§11. Joining and Heat Load Test of Tungsten Divertor

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Since tungsten materials have high heat resistance, high thermal shock resistance and excellent erosion resistance, they have used for heat resisting structural materials in various fields. From viewpoints of thermal characteristics and plasma particle control, the tungsten materials are particularly expected to be used as an armor tile material of the next divertor plate for the LHD during the steady state and the long pulse operations. In this study, the divertor plate models made of tungsten materials are manufactured to contribute to the development of the plasma facing components having high performances. And the integrity of the divertor model is tested by a deflection-type electron beam heating apparatus.

Tested materials are the stress removal and the re-crystalline processing specimens of the pure tungsten material made by Allied Materials Corp. The re-crystalline processing tungsten material is treated further to the stress removal one for obtaining the grain size from 10 to 20 micron.

Fig.1 shows the joining method of tungsten divertor model. Tungsten specimens of 4 pieces (20x5x5 mm) are joined with an oxygen-free copper block (20x20x20 mm) having a cooling pipe (7 mm in inner diameter, 10 mm in outer diameter and 70 mm in length) after polishing and acetone washing. Titanium and copper foils (0.05 mm in thickness) are inserted for the joining. And an interlayer (20x20x1 mm) of Mo or Ni or Pt is also inserted for the prevention of crack propagation and the relaxation of thermal stresses. The joining specimens are held for 40 minutes at 1000 degrees C in a vacuum of $1x10^{-4}$ Torr. [1]

In heat load tests, heat fluxes from 0.5 to 15 MW/m^2 are irradiated to the tungsten divertor models by a deflection-type electron beam heating apparatus. The one cycle is 10 seconds irradiation and 15 seconds interval. The speed and the temperature of the water coolant are 15 l/min and 15 degrees C, respectively. And the temperatures of the surface and the joining part are measured by a radiation thermometer and CA thermocouples, respectively. The microstructures are observed by SEM before and after the heat load tests.

Fig.2 shows a photograph near the joining part inserted a interlayer of Pt. Good joining without cracks is observed. The good joining technique between tungsten and copper materials has been established by inserting the interlayer in this study.

Fig.3 shows the relationship between temperatures of the tungsten divertor model and the heat flux. In this figure, the data of the tungsten divertor model inserted a interlayer of Pt are a little higher than another model without the interlayer, and are lower than the model made of the re-crystalline pure tungsten. One of the reasons is considered that the interlayer has lower thermal conductivity and affects heat resistance. On the other hand, the temperatures of the joining parts are nearly the same because of the good heat transfer.

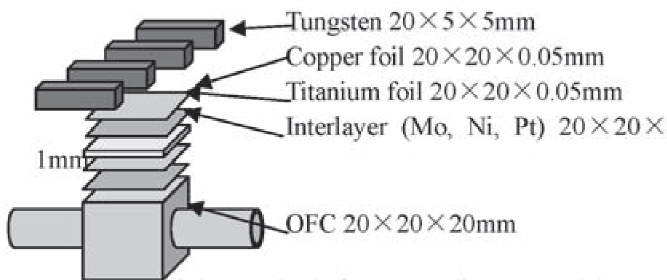

Fig.1 Joining method of tungsten divertor model.

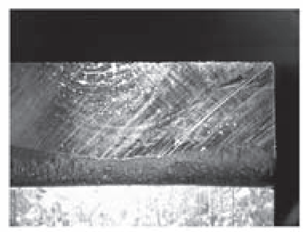

Fig.2 Observation near the joining part with Pt interlayer.

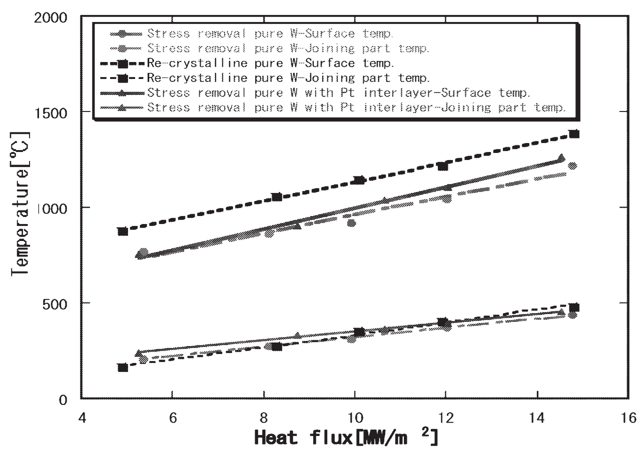

Fig.3 Relationship between temperatures of the tungsten divertor model and the heat flux.

Ref. [1] Suzuki,A., Imamura,Y., Kurumada,A., et al., Extended Abst. of Ibaraki District Conf. (2003.9.19) 55-56.