UNIVERSITI TEKNOLOGI MARA

MICROSTRUCTURAL EVALUATION AND CORROSION BEHAVIOUR OF Fe-Cr-Ni-Mn-Co AND $Al_{0.5}$-Fe-Cr-Ni-Mn-Co HIGH-ENTROPY ALLOYS (HEA) WITH ELEMENTAL ADDITIONS

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ABSTRACT

Equiatomic or near-equiatomic multicomponent alloys, often termed as high-entropy alloys (HEAs), are an emerging class of metallic materials that are being investigated for a wide range of technical applications. Most studies have been focused on optimizing microstructures or mechanical properties of HEAs and relatively few have designed an alloy for investigating corrosion behavior of HEAs. This study describes the microstructural and corrosion behaviour together with mechanical properties of six HEAs that were designed with the intent to provide high corrosion resistance whilst offering the possibility for high temperature applications. The basic components of the alloys are composed of five elements that are commonly utilized in high temperature alloys, Fe, Cr, Ni, Mn and Co. A sixth element, Al, was also added. Another elements that had been selected as the alloying elements, particularly due to their remarkable properties were Zr, Ta and Sc. Detailed microstructural and chemical analysis have confirmed the presence of the expected BCC and FCC solid solution phases, however, the minority phases in all of the alloys were found to be ordered intermetallics. The hardness investigation demonstrated that the hardness values increased gradually for all alloys due to the formation of the intermetallic compounds. The FeCrNiMnCo alloy density reached up to 8.056 g/cm^3 meanwhile the introduction of Al to the alloy apparently reduced the density to 7.533 g/cm^3. The enhancement of Ta to the high-entropy alloys has improved the densification of the systems caused by the higher density of Ta atom amongst other constituent elements. $FeCrNiMnCoTa_{0.6}$ alloy reached the highest density up to 9.455 g/cm^3. The increase of Zr and Ta content has lowered the thermal stability of the systems whereas Sc alloying has showed vice versa. Electrochemical study revealed that all elemental additions significantly increased the corrosion resistance. The comprehensive atomic radius δ, the mixing enthalpy ΔH_{mix} and the mixing entropy ΔS_{mix} of alloys were also calculated according to relevant equations using the phase selection rules. Collectively, these results have confirmed that complex multicomponent HEAs can be designed and processed using the existing phase selection rules. These results also reiterated the need for refinement of the phase selection rules for HEA formation and improved thermodynamic databases to facilitate the design of better HEAs.

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CHAPTER ONE
INTRODUCTION

1.1 BACKGROUND OF STUDY

Conventional alloys are usually developed based on one major principal element for the matrix formation of the system, such as copper in bronzes and brasses, iron in steels, nickel in superalloys, titanium in titanium-based alloys and aluminium in aluminium-based alloys. A number of elements is specifically added to enhance the particular properties of the materials. To be precise, this model majorly restricts the number of the practical alloy systems and consequently, limits the broader application of alloying elements to obtain more desirable properties. Besides, higher alloying additions in the most practical alloys were expected to result in the formation of intermetallic compounds with the possibility of complex microstructures, thus lead to the embrittlement, difficulty in microstructure analysis and deterioration of mechanical properties (Li, Li, Zhao, & Jiang, 2009; Shun, Hung, & Lee, 2010). Driven by this, Yeh, Chen, Y. L., Lin, and Chen, S. K. (2007) have proposed a new class of alloys termed high-entropy alloys (HEA) as a new approach for alloy design to improve the weaknesses of the conventional alloys. The large number of alternatives considering the total 80 metallic elements in the periodic table results in countless number of HEAs that can be produced. Yeh et al. (2004) have defined that HEA is composed of at least five principal metallic elements in equimolar or non-equimolar ratios which contains the concentration of each element being between 5 and 35 atomic percentage (at. %).

Recently, the fabrication of HEAs has attracted great attentions especially on the developing and overcoming the constraints arise from traditional alloys. Many reports have been concentrated on this new concept of alloy design due to their interesting features which tend to form simple solid solution phases thermodinamically, such as face-centred cubic (FCC) and body-centred cubic (BCC) phases. They may exhibit nanostructures or amorphous structures with good thermal stability, ductile, working-hardenable, high strength and also excellent resistance to anneal softening (Yeh et al., 2007).