# §27. R&D of Advanced Cooling Unit of Diverter and its Non-destructive Inspection

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A mono-block (MB) type tungsten (W) plasma facing mock-up, built-in cooling tube made of copper alloy, has been considered as a diverter cooling unit of ITER. For steady and safe operation of the diverter, the development of evaluation technology of damages such as melting or cracking in W-MB is essential.

This research aims to investigate the damage evolution in W-MB mock-up during high heat load test with focusing on the influence of the thickness of W from the heat-loaded surface to the cooling tube in the W-MB.
In order to evaluate the effect of heat loading on W-MB, the metallographic micro-structure was observed by a scanning electron microscope after etching and the micro-Vickers hardness test was carried out. Furthermore, in order to measure the dislocation density, transmission electron microscope observations were done for the parts of W-MB with and without heat loading.

Test mock-ups were composed of pure W blocks, a cooling tube made of CuCrZr alloy, and an oxygen-free copper buffer layer between the W-MB and Cu tube. ITER-grade W was used in this research. As shown in Fig.1, two types of W-MB mock-ups were fabricated: a MB has 3 mm thickness from the heating surface to the cooling tube, and another has 6 mm thickness, and hereafter, they are referred to as W-MB-3 and W-MB-6.

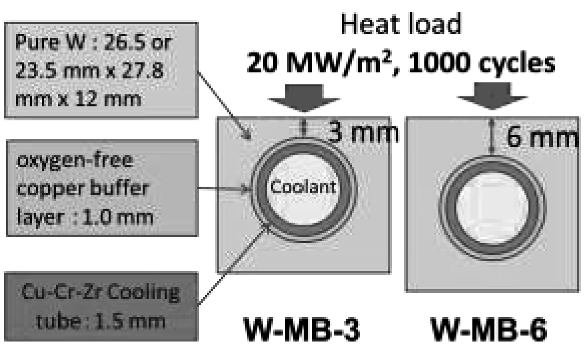


Fig. 1: W-MBs used in this research

As for high heat load tests, cyclic loading of electron beam more than 20 MW/m$^2$ was carried out 1000 thermal cycles while flowing pressurized cooling water. After the heat loading, the inspection of the damages was assessed for the W-MB. Fig. 2 shows the overall feature of the cooling components just after heat loading. Top view is of W-MB-6, and the surface was melted but no crack was observed. The bottom is of W-MB-3, and in this case although no melting was observed but cracking was observed. In addition, as shown with the different color, dark gray, recrystallization or grain growth occurred in the area close to the heating surface of both WMB6 and WMB3. The gray area expands at the edge of the MB, of which the thickness depends on the distance from the cooling tube not only the distance from the heated surface.

According to the detailed microstructure of W-MB-3, a long crack is along with the grain boundaries. The crack depth at the end measures 3.4 mm, but it does not reach until the cooling tube. The location of the crack is determined by the trade-off of the magnitude of the tensile stress applied to the specimen surface during the time of cooling after heating with reduction of the grain boundary strength by recrystallization. Finally, it is concluded that regardless of the thickness of W, recrystallization depends on the distance from the cooling tube, and W was softened due to coarsening of grains. Recrystallization was accompanied by the recovery of dislocations, and the dislocation density was reduced by about one order of magnitude.

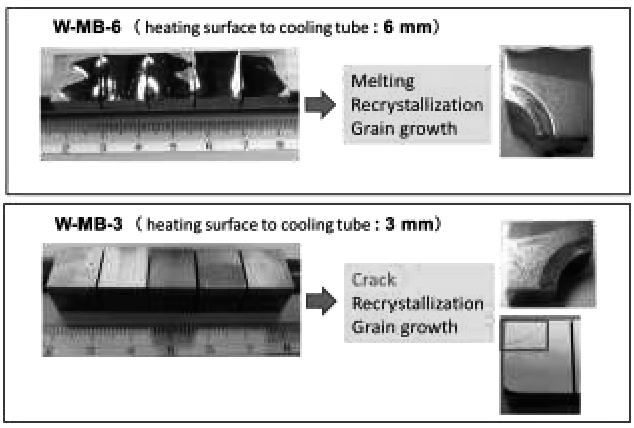


Fig.2: The patterns of damages caused by heat loading.