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Failure and Melting of Intentionally Misaligned Tungsten Castellated Blocks under High Heat Flux

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High heat load test were performed by using 1) E-beam for tungsten blocks and divertor mock-up, and 2) Long pulse H-mode plasmas in KSTAR for tungsten blocks mounted on stainless steel base.
Tungsten blocks are exposed to a heat flux of 13 MW/m2 from the top with a beam spot size around 11.5 mm in diameter, 100 kV and 12.5 mA, while the divertor mock-up is exposed to much higher heat flux up to 130 MW/m2. In the case of KSTAR experiments, inter-ELM heat flux at the central divertor is in a range between 0.5-3 MW/m2, while that during ELM is up to 50 MW/m2.
Two tungsten blocks exposed to 13 MW/m2 e-beam show that the Cu interlayer is melted within 4 sec, while the surfaces of the tungsten layer show recrystallization.
From COMSOL modeling, the temperature of Cu interlayer reaches its melting point (1100 deg C) in 3.7 sec, which is consistent with the experimental observation: The temperature of tungsten layer is around 2100 deg C well above the recrystallization temperature (1400 deg C). With the extreme case of 130 MW/m2 and longer exposure time, Cu interlayer is completely melted and some part of CuCrZr base is melted down. Tungsten blocks exposed to KSTAR H-mode shows melting of Cu interlayers with closed gaps between two tungsten blocks by molten Cu. Simulation with q=3 MW/m2 shows that an exposure time of 15.8 sec is required to elevate the temperature of Cu inter-layer up to the melting point. These results indicate that bonding between tungsten and Cu layers will be failed at a temperature over 1000 deg C resulting in poor thermal contact. Melting of Cu interlayer also causes further misalignment, which can cause further increase of temperature of the tungsten layers up to melting point of tungsten.

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