

§5. Properties of Ceramic Coating Material AlN for CTR Liquid Blanket

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In fusion reactor designs, liquid blanket concept is a promising one to realize a DEMO reactor of high power density, because it has advantages such as continuous replacement of breeders for reprocessing, no radiation damage for breeders, larger TBR, simpler blanket structure and better thermal transfer than solid blanket concept. On the other hand, it has several critical issues; (1) a large MHD pressure drop requires large pump power, in particular in self-cooled designs, (2) liquid breeders have low compatibility with structural materials, and (3) a large amount of tritium may leak to environment due to permeation through tubing walls, particularly in case of Li17-Pb83 blanket concepts.

In order to solve these critical issues, a ceramic coating on the surface of tubing materials is proposed. The coating should have high electrical resistivity, high corrosion resistance, low tritium permeability and high thermomechanical integrity. Of course, all these properties are not necessarily required at the same time, and they depend on blanket concept. Aluminum nitride (AlN) has been already proposed as a coating material for self-cooled Li blankets and some studies have been carried out on preparation, tritium permeability and compatibility with liquid metals.

The main impurity in AlN coatings is considered to be oxygen, which may exist as Al_2O_3 . Since Al_2O_3 is severely corroded and dissolved in liquid lithium, it is necessary to reduce Al_2O_3 impurity in AlN coatings. In this study, the compatibility of sintered AlN specimens, whose impurity levels are different, and AlN coatings made on SUS430 substrates with liquid lithium were examined.

We examined two kinds of sintered AlN specimens; sintered aluminum nitride (AlN) containing Y_2O_3 as the sintering aid ($15 \times 15 \times 1$ mm; 0.75 g) and sintered AlN without Y_2O_3 ($15 \times 7 \times 1$ mm; 0.35 g). Generally speaking, some amount of oxygen is included in nitride specimens, which tends to exist as Al_2O_3 in sintering-aid-free AlN specimens. In case of AlN specimens with Y_2O_3 sintering aid, on the other hand, Al_2O_3 concentration (0.7 at.%) in the specimens became much lower by the addition of Y_2O_3 (Y_2O_3 : 0.8 at.%) than that in the sintering-aid-free specimens (1.6 at.%). Therefore, less corrosion is expected

in case of specimens containing Y_2O_3 . The corrosion experiment was carried out by a static method. In a glove box with Ar gas, a crucible loaded with specimens and 20-30 g of lithium (99.9% in purity) was set in a heating container made of AISI type 316 stainless steel. At 773K, a flow of Ar gas was introduced over the liquid. After the prescribed time, a corroded specimen was taken out from the crucible and lithium metal adhering to the corroded specimens was cleaned off with water and ethyl alcohol. The corroded specimens were analyzed as follows; (1) observation of the appearance, (2) weight change measurement, (3) XRD analysis, and (4) electrical resistivity measurement by two-probe method.

The compatibility test of AlN coatings with liquid lithium was also carried out. AlN coatings with less oxide impurity were prepared on SUS430 substrates by the RF sputtering method. In order to improve the bonding between the coating and the substrate, some AlN coated specimens were heated at 1073 K for 100 h. The electric resistivities of the AlN coatings (about 9 μm) before and after heat treatment were larger than the measurable limit of about $10^{11} \Omega\text{m}$. In a glove box with Ar gas, 0.5 g of lithium was set on the AlN-coated specimen with a SUS430 lid to avoid lithium vaporization, and the specimen was put in the heating container. At 773K, a flow of Ar gas was introduced over the specimen. After 50 h, the specimen was taken out and immersed in water for 3 h to remove the lid and for another one hour to remove lithium on the coatings. After the corrosion experiment, the AlN coatings with and without the heat treatment changed their original color of light yellow to metallic gloss with some white parts. Only the SUS430 peaks were observed in the XRD patterns of this specimen. The electric resistivity of this specimen was almost nothing. These mean almost all the AlN coating disappeared in the corrosion experiment to leave only the substrate.

Sintered AlN with or without the sintering aid of Y_2O_3 examined in lithium at 773K for 1390 h showed the slight decrease of electric resistivity because of the reduction of Al_2O_3 impurity, though AlN and Y_2O_3 components in themselves were subject to no severe corrosion. On the other hand, AlN ceramic coatings on SUS430 with high resistivity ($>10^{11} \Omega\text{m}$) fabricated by the RF sputtering method disappeared in liquid lithium at 77 K in 50 h. This may be because cracks were formed due to the difference in thermal expansion between the coatings and the substrate or the oxide formed between the two was removed by liquid lithium.