§75. 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).

In this study, the effects of neutron irradiation on the hardness of W-coated ODS steels were investigated. Vacuum plasma spraying (VPS) technique was employed to fabricate W layer on the substrates. Substrate materials were K1-, K4-ODS ferritic steels and F82H steel, which are 3mm thick plates. Tungsten powder of 99.9% high purity was used for VPS process. The powders were sprayed by the plasma jet of argon and hydrogen mixture to the surface of substrates pre-annealed at 550 °C. VPS-W coated specimens were irradiated at 500 °C to 1.2 or 9.6 dpa in the High Flux Isotope Reactor (HFIR). To investigate the effect of neutron irradiation on joint area, the hardness distributions were evaluated on the cross section using a micro Vickers hardness tester with 100gf for 10s at room temperature in a regular interval of 100 μm.

Microstructure analysis by SEM revealed that pure W was successfully coated on ODS steel substrates by VPS process, in spite of mismatch of the CTE between two materials, although the hardness of W was significantly varied from 260 to 480HV because of inhomogeneous solidification and cooling rate during VPS process, as shown in Fig.1. As for the neutron irradiation effect, the hardness changes in the joint of VPS-W and K1-ODS steel are shown in Fig. 2. A remarkable increase in the hardness is observed for VPS-W, while no such a significant change is observed for K1-ODS steel. Almost null hardening in the ODS steel is well understood in terms of unstable dislocation loops under neutron irradiation at 500 °C. A part of the neutron irradiated joints were shipped from ORNL to Tohoku University in last March, and TEM microstructural observations will be performed to make clear the hardening mechanism of W.

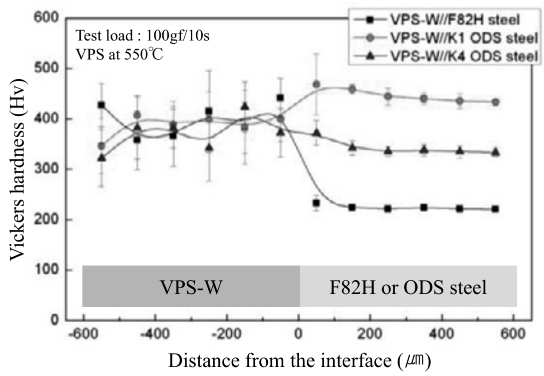

Fig. 1: The hardness distribution across the joint boundary of VPS-W and substrate materials.

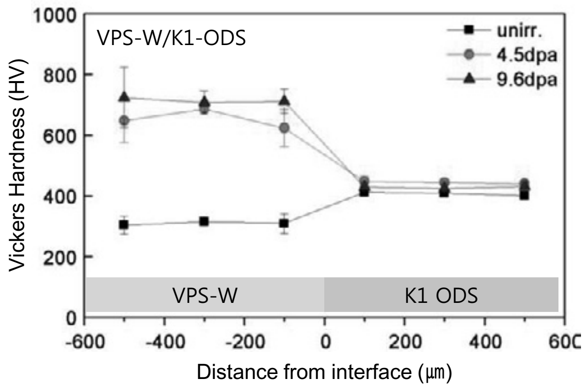

Fig. 2: The effect of neutron irradiation on the hardness of W-plasma sprayed ODS steel.