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High Entropy Alloy AlCoFeNiMoTi Particles as Reinforcement in an Al 2024 Matrix Synthesized by Powder Metallurgy

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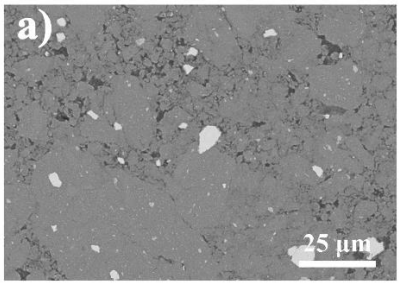
Aluminium is one of the most lightweight structural metals. Its alloys offer the greatest potential for energy efficiency improvements in a variety of industrial sectors. This is because of its attractive qualities such as low density and high strength-weight ratio. It is also the most abundant metallic element of the Earth's crust, which makes it one of the most precious and useful materials. However, aluminium is far from being an ideal material, since, under special working conditions, its disadvantages stand out, such as moderate mechanical strength, limited wear resistance and low hardness. The manufacture of aluminium matrix composites (AMC) is an increasingly popular alternative to improve the properties of aluminium and its alloys. In this way, the benefits of aluminium as a matrix are taken advantage of and improved with the incorporation of reinforcements, which add specific strength and hardness. A novel reinforcement option in aluminium matrices, which has gained greater interest in recent years, is high entropy alloys (HEA). Due to the physical and chemical nature of the matrix and reinforcement, they will not have the disadvantages of low wettability and weak adhesion that are present when using conventional ceramic reinforcements such as oxides, nitrides, or carbides. There are different methods, processes, and modifications with which it is possible to synthesize AMC, where it is sought to take advantage of the benefits of the constituents that make it up and, as far as possible, to optimise manufacturing time and costs. Therefore, the present work studies the microstructure and microhardness of aluminium 2024 composite materials reinforced with high entropy AlCoFeNiMoTi alloy particles, using a powder metallurgy synthesis method that includes hot pressing by electromagnetic induction to help reduce sintering times and temperatures.

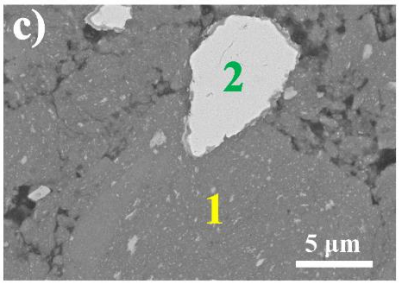
Elemental powders of Al, Co, Fe, Ni, Mo, and Ti with a purity greater than 99.5% and a size of less than 75 μm, were used for the synthesis by mechanical alloying of the AlCoFeNiMoTi equiatomic HEA. The time of alloy was 15 hours in a SPEX 8000M mill, using a vial and hardened steel balls as the grinding medium, a ratio weight 10:1, argon atmosphere used to prevent oxidation, and methanol as a process control agent. AlCoFeNiMoTi alloy particles were dispersed in an aluminium 2024 matrix in amounts of 1, 3, and 5% by weight by mechanical milling for 2 hours in an inert argon atmosphere. The powders obtained from this combination were hot-formed by uniaxial load and electromagnetic induction sintering at 300 MPa and 280 °C for 5 min. A2024/AlCoFeNiMoTi composites were characterised by scanning electron microscopy, energy dispersive spectroscopy, and microhardness testing.

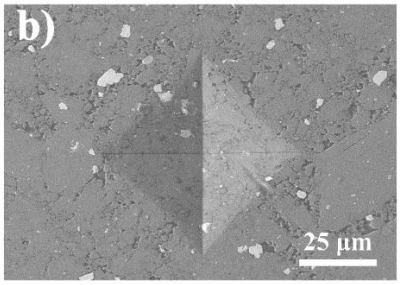
Two regions are distinguishable in the composites, continuous phase A2024 and dispersed phase AlCoFeNiMoTi, moreover defects and pores characteristic of materials obtained by powder metallurgy. It was observed that mechanical milling generated a homogeneous dispersion of HEA particles in the A2024 matrix, which remained even after the hot forming process (Figure 1a). With the detailed image

of matrix/reinforcement interaction shown in Figure 1c and by EDS, Figure 1d, it is confirmed that there was no material transfer between constituents. It is evidenced that no new phase was generated, the solute being stable and immiscible with the matrix, preserving the heterogeneity between the parts that integrate the composite. The results of the microhardness test indicate an increase as a direct function of the reinforcement content, Figure 2, going from 139 HV in the A2024 without reinforcement to 257 HV for the A2024/AlCoFeNiMoTi with 5% reinforcement. An example of a footprint left on the material during the test is shown in Figure 1b.

In this research, HEA AlCoFeNiMoTi particles were incorporated into alloy A2024 by powder metallurgy, which included hot pressing by electromagnetic induction. Obtaining composite materials at a low temperature, with good particles dispersion and a considerable increase in microhardness.







d)

	A2024/AlCoFeNiMoTi	
	1	2
	%at	%at
Aluminum	95.9	18.1
Copper	2.2	0.6
Magnesium	1.5	
Iron		17.4
Manganese	0.4	
Cobalt		16.5
Nickel		15.9
Molybdenum		16.7
Titanium		14.5

Figure. 1. a) SEM micrography A2024/AlCoFeNiMoTi
b) Amplificación SEM micrography A2024/AlCoFeNiMoTi
c) Indentation mark during microhardness testing
d) Elemental composition of composite constituents obtained by EDS.

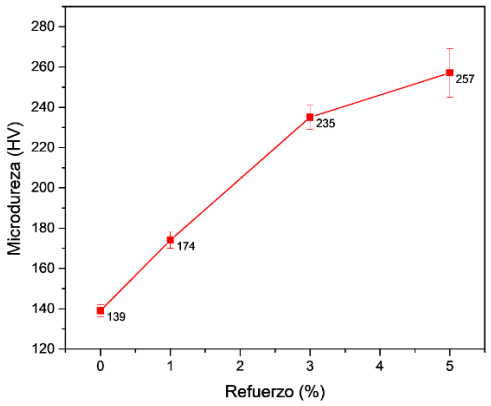


Figure 2. Microhardness testing A2024/AlCoFeNiMoTi.

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