Design and Development of a Low Density Ti35Zr35Nb15Mo5Fe5Cr5 Complex Concentrated Alloy for Biomedical Application

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Abstract

The present work deals with the alloy design strategies adopted to develop complex concentrated alloys (CCAs) for biomedical applications. Keeping property requirements in mind, a Ti35Zr35Nb15Mo5Fe5Cr5 CCA was designed using ThermoCalc. The objective was to achieve high strength-to-weight ratio, corrosion resistance and biocompatibility, and sufficiently low elastic modulus suitable for biomedical implant material. The aforementioned alloy was fabricated using the vacuum arc melting technique. Annealing treatment of the as-cast alloy was performed at various temperatures, such as 700C, 900C, and 1100C for 20h. The microstructural evolution, phase stability, instrumented micro-indentation, corrosion behavior and biocompatibility of the as-cast and as-annealed alloys were investigated. Optical microscopy and SEM were used to analyze the microstructure of the alloys, and chemical composition was determined using SEM-EDS. XRD analysis shows that the as-cast alloy has two BCC phases with a small amount of Laves phase. However, in the annealed specimens, the amount of the Laves phase increases with increase in the annealing temperature. The measured density, average microhardness, and elastic modulus of as-cast alloy are 6.37 g/cm3, 618 HV, and 97 GPa, respectively. The microhardness of the as-annealed alloy increases as the annealing temperature increases because the amount of hard Laves phase increases. In-vitro biocompatibility (cell adhesion and cell proliferation) of the CCA was investigated in human MG-63 osteoblast cells. A potentiodynamic polarization experiment in simulated body fluid (SBF) solution and electrochemical impedance spectroscopy were used to investigate the corrosion behavior. The Ti35Zr35Nb15Mo5Fe5Cr5 CCA exhibits superior corrosion resistance compared to 316L stainless steel and CP-Ti in SBF solution. Thus, a novel biocompatible CCA with the unique combination of low density, high strength, high corrosion resistance and low elastic modulus was developed.

Keywords: Biocompatible complex concentrated alloy, Microstructural characterization, Microhardness, Corrosion, Electrochemical impedance spectroscopy

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