RESEARCH ON HIGH ENTROPY ALLOYS

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Abstract: *In this paper we will present an overview of high entropy alloys and also will expose the research to date on these alloys.*

In 1995, Yeh suggested the formation of an alloy made up of at least five metallic elements which have large mixing entropy solutions with many elements forming solide alloys. This alloy appeared because traditional alloys are characterized by high fragility and are difficult to process. High entropy alloys are alloys which have approximately equal concentrations, formed by a group of 5 to 11 elements majority in composition, mole fraction of each major metallic element in the alloy is between 5% and 30%.

During the research it has been proved that this alloy has a high hardness and it is also corrosion proof and also resistance and good thermal stability.

High entropy alloys shows properties superior to conventional alloys. These high entropy alloys allows us to be used in as many applications such as tools, forms, dies, machine parts and oven parts that require resistance, thermal stability and resistance, wear and oxidation temperature application up to 800 ° C.

Keywords: *high entropy alloys,, Property of alloys, Application domains, Thermal stability*

1. Introduction

A new approach for alloy design, ,"high entropy alloys" was started in Tsing Hua University of Taiwan since 1995 by Yeh et al. We could define high entropy alloys as having approximately equal concentrations, made up of a group of 5 to 11 major elements in the composition, mole fraction of each major metallic element in the alloy is between 5% and 30%. As elements we can use the main metals: beryllium (Be), magnesium (Mg), aluminum (Al), scandium (Sc), titanium (Ti), vanadium (V), chromium (Cr), manganese (Mn), iron (Fe) , cobalt (Co), nickel (Ni), copper (Cu), zinc (Zn), yttrium (Y), zirconium (Zr), niobium (Nb), molybdenum (Mo), rutheniu (Ru), rhodium (Rh) , palladium (Pd), silver (Ag), hafnium (Hf), tantalum (Ta), tungsten (W), platinum (Pt), gold (Au), lanthanum (La), cerium (Ce) and so on. Of course in addition to these items we can add minor elements, named like this because their molar fraction in the alloy is lower than 3.5%. In a high entropy alloy, the elements can be metallic or nonmetallic and can be selected from the following elements: lithium, sodium, scandium, titanium, vanadium, chromium, manganese, iron, cobalt, nickel, copper, zinc, gallium, germanium, strontium, yttrium, zirconium, niobium, molybdenum, rutheniu, rhodium, palladium, silver, cadmium, indium, platinum, gold,bismuth, lanthanum metal . Non-metallic elements may be for insatnce, carbon, boron, silicon, phosphorus, sulfur, hydrogen, oxygen, nitrogen and so on.[1]

They have concluded that high entropy alloys could be made, processed and analyzed like conventional alloys.Moreover they exhibit several interesting features as previously reported:

- Tend to formed simple solution phases, such as FCC and BCC phases, with nanostructures or even amorphous structures;
- Range form 100 to 1100 in hardness;
- Have microstructures with good thermal stability;
- Can have high-temperature precipitation hardening between 500 and 1000°C;
- Can have a positive temperature coefficient of strength and hence maintain a high strength level at elevated temperatures.
- Can possess excellent corrosion resistance, wear resistance and oxidation resistance.[1]

In alloys with high entropy will be no element mole fraction greater than 30% so there will be no metal matrix in alloy composition. Studies of high entropy alloys have shown that they have a almost amorphous structure demonstrated by X-ray diffraction and differential scanning calorimetric analysis. HEA has a high atomic disorder with mechanical properties comparable to the glass therefore are brittle. [2]

The research performed showed that this alloy exhibits high hardness and corrosion resistance and good thermal stability as well. [3,4]

High entropy alloys could have many applications for example: tools, molds, dies, mechanical parts and furnace parts foundries and marine application for piping and pump components which requires an excellent corrosion resistance, hard and antisticking coating for molds and tools and so on.[1]

The principal factor which makes the constituent phases of most high-entropy alloys become simple is the entropy of mixing [9]. The explanation is based on the Second Law of Thermodynamics for a system in an isothermal and isobaric process: equilibrium is attained when the Gibbs free energy, G, reaches its minimum value.[1]

2. Progress in High-entropy Alloys

New ideas and new direction of alloy research can be continuously expanded by researching the organization, structure and properties of high-entropy alloys. Research results existing show that high entropy alloy is a synthesized, processed, analysised, and applicated alloy world. When the traditional alloy tends to be saturated, diversified property and applicating alloy are extremely developed by alloy design, unique high entropy, slow diffusion, heavy lattice distortion and cocktail effect. So, the value of academic research and industrial development potential is great higher[5]. S.Ranganathan[6] considered high-entropy alloys, bulk metallic glass and rubber metal as the three major breakthroughs alloying theory in recent decades. As more and more people joining in the research ranks, the research field will not be limited to the organizational structure and performance, and began to go deep into thepurpose composition design. The cocktail preparation situation of high-entropy alloys will be replaced by general laws.[7]

3. Experimental procedures

Our first attempt to get such a high entropy alloy was by alloying Al, Fe, Cr, Mn, Ni. For the elaboration of this alloy we used an medium frequency induction furnace of 8000Hz. Percentages were used to obtain AlFeCrMnNi alloys were: Fe 36%, Cr 22.19%, 23.67% Mn, 13.76% Ni, 3.52% Al.

Crucible induction furnaces are used to make high-quality steels, cast iron, non-ferrous metals and alloys such as aluminum, copper, nickel, etc.

In terms of supply voltage frequency, crucible furnaces include:

- industrial frequency (50 Hz)
- Medium frequency (100 ... 10,000 Hz)
- High frequency (50 ... 400 kHz

They can work in a vacuum - condition required recently metal and aerospace alloys necessary, nuclear centers. Into Figure 1 it is a schematic diagram indictor medium frequency furnace crucible.

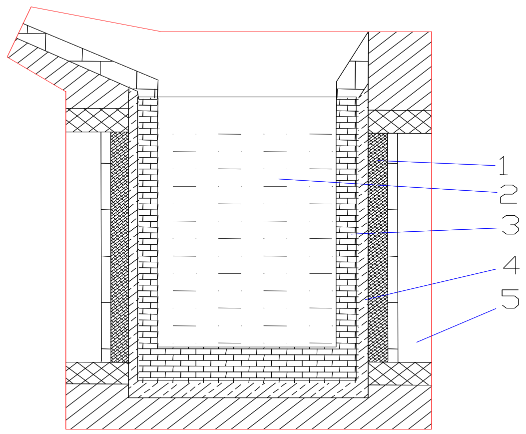

Figure 1 *Schematics induction heating furnace crucible: 1 – inducer, 2 - the molten metal, 3 - refractory crucible, 4 - cylinder asbestos, 5 - screens ferromagnetic [8]*

3.1 Analysis by scanning electron microscope

AlFeCrMnNi alloy was subject to a SEM analysis following this analysis we could notice that the AlFeCrMnNi alloy has an polygonal and non-uniform grain size. The following figures show the microstructure of the alloy at different magnification of the microscope SEM.In Figure 2 highlight non-uniform polygonal grains (fig. 2.1) and grain boundaries (fig.2.2).

The alloy has a structure dendritic and interdendritic. The region where there are dendritic structure has a higher content of Al and Cr than the region where is located interdendritic structure. Therefore we may say that in the area were is a dendritic structure we have a BCC structure and in the interdendritic area a FCC structure.

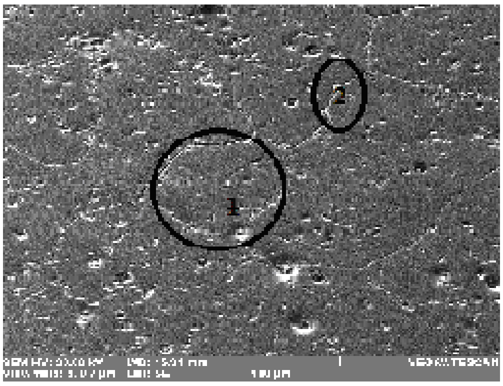

Figure 2. *Sem Analysis of alloy AlFeCrMnNi X500 power x500: 1) non-uniform polygonal grains, 2) limit grain.*

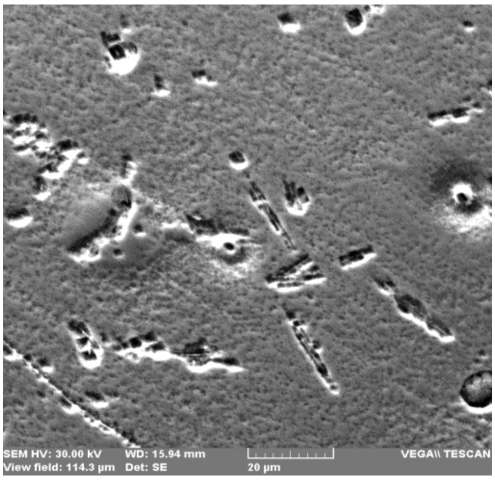

Figure 3 *Image SEM 2.5kx*

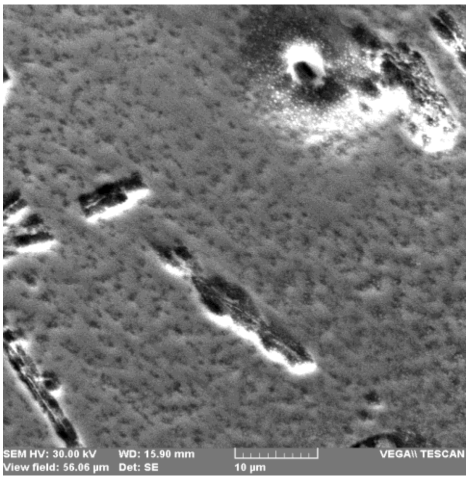

Figure.4 *Image SEM 5kx*

Figure 5 shows the selected area AlFeCrMnNi alloy, used for observing the distribution of alloying elements. Figure 6 shows the distribution of chemical elements on the selected area.

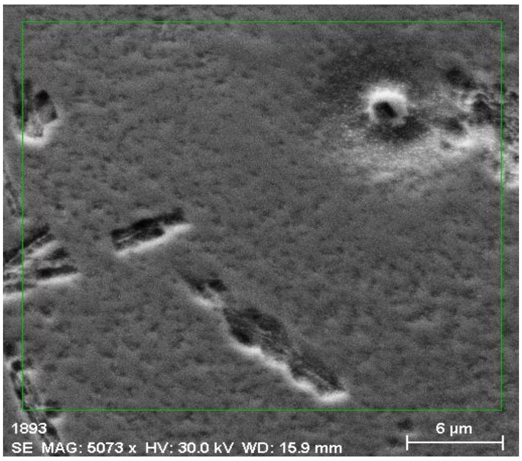

Figure 5. *Selected area of the alloy AlFeCrMnNi for observing the distribution of alloying elements.*

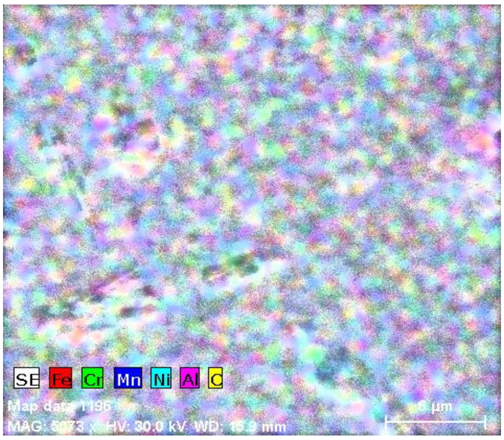

Figure 6. *Distribution of chemical elements on the surface of the alloy AlFeCrMnNi*

To highlight the distribution of each chemical element we have chosen different colors for highlighting, so following figure shows the structure of each chemical element AlFeCrMnNi alloy.

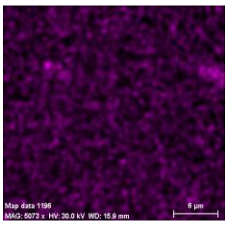

Figure 7. *Al alloy*

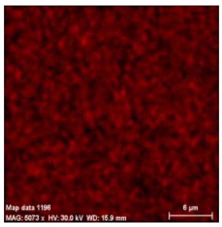

Figure 8. *Fe alloy*

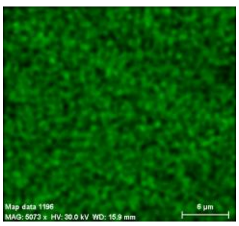

Figure 9. *Cr alloy*

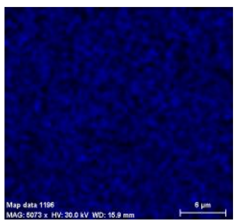

Figure 10. *Mn alloy*

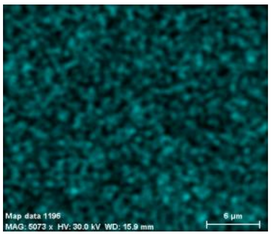

Figure 11. *Ni alloy*

4 Conclusions

High entropy alloys might be processed and analyzed like conventional metals. Because of their special microstructure and properties, many opportunities in creating novel alloys,better than traditional ones in a wide range of applications, are waiting for exploitation.[1]

Analyzing alloy AlFeCrMnNi whit the scanning electron microscope we observed that the alloy forms a cubic structure and solidifies dendritic .

5. References

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