§2. Property of MHD Coatings Fabricated by RF Sputtering Method

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A liquid blanket system is attractive for a DEMO (demonstration) fusion reactor, because liquid tritium breeding material can be continuously conducted for reprocessing, it has no radiation damage and lager TBR (tritium breeding ratio), and thermal transfer is higher than the solid breeders. Liquid lithium is considered to be one of the best candidate breeding materials for a self-cooled liquid blanket system, in which, the liquid lithium can also be used as a coolant for the blanket system. In this system, the sufficient TBR can 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 an economic blanket system with simple structure.

One of a critical issue for a self-cooled liquid lithium blanket concept is so-called MHD pressure drop (Magneto-HydroDynamics). An intolerably large pumping power for the metallic coolant in the magnetic field will be required due to the pressure drop induced by electric current between the coolant and the pipe wall. To solve this problem, it is proposed to fabricate the electrically insulate ceramic coatings on the inner surface of pipe walls. These coatings should have high electrical resistivity, high corrosion resistance, high thermo mechanical integrity and no nucleus reactiveness. Aluminum nitride (AlN), yttrium oxide (Y_2O_3) and erbium oxide (Er_2O_3) have been chosen as candidate materials by the former investigations on compatibility with liquid lithium. However, studies on the coating fabrication with these candidate materials show it is important to fabricate coatings with sufficient abilities as the bulk candidate.

In this study, the coatings of AlN, Y_2O_3 and Er_2O_3 were fabricated by the RF sputtering method. The RF sputtering method is one of PVD methods to realize a high density and high crystalline coatings with a high deposition rate. The coatings fabricated were annealed at 400-500 C for 75-100 h in Ar atmosphere or sintered in liquid lithium at 300-500 C for 75-100 h.

The parameters to fabricate coatings by the RF sputtering method are shown bellow:

(1) Target material (60mm in diameter and 5mm in thickness): AlN (99 % in purity), Y_2O_3 (99.9 %), or Er_2O_3 (99.9 %)
(2) Substrate material: SUS430 or V-4Cr-4Ti (NIFS-heat II)
(3) Gas composition: Ar or N_2 for AlN, Ar for Y_2O_3 and Er_2O_3
(4) Gas pressure: 0.6-0.8Pa
(5) Substrate temperature: 573K
(6) Distance between Target and substrate: 40mm
(7) Input RF power: 100-300W
(8) Sputtering time: 150-180 min

The coatings fabricated by RF sputtering were transparent and had interference fringes. Analyzed by XPS, Y_2O_3 and Er_2O_3 have little impurity. AlN had 1-10 at% of Oxygen impurity but they do not have any other impurity. The coatings were high crystalline by XRD analysis. Electrical resistivity of the coatings were about 10^{12}-10^{14} Ωm, these are much higher than 10^{2}-10^{4}Ωm which is considered to be needed in fusion reactor environment.

After annealing tests for the coatings, some Y_2O_3 and Er_2O_3 coatings have generated many pits and cracks on their surfaces, while AlN coatings have occurred no change. This is considered to due to difference of thermal expansion of substrates and coatings.

After sintering in liquid lithium, all of the coatings had damaged. In case of sintering test at 300 C, a part of the coating is peeled off as shown in Fig. 1. The peeling off were severe at higher temperature. Fig. 1 shows that coatings were pealed off from the surface. However, it also shows the coatings themselves were not dissolved in liquid lithium. These indicate that the high crystalline coating themselves have succeeded to stand chemical attack of liquid lithium. The peeling off occurred by sintering in liquid lithium is due to the same reason as the cracks generation by annealing test.

The results of annealing and sintering tests suggest that high crystallization of coatings improved their corrosion resistance. It must be needed to develop higher crystalline coatings in further research.

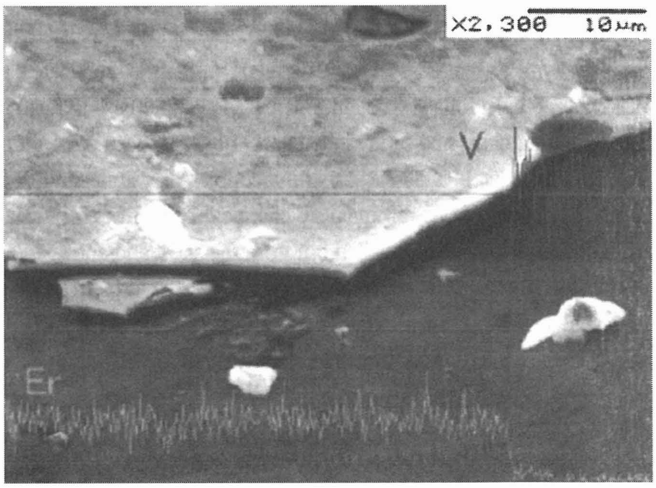

Fig. 1 SEM-EDS analysis of the Er_2O_3 coatings after sintering test.