Materials and Design 32 (2011) 4598–4602

Contents lists available at ScienceDirect

Materials and Design

journal homepage: www.elsevier.com/locate/matdes

Short Communication

Zr–Si biomaterials with high strength and low elastic modulus

Chunliu Li, Yongzhong Zhan *, Wenping Jiang

Key Laboratory of Nonferrous Metal Materials and New Processing Technology, Ministry of Education, Guangxi University, Nanning, Guangxi 530004, PR China

ARTICLE INFO

Article history:
Received 24 January 2011
Accepted 26 March 2011
Available online 8 April 2011

ABSTRACT

In order to develop new biomaterials for hard tissue replacements (HTR), the Zr–8.8Si–xNb (x = 0.0, 0.3, 0.6 and 0.9) alloys with required properties were designed and prepared for the first time. Experimental results show that these alloys can provide excellent mechanical compatibility for the special demands for substitution of human bones. The highest compression strength of the alloys is 1189.30 MPa, while the highest yield strength of alloys is 850.25 MPa. The elastic energy is determined to be 5.001–12.01 MJ/m^3, and the Young's modulus is in the range of 25.08–29.63 GPa. The composition of high strength and low elastic modulus of Zr–8.8Si–xNb alloys offer potential advantages for biomedical applications.

1. Introduction

Bone-related degeneration such as necrosis of head of femur, sport injury of joints, wear and corrosion of teeth, often occurs in human body, which makes the patients frequently suffer from pain and partial or complete loss of the functionality. So in the past decade, replacement of diseased teeth, bones or even the joints by artificial materials is urgently required in orthopedic surgery in order to relieve pain and recover the functioning. To achieve this goal, implant materials are required. However, as far as we know, selection of materials for different components in biomedical devices depends especially on several factors. Firstly, the implant materials must possess an excellent biocompatibility without adverse reactions. Secondly, it must have a good combination of excellent corrosion resistance in body fluid, high mechanical strength and fatigue resistance. Moreover, low elastic modulus (close to that of a human bone (15–30 GPa)) and good wear resistance are required, in order to transfer the adequate mechanical stress to the surrounding bones [1,2].

Traditionally, the Ti–6Al–4 V alloy had been developed for aerospatial and naval industries. Moreover, it was one of the first titanium biomaterial introduced in implantable components and devices. However, recently many studies have shown that both Al and V ions may cause long-term health problems. The element V has been found to react severely with tissue in animals, and Al may be connected to neurological disorders and Alzheimer's disease. Another problem is that the modulus of Ti–6Al–4 V reaches about 110 Ftp, which is substantially higher than that of natural human bone (10–30 Ftp) [3,4]. For solving these problems and further improving the biological and mechanical properties, lots of new Ti alloys have been developed for the biomedical application. For example, designing single β-Ti phase type alloys can obviously reduce the elastic modulus. Generally, β-structure exhibits about 60–80 GPa of Young's modulus [5,6]. However, long-term studies have indicated that there is a contradiction between elastic modulus and the other mechanical properties in those β-Ti alloys. When the elastic modulus is reduced, the strength of the Ti alloys is also decreased [1]. Therefore, in order to make up the shortage of Ti-based biomaterials, it is very necessary to explore some novel biological materials.

Some previous researches on the biological behavior of metals have shown that Zr is similar to Ti and is favorable non-toxic metal with good biocompatibility. Zr and its alloys are also known as excellent bioactive metallic biomaterials because they can form a bone-like apatite layer on their surfaces in the living body. In particular, Zr is a metal with a strong glass-forming ability and bulk amorphous, and exhibits high mechanical strength, high fracture toughness and good corrosion resistance [7–10]. However, up to now research on Zr alloys developed as biomedical materials can rarely be found. In order to solve the current problem of a biomechanical mismatch of the elastic modulus and the intrinsic structural difference, it is crucial to develop new alternative materials to achieve both low elastic modulus and high strength at the same time.

In the present study, the novel biocompatible Zr–8.8Si–xNb alloys were designed and prepared. Si element is used here for it has excellent biocompatibility and can be expected to act as reinforcement by forming intermetallic compounds with Zr. Nb is selected as alloying element because it can be dissolved into liquid Zr during solidification [11] and then improve the mechanical properties. What is more, both Si and Nb have been judged to be non-toxic and non-allergic [12], and are considered as safe alloying elements for biomedical alloys. Investigation on these Zr–8.8Si–xNb alloys may

* Corresponding author. Tel.: +86 771 3272311; fax: +86 771 3233530.
E-mail address: zyzmatres@yahoo.com.cn (Y. Zhan).

0261-3069/$ - see front matter © 2011 Elsevier Ltd. All rights reserved.
doi:10.1016/j.matdes.2011.03.072