Self-Passivation Tungsten Alloys for Plasma Facing Materials

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1. Introduction

In order to be realized nuclear fusion as a future energy, it is essential to develop plasma facing materials which can withstand harsh environment over the long term. Compared with other materials, tungsten has many advantageous properties in a plasma environments. For examples, tungsten has the merit of very low sputter erosion under bombardment by energetic particles like D, T, He ions from the plasma. And it also is high melting point and high thermal conductivity which is good properties for resisting to high thermal load [1].

A potential problem with using pure tungsten in a fusion reactor is the formation of WO3 which is radioactive and highly volatile compound and there is possibility that it may get released under accidental scenario.[2] A feasible way for avoiding this is developing a self-passivating oxide layer at the surface of tungsten.

Therefore, self-passivating W based alloys are developed. There are studies to create new composition of alloys for self-passivating and a variety of ternary system have been reported.[3] Among them we developed W-Cr-Ti system alloys with changing composition using powder metallurgy.

2. Methods and Results

2.1 Methods

The powders of W, Cr and Ti were mixed by 2 different ways with 4 different composition. In method, One is high-energy ball milling and another one is mixing to develop tungsten-based self-passivating alloys. And in composition, it is as follows: WCr14Ti2 (in wt.%), WCr18Ti2 (in wt.%), WCr10Ti2 (in wt.%) and WCr10.3Ti1.1 (in wt.%). Therefore the total samples which is studied are eight. The high-energy ball milling was carried out with in a TC jar at 300 rpm for 30 hours and ball to powder ratio is 1:1. The mixing was carried out with in a plastic bottle at 30 rpm for 4 hours. Sintering was done at 1400 ^{O}C and 50 MPa for 10 minutes. The compression test at room temperature was done and thermal properties of samples were measured.

2.2 Results

Fig. 2 is the compressive strength of various composition samples. In all composition, all samples made by mechanical alloying have higher compressive strength than mixing samples. Among mechanical alloying samples, PCr10 sample exhibits a significantly higher strength than other samples.

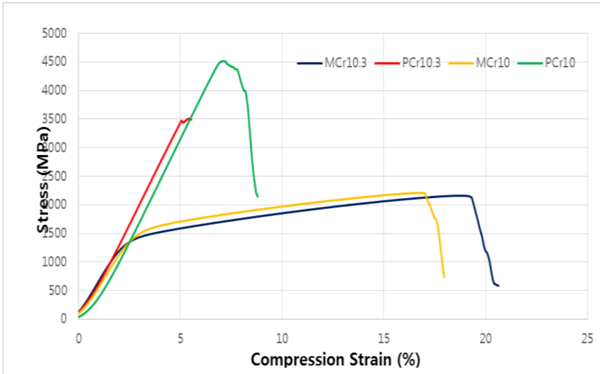

Fig. 1 Stress-strain curves from compression test on four samples.

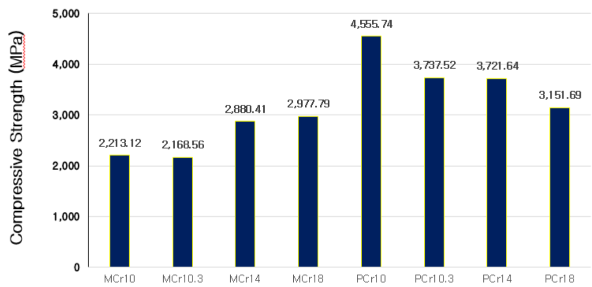

Fig. 2 The result of compressive strength of all samples.

In mechanical alloying samples, as expected, the less of chromium content shows the better mechanical performance.

Fig. 3 shows the TGA (Thermogravimetric analysis) results in three kinds of temperature, 873K, 1073K and 1273K. At 873K isothermal TGA, there were no significant weight gain in all samples. This indicate that in 873K all samples have enough oxidation resistance. And at 1073K, the result starts to show the difference of oxidation behavior between samples. MCr10, MCr10.3 and PCr10.3 samples have more oxide gain weight than others. At 1273K TGA result, it shows the clear difference of weight gain between the samples. Based on the result of 1073K and 1273K, it can be said as follows: PCr18 and MCr18 show good performance in terms of oxidation resistance. On the other hand, PCr14, MCr10 and MCr10.3 have bad oxidation resistance.

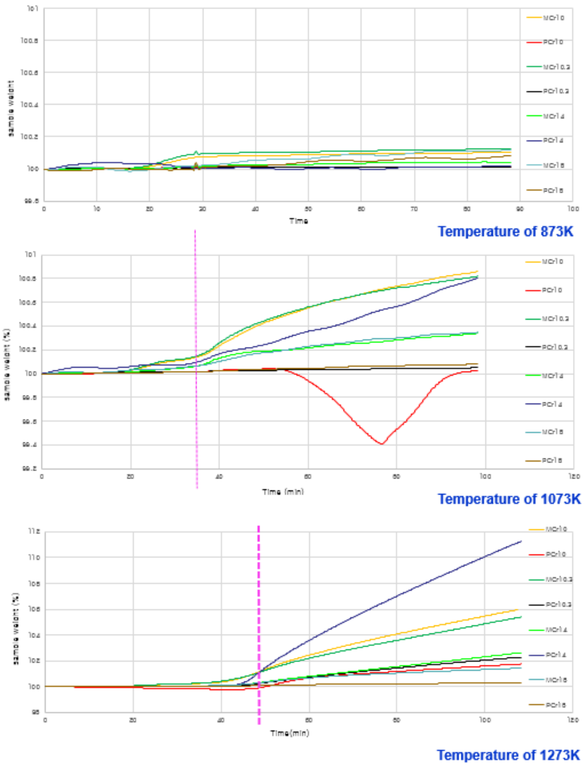

Fig. 3 TGA was done with different three temperature (873K, 1073K, 1273K). Test was conducted in 80% of N_2 + 20% of O_2 gas flow atmosphere. Flow rate is 30ml / min and heating rate is 20℃/min. All test had 1 hour holding time at peak temperature namely, isothermal at peak temperature.

3. Conclusions

W-based self-passivation bulk alloys were successfully fabricated by the high energy planetary ball milling and simple mixing. And also spark plasma sintering is good for fabricating them. As compared to simple mixing samples, mechanical alloying samples have better mechanical properties. Especially PCr10 sample exhibits impressive performance in terms of compressive strength. In oxidation test, there were no significant difference between simple mixing sampes and mechanical alloying samples. In a variety of composition samples, Cr18 samples have best oxidation resistance.

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