100 nm hydroxyapatite (HA) layer following a wet biomimetic route developed by Carino et al[1].

Among the considered post-processing methods, Acid-Etching gave the best results. Most of the titanium particles left by the manufacturing process are removed leading to a mass loss of about 10%. Vibratory Grinding and Ultrasonic Cleaning are shown to be less effective methods that leave aluminum and silicon contaminations on the outer and inner surfaces respectively. This indicates that corundum particles could not enter the lattice structure due to their size while Ultrasonic Cleaning does not provide sufficient energy to the smaller SiC particles to scour the samples surface and SiC remain trapped into the porous structure. Acid treatment on the other hand does not leave any contamination and forms a micro-rough surface that enhance osseointegration.
The final HA coating process demonstrates that it is possible to coat (particle-free) inner surfaces of lattice structures otherwise not reachable via conventional coating methods such as plasma spray. The sub-micrometer thickness of the HA layer also preserves all the surface features including the micro-roughness formed during the Acid-Etching step.

[1]A. Carino, et al. *Formation and transformation of calcium phosphate phases under biologically relevant conditions: Experiments and modelling*, Acta Biomaterialia 74:478 2018

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