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Influence of Sintering Temperature on AlCoCrFeNiMo(Ti_x, x=0,1) High Entropy Alloys

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In several reported investigations related to powder metallurgy, the manufacture of consolidated specimens by advanced sintering techniques such as hot pressing and spark plasma sintering is preferred, since denser products with better mechanical properties can be obtained. However, the use of these techniques is limited due to the process difficulty and high costs. Hence, most industrial powder metallurgy processes involve conventional sintering.

In the metallurgy field, the proposed alloy design of high entropy alloys (HEA), which involve multiple elements in equimolar or near-equimolar compositions [1], has directed the scientist's attention to processing techniques. For high melting points alloying metals like Mo, the mechanical alloying process can be an alternative route in solid state for the synthesis of these advanced materials with promising properties. Several investigations have reported the use of spark plasma sintering for the fabrication of high entropy alloys [2, 3]. In the other hand, the conventional sintering has been poor explored for the HEA processing. In previous investigations 1200°C has used as the sintering temperature for the consolidation of mechanically alloyed HEA under vacuum [4]. Therefore, the aim of this work is to study the effect of sintering temperature and sintering time on the densification and hardness of AlCoCrFeNiMo(Ti_x, x=0,1) high entropy alloys.

Pure elemental powders were used as starting materials for the synthesis of two equiatomic high entropy alloys, AlCoCrFeNiMo and AlCoCrFeNiMoTi, by mechanical alloying. The powders were pressed into cylindrical pellets (diameter of 5 mm and thickness ~3 mm) using a uniaxial steel die under a constant load of ~3 tones. Green samples were sintered at 1200 and 1300 °C with a step of 10 °C/min, under argon atmosphere. A constant dwell time of 1, 2 and 3 h was maintained for each sintering temperature in a controlled programmable furnace in Ar atmosphere.

The X-ray diffraction (XRD) patterns and microhardness values of sintered alloys are shown in Fig. 1. Densification by sintering at 1200 °C was more difficult for the AlCoCrFeNiMoTi alloy. For both alloys, an increase of hardness and densification as a function of sintering time was observed when the sintering temperature was 1200 °C. After 3 h of sintering at 1200°C, characteristics peaks corresponding to the Al_2O_3 formation were observed in the AlCoCrFeNiMo alloy.

At 1300 °C, the greatest hardness value for both alloys was achieved after 2 h of sintering. In Fig. 2 are presented SEM micrographs showing the microstructure evolution of AlCoCrFeNiMoTi alloy as a function of sintering time. The increase of time reduces the grain boundary and increases the

densification. EDS analysis revealed that grain boundaries act as nucleation sites for aluminum oxide. It can be suggested that the decrease of grain boundaries decreases the amount of alumina, and therefore also affects the material hardness. For the studied HEA systems, the increase of hardness at higher temperature may be closely related to a combination of greater densification and the formation of aluminum oxide, while the addition of Ti has not a significant effect on sintered alloys hardness.

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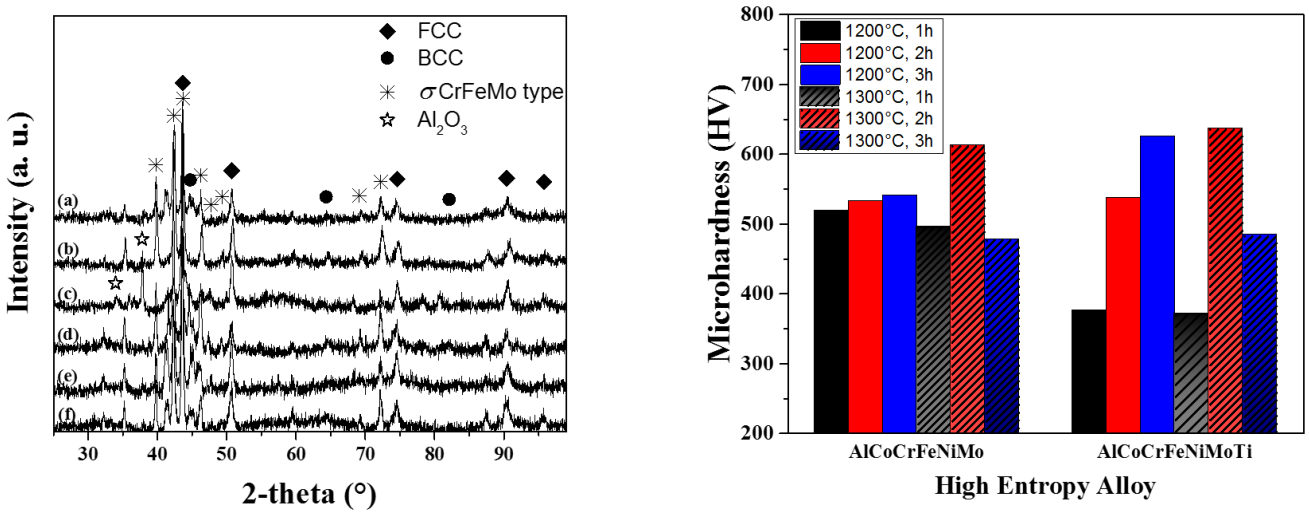

Figure 1. XRD patterns (left) of sintered alloys: (a) AlCoCrFeNiMo-1200°C-1h, (b) AlCoCrFeNiMo-1200°C-2h, (c) AlCoCrFeNiMo-1200°C-3h, (d) AlCoCrFeNiMoTi-1300°C-1h, (e) AlCoCrFeNiMoTi-1300°C-2h and (f) AlCoCrFeNiMoTi-1300°C-3h. Microhardness values (right) of sintered alloys.

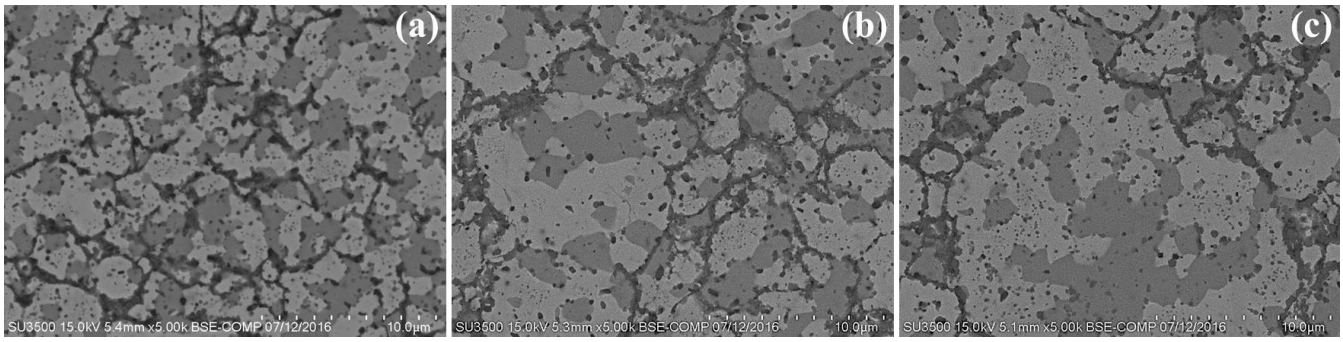

Figure 2. SEM-SE micrographs of sintered AlCoCrFeNiMoTi alloy at 1300 °C during: a) 1, b) 2 and c) 3 hours under Ar atmosphere. For these alloy, the increase in sintering time reduces the grain boundaries, improving densification effect.

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