ABSTRACT

Wear and corrosion, stress-shielding and inadequate biological fixation are the major causes behind the failure of load bearing orthopaedic implants. Multi-scale surface architecture, implants with graded porosity, improved wear and corrosion resistance would promote improved cell adhesion, tissue ingrowth which eventually increases lifetime of the implant. The thesis explores three different processing routes to improve such biofunctionalities of uncemented total hip replacement (THR) implants. Porous constructs would facilitate bone ingrowth and reduce stress shielding effect by tailoring elastic modulus of the implant. Accordingly, first part of the work involves designing and manufacturing of orthopaedic implants through laser-based additive manufacturing route, namely, direct metal laser sintering of Ti6Al4V powder. A method was developed to design acetabular cup with varying porosity and pore sizes along the radial direction. The developed method utilizes slice-wise modification approach to ensure a continuous gradation of properties. Suitable build strategies and process parameters were identified to manufacture the designed model. In the second part, laser remelting of Ti6Al4V surfaces was carried out and the induced changes in different physicochemical, mechanical and biological properties were evaluated. Pulsed laser remelting of surfaces generated ripple-like structures and the resultant surface features influenced proliferation, differentiation and orientation of the MG63 and hMSC cells. Also, the evolved microstructure was beneficial for augmenting wear and corrosion resistance of the surfaces. Finally, anodic oxidation of the laser-treated Ti6Al4V surfaces was performed in fluoride containing electrolytes to study the influence of process parameters like electrolyte composition and applied potential on nano-morphologies of the evolved surfaces. Growth of uniform arrays of titania nanotubes with controlled dimensions was observed on the laser-remelted surfaces, and such nano-topographies helped to augment the corrosion resistance as well as the osteogenic potential of the surfaces.

Keywords: Graded porous implant, Direct metal laser sintering, Laser surface remelting, Anodic oxidation, Hierarchical surface topography, Osteogenic potential