§15. Measurement of Mechanical Strength of the First Wall Coating by Means of Laser-shock Method

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It has been demonstrated that controlling of interstitial impurity levels by means of modification of melting process or addition of scavenging elements like yttrium improved the material performance through evaluation of baseline properties and irradiation behaviors for V-4Cr-4Ti alloy. As for an important issue to reduce MHD (Magneto Hydro Dynamic) pressure drop, a laser shock method have been utilized for the evaluation of bonding strength between vanadium alloys and yttrium oxide coating as electrical insulator. In order to improve the methodology, metal/metal bonds like nickel-titanium and copper-nickel, and ceramics/metal coating like magnetite-steel were also evaluated. The first wall coating of tungsten on structure materials for fusion reactor is of interest from the view point of the bonding strength. In this study, mechanical properties of the first wall coating and the insulator coating on vanadium alloys were examined by means of the laser shock method to understand the bonding strength between dissimilar materials in the fusion reactor components.

The laser shock apparatus to measure the bonding strength have been installed. A Nd:YAG laser with wave length of 1064 nm and maximum 1.6 J power at single-pulse mode (pulse width was 7 ns of full width at half maximum) to apply tensile stress at the interface and a displacement laser interferometer using a single mode diode-pumped solid-state (DPSS) laser with wave length of 532 nm. The procedure consisted of three steps. (1) Irradiation. The Nd:YAG laser shots created shock wave that caused tensile stress after reflection at free surface. (2) Measure surface velocity. The stress depended on laser power and was estimated by the surface velocity profile measured by laser interferometer. (3) Estimation of the strength. The bonding strength was determined by the critical laser power that caused exfoliation of the bonding interface.

The target first wall coating of tungsten was under preparation. Yttrium oxide coating on vanadium alloys were measured by the laser shock method to reveal the applicability to the first wall coating. The critical laser power of the yttrium oxide coating was able to estimate as shown in fig.1. Clear exfoliation was observed after laser shots of 112 and 197mJ. The brighter area in the circles showed the exfoliation. It was hardly observed exfoliation after 89mJ-shot or less power-shots. The corresponding exfoliation was clearly observed from cross sectional view of the coating after laser shots as in fig.2. The evaluated strength in this case was less than 390MPa. Several issues to improve in the precision of the measurement were found, such as exfoliation in the coating, effects of laser profile and thickness.

The results of the evaluation of the bonding strength between yttrium oxide and V-Cr-Ti-Y type alloys indicated that the laser shock method can be powerful tool for the research and development of the first wall coating. Further improvement of the precision and application to the tungsten coating on the structure materials such as vanadium alloys and reduced activation ferrous materials are going to be conducted.

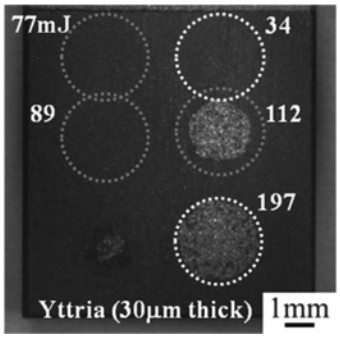

Fig. 1 Surface morphology after several laser shots on V-4Cr-4Ti-0.2Y alloy to determine the critical energy. Dotted circles indicate irradiation area and the numbers are laser energy in mJ. The brighter area indicates exfoliation of yttria coating, irradiated with 112 and 197 mJ.

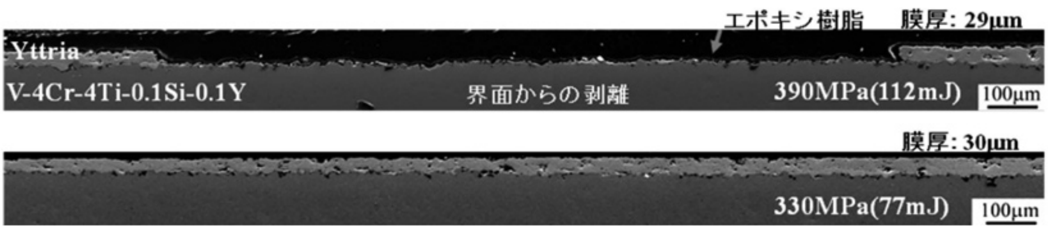

Fig. 2 Scanning electron microscopy of the cross-section of interface between yttria and vanadium alloys.