Research on Powder Metallurgy Technology in Fusion Materials in China

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Abstract

In the viewpoint of engineering, materials problem is a key problem, which determines whether the exploitation of fusion energy will be success. The most important class of fusion materials is plasma-facing materials (PFM). W, as high Z high melting-point metal is one of the most important candidate materials due to its high plasma erosion resistance. Improving the ductility of W and W based alloy, lowering its ductile-brittleness transition temperature for meeting the requirements of fusion application is an important task. In this paper, severalpowder meatllurgy methods of fabricating W and W based materials are being investigated.

Keywords: powder metallurgy, fusion material, ITER, W

1. Introduction

In the next 25 years, 5 billion tons petroleum annually will be consumed in the world. To change this situation, strategic new energy resources have to be found. China is consuming large quantity of coal-the important raw materials for chemical industry. Based on the reaction: D+T=4He +n+17.6MeV, the fusion energy evolved is about 4 times of fission energy per unit mass. The raw materials for fusion are almost unexhaustible. Fusion is much more safe and clean than fission. Fusion energy is an ideal alterative energy source, which can secure increasing energy needs of China and the world and is recognized as the final strategic energy resource of human beings.

ITER is a milestone, while announces that the great work of human beings on exploring the fusion energy has stepped from the demonstration of physical availability to the demonstration of engineering availability. In the viewpoint of engineering, materials problem is a key problem, which determines whether the exloitation of fusion energy will be success. The most important class of fusion materials is plasma-facing materials (PFMs).

PFMs include the armor materials of the first-walls, divorters and limiters etc., which directly faces the plasma in the Tokamak facilities.

Graphite is widely used in present Tokamak facilities and a C/C composite has been selected as one of the candidate materials for the ITER. But C-based material has excessive chemical sputtering yield at 600-1000K and exhibits irradiation-enhanced sublimation at ＞1200K under plasma erosion conditions, causing serious contamination of plasma. Hence, various measures are being taken to solve this problem [1-3]. W, as high Z high melting-point metal is the most important candidate materials due to its high plasma erosion resistance.

China has made great efforts on establishing a series of Tokamak facilities and on research on fusion in past 50 years, and has obtained a series of research achievements. And now China is one of the partners of ITER. This paper is related to the development of a new kind of plasma-facing materials for the future generation of Tokamak facilities of China.

2. The requirements of properties for PFM

There are strong interactions between the edge of fusion plasma and the PFM in fusion facilities. For operation of the Tokamak facilities, the following requirements should be satisfied:
1. High heat conductivity, hot shock resistance and high melting point are for effectively removing the heat which irradiates on the surface of the PFM;
2. Low sputtering yield for effectively controlling the impurities, which enter into the plasma;
3. Low H (D,T) recycling performance, that is, low gas absorption ability for H(D,T)
4. PFM should be low activation material. Besides, PFM should match with the operation life, reliability and maintenance of the reactor and protect other components from damage by the plasma during abnormal disruption of operation.

Comparing with the low Z materials, such as graphite, W is the high Z metal with high melting point, high thermal conductivity, low tritium retention and high plasma erosion resistance ability, thus would achieve much higher working life. W became one of the most prospectively PFM candidate materials [4,5].

3. Research on pure W with Ultra-fine grains

Nano technology was used to reduce the grain size of W and W alloys. Utilization of plasma activation sintering for nano-size powders can reduce the sinterin temperature about 200K. The grain size is less than 1 μm after sinteringof powder with particle of 280 nm. Besides, the authors utilized a new method named resistance sintering under ultra-high pressure, with which sub-micron W powder has been successfully fabricated, and the grain sizeafter sintering is less than 1 μm.

Fig.1 is the SEM fractography of W specimen. The relatively density is above 96%. Mechanical properties of these specimens were improved while the grain size was reduced (Table 1).

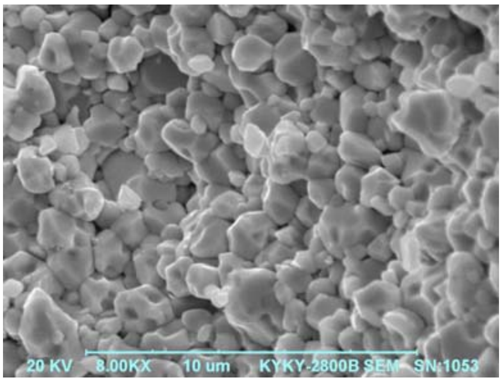

Fig. 1. the SEM fractography of W spacemen

Table 1. The relationship between particle size and mechanical properties of W

Particle size/ μm	0.2	1	3
Hardness/HV	1169.80	772.30	611.50
Bend strength/MPa	596.29	561.12	483.21

4. Research on W based alloys

Presently, second phase dispersion strengthening is widely used in W based alloys, the research on W in overseas indicated that the quality percentage of the second phase is below 10%. Recently percentage (10%, 20%, 30%, 40%) with TiC and ZrC as the second phase have been studied and developed. The highest bending strength of these materials at room temperature is 889MPa while rupture strength is 843MPa. The bending strength of the well-fabricated W based alloy in 1273K is 7.5 times as it in room temperature.

5. Joining technology for W and Cu

Welding, including brazing, diffusion welding and electron beam welding, is one of the main joining technology for PFMs and heat sink materials. Vacuum brazing has been widely used for joining of W and Cu. HIP (Hot Isostatic Pressing), Single-axis hot-pressing, Active metal casting also have been successfully used for joining W and Cu. The design idea of FGM (Functionally Graded Materials), is considered as one of the optional way for solving the problem of the mismatch of thermal expansion coefficient of W and Cu which leads to crack formation and failure of the materials. Infiltration, plasma spraying, spark plasma sintering, have been developed to fabricate these FGMs, but the related research reports is still limited. Resistance sintering under ultra-high pressure has been successful in producing this kind of FGM with a designed compositional distribution [6].

6. Conclusion and prospect

W is one of the most important PFMs. However, it is necessary to avoid the brittleness of tungsten and to develop joint technology between W and structure materials. China is the country with largest storage of tungsten, and China has taken part in ITER. The research on improving the properttes of W alloy is one of the fundamental tasks for Chinese materials scientists, especially, for Chinese fusion materials scientists.

7. References

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