§27. Development of the Tungsten Materials for High Heat Flux Components Application to Neutron Irradiation Conditions in Fusion Reactor

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1. Objectives

The objectives of this study are to design and fabricate new tungsten alloys for diverter of fusion reactor. It is well known that tungsten is hard and brittle metals, but the mechanical properties of tungsten can be improved by grain size and structure control of fabrication process and alloying. Powder metallurgy process is one of industrial processes for refractory metals including tungsten without melting. Using powder metallurgy process, fine grain size and layered structure by thermo-mechanical process can be introduced in tungsten and these are expected to suppress the grain boundary embrittlement. Various type of tungsten alloys have been fabricated by this method to apply high temperature use such as filaments of light bulbs, electrode and heater. Recently, tungsten block are suggested as diverter tile of fusion reactor, but only pure tungsten can be supplied by manufactures as the thick plate because optimization of the structure control and alloying of the thick tungsten plates have not been established. From the view point of fusion reactor engineering, a large scale ingot of various type of tungsten alloys that can be conducted heat load test, hydrogen retention and permeation test, particle irradiation test and mechanical property test using the same ingot is required.

The purposes of this work are 1)design and fabrication of various type tungsten thick plate for diverter applications, 2) improvement of the thick tungsten plate properties by alloying and fabrication process, 3)evaluation of various properties required for diverter design. In 2011, we had investigated the present status of tungsten and its alloys and required size of specimens to evaluate these material properties, fabricated the reference material and alloys by the powder metallurgy process by industrial scale and prepared specimens for the property evaluation.

2. Experimental procedure

In order to evaluate anisotropies of various tungsten alloys thick plate fabricated by powder metallurgy process, pure W, W-1%Re alloy and K-doped W alloy with 80 x 80 x 5 mm were fabricated by A.L.M.T. Corporation. These materials were supplied after the final heat treatment at 900°C for 1 hour following the sintering and hot-rolling at 900-1600°C. After the surface polishing and etching of these materials, anisotropy of grain structure in the plate was investigated. The specimens to investigate the anisotropy of strength, ductility, thermal conductivity and hydrogen retention and permeation were also prepared. To study the delamination resistance of the layered structure introduced by rolling, bend test and torsional test were conducted. Optimization of the specimen size and the shape of the torsion type specimen to minimize the volume were conducted using finite element method (FEM).

3. Result

Microstructural anisotropies of each as-received samples fabricated are shown in figure1. The rolling direction is shown as arrows in the figure. The grains observed in A and B sides were compressed by the rolling, and the grains in C side were elongated to the rolling direction. The grain size of pure-W in C side are about 200x50μm, 200x20μm in B side and 20x50μm in A side. These structures were typical grain structure of powder metallurgy processed materials. In the case of W-1%Re alloy, the grain sizes were about 200x50μm in C side, 200x30μm in B side and 30xx50μm in A side. In the case of K-dope W, 100x20μm in C side, 100x10μm in B side and 10x20μm in A side. In the K-dope process, higher compression were introduced to achieve the uniform distribution of K dope holes. Re-crystallization behavior, the microstructural change by heat treatment and anisotropic effects on various properties will be investigated in 2012 using these samples and preparing new alloys by the powder metallurgy process or mechanical alloying process will be conducted based on these results. We will also distribute the well defined specimens treated the same heat treatment and surface polishing to the collaborative researchers of the LHD programs to evaluate accurate properties of these reference materials.

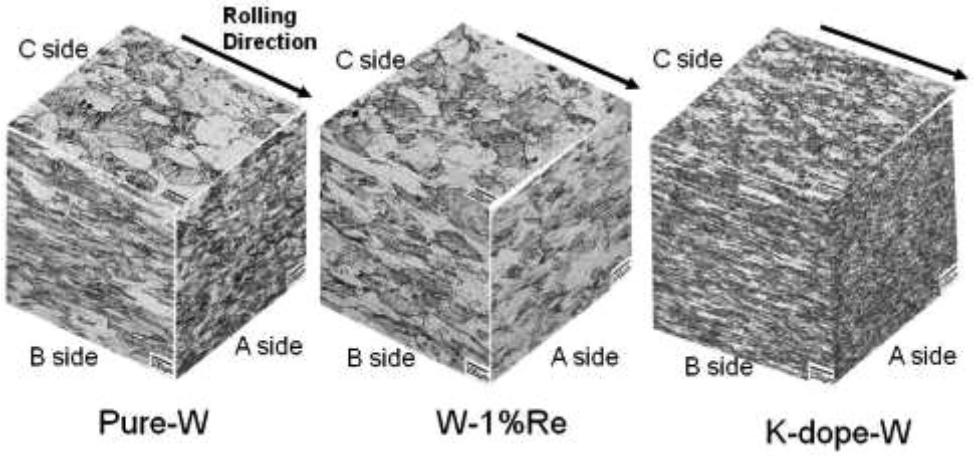

Fig. 1 Grain structure of as-received materials fabricated by powder metallurgical process. The size of these cubes is about 1x1x1mm.