

§1. Development of Anti-corrosion Coating on Low Activation Materials against Fluoridation and Oxidation in Flibe Blanket Environment

Nagasaka, T., Kondo, M., Muroga, T., Sagara, A., Motojima, O., Tsutsumi, T., Oishi, T. (Shinto Industrial Co., LTD)

Liquid breeder blanket is promising for DEMO and commercial fusion reactors. Flibe molten salt ($\text{BeF}_2 + \text{LiF}$) is a very attractive liquid breeder material. Corrosion of structural materials by HF (TF from tritium breeding) is one of critical issues for Flibe blanket system. In addition, oxidation has been identified as a potential corrosion process in Flibe with moisture impurity. In the present study, tungsten (W) coating was fabricated by vacuum plasma spray (VPS) process. Chromium coating was fabricated by chromizing process. The present study seeks to evaluate feasibility of the coatings for fusion low activation materials, to characterize microstructure, and to examine chemical stability of coatings by fluoridation and oxidation tests.

The low-activation materials used were 1-inch-thick plates of JLF-1 JOYO-II heat ($\text{Fe}-9.00\text{Cr}-1.98\text{W}-0.090\text{C}-0.015\text{N}-0.20\text{V}-0.083\text{Ta}$) and NIFS-HEAT-2 (NH2, $\text{V}-4.02\text{Cr}-3.98\text{Ti}-0.0069\text{C}-0.0122\text{N}-0.0148\text{O}$). The W powder was melted and sprayed on the substrate by a plasma jet of argon and hydrogen mixture in a vacuum chamber. The resulting thickness of the W coatings was about 0.4~0.8 mm. Chromizing was performed by using chemical vapor deposition with NH_4Cl and pure Cr powders. The coupon specimens were exposed to $\text{H}_2\text{O}-47\%\text{HF}$ solution at room temperature (RT) for 2 min and $\text{He}-1\%\text{HF}-0.06\text{H}_2\text{O}$ gas mixture at 823K for 2.5 hr.

Figs. 1 and 2 present a cross section of the VPS-W coatings and Cr coatings by chromizing, respectively. About 80 μm -thick coating was successfully obtained for JLF-1, however mean coating thickness for NH2 was estimated as less than 5 μm . Easily peeling layer considered as oxide was formed, instead, on the NH2 substrate. Since the mean coating thickness was too small for NH2, the chromized NH2 was not transferred to the subsequent corrosion tests.

Fig. 3 plots the weight change after the corrosion tests. JLF-1 and NH2, exhibited similar weight losses each other. In the $\text{H}_2\text{O}-\text{HF}$ solution tests, pure Cr and W exhibited a 1/30 to 1/50 weight loss compared with the low-activation materials. VPS-W specimens machined from the VPS-W part showed 1/3 to 1/5 weight loss compared with the low activation materials, however it is 10 times larger than that of pure W. Chromized JLF-1 (Cr-JLF-1) indicated similar weight loss to pure Cr. In the $\text{He}-\text{HF}-\text{H}_2\text{O}$ gas corrosion tests, the VPS-W showed weight loss, while the others resulted in weigh gain. The weight gain of NH2 was 10 times greater than that of JLF-1. The weight gain of Cr-JLF-1 was similar to that of JLF-1.

According to XPS analyses, both the VPS-W and Cr-JLF-1 suppressed fluoride formation compared with JLF-1 or NH2. It is well known that V alloy is easily oxidized at elevated temperature, as the large weight gain and were indicated for the gas condition test in Fig. 3. Suppression of oxide formation is especially expected for

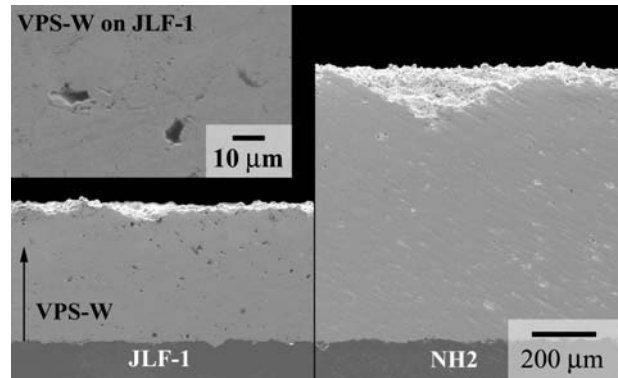


Fig. 1 SEM images of the cross section of W coating.

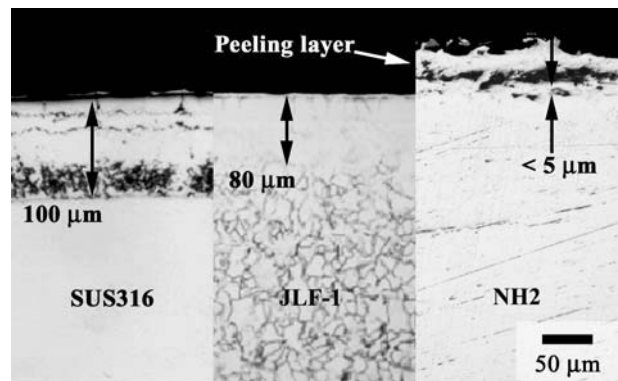


Fig. 2 OM images of the cross section of Cr coating.

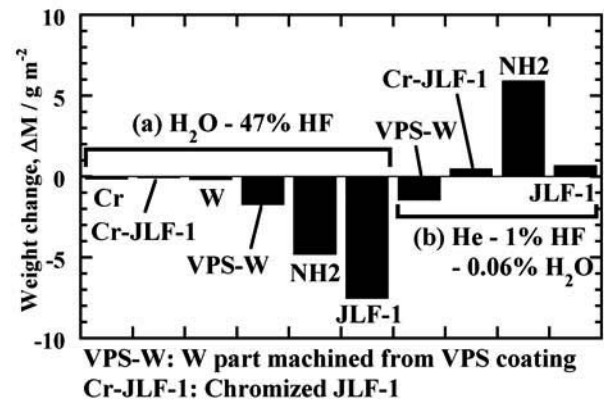


Fig. 3 Weight change after corrosion tests.

NH2 by W coating.

Cr coating decreased fluoridation and oxidation in $\text{H}_2\text{O}-\text{HF}$ solution condition, however much Cr_2O_3 was produced in $\text{He}-\text{HF}-\text{H}_2\text{O}$ gas and may be dissolved into Flibe. Protective and thin Cr_2O_3 layer common in high Cr stainless steel was not formed in the present study. Systematic research with various oxygen potential, for example, by control of moisture level in the corrosion gas, is expected to produce protective layer. It must be, however, noted that Cr concentration decreases with the depth from the coating surface, and that corrosion behavior will be changed once the surface is removed. Effect of concentration of Cr has to be investigated further.

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