Accepted Manuscript

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PII: S0925-8388(16)32254-X

DOI: 10.1016/j.jallcom.2016.07.219

Reference: JALCOM 38388

To appear in: *Journal of Alloys and Compounds*

Received Date: 15 January 2016

Revised Date: 15 July 2016

Accepted Date: 20 July 2016

Please cite this article as: B. Gorr, F. Mueller, H.-J. Christ, T. Mueller, H. Chen, A. Kauffmann, M. Heilmaier, High temperature oxidation behavior of an equimolar refractory metal-based alloy 20Nb-20Mo-20Cr-20Ti-20Al with and without Si addition, *Journal of Alloys and Compounds* (2016), doi: 10.1016/j.jallcom.2016.07.219.

High Temperature Oxidation Behavior of an Equimolar Refractory Metal-based Alloy 20Nb-20Mo-20Cr-20Ti-20Al with and without Si Addition

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Abstract

The high temperature oxidation behavior of a refractory high-entropy alloy (HEA) 20Nb-20Mo-20Cr-20Ti-20Al at 900°C, 1000°C and 1100°C was investigated. The oxidation kinetics of the alloy was found to be linear at all temperatures. Oxide scales formed are largely inhomogeneous showing regions with thick and porous layers as well areas with quite thin oxide scales due to formation of discontinuous chromium-rich oxide scales. However, the oxidation resistance can be moderately improved by the addition of 1 at.% Si. The thermogravimetric data obtained during oxidation of the Si-containing alloy at 1000°C and 1100°C reveal pronounced periods of parabolic oxidation that, however, change towards linear oxidation after prolonged exposure times. Microstructural investigations using scanning electron microscopy (SEM) and transmission electron microscopy (TEM) document that the Si addition gives rise to a nearly continuous alumina-rich layer which seems to be responsible for the good protection against further oxidation. Pronounced zones of internal corrosion attacks consisting of different oxides and nitrides were observed in both alloys. In order to determine the chemical composition of the corrosion products and their mass fraction, quantitative X-ray diffraction (XRD) analysis was performed on powdered oxide scales that formed on the alloys after different oxidation times. Rutile was identified as the major phase in the oxide scales rationalizing the relatively high mass gain during oxidation.

1. Introduction

Equiatomic multicomponent alloys have attracted great attention among material scientists worldwide in the last few years [1,2] due to their unique properties. Regarding the microstructure, HEAs stand out due to their tendency to possess simple, highly symmetric crystal structures, which often lead to single-phase microstructures [3], to nanoparticles in the matrix [4] and to sluggish diffusion of elements [5-7]. High temperature stability was reported by Hsieh et al. and Liu et al. for the alloy systems AlCrFeMnNi and FeCoNiCrMn, respectively [8, 9]. With respect to mechanical properties, the so-called Cantor alloy sticks out in having simultaneously high strength and ductility, both of which increase with decreasing temperature [10, 11]. Refractory HEAs exhibit extremely high strength at elevated temperatures exceeding even the levels provided by advanced Ni-based superalloys [12].

Characterization of the oxidation resistance of the alloy $AlSiTiCrFeCoNiMo_{0.5}$ and $AlSiTiCrFeNiMo_{0.5}$ was in part studied by Huang et al. who mainly focused on processing, microstructure, and wear resistance of the alloys [13]. It was concluded that the formation of the chromia-based layer underneath the outermost titanium oxide scale accounts for the good oxidation resistance of these materials. Daoud et al. characterized the oxidation behavior of three alloys based on the alloy system Al-Co-Cr-Cu-Fe-Ni [14]. Thin layers of α-Al_2O_3 and Cr_2O_3 were identified after 200h of oxidation at 1000°C, however severe spallation of oxide scales was also observed. High