§104. 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 fiscal year, tensile testing of W material was performed up to at 1600 °C to obtain stress-strain curves. In addition, observation of fracture surface was carried out to investigate fracture behavior. In addition, 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, dependence of strain rate in tensile test has been investigated. In addition, tensile tests of recrystallized W has been carried out.

W material used in the present work was ITER grade W. Tensile testing was performed on dog-bone shaped tensile test specimens with an overall length of 16 mm, a gauge length of 5 mm and an effective cross section of 0.6 mm^2. The orientation of the specimens used were parallel (L-R type) and perpendicular (T-R type) directions to rolling direction along rolling surface, respectively. Heat treatment for recrystallization has been performed at 1800 °C for 1h in high vacuum. The tests were conducted at 800, 1300 °C and 1600 °C at a strain rate of 2 $x10^{-4}$ s^{-1}, 2 $x10^{-3}$ s^{-1} and 2 $x10^{-4}$ s^{-1}. After the tensile tests, the Surface of the tensile specimens and the fracture surfaces were observed using an SEM.

Figure 1 shows stress-strain curves at 800 °C of L-R type W when the strain rate was changed. The strain curve of the recrystallized W at 2 $x10^{-4}$ s^{-1} is also added in the figure. Yield stress and tensile strength does not change when the strain rate is changed, however, elongation increases with about a few 10 % with increasing strain rate. Figure 2 shows stress-strain curves at 800 °C of recrystallized L-R and T-R type tensile specimens when the strain was changed. In the case of recrystallized specimens, tensile strength and yield stress decreases about half and 30 to 40 % that of non-recrystallized specimens, respectively. On the other hands, elongation increase by a factor of about 5. This is considered to be softening by grain growth and recrystallization, and plastic deformation is easy to occur comparing with brittle fracture at grain boundaries even if grain boundaries become to be week due to recrystallization. Figure 3 shows stress-strain curves of recrystallized L-R type specimens at 1300 °C and 1600 °C. Yield stress and tensile strength decrease with increasing test temperature, however, elongation does not change largely when test temperature changes. Figure 4 shows SEM images of fracture surface of non-recrystallized and recrystallized specimens at 800 °C when strain rate is changed. Striped fracture surface as well as many dimples are seen in non-recrystallized specimen at strain rate of $2x10^{-4}s^{-1}$. On the other hand, many dimples are only seen in non-recrystallized specimen at strain rate of $2x10^{-2}$ s^{-1}. In the case of recrystallized specimens, many dimples are seen. In addition, dimples with large size were seen at a test temperature of 1600 °C. The strain-stress curves will be modeled for thermal stress analyses using FEM.

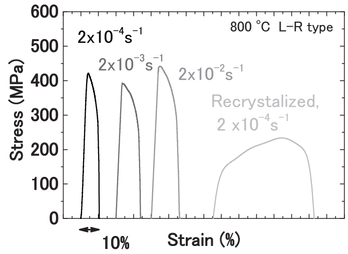

Fig.1. Strain-stress curves

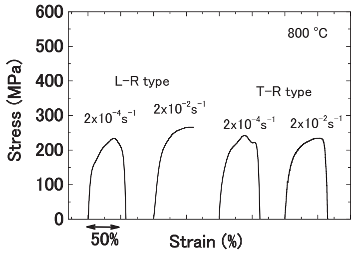

Fig.2. Strain-stress curves

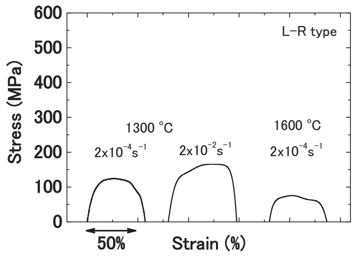

Fig.3. Strain-stress curves

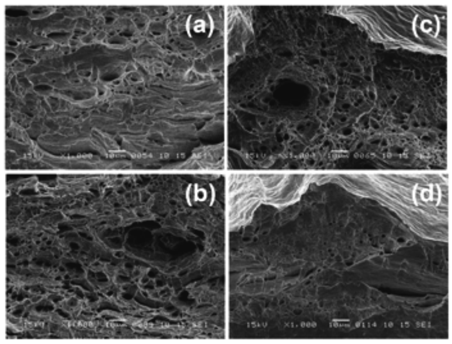

Fig.4. SEM images of fracture surface. Test temp.:800 °C, (a)Non-heat treatment, L-R type, $2x10^{-4}s^{-1}$, (b) Non-heat treatment, L-R type, $2x10^{-2}s^{-1}$, (c)Recrystallized, L-R type, $2x10^{-4}s^{-1}$, (d) Recrystallized, L-R type, $2x10^{-2}s^{-1}$