STRUCTURE AND MICROHARDNESS OF AlCuNiFeCr HIGH ENTROPY ALLOY REZULTED FROM MECHANICAL ALOYING AND ANNEALING

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Alloys traditionally have been based on a solvent element to which various solute atoms are added for improving specific properties. As a new focus on materials research and a novel alloy design concept, high entropy alloys (HEAs) have been achieved successfully and have attracted great attentions of material researchers since it was proposed in 2004 [1,2]. HEAs exhibit promising future for engineering applications due to their good thermal stability, high hardness and high strength, excellent wear resistance, as well as many other outstanding properties [1-3]. Most of multi-component HEAs were designed as equi-atomic or near equi-atomic and were mainly prepared by vacuum arc melting.

This study reports the structural evolution of equiatomic high-entropy AlNiCoFeCrTi alloy from elemental materials to metastable solid solution during mechanical alloying (MA), and further, to equilibrium phases during subsequent thermal annealing. Hardened steel vial and balls were used as a grinding media and gasoline was used as a process controlling agent. The effects of milling duration and subsequent annealing at temperature 1200 °C on the structure and phase transformation were investigated by means of Rigaku Ultima IV X-ray diffractometer (XRD) with Cu Kα radiation. A scanning electron microscope with an energy dispersive spectrometer (EDS) was used to observe microstructures and measure the elemental composition of powder alloy. Microhardness measurements were performed using a conventional microhardness machine equipped by standard Vickers' pyramid. Microhardness numbers were determined under indentation loads not higher than 1.0 N.

It was justified experimentally that MA of Al-Ni-Co-Fe-Cr-Ti powder mixture during 3 hours resulted in a single-phase nanocrystalline HEA with a structure of BCC-solid solution (Fig. 1). BCC solid solutions appear when the blended powder is ball milled for 1h. The 3h ball milled alloy powder shows excellent chemical homogeneity and refined morphology with mean particle size of less than 50 μm. The 3h ball milled microscaled particles are actually hard agglomerations of nanoscaled crystallites with crystal size of about 35 nm. The phase composition transforms to BCC and FCC solid solutions when the mechanically alloyed powder was annealed at 1200 °C for 1h, as can be seen in Fig. 2. The results of XRD analysis identify that during thermal annealing precipitation of TiC and grain growth of equilibrium phases occur. The formation of TiC is associated with the high activity of Ti, which is not completely dissolved in BCC solid solution during MA, and as a result, during annealing, Ti also reacts with carbon, which is a component of petrol, used as a process controlling agent. Simple equilibrium phases obtained in the annealed state of MA powders confirm that the high-entropy effect enhances the formation of simple solid solution phases instead of complex compound phases.

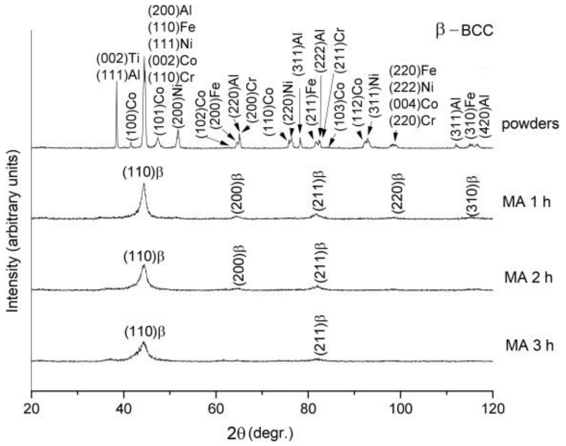

Fig. 1. XRD patterns of MA AlNiCoFeCrTi powders with different milling times

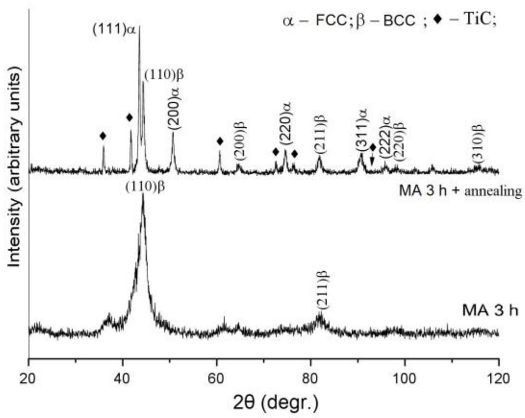

Fig. 2. XRD patterns of MA AlNiCoFeCrTi HEA powders after thermal annealing at temperatures 1200°C during 1 h

The Vickers microhardness of powder AlNiCoFeCrTi alloy after 3h of MA is 7.1±0.25 GPa.. The microhardness, HV, of 3h milled alloy powder after annealing in vacuum at 1200 °C for 1h increases and is 10.4±0.29 GPa. The high hardness could be attributed to the nanocrystalline nature of the alloy, the solid solution strengthening equiatomic nature of the phases and the presence of hard particles of carbides TiC. The very high hardness of 10 GPa prove the promising future of the alloy.

[1] High-Entropy Alloys. Fundamentals and Applications. Editors M. C. Gao , J.-W. Yeh, P. K. Liaw, Y. Zhang. Elsevier, 2015, 516 p.
[2] B.S. Murty, J.W. Yeh and S. Ranganathan. High-Entropy Alloys. Elsevier, 2014, 218 p.
[3] D.B. Miracle, O.N. Senkov. A critical review of high entropy alloys and related concepts // Acta Materialia. 122 (2017) 448-511.