Effect of minor boron addition on the microstructure of the AlCoCrFeNi high entropy alloy

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The advent of high entropy alloys (HEA) provided an exponential increase in the number of possible multicomponent alloys with different properties. The increase in the number of principal elements leads to a large configurational entropy and thus, high entropy of mixing. These alloys tend to form solid solutions with simple crystal structures like FCC, BCC, or a mixture of both, rather than intermetallics or other complex phases. Several HEAs have been explored and very promising properties such as high strength, ductility, excellent fracture toughness at cryogenic temperatures, good resistance to wear and oxidation have been found. In order to tailor the properties of an alloy, some intermetallic or complex phase in addition to the simple FCC or BCC phases may be desired. Understanding how the microstructures are formed during solidification and how small variations on chemical composition changes the final microstructure is paramount for alloy design. In this context, advanced characterization techniques such as TEM, STEM, HAADF, EDS, phase mapping using precession diffraction (ASTAR) are very important tools. In this work, these microscopy techniques, coupled with CALPHAD computational simulations, were used to evaluate the effects of a minor boron addition on the microstructure of the equiatomic AlCoCrFeNi HEA produced by arc-melting. It was found that the as-cast AlCoCrFeNi alloy shows a dendritic solidification behavior, forming two different regions (dendritic and interdendritic) with a small chemical segregation. The as-cast alloy is composed of Al-Ni rich B2 matrix (primary phase), which decomposes into Fe-Cr rich BCC precipitates (Figure 1) and, in the interdendritic region, small FCC islands. Whereas the dendritic region is composed of small BCC precipitates with cuboidal morphology, the interdendritic region is composed of larger and interconnected BCC precipitates. Minor boron addition ($AlCoCrFeNiB_{0.1}$) leads to the formation of needle-like Cr rich M_2B-type borides in the interdendritic region as shown in Figure 2. As consequence, the FCC phase fraction increases, and the chemical segregation become more intense. The boron addition on the AlCoCrFeNi system modifies the solidification sequence in the interdendritic region, forming a 4-phase complex structure composed of Fe-Cr rich BCC matrix, Al-Ni rich B2 precipitates, FCC islands and M_2B type borides, as can be seen in figure 3, and such microstructure change may be of interest for wear properties of these novel family of alloy. Also, the presence of a continuous BCC matrix on the interdendritic region rather than a continuous B2 matrix, found in the equiatomic alloy, might be beneficial for the ductility and toughness of the alloy.

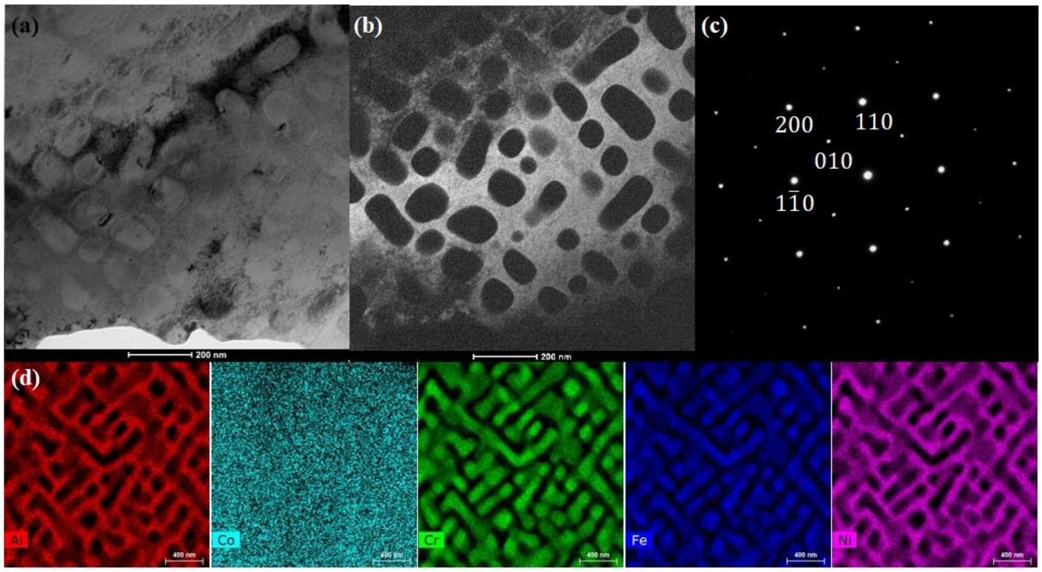

Figure 1: Primary dentritic region of the AlCoCrFeNi alloy. **(a)** Bright Field; **(b)** Dark field using the 010 reflection of the B2 phase; **(c)** BCC/B2 diffraction pattern at 001 zone axis; **(d)** EDS chemical mapping.

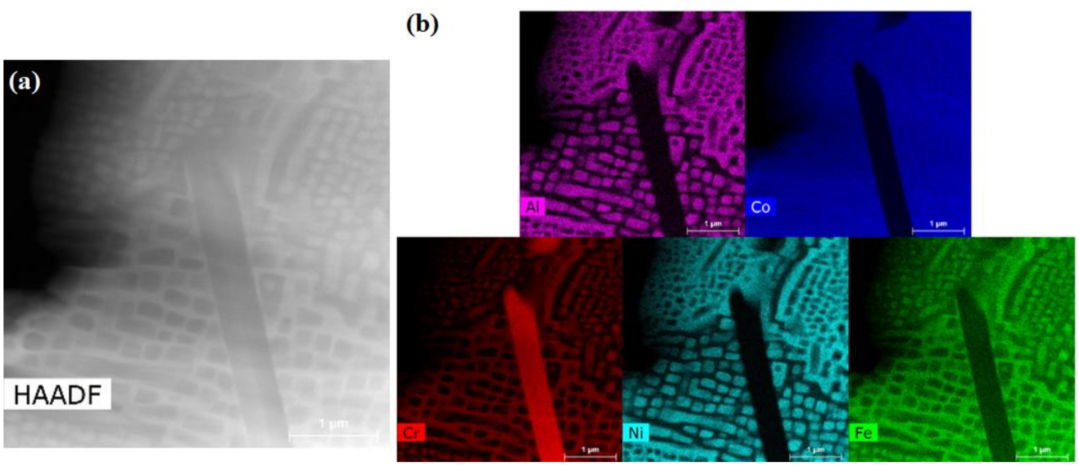

Figure 2: Interdentric region of the AlCoCrFeNi alloy. **(a)**HAADF image; **(b)**EDS chemical mapping showing the Cr-rich need-like boride.

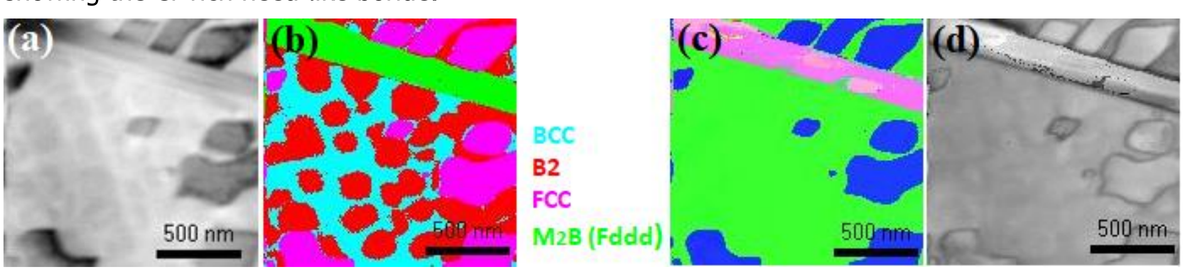

Figure 3: Phase/orientation mapping using precession diffraction technique (ASTAR system) of theinterdentric region of the $AlCoCrFeNiB_{0.1}$ alloy. **(a)**Virtual Bright Filed; **(b)** phase map; **(c)** orientation map; **(d)** Index quality map.