§76. Irradiation Effects on Joining/Coating of Low Activation Structural Materials

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In a variety of fusion power plant concepts, such as, water-cooled lead-lithium (WCLL), helium-cooled ceramics/beryllium pebble bed (HCPB) and dual-coolant (DC) blanket systems, joining technologies of dissimilar materials are essentially required. Oxide dispersion strengthened (ODS) steel and tungsten (W) are considered as promising candidate materials for structural and plasma facing materials of the first wall and divertor components in fusion reactors. ODS steel shows excellent elevated temperature strength, corrosion resistance, radiation resistance, and W has high sputtering resistance and low tritium retention in fusion environment. Therefore, it is considered that the joining of ODS steels and W and its evaluation are a critical issue for the development of fusion application. However, the joining between dissimilar materials is very challenging process because of significant differences in their physical properties, particularly the mismatch of coefficients of thermal expansion (CTE).

Solid state diffusion bonding between pure W and ODS steel with a double layered insert made of a pure iron film and an amorphous (Fe-3B-5Si wt.%) was fabricated at 1513 K for 1 h at a bonding pressure of 10 MPa. Three-point bending tests of the joints indicated the maximum bending fracture stress of the joints was 280 MPa in average of 6 tests. The cracks formed near the joint boundary are shown in Fig. 1, showing that the cracks were observed not on the boundary or in the insert layer but in tungsten close to the boundary. This result indicates that the joint with a double layered insert has a enough bonding strength for application to fusion blanket components [1].

Figure 2 shows the dose dependence of the irradiation hardening of vacuum plasma sprayed tungsten (VPS-W) irradiated in HFIR at 773K up to 2.7 dpa. A remarkable irradiation hardening was observed in VPS-W, which is contrast to the behavior that the other metallic materials such as iron, copper, nickel and many sorts of steels showed almost no change or even softening by the irradiation at 773 K. Generally, the irradiation hardening observed in many metallic materials is mainly due to the formation of interstitial type dislocation loops which are stable at temperatures below 693 K. The temperature range adequate for irradiation hardening is not affected by the melting temperature of the materials. The irradiation hardening observed in VPS-W can be attributed to radiation-induced phase changes like a precipitation of tungsten carbides and oxides which are contained in the VPS-W as impurities. TEM observations are necessary to investigate the mechanism of the hardening.

1) H. Noto, A. Kimura, H. Kurishita, S. Matsuo, “Diffusion bonding of W-1.1%TiC and 15Cr-ODS ferittic steel for diverter application”, 27th Symposium on Fusion Technology (SOFT 2012), P2.152, September 24-28, 2012, Liege, Belgium.

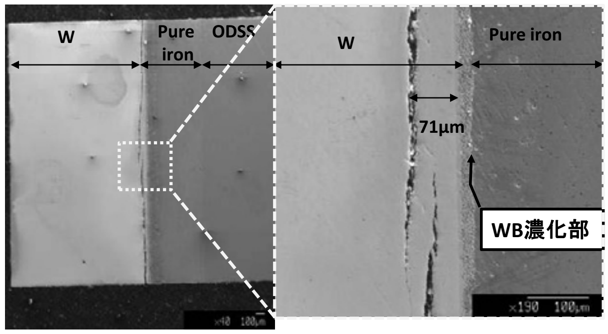

Fig. 1: Cracks formed in the W-ODSS joint produced with a double layered insert Fe/amorphous after bending test..

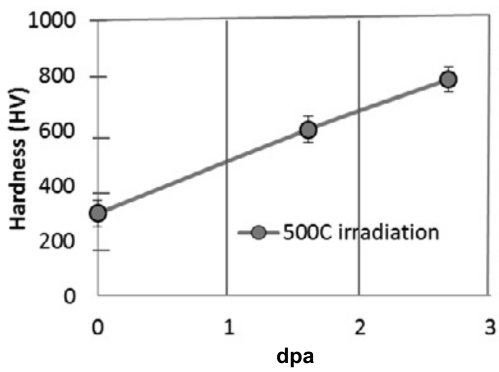

Fig. 2: Dose dependence of irradiation hardening of VPS-W irradiated at 773K.