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Title : MICROSTRUCTURE, PHASE FORMATION AND HARDNESS INVESTIGATION OF ARGON ARC MELTED Al-Co-Cr-Fe-Ni AND Al-Cu-Cr-Fe-Ni HIGHENTROPY ALLOYS (HEA) WITH ELEMENTAL ADDITIONS

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Traditional alloying is one of the methods to enhance the performance of pure metals by adding other metals or non-metals. However, as multiple alloying elements in an alloy may lead to the formation of many intermetallic compounds with complex microstructures and poor mechanical properties, new types of metallic alloys called High Entropy Alloy (HEA) with at least 5 elements with equimolar ratios were developed. This thesis reports the microstructural studies, mechanical properties and thermal properties of $AlCuCrFeNiTi_xNb_y$; (x and y= 0.5, 1.0, 1.5), $AlCoCrFeNiZr_x$; (x= 0.2, 0.4, 0.6, 0.8, 1.0) and $AlCoCrFeNiMo_xNb_y$; (x and y= 0.1, 0.2, 0.3) HEAs that have been prepared using Ar arc melting technique. Effect of adding elements with large atomic radius, nano precipitate formation and high melting point on the phase formation, microstructural development and mechanical properties of HEAs prepared in this study were investigated in detail. Thermodynamic calculations and structural parameters for HEA phase formation criteria were carried out and correlated with the experimental results of the HEAs prepared in this study. Microstructural studies using scanning electron microscope (SEM) and XRD showed that Ti addition promoted secondary BCC_2 phase. Results also showed that Nb promoted FCC phase as well acted as FCC stabilizer. Samples with both Nb and Ti addition showed FCC_1 and FCC_2 structure with Nb rich FCC dendritic phase as dominant phase. $AlCoCrFeNiZr_x$ (x= 0.2, 0.4, 0.6, 0.8, 1.0) HEAs consist of mixed FCC and BCC solid solution phase regions and there are no intermetallic phases found. Addition of Zr in the HEA did not result in a preferential solidification of either BCC or FCC phase since both phases present at all compositions until x=1.0% Zr. The BCC solid solution phase was observed in XRD patterns of both Nb and Mo added AlCoCrFeNi HEAs. SEM-BSE micrographs of Mo added AlCoCrFeNi HEAs revealed spinodal decomposition of the high temperature solid solution. Nb added HEAs showed Nb rich eutectic mixture at interdendritic regions. Though, individual Nb and Ti additions to AlCuCrFeNi HEAs had resulted in increase in hardness, combined additions had resulted in highest hardness of 797 HV. AlCoCrFeNi HEA with 0.2% Zr had displayed high hardness value compared to the base HEA. The hardness of Mo added HEAs were highest among all the HEAs prepared, which could be attributed to the spinodally decomposed microstructure. The values of H_{mix} that were calculated from the EDX data were within -22 and 7 kJ/mol for all $AlCuCrFeNiTi_xNb_y$, $AlCoCrFeNiZr_x$ and $AlCoCrFeNiMo_xNb_y$ HEAs, satisfying the requirements to obtain simple phases as evidenced by XRD data. Atomic size difference (δ) that was calculated from the EDX data for all of the phases for $AlCuCrFeNiTi_xNb_y$ showed $\delta \leq 8.5$ satisfying the conditions for all the samples to have simple solid solution phases. ΔS_{mix} for $AlCoCrFeNiZr_x$ HEAs were bigger than 11 J/ (K mol). For $AlCoCrFeNiMo_xNb_y$ HEAs, addition of Nb had resulted in overall increase in melting temperature of AlCuCrFeNi HEAs as observed from DSC results. Addition of Zr in AlCoCrFeNi HEA increased the melting point of the HEA as evidenced by DSC data. All the AlCoCrFeNi HEAs with Mo and Nb addition had displayed higher melting temperature values compared to AlCoCrFeNi HEA and this higher melting temperature values could be attributed to high melting points of Mo and Nb compared to other elements in the HEA.