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Microstructure and Phase Composition of CrNiX (X = Co, Al, Mn) Low-Entropy Alloys

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Alloying chromium-nickel with cobalt (Co), and manganese (Mn) offers the possibility of creating alloys with high yield strength and fracture toughness, while alloying chromium-nickel with aluminum (Al) also contributes yield strength and fracture toughness, along with low density. This study probed the phase composition and microstructure of the low entropy CrNiX system by considering X = Co, Al, Mn. The phase formation rules of low-entropy alloys are explored using empirical formation rules of simple solid solutions. A single phase is likely to form when the mixing enthalpy (H_mix) is within the range -20≤H_mix≤5 kJ.mol^(-1), configurational entropy (ΔS_conf) values 12≤ΔS_conf≤17.5 J.K^(-1).mol^(-1), and atom-size difference (δ)≤6.6%. CrNiCo, CrNiAl, and CrNiMn all fall within the ΔS_conf range at 13 J.K^(-1).mol^(-1), although CrNiAl is outside the H_mix range, with H_mix=-51.485 kJ.mol^(-1). In contrast, CrNiCo and CrNiMn fall within the H_mix range with values of -14.52 kJ.mol^(-1) and -17.16 kJ.mol^(-1), respectively. CrNiCo, CrNiAl, and CrNiMn alloys meet the atomic size misfit criterion with δ values of 0.17%,3.44%, and 3.75 %, respectively. Multicomponent alloys CrNiX (X = Co, Al, Mn), in equal atomic proportions, were then synthesized by arc melting. The chemical composition and elemental segregation were analysed using scanning electron microscopy (SEM), energy dispersive spectroscopy (EDS), and electron probe microanalysis. The crystal structure was identified using X-ray diffraction (XRD) analysis. CrNiCo exhibited a face-centered cubic structure (FCC), spacegroup Fm-3m, with a lattice parameter of 3.57±0.54 Å, CrNiAl showed a body-centered cubic (BCC) structure, space group Pm-3m, with a lattice parameter of 4.07±0.36 Å and CrNiMn demonstrated both FCC (spacegroup Fm-3m) and BCC (spacegroup Im-3m) with an average lattice parameter of 3.35 ±0.23 Å. Resistivity measurements were done over a temperature range of 0-300 K. For both CrNiCo and CrNiAl, resistivity increases with temperature, which is typical for metals due to increased phonon scattering. Between 0-50 K, the resistivity levels off, indicating residual resistivity from impurities or defects, which were observed in both electron probe microanalysis and EDS. Furthermore, the resistivity of both CrNiCo and CrNiAl follows a linear trend between 50-213 K and 50 -240 K, respectively. Magnetic transitions were observed at 213 K for CrNiCo and 240 K for CrNiAl.

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