How to obtain nanostructured high entropy alloys by powder metallurgy?

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Highlights

- New strengthening strategies for high entropy alloys are considered
- Ball milling is used to reduce significantly the crystallites size
- SPS is applied on ball-milled powder to induce grain boundaries strengthening

1. Introduction

Discovered in 2004, high entropy alloys are multi-component metallic alloys, all elements being very concentrated, such as the single-phased $Co_{20}Cr_{20}Fe_{20}Mn_{20}Ni_{20}$ HEA [1]. In these alloys, the traditional distinction between major and minor elements is not relevant anymore and they exhibit a very promising combination between mechanical strength and ductility [2]. However, for some very demanding applications, their yield strength remains too low and needs further improvement. Thus HEA would benefit from a supplementary strengthening mechanism. Strengthening HEA by decreasing grain size appears as a promising strategy. Indeed, ultra-fine grain HEA were processed and they exhibit a higher yield strength than their coarse grain counterparts [3]. Moreover, the loss of ductility is limited. So grain boundary strengthening in HEA seems to overcome the usual compromise between mechanical strength and ductility.

The aim of this study is to assess the strengthening effect of nanograins in HEA. To do so, the first objective is to determine the relevant processing conditions. The second objective is to measure the hardness of an HEA with nanograins and to compare it to the hardness of an HEA with coarse grains. The $Co_{20}Cr_{20}Fe_{20}Mn_{20}Ni_{20}$ HEA was selected.

2. Methods

$Co_{20}Cr_{20}Fe_{20}Mn_{20}Ni_{20}$ HEA are produced using induction furnace, then melt-spinning to get thin ribbon. These metallic ribbon are then cut and ball-milled before being sintered using Spark Plasma Sintering, as described in the following picture. At each step of processing, samples were characterized by X-ray diffraction, scanning electron microscopy coupled with Energy Dispersive Spectroscopy. The density was also measured. Finally, the hardness was determined by nanoindentation.

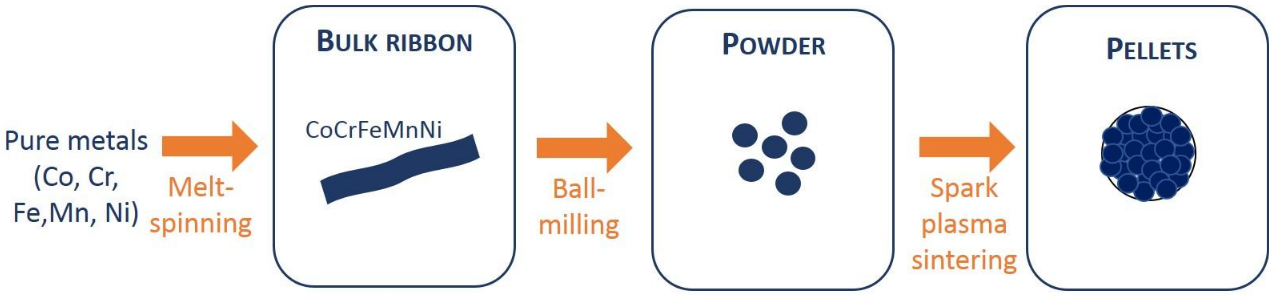

Figure 1. Elaboration strategy to obtain high entropy alloys by powder metallurgy.

3. Results and discussion

In this talk, the ball-milling conditions will be discussed regarding the mechanical properties of HEA alloys. Contamination problems and their consequences will also be described. Concerning the sintering, experimental parameters of SPS will be compared to natural sintering, from the microstructure point of view, the phases present and the mechanical properties. The talk will focus on the densification, the crystallites size and the possible formation of secondary phases. Finally, nanoindentation tests will be presented to locally study the mechanical behavior.

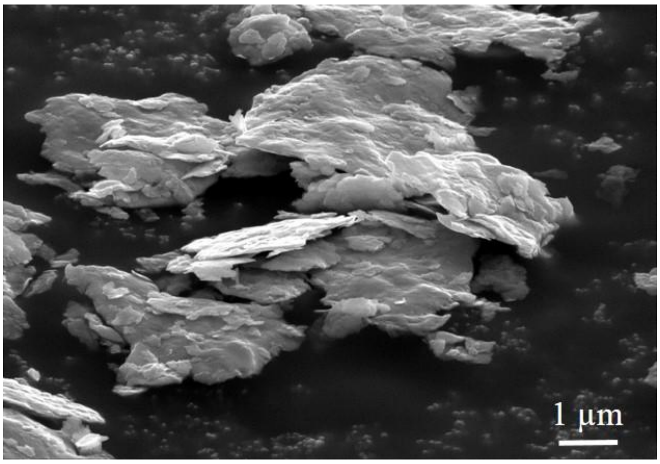

Figure 2. HEA powder after a cryogenic ball-milling

References

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Keywords
High entropy alloys, powder metallurgy, multi-scale architecturation, mechanical strengthening