## §26. Development of Plasma-Spray Technique and Evaluation of Coating Properties for LHD

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Testing W divertor in LHD is an important subject for the selection of divertor material for a helical DEMO reactor. The most realistic option is to fabricate W coatings on the present divertor plates made of isotropic graphite (IG-430U). Low pressure plasma spraying (LPS, also known as vacuum plasma spraying VPS) is an attractive technique for this purpose. In LPS, powder particles of W are put into arc-discharged Ar plasma and deposited on the substrate. Properties of fabricated coatings are dependent on various parameters such as particle size, substrate temperature, etc., and therefore the optimization of fabrication conditions is required. A previous study has indicated that melting tungsten particles in the arc-plasma induced columnar grain growth along the coating direction and resulted in good thermal conductivity.[1)] However, the appropriate particle size has not been fully identified. In addition, the substrate was heated solely by heat flux from the plasma in the previous study[1)], and hence plasma conditions and substrate temperature could not be controlled independently. In this study, for further optimization of fabrication conditions, the correlation between microstructure of coatings and size of powder particles was examined. A heater made of carbon-fiber-composite (CFC) was prepared for independent control of substrate temperature and plasma conditions. Retention of tritium (T) implanted as low energy ions was also examined for a coating fabricated with a conventional powder and compared with that of IG-430U.

Three-types of W powder in three different particle sizes were used; SG: 10–25 μm, MG: 25–38 μm and LG: 25–45 μm. After roughening the surface using a sand blast technique, LPS-W coatings were prepared on E-type LHD divertor tile made of IG-430U at around 1073 K in Tocalo Co., Japan. The cross-sectional observation of the coatings and micro-crystallography were performed using a scanning electron microscopy (SEM) and an electron back scatter diffraction (EBSD) technique. Irradiation of DT ions (0.5 keV) was performed in Univ. Toyama at room temperature to the coating fabricated with a conventional W power (25–45 μm) which was not subjected to heat treatment to sinter weakly-bounded aggregates. T retention was measured using an imaging plate (IP) and β-ray induced X-ray spectrometry (BIXS), and compared with those of IG-430U and LPS coating prepared by Plansee Aktiengesllshaft.[2)]

The EBSD images of cross sections of fabricated coatings are shown in Fig. 1. The coatings prepared with the MG powder showed that the highest fraction of the columnar grains together with the lowest fraction of large equiaxial grains resulted from the deposition of unmelting particles. Too large grains cannot be melted in the plasma, and too small grains are resolidified before reaching the substrate due to too small heat capacity. It was concluded that 25–38 μm is the optimum particle size under the present conditions. The mass density of the fabricated coatings were above 95% of the theoretical density. The heat conductivity was about 75 $Wm^{-1}K^{-1}$.

The fabrication at far higher temperature (>1273 K) with moderate local heat flux from the arc plasma was successfully performed using the newly prepared CFC heater. The microstructure analysis is in progress and the results will be reported in the near future.

BIXS spectra showed that implanted T was localized in shallow regions near the surfaces. The intensity of photo-stimulated luminescence (PSL) from IP is plotted in Fig. 2 against the elapsed time after the implantation. The concentration of T retained in LPS-W prepared in this study was lower than that in IG-430U by orders of magnitude and comparable with that in the coating fabricated by Plansee Aktiengesllshaft.

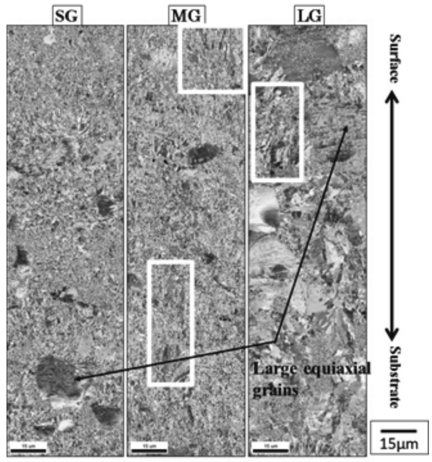


Fig. 1. EMSD images of cross sections of coatings.

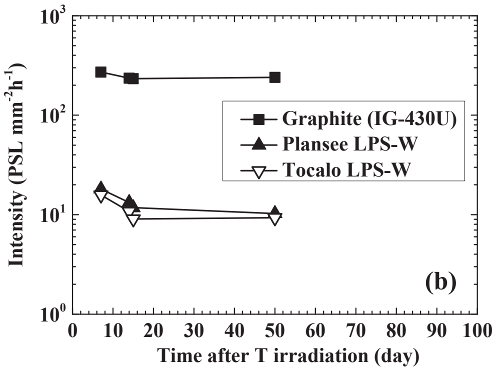


Fig. 2. Intensity of PSL induced by β-rays from T implanted in IG-430U and LPS-W fabricated in this study in Tocalo Co. and by Plansee Aktiengesllshaft.

1) Tokunaga, T. et al.: J. Nucl. Mater. **442** (2013) S287.
2) Tamura, S. et al.: J. Nucl. Mater. **329–333** (2004) 711.