§19. Development and Synthetic Evaluation of High-Z Plasma Facing Materials

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High Z materials, especially tungsten (W) and its alloys, are very promising for use as PFM and PFC because of their excellent resistance to high heat load etc. However, there are disadvantages that W and its alloys exhibit severe embrittlement, including the low temperature embrittlement, recrystallization embrittlement, radiation embrittlement and helium embrittlement. In addition, the data on the physical and mechanical properties required for use of W and its alloys as PMC/PFC are very limited. Therefore, a research group consisting of PSI and materials researchers from universities, NIFS, JAERI and company was organized in 2001 as one of LHD projects aiming at developing advanced W alloys with improved mechanical properties and joining technology and evaluating a variety of properties for PMC/PFC, together with baseline properties, for several commercially available W alloys to construct their data base.

1. Alloy development

The improvement in the resistance to embrittlement totally depends on the microstructure to be introduced. The studies of alloy development for Mo and W performed so far showed that the microstructure with fine grains and finely dispersed particles of transition metal carbides such as titanium carbide would be the most effective in improving the resistance to embrittlement. Such a microstructure can be introduced by powder metallurgical methods including mechanical alloying (MA), vacuum hot pressing (VHP) and hot isostatic pressing (HIP) treatments. In this study, the optimum conditions for MA, VHP and HIP to fabricate W alloys with improved ductility were examined: For MA, planetary-type ball mill with pots and balls made of WC/Co was used and for VHP and HIP, apparatuses were newly installed in the Oarai branch, IMR, Tohoku University and was used. The main results obtained are as follows:

Even very fine precipitates of W_2C that are undetectable by the X-ray diffraction method give a detrimental effect. The key issue for ductility improvement in W alloys is to control so that any precipitation of W_2C does not occur. For this purpose, pre-coating of MA-pot wall and ball surfaces with mechanically alloyed Mo powder is effective because Mo forms Mo_2C that is much less harmful and more stable at high temperatures than W_2C, resulting in no occurrence of W_2C precipitates.

Another method to introduce fine-grained microstructure was proposed and is applied to W alloys.

2. Synthetic Evaluation

As the material for the synthetic evaluation, pure (99.95%) tungsten sheets having both the stress relieved microstructure and the fully recrystallized microstructure with the average grain size of approximately 30 μm were specially fabricated with the dimensions of 100 x 100 x 5 mm and 100 x 100 x 1 mm. The sheets were machined and mechanically polished to the dimensions so as to meet the demand of each researcher who will evaluate the effect of irradiation with p, d and He on erosion and damages, radiation embrittlement, high heat load properties, thermal properties, mechanical properties such as fracture toughness and high temperature creep and hydrogen retention, and develop joining technology. Such studies are now in progress.