§8. Evaluation of Bonding Interface in Advanced Structure Materials for Fusion Reactors

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It is known that bonding and coating techniques between metal and insulator ceramics which reduce magneto hydrodynamics pressure drop are need to use vanadium alloy, which is one of the advanced fusion reactor structure materials, with liquid lithium self-breeding coolant material in strong magnetic field. In the case of SiC composite used as high temperature structure materials, soundness of the interface between fiber and matrix is important to maintain pseudoductility which is a characteristic of composite material. Thermal stress and thermal conductivity are particularly important in bonding between tungsten divertor and copper alloy as heat sink material. There are various kinds of bonding interface between different materials in fusion reactor system components, and evaluation under operation environment such as a thermal characteristic, a mechanical property, an electric property is important at all for engineering point of view. In this study evaluation of mechanical property of the interfaces by a direct measurement and a calculation experiment, to understand and to deepen knowledge of bonding and coating between different materials in the components of fusion reactors.

In this short report, results in coating with insulator ceramics for reduction of MHD pressure drop as one of the interface in nuclear fusion reactor system are described. A systematic experiment of coating was enabled by using V-4Cr-4Ti alloy NIFS-HEAT. In addition, comparatively large-scale heat of several-ten kg of the vanadium alloy that contains small amounts of yttrium which could reduce influence of interstitial impurities on the mechanical properties was enabled to prepare various kinds of coating for evaluation include solid-state diffusion bonding, physical vapor deposition, plasma spray and dipping followed by heat treatment. Because of its low induced radio activity, compatibility with lithium and the insulation characteristics up to 700C, yttrium oxide coating was selected to evaluate as a function of substrate.

Thickness of about 100 micron of yttrium oxide was made by means of plasma spray in a vacuum both on the substrates of V-4Cr-4Ti alloy and V-4Cr-4Ti-Y alloys. It was attempt to make solid-state diffusion bonding between yttrium oxide and V-4Cr-4Ti alloy in 1000C with a loading condition of 6MPa, but strong bonding was not yet obtained. Physical vapor deposition by DC sputtering by argon gas at room temperature was attempted using yttrium metal target. Additional heat-treatment at 1000C for 3.6ks made the coating better crystallinity comparable to the bulk material as shown in fig. 1. The diffraction pattern near (222) plane of Y_2O_3 seems shifted to lower angle side. Such a strain may have an influence on mechanical property or corrosion resistance of the coating. A computer calculation of atomistic scale level was performed to examine bonding strength and elastic properties of such strained coating.

Bonding and coating with ceramics on the substrates of vanadium alloys provided by the comparatively large-scale heats were attempted to examine bonding strength and mechanical properties of the coating films. It was founded that the bonding and coating method and degree of the strain of the coating films and crystallinity were affected to the interface properties include bonding strength. Knowledge from atomistic scale calculation by a computer experiment was effective for interpretation of the interface strength.

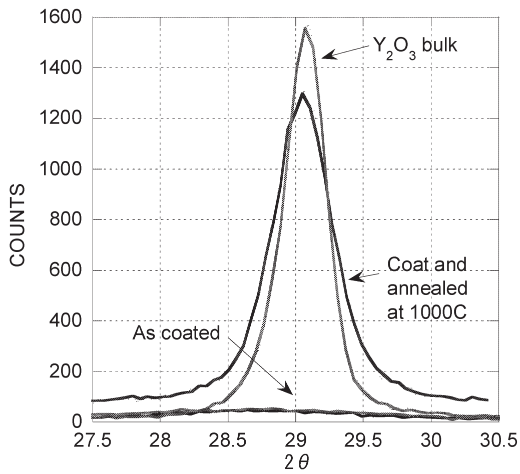

Fig. 1 X-ray diffraction patterns of the coating on vanadium alloy by means of DC sputtering in argon gas atmosphere at room temperature, followed by heat-treatment at 1000C for 3.6ks in a vacuum. For comparison, x-ray diffraction patterns as coated condition and bulk yttrium oxide are also shown.