Investigation of FeNiCrWMn – a new high entropy alloy

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Abstract. The term of high entropy alloys started from the analysis of multicomponent alloys, which were produced at an experimental level since 1995 by developing a new concept related to the development of metallic materials. Recent developments in the field of high-entropy alloys have revealed that they have versatile properties like: ductility, toughness, hardness and corrosion resistance [1]. Up until now, it has been demonstrated that the explored this alloys are feasible to be synthesized, processed and analyzed contrary to the misunderstanding based on traditional experiences. Moreover, there are many opportunities in this field for academic studies and industrial applications [1, 2]. As the combinations of composition and process for producing high entropy alloys are numerous and each high entropy alloy has its own microstructure and properties to be identified and understood, the research work is truly limitless. The novelty of these alloys consists of chemical composition. These alloys have been named high entropy alloys due to the atomic scale mixing entropies higher than traditional alloys. In this paper, I will present the microscopy and the mechanical properties of high entropy alloy FeNiCrWMn.

1. Introduction

High entropy alloys are alloys that have in their composition 5 to 11 metallic elements. The percentage of each element in a composition of a high entropy alloys is between 5% and 35%. Mainly in the composition of a high entropy alloys it is found some principal and some secondary metallic elements [2]. They are called principal elements because their molar fraction is higher than 5 % and the secondary their molar fraction below 5%. In this work, we selected Fe, Ni, Cr, W, Mn, to prepare the high entropy alloy FeNiCrWMn and we investigated the mechanical properties of these high entropy alloy.

2. Materials and method

To obtain this alloy we used in chemical composition metallic elements as: Fe, Ni, Cr, W and Mn. As a method of prepare this high entropy alloys we used a medium frequency induction furnace for 8000 Hz which is in the inside of Faculty of Science and Engineering Materials from Iasi.

The alloy obtained was poured into molds made of furan resin-shaped specimens with a diameter of 10 mm.

Figure 1. Induction heating furnace of medium frequency 8000 Hz.

Figure 2. Example of specimen for characterization properties of high entropy alloy FeNiCrWMn.

3. Microstructural analysis

For microstructural characterization, the samples were mechanically processed by grinding and chemical attack with NITAL. For the microstructural characterization, we used an electron microscope on LMHII VegaTescan equipment using a secondary electron detector (SE) at a voltage of 30 kV electron gun.

In image 3 we can see the chemical composition for high entropy alloy FeNiCrWMn in 3 points.

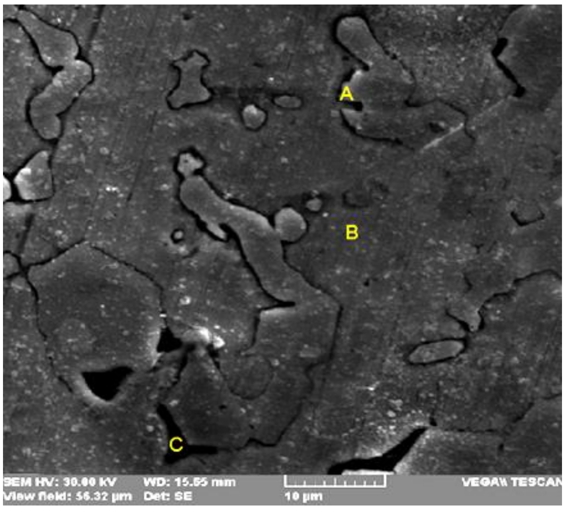

Figure 3. SEM image of a high entropy alloys FeNiCrWMn.

Table 1. Chemical composition (wt.%) and (at%) of the high entropy alloy FeNiCrWMn in point A.

Element	(wt.%)	(at.%)
Chromium	70.40	76.19
Manganese	9.97	10.22
Tungsten	8.44	2.58
Iron	6.07	6.11
Nickel	5.09	4.88
Total	99,94	99,98

Table 2. Chemical composition (wt.%) and (at%) of the high entropy alloy FeNiCrWMn for B point.

Element	(wt.%)	(at.%)
Chromium	13.98	15.56
Manganese	21.97	23.15
Tungsten	4.21	1.32
Iron	18.82	19.51
Nickel	41.00	40.44
Total	99,98	99,98

Table 3. Chemical composition (wt.%) and (at%) of the high entropy alloy FeNiCrWMn for C point.

Element	(wt.%)	(at.%)
Chromium	8.67	9.61
Manganese	32.07	33.63
Tungsten	2.91	0.91
Iron	10.79	11.13
Nickel	45.54	44.70
Total	99,98	99,98

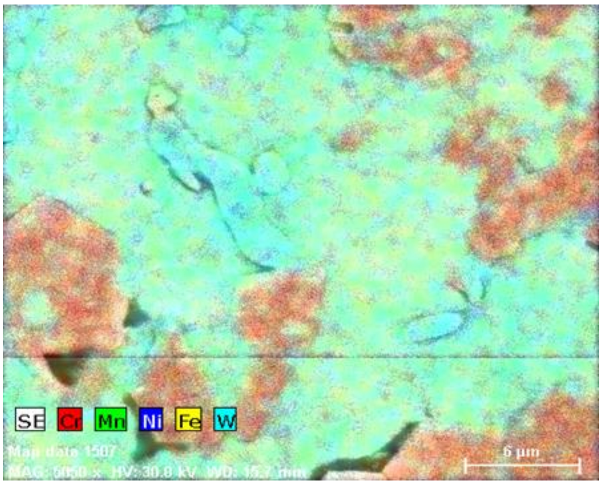

Figure 4. Distribution of chemical elements in high entropy alloy FeNiCrWMn.

We chose to do the chemical composition at various points to observe the degree of mixing of the chemical elements after casting the high entropy alloy FeNiCrWMn.

So, in point 1 we have predominant chemical elements as chromium and manganese, in point 2, manganese and nickel and in point 3 we have manganese and nickel.

In figure 4 we can see the distribution of elements in the high entropy alloy FeNiCrWMn and rich areas in chromium and manganese. Also, from figure 4 it can be seen that tungsten is distributed uniform throughout area the high entropy alloy FeNiCrWMn.

4. Analysis by optical microscopy

The optical analysis of FeNiCrWMn was performed using a X7P- 6A metallographic microscope and Materials Plus Software was used for the metallographic analysis. The following figures reveal non uniform grain sizes of the FeNiCrWMn alloy. The samples analyzed with Materials Plus Software had a grain size of 300 μm.

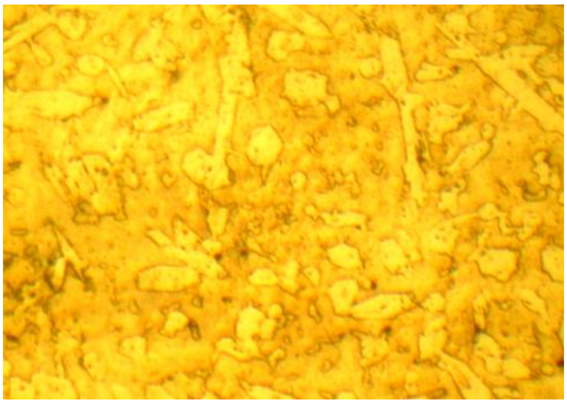

Figure 5. Optical microscopy of high entropy alloy FeNiCrWMn, 150X.

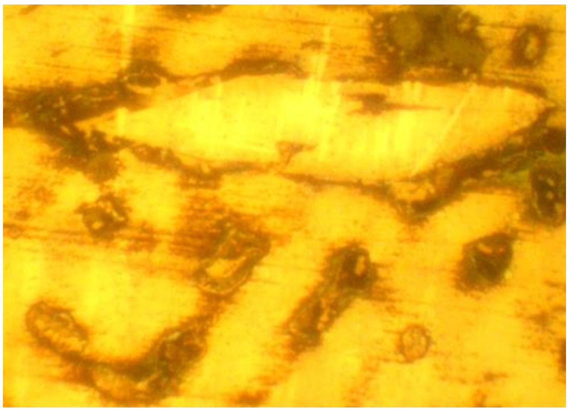

Figure 6. Optical microscopy of high entropy alloy FeNiCrWMn, 500X.

Figure 5 and 6 display micrographs of the surface microstructure of the FeNiCrWMn obtained by optical microscopy. In these pictures it can be observed dendrites with various dimensions and columnar grains.

5. Analysis by optical microscopy

To determinate the results for tensile test high entropy alloys FeNiCrWMn we used the machine Instron 3382.

In figure 7 is presented the characteristic curve of the tensile test. For this analysis we made three samples with the dimension d0 = 4 mm, D = 6 mm, h = 20 mm, L0 = 20 mm. Table 4 presented the results of the tensile test for the high entropy alloy FeNiCrWMn, here we can see that our samples suffered a break at 1,87% for sample 1, for sample 2 the break occurred at 2.03 %, in the case 3 the break occurred exactly like for sample 1.

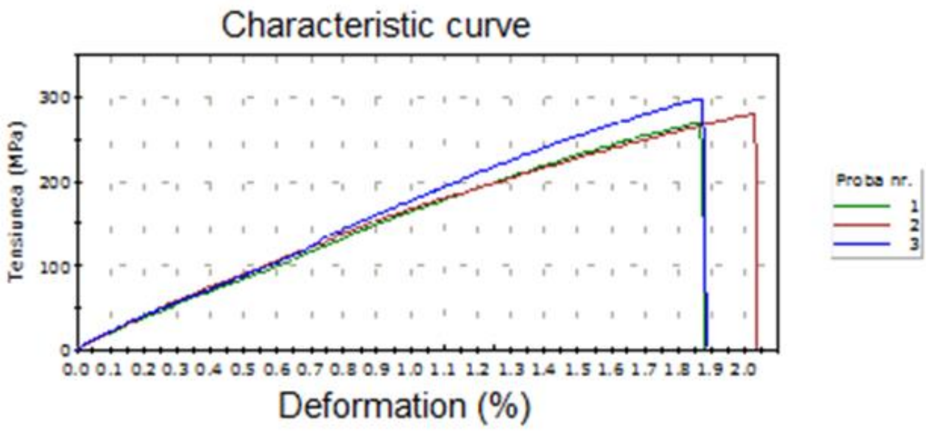

Figure 7. Tensile test of high entropy alloy FeNiCrWMn.

Table 4. Tensile test results for high entropy alloy FeNiCrWMn.

Sample	Maximum Load (N)	Modulus (E modulus)(MPa)	Tensile strain at Break (Standard)(%)	Tensile stress Yield (offset 0,2% MPa)
Sample 1	3,38	15,65	1.87	267.55
Sample 2	3,52	14,69	2.03	274.40
Sample 3	3,75	17,37	1.87	293.35

6. Hardness tests
Hardness is a characteristic of a material who is defined as the resistance to indentation and it is determined by measuring the permanent depth of the indentation. The Rockwell hardness test method as defined in ASTM E-18, is the most commonly used hardness test method. The medium value for high entropy alloy FeNiCrWMn is 38.7 HRC.

7. Conclusions
The high entropy alloy FeNiCrWMn is a new alloy which was successfully obtained and characterized. Results for hardness test show that medium value for high entropy alloy FeNCrWMn is 38. 7 HRC and the tensile stress is 293.359 MPa. Analyzing alloy FeNiCrWMn with the scanning electron microscope and optical microscopy we observed that alloy forms a dentritic structure.

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