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Effect of entropy on microstructure of $Al_x(CoCrMnMo)_{100-x}$ (x=15, 30, 45, 60) high-entropy and medium-entropy alloys produced by mechanical alloying

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High-entropy alloys (HEAs) and medium-entropy alloys (MEAs) are constituted by multiple elements with a mixing entropy that favours solubility between the elements, giving rise to solid solutions (SS) with a simple structure type BCC or/and FCC [1]. In the past decade, the individual effects of some elements by varying their concentration in popular HEA systems such as AlCoCrMnMo or CoCrFeMnNi have been reported [2]. However, the effect of entropy in varying the concentration of an element, converting an HEA to an MEA, is rarely studied. HEAs were first fabricated by melting, and for years, it has been the main processing route for these alloys. Unfortunately, the melting route leads to the segregation problem. An alternative is mechanical alloying (MA), an alternative process for the development of HEAs and MEAs that improves solubility, avoiding element segregation and being able to process metals with extremely high melting points [3]. Therefore, the present work aims to evaluate the effect of entropy by varying the concentration of aluminium in the CoCrMnMo system produced by MA.

Elemental powders with a purity higher than 99.5% were used as starting materials for the synthesis of Alx(CoCrMnMo)100-x alloy by varying the Al concentration (x=15, 30, 45, 60). The powders were mechanically alloyed in a high energy mill (SPEX 8000M) for 10 h. A vial and hardened steel balls were used as grinding media, with a 5:1 ball-to-powder weight ratio. To reduce excessive oxidation, a protective argon atmosphere was generated, and to avoid particle agglomeration, methanol was added as a process control agent. The microstructural changes experienced by the alloys were studied by XRD (Bruker D8 Advance) and SEM (LEICA Stereoscan 440).

The alloys presented rough surfaces and irregular shapes; distinctive characteristics of powders obtained by MA. In addition, the chemical composition of the powders was similar to the proportion of the starting elemental powders, which was corroborated based on the SEM/EDS analysis (Fig. 1). The powder size after grinding was the main difference between the alloys. The alloys exhibited a smaller particle size when their mixing entropy was higher (Fig 1a-1b) and a larger particle size when their mixing entropy was lower (Fig 1c-1d). In addition, the powders showed little agglomeration, which means that the grinding conditions favoured a balance between the fracture and welding processes during the MA. Fig 2. shows the XRD patterns of the alloys where the tendency to form BCC-type SS, reduced crystal sizes (in the nanometric order) and severe lattice distortions stand out. This is due to the constant fracture and welding processes that are characteristic of MA. In particular, HEAs formed 2 BCC phases, a BCC1 phase (Mo type) and a BCC2 phase (Cr type). The BCC2 phase transforms into an FCC phase by decreasing the entropy of mixing due to the high concentration of aluminium in the MEAs. Finally, the decrease in mixing entropy generated an increase in particle size and also an increase in crystallite size.

HEAs and MEAs were successfully produced by MA from the $Al_x(CoCrMnMo)_{100-x}$ system. All alloys were dominated by the formation of SS with a BCC1 (Mo-type) structure. Entropy has a significant effect on the alloys since, unlike HEAs, the increase of aluminium does not necessarily favour the formation of SS with BCC structures in MEAs.

References:

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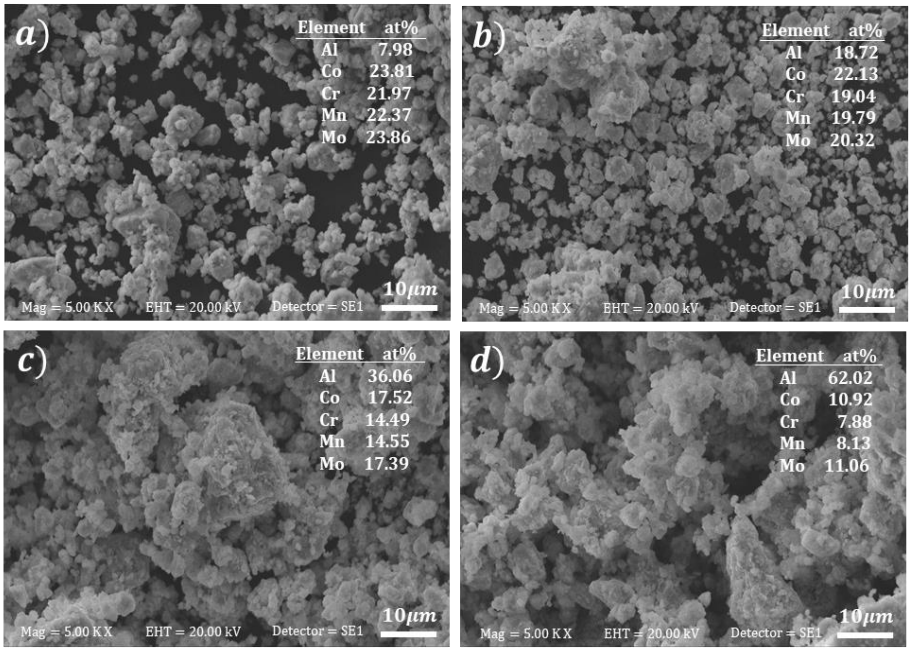

Fig 1. Powders mixed SEM micrographics: HEAs (a) $Al_{15}(CoCrMnMo)_{85}$; b) $Al_{30}(CoCrMnMo)_{70}$ and MEAs (c) $Al_{45}(CoCrMnMo)_{55}$; (d) $Al_{60}(CoCrMnMo)_{40}$

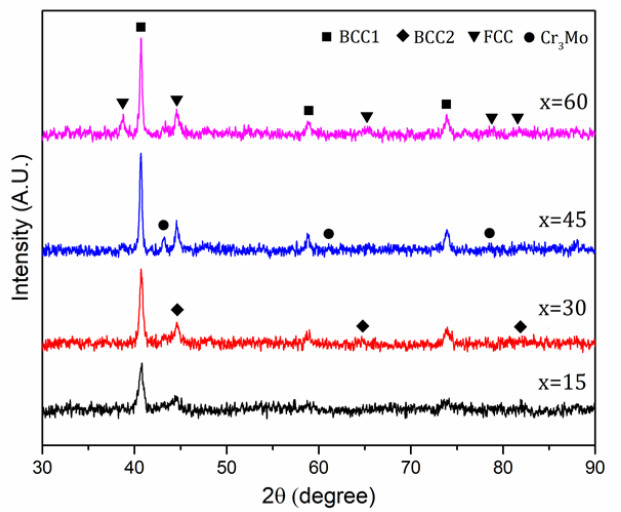

Table 1. Mechanical alloyed HEAs and MEAs microstructural parameters:

Alloy	Structure	Lattice (nm)	Cristal Size (nm)	Micro-strain (%)
HEA $Al_{15}(CoCrMnMo)_{85}$	BCC1	0.314	13.1	0.763
	BCC2	0.288	5.7	1.610
HEA $Al_{30}(CoCrMnMo)_{70}$	BCC1	0.314	18.2	0.542
	BCC2	0.288	7.7	1.180
MEA $Al_{45}(CoCrMnMo)_{55}$	BCC1	0.314	26.2	0.381
	BCC2	0.288	17.1	0.536
	Cr_3O	0.296	25.6	0.368
MEA $Al_{60}(CoCrMnMo)_{40}$	BCC1	0.314	26.7	0.373
	FCC	0.403	13.3	0.645
	Cr_3O	0.296	*	*

* It was not possible to calculate based on the observed XRD patterns

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