§100. Mechanical Property of Plasma Facing Materials Irradiated by Neutron/Ion

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Tungsten (W) is a primary candidate for use as plasma facing materials/components (PFM/PFC). PFM/PFC will be subjected to heavy thermal loads in the steady state or transient mode combined with high energy neutron irradiation that will cause serious material degradation. It is necessary to clarify mechanical strength to evaluate thermal behavior of tungsten materials by high heat loading. In the last two fiscal years, tensile testing of W material was performed up to at 1600 ^{o}C to obtain stress-strain curves. In addition, observation of fracture surface was carried out to investigate fracture behavior. Furthermore, thermoelasto-plastic stress analyses using a finite element analyses (FEA) were performed to evaluate the thermal behavior and modification of the ITER W divertor mock-up during the high heat loading. In this fiscal year, high temperature tensile tests on He irradiated W have been carried out to investigate the fundamental combined effects of stress loading and implanted He on surface modification.

W small specimens for tensile test (gauge length; 5 mm, gauge width; 1.2 mm, total length; 16 mm, thickness; 0.5mm) were fabricated from ITER grade W. Heat treatment for the specimens was conducted at 2073 K for 1 h. Grain size is about 50 μm. One side of central area with 6mm x 1.2mm of specimens were irradiated with 10 keV helium ions at RT up to the fluence of 5 x 10^{21} ions m^{-2} using an ion gun equipped with an ion selector. Tensile tests were performed at 1073 K at a strain rate of 2 x 10^{-4} s^{-1}. Specimens were tested to plastically strained to 2%, 5%, 10%, 20%. After the tensile test, surface modification before and after the tensile test plastically strained to 2%, 5%, 10% and 20% was examined with a field emission type scanning electron microscope (FE-SEM).

Figure 1 shows unirradiated surface after the tensile test plastically strained to 10%. In the case of 2% plastic strain, it seemed that there was little change comparing with the surface before the tensile test. On the other hand, in the cases of 5% strain, surface modification such as slip bands occurred. Surface modification such as slip bands and uneven surface increases with increasing with plastic strain, however, micro and micro cracks were not formed. On the other hand, in the case of the He irradiated surface, it seemed that there were no difference between the surfaces before and after the tensile test plastically strained to 2%. On the other hand, micro cracks along slip bands could be seen on the He irradiated surfaces after the tensile test plastically strained to 5%. In this case, although a direction of the slip bands was at an angle to the tensile direction, direction of the micro cracks were almost perpendicular to the tensile direction. In addition, transgranular cracks wew seen in addition to intergranular cracks. Formation of the intergranular cracks is considered to be attributed to result from weakening of grain boundaries by formation of He bubble along the grain boundaries. Figure 2 shows the He irradiated surface after the tensile test plastically strained to 10%. Micro-cracks and exfoliation in the part of slip bands were formed as shown in the figure. In the case the He irradiated surfaces after the tensile test plastically strained to 20%, exfoliation and departure of surface layer in the part of slip bands were clearly seen and micro-cracks were also formed all around the surface between the slip bands.

The present results indicate that He irradiation may strongly influences mechanical properties of W and surface modification of the W divertor armor by thermal stress due to heat loading from plasma. Detailed works which experimental condition is changed will be required to make a prediction of precise material damage and lifetime of the W armor.

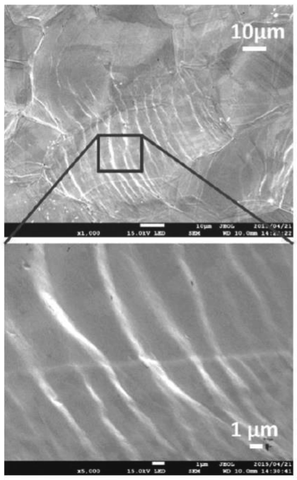

Fig.1 SEM images of unirradiated surface after tensile test plastically strained to 10%

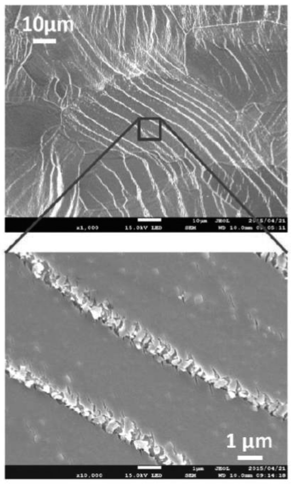

Fig.2 SEM images of He irradiated surface after tensile test plastically strained to 10%