§20. Lithium Compatibility of MHD Coatings Fabricated by Arc Source Plasma Deposition Method

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For a D-T fusion reactor system, a blanket is a necessary component, where tritium is produced from lithium, heat is generated, and radiation is shielded. In fusion reactor designs, the liquid blanket concepts are the promising ones in order to realize a DEMO (demonstration) fusion reactor system of high power density, because it has advantages such as continuous replacement of breeders for reprocessing, no radiation damage for breeders, larger TBR (tritium breeding ratio) and better thermal transfer than solid blankets. Liquid lithium is considered to be one of the most attractive candidates as a liquid breeding material. In the self-cooled liquid lithium blanket system, the liquid lithium can be used not only as the tritium breeding material, but also a coolant for the blanket system. Moreover, sufficient TBR could be obtained without neutron multipliers, such as Be, due to high lithium density in the blanket. Thus, the liquid lithium blanket concept has a possibility to propose a blanket with the simplest structure.

A crucial issue for the self-cooled liquid lithium blanket concept, so-called magnetrohydrodynamics (MHD) pressure drop, however, had been pointed-out that a large pumping power may be required due to the pressure drop in the conductive coolant induced by MHD effect with the magnet field. In order to solve this issue, insulating ceramic coatings on the inner surface of the tubing for the liquid lithium had been proposed. The coating should have high electrical resistivity, high corrosion resistance, and high thermomechanical integrity. Aluminum nitride (AlN), yttrium oxide (Y_2O_3), erbium oxide (Er_2O_3) have been chosen for the coating candidate materials by the investigations on compatibility with liquid metals. Some studies on the application of these candidate materials to the MHD coating shows fabrication of the coating with sufficient abilities is an important investigation point. In this study, erbium oxide coatings were fabricated and exposed in liquid lithium to observe compatibility with liquid lithium.

Arc source plasma assisted deposition method was used to fabricate erbium oxide coatings. In this method, 99.9% purity of erbium metal target was used as cathode. Vanadium metal or V-4Cr-4Ti alloy of 25 x 25 x 1 mm^3 plates were used as substrates, current of 80 A was introduced to generating arc on the cathode. Erbium ions were accelerated with the bias of 15 V and turned by magnetic field and went through the oxygen plasma, which oxygen gas was introduced at 5 x 10^{-2} Pa. Erbium ions and oxygen ions formed erbium oxide on the substrates, where DC bias of ~ 690 V voltage were applied with 100 V radio frequency voltage to accelerate ions. The substrate was heated up to ~ 700 K, and deposition time was 0.25-1.5 h. The coated specimens were exposed to liquid lithium to observe compatibility. In the experiment, lithium was heated up to ~ 973 K. After the exposure, residual lithium on the specimens were heated and distilled in the vacuum chamber.

The coatings fabricated by arc source plasma assisted deposition were transparent and had uniform thicknesses. The coatings fabricated at room temperature and 576 K were observed by XRD. The coating fabricated at low temperature had a few sharp peaks, some of the JCPDS peaks were not observed. On the other hand, the pattern of the coating fabricated at 576 K has many sharp peaks, and they were close to JCPDS peaks angle. It is considered that the coatings fabricated at low temperature had orientation, and the orientation was lost and the crystal grains grow at random as the temperature of fabrication became higher. Some of the coatings fabricated at low temperature had many peaks and the peaks shifted to JCPDS peaks by annealing. It is considered that the crystal grains became random as higher the fabricating temperature of the coating by annealing process after fabrication of the coatings.

After the exposure, the specimens were removed the residual lithium on the surface and observed. The specimen exposed at 973 K for 1000 h were stable as shown in Fig. 1. In the figure, upper area is coated area, and lower metallic area is uncoated area and the substrate of NIFS-HEAT-2 is revealed. On the other hand, the coatings exposed at lower temperatures (773 K or 873 K) were peeled off from the substrates as shown in the Fig. 2. In the figure, upper dark area is coated area, and lower metallic area is where the coatings were peeled off and the substrate of NIFS-HEAT-2 is revealed. It is considered as follows; there were vanadium oxides interlayer between the coatings and the substrates, which were unstable in liquid lithium. In the exposure of lower temperature, liquid lithium went through the cracks of the coatings and dissolved the interlayer, and caused peeling off of the coatings. In the exposure of higher temperature, the interlayer disappeared by the movement of oxygen to vanadium layer of the substrates, and the coatings became more adhesive.


Fig. 1. Specimen after 973K 1000h exposure

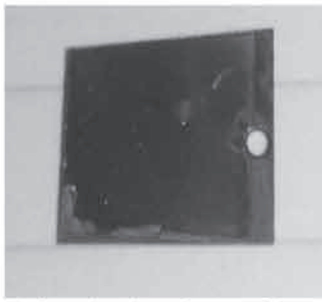
Fig. 2. Specimen after 873K 1000h exposure