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Abstract

Design of High-C Cr-Co-Ni medium Entropy Alloy for Tribological Applications †

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Medium and high entropy alloys (MEAs/HEAs), which typically have three or more main elements, were initially designed to have high configurational entropy (S_{conf}) stabilizing a simple, single-phase solid solution (SS) over multi-phase alloys. Having multiple main elements will indeed increase the S_{conf} of simple SSs, but it may decrease the enthalpy also increase, in a lower degree, S_{conf} of other complex phases, leading to multi-phase microstructures. Therefore, although the initial idea behind MEAs/HEAs was refuted, the interest remains, the focus shifted to exploring its vast compositional field, which includes an almost infinite number of alloys. Some of them with potentially better properties than those existing today. The Cantor alloy (equiatomic CrMnFeCoNi) and the equiatomic CrCoNi alloy, both single-phase with face-centered cubic (FCC) structure, are among the toughest materials ever reported. In this work, computational thermodynamic calculations (CALPHAD method) predicted that C additions in the $Cr_{40}Co_{40}Ni_{20}$ MEA favor the formation of a promising multi-phase microstructure for wear applications. A large amount of C was incorporated into the alloy by melting in a graphite crucible, this process allowed C saturation in the melt, which as will be shown, can be well controlled by carefully selecting the casting temperature, in this case we achieved 24 at% C by melting at 1600 °C. A $Cr_{30.4}Co_{30.4}Ni_{15.2}C_{24}$ MEA was produced, characterized by X-ray diffraction (XRD) and scanning electron microscopy (SEM) equipped with energy-dispersive spectroscopy (EDS). Experimental results revealed a microstructure composed of: graphite flakes, hard primary Cr-rich carbides, and a tough eutectic matrix of FCC phase and carbides; in good agreement with thermodynamic calculations. These findings highlight the great flexibility and potential in MEAs/HEAs design, making it possible to obtain microstructures and sets of properties that are beneficial for a given application.