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Materials Science and Engineering A 491 (2008) 154–158

MATERIALS SCIENCE & ENGINEERING A

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Microstructure and compressive properties of AlCrFeCoNi high entropy alloy

Y.P. Wang *, B.S. Li, M.X. Ren, C. Yang, H.Z. Fu

School of Materials Science and Engineering, Harbin Institute of Technology, Harbin 150001, PR China

Received 7 January 2008; received in revised form 24 January 2008; accepted 24 January 2008

Abstract

An AlCrFeCoNi high entropy alloy was prepared by vacuum arc melting. Only diffraction peak corresponding to a BCC crystal structure is observed for this AlCrFeCoNi high entropy alloy. The microstructure of this AlCrFeCoNi alloy is polygonal grains with intragranular dendritic segregation. Dendritic segregation area is found to be Al, Ni rich and Cr, Fe deplete, while interdendritic segregation area is Cr, Fe rich and Al, Ni deplete. The distribution of Co is essentially identical. The fine microstructure of dendritic segregation area and of interdendritic segregation area is found to be nanoscale spherical precipitates morphology and basket-weave morphology, respectively. Results of EDS attached on high resolution scanning electron microscope (SEM) revealed that these morphological characteristics are also resulted from elements segregation. This AlCrFeCoNi high entropy alloy exhibits excellent compressive properties. The yield stress, compressive strength and plastic strain of the alloy reaches 1250.96, 2004.23 MPa, and 32.7%, respectively. The fracture mechanism of this AlCrFeCoNi high entropy alloy is observed as cleavage fracture and slip separation.

Keywords: High entropy alloy; Microstructure; Compressive properties

1. Introduction

Traditional metallurgical theory suggests that multiple alloying elements in an alloy may lead to the formation of many compounds with complex microstructure and poor mechanical properties [1]. Recently this paradigm has been broken by high entropy alloy developed by Yeh et al. [2]. High entropy alloys are defined as alloys that have at least five principal elements and the concentration of each element is between 5 and 35 at.%. Yeh and co-workers [3–5] found that high entropy alloys may possess simple solid solution structure. They considered that the high mixing entropy of multi-principal elements induces the formation of multicomponent solid solution. The high entropy alloys possess excellent properties as well. With proper composition design, promising properties in hardness, wear resistance, oxidation resistance, and corrosion resistance can be obtained [6–9].

These discoveries brought about a new alloy design concept and opened a new research field of metallic materials. Many high entropy alloy systems have been exploited in the past decade, and most of the reported alloy systems contain Cu [2–7,9]. Cu tends to segregate at grain boundary and improves the plasticity of high entropy alloys [3,10,11]. Chen et al. [11] found the rupture of $AlTiFeNiCr_x$ alloy during cooling, and they considered Cu is the necessary element for high entropy alloy. Zhou et al. [12] studied the room temperature mechanical properties of $AlCoCrFeNiTi_x$ system. They found that the plastic strain of both Ti_0 and $Ti_{0.5}$ alloys exceeded 20%. This indicates that not all the high entropy alloy systems without Cu are brittle. Therefore, in this paper an AlCrFeCoNi high entropy alloy was prepared, and its microstructure and compressive properties were investigated intensively.

2. Materials and experimental details

A high entropy alloy AlCrFeCoNi (nominal composition is equimolar for each element) was prepared using a vacuum arc melting furnace. The purity of all the raw elemental metal is above 99.9%. Melting atmosphere was Ti-gettered high-purity argon. The ingot was remelted four times to improve chemical homogeneity.

* Corresponding author. Tel.: +86 451 86412198; fax: +86 451 86413955.
E-mail addresses: wangyphit@163.com (Y.P. Wang), lbs@hit.edu.cn (B.S. Li).

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doi:10.1016/j.msea.2008.01.064

The crystalline structure of alloy was characterized using D/max-rB X-ray diffractometer (XRD). A FEI sirion scanning electron microscope (SEM) was used for microstructure observation. A Hitachi S-5500 scanning electron microscope equipped with EDS was used to identify the element distribution in nanoscale. Room temperature compressive properties was tested on an Instron 5500 testing machine with a loading speed of 0.5 mm/min. The test specimens were cylindrical, $\Phi 3\,mm \times 5\,mm$. Three compression tests were performed to obtain the average value.

3. Results and discussion

3.1. Crystal structure determination

The XRD pattern of the AlCrFeCoNi high entropy alloy is shown in Fig. 1. Only diffraction peak corresponding to a BCC crystal structure whose lattice constant is 0.2873 nm is observed. Thus Al, Cr, Fe, Co, Ni elements are expected to distribute in the crystal lattices and form quinary BCC solid solution.

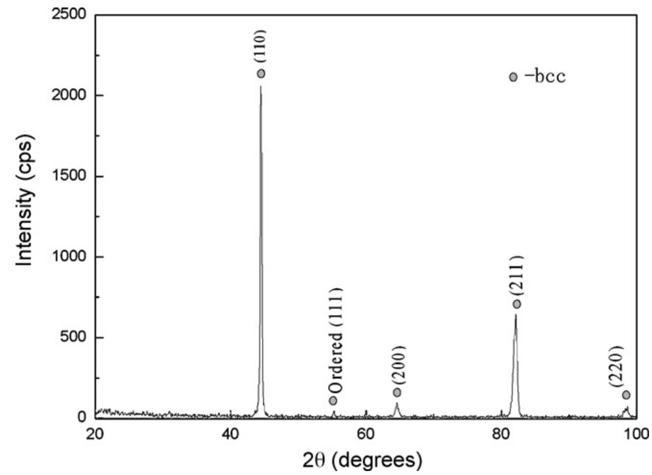

Fig. 1. XRD pattern of AlCrFeCoNi high entropy alloy.

3.2. Microstructure

Fig. 2 shows the SEM images of the as-cast AlCrFeCoNi high entropy alloy. It was found that the produced AlCrFeCoNi

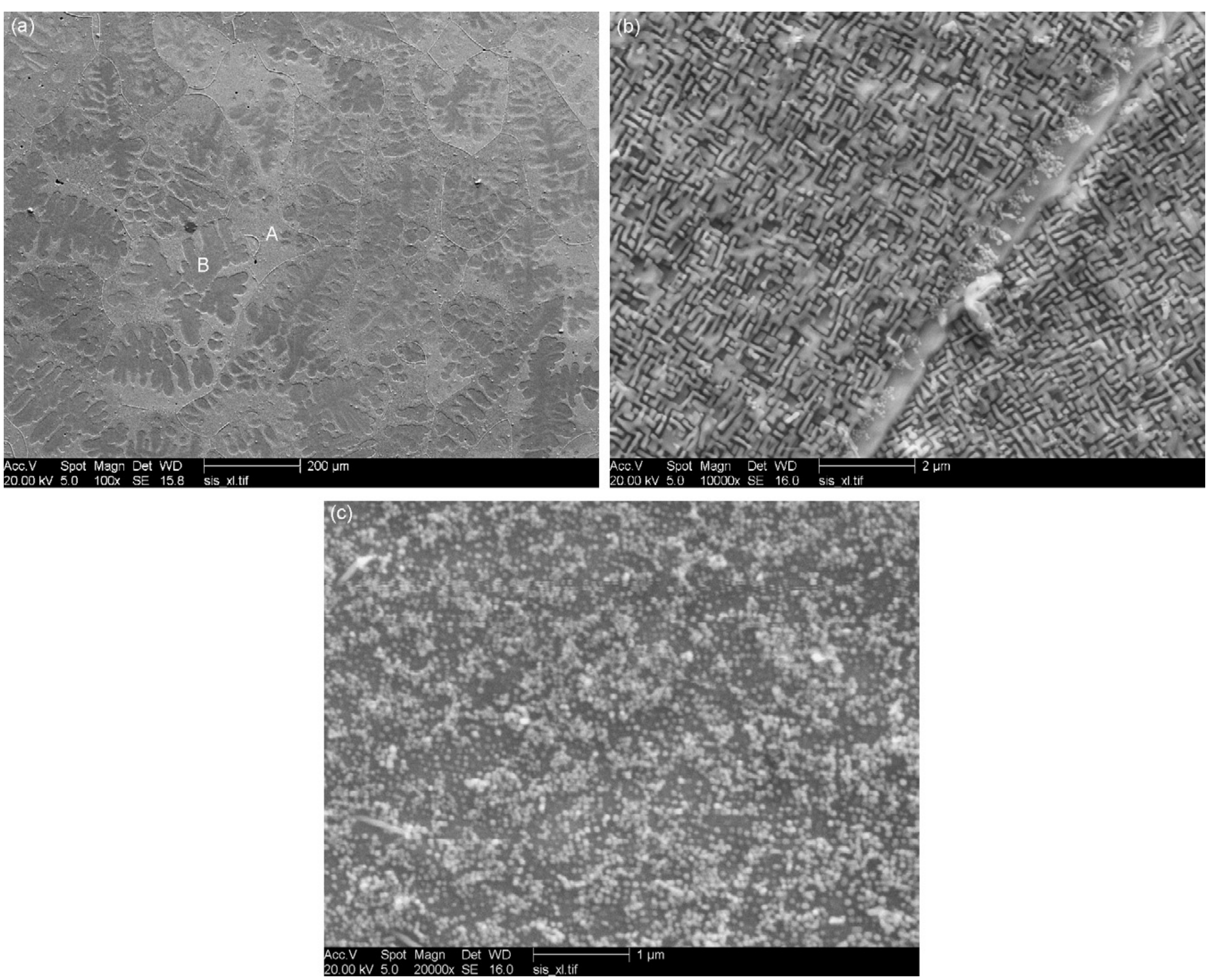

Fig. 2. SEM microstructure of AlCrFeCoNi high entropy alloy. (a) Low magnified image, (b) high magnified image of zone A in (a), (c) high magnified image of zone B in (a).