Design of a biomedical titanium alloy for additive manufacturing

E. Alabort[1], D. Barba[2], and R.C. Reed[2]

[1]OxMet Technologies Ltd., Unit 15, Oxford Industrial Park, OX5 1QU, United Kingdom
[2]Department of Materials, University of Oxford, Parks Road, Oxford, OX1 3PJ, United Kingdom

Abstract

Most existing implants are inherently limited by the mismatch between the performance of metals and biological bone tissues. Moreover, most common biomedical alloys raise toxicological concerns. In this paper, alloy design is used to find optimal metallic titanium compositions which are bio-compatible, and which offer inherent lower modulus of elasticity for optimal bone compliance. The alloys were also optimised for additive manufacturing: alloys with low cracking susceptibility and tendency to form fine microstructures were isolated. An optimal alloy composition was then produced and manufactured by 3D printing. Mechanical experiments on manufactured material under tension reveal the stiffness and strength of the alloy. This work confirms the suitability of the titanium alloy to lower the stiffness of traditional biomedical alloys while being additively manufacturable and strong.

1 Introduction

Mechanical compatibility between medical implants and human bone is vital for successful long-term implantation [1]. Stiffness mismatching between metal and bone causes stress shielding [2–4], which weakens the bone tissue next to the implant and risks bone resorption, loosening and implant rejection. The elastic modulus of bone and metals differ greatly. Human spongy bone ranges from 0.02 to 5 GPa [5, 6], while for cortical bone – the harder more dense tissue found in the periphery – values range from 10 to 40 GPa [5, 6]. These are substantially lower than those of most commonly used metals: pure titanium and Ti-6Al-4V (110-120 GPa), Co-Cr alloys (190-210 GPa), and 316L stainless steel (210-250 GPa). These may impair implant compatibility and osseo-integration [7]. Although titanium and its alloys have good corrosion resistance [8] and bio-compatibility [9], concerns around the cytotoxic V and Al still exist. There is evidence