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Microstructural Characterization of a Metal Matrix Composite CoCrFeMnMoNi-ZnO Nanoparticles.

C.D. Gómez-Esparza[1], F.J. Baldenebro-López[1,2], R. Martínez-Sánchez[3], I. Estrada-Guel[3], H. Camacho-Montes[1], C. López-Díaz de León[1], C.A. Rodríguez-González[1]

[1.] Instituto de Ingeniería y Tecnología, Universidad Autónoma de Ciudad Juárez (UACJ), Av. Del Charro 450 norte, 32310, Cd. Juárez, Chihuahua, México.
[2.] Facultad de Ingeniería Mochis, Universidad Autónoma de Sinaloa. Prol. Ángel Flores y Fuente de Poseidón S/N, 81223 Los Mochis, Sinaloa, México.
[3.] Centro de Investigación en Materiales Avanzados (CIMAV), Laboratorio Nacional de Nanotecnología, Miguel de Cervantes No. 120, 31136 Chihuahua, Chihuahua, México.

High-entropy alloys (HEA) developed by Yeh *et al.* are multicomponent solid solutions consisting of at least five principal elements in equimolar or near equimolar ratios. Due to their superior mechanical properties, singular microstructure and a wide variety of applications as advanced metallic materials, different chemical compositions of high-entropy alloys have been investigated since 2004. The CoCrFeMnNi was one of the earliest reported HEA and is considered to be a single solid-solution phase alloy [1]. Previous researches discovered that Mo possesses the dual characteristics of being a strong BCC stabilizer and a high solid solution strengthener in HEA [2]. On the other hand, the exploration of microstructural behavior through chemical variations has conducted to the formation of ordered/disordered nanoparticles in HEA; however, the reinforcement of high-entropy alloys by the addition of oxide nanoparticles has not been reported yet. Metal matrix composites reinforced with nanoparticles are being investigated in recent years, due to their promising properties for structural applications. The purpose of this investigation is the synthesis of a high-entropy CoCrFeMnMoNi-based composite reinforced with ZnO nanoparticles (ZnO-*np*) by mechanical alloying and the study of their microstructural and hardness behavior as a function of the nanoparticles concentration.

Equiatomic CoCrFeMnMoNi alloy was synthesized by mechanical alloying from elemental powders for a 10 h period in a SPEX 8000M mill using hardened steel vial and balls. The ball-to-powder weight ratio was kept to 5:1, methanol was used a process control agent and the milling was performed under an Ar atmosphere. ZnO nanoparticles (Fig. 1) were synthesized by sol-gel process and recycling waste Zn-batteries as raw material. The dispersion of nanoparticles was carried out by milling for 2 h under the same conditions. 0.5, 1 and 2 wt. % of ZnO-*np* concentrations were used as reiforcements.

SEM micrographs of the powders composites presented in Fig. 2 show a slightly decrease in particle size with the addition of ZnO-*np*. The results of microhardness test of powder composites (Fig. 3) show that a higher reinforcement of the equiatomic CoCrFeMnMoNi alloy was reached with the 0.5 wt% of ZnO-*np* (27% of increment of hardness). There is necessary deeper microstructural characterization to understand the interaction of ZnO-*np* with metallic matrix and which are the strengthening mechanisms working in these materials.

References:

[1] F. Otto, N.L. Hanold and E.P. George, Intermetallics **54** (2014), p. 39-48.

[2] B.S. Murty, Jien-Wei Yeh and S. Ranganathan in "High-entropy alloys" (Butterworth-Heinemann) p. 107. The authors are grateful to the Laboratorio Nacional de Nanotecnología of the Centro de Investigación en Materiales Avanzados (CIMAV) for the technical assistance.

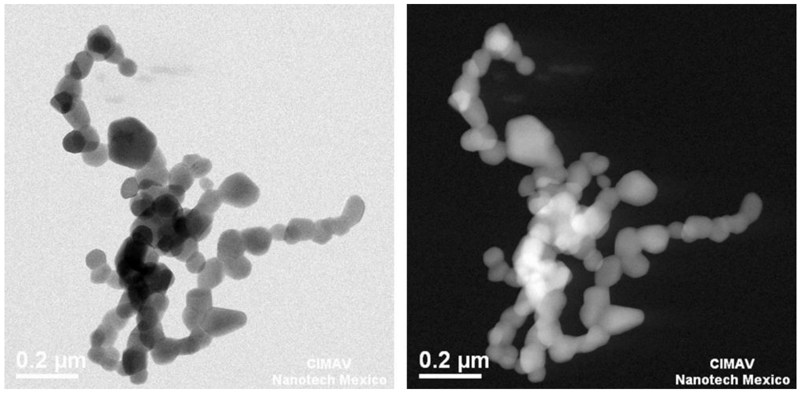

Figure 1. TEM images of ZnO nanoparticles in Brigh Field (left) and Z-contrast (right) modes.

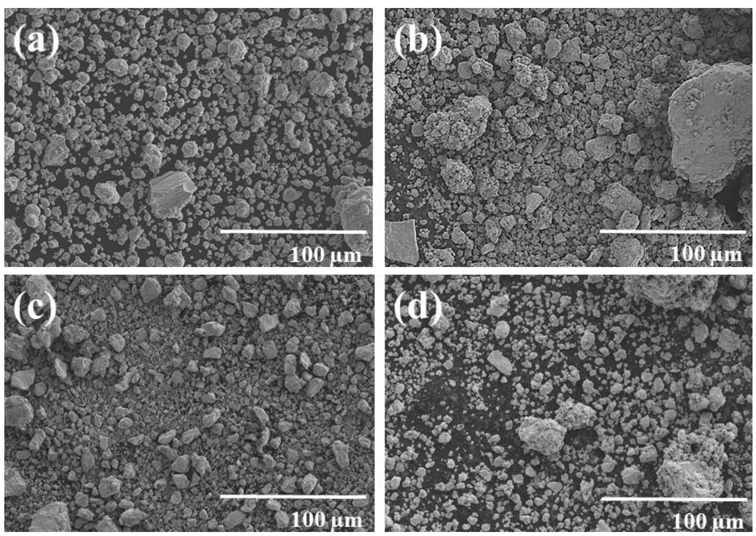

Figure 2. SEM images of the morphological evolution of the CoCrFeMnMoNi-based composite as a function of the ZnO-*np* content: (a) 0%, (b) 0.5%, (c) 1% and (d) 2%.

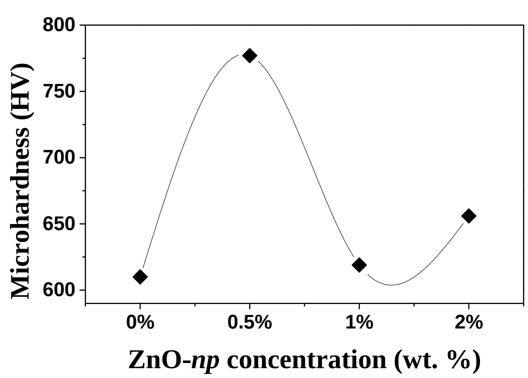

Figure 3. Microhardness Vickers results of the CoCrFeMnMoNi—ZnO-*np* composites as a function of the nanoparticles content.