NANOSTRUCTURING OF AN ADDITIVELY MANUFACTURED CoCrFeNi MULTI-PRINCIPAL ELEMENT ALLOY USING SEVERE PLASTIC DEFORMATION

Kamilla Mukhtarova, Eötvös Loránd University, Budapest, Hungary
kamillamsh@student.elte.hu
Megumi Kawasaki, Oregon State University, Corvallis, USA
Zoltán Dankházi, Eötvös Loránd University, Budapest, Hungary
Márk Windisch, Eötvös Loránd University, Budapest, Hungary
György Zoltán Radnóczi, Centre for Energy Research, Budapest, Hungary
Károly Havancsák, Technoorg Linda Co. Ltd, Hungary
Jenő Gubicza, Eötvös Loránd University, Budapest, Hungary

Key Words: laser powder bed fusion, multi-principal element alloy, high pressure torsion, nanostructure, dislocation density

Multi-principal element alloys (MPEAs) contain several main elements in equal or near-equal atomic proportions [1]. These materials exhibit high hardness, good wear resistance, excellent strength at both high and low temperatures [2]. MPEAs are generally produced by conventional casting methods, however, coarse columnar dendrites and dendritic segregation of alloying elements are formed that can deteriorate the mechanical properties. Additive manufacturing (AM) can overcome several limitations of conventional processing. AM provides high cooling rates leading to finer cellular dendrite structure which improves mechanical strength. Mechanical properties also can be improved by tailoring the microstructure, for instance, by using severe plastic deformation (SPD) which is a powerful approach to achieve nanostructure. Among the SPD methods, high pressure torsion (HPT) yields the highest grain refinement and strength improvement. In this study, the evolution of microstructure and hardness of CoCrFeNi MPEA produced by an AM technique and subsequently processed by HPT was investigated. The microstructure was studied by X-ray diffraction (XRD), transmission electron microscopy (TEM) and scanning electron microscopy (SEM) techniques. The CoCrFeNi alloy was manufactured by laser powder bed fusion with two different laser scan speeds. The microstructure of the as-built alloy consisted of columnar and equixed dendrites with the size of range of 5-100 microns. The sample processed with the higher laser scan speed had dendrites with a smaller size. HPT was carried out at 1 rpm under 6 GPa and for ½, 1, 5 and 10 turns at room temperature. The resulted X-ray diffractograms showed that all samples have a single-phase face-centered cubic (FCC) structure for all conditions. X-ray line profile analysis (XLPA) was used to determine the crystallites size, dislocation density and probability of twin faults. The crystallite size of the as-built samples was higher than the detection limit (about 800 nm), the dislocation density was about $3 \cdot 10^{14}$ m^{-2} for both laser scans. The HPT for ½ turn led to significant decrease of crystallite size to about 65 nm, while the dislocation density increased to about $130 \cdot 10^{14}$ m^{-2}. Further increase of HPT turns led to crystallite size decrease, dislocation density and twin faults probability increase. The XRD texture analysis revealed the presence of fiber texture in the as-built samples as well as in HPT processed samples for 10 turns. TEM study on the samples processed for 10 turns revealed elongated columnar grains with the size of 50-300 nm for both laser scan speeds. Additionally, twins and stacking faults were also observed. The initial hardness of the AM-processed MPEA samples (for both laser scan speeds) was 2800 ±100 MPa. The formation of nanostructure with high lattice defect density during HPT resulted in a very high hardness value of about 5500 MPa in AM-processed CoCrFeNi MPEA samples for both laser scan speeds.

References:

[1] Cantor, B., Chang, I. T. H., Knight, P. & Vincent, A. J. B: Microstructural development in equiatomic multicomponent alloys. In: Materials Science and Engineering: A 375–377, 2004, P.213–218.
[2] Campari, E.G.; Casagrande, A.: Microstructural Study of CrNiCoFeMn High Entropy Alloy Obtained by Selective Laser Melting. In: Materials, 15, 2022, 5544.