Composition design and mechanical properties of BCC Ti solid solution alloys with low Young’s modulus

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Abstract

(Ti-Zr)-Mo-Nb alloys were studied to find some stabilized BCC solid solution with low Young’s modulus. We propose a cluster-plus-glue-atom model to solve the composition design of multi-component complex alloys from the structure viewpoint. The alloy composition is expressed with [cluster](glue atom)x according to the model, x denoting the number of glue atoms matching one cluster. Alloy structures were identified with XRD and optical microscopy (OM), and mechanical tests were finally carried on to the BCC alloys. The experimental results indicated that a series of β-Ti solid solution alloys with low Young’s modulus and good synthesized mechanical properties can be obtained with the cluster model, where the [CN14 cluster](glue)x alloys given by 1:1 cluster model have the optimum properties.

Keywords: Cluster-plus-glue-atom model; Composition design; Low Young’s modulus; (Ti-Zr)-Mo-Nb alloys

1. Introduction

Ti and Ti-alloys possess excellent properties including high specific strength, high toughness, good resistances to high temperature and corrosion, and good forge ability, etc., which are ideal materials in the fields of aero-space, navigation, automobile, petroleum, chemical industry and medicine [1-4].

There are a variety of Ti and Ti-alloys. Usually we separate them as \(\alpha\)-Ti, \(\alpha+\beta\)-Ti and \(\beta\)-Ti alloys. Among them, \(\beta\)-Ti solid solution alloys with BCC structure are applied widely with respect to the mechanical properties, process abilities [5, 6]. Compared with \(\alpha\)-Ti and \(\alpha+\beta\)-Ti alloys, \(\beta\)-Ti solid solution alloys exhibit the highest specific strengths, lowest Young’s Modulus, high ductility and good corrosion resistances.

2. Experimental procedures

2.1 The design thought of compositions

For the solid solution which can be described as [cluster](glue)x, the change of glue atom x corresponds to the alloys with different solid solubility [4, 5]. Because of the strong interaction of the component, the largest decomposition of the solute atoms and solvent atoms of BCC solid solution are the first neighbor position and the second neighbor position [6]. So we chose the coordination polyhedron CN14 among the BCC structures to be the cluster model, the first neighbor shell possesses 8 atoms and the second neighbor shell possesses 6 atoms which indicate the chemical short range order of the localized structure of solid solution; the disordered distribution of these isolated clusters indicated the chemical long range disorder of the solute atoms. As Fig. 1 shown, CN14 cluster can form super cluster structure icosahedrons, white atoms represent cluster center atoms while black atoms represent...
The corrosive liquid was 8% HF + 15% HNO₃ + 77% H₂O. Tensile test was taken on MTS 810, the rate of extension was 0.5 mm/min. The tensile test sample size was shown in Fig. 4.

2.2 Experimental procedures

Ti-Zr-Mo-Nb series master alloys were prepared by Vacuum arc furnace in pure argon atmosphere. The purity of raw materials were Mo: 99.99 %, Ti: 99.99 %, Nb: 99.95 %, Zr: 99.99 %. Master alloys were melted repeatedly to homogenize the components, then, alloy bars which were 3 mm and 6 mm were prepared by copper mould suction highly vacuumed. The vacuum arc furnace working principle is shown in Fig. 3. The alloy structures were tested by Bruker D8 Focus X-ray diffractometer (Cu, Ka radiation, λ=0.15406nm), the micro structures were taken by OLYMPUS optical microscope, the corrosive liquid was 8% HF + 15% HNO₃ + 77% H₂O. Tensile test was taken on MTS 810, the rate of extension was 0.5 mm/min. The tensile test sample size was shown in Fig. 4.

3. Experimental result

We are mainly adding low Young’s Modulus component Zr into the ternary alloy Ti-Mo-Nb, developing Multi-element alloy, to get low Young’s Modulus alloy. Table 1 shows (Ti,Zr)-Mo-Nb multi-component alloy’s cluster formula, composition (at%) and composition (wt%) in detail. Figs. 5 to 7 are the XRD diagrams, we can see that if there is a Mo in the as-cast structure no matter how the glue Ti atoms or the shell Ti atoms change, the structure of the alloy is...