§1. Optimization of Atmosphere and Temperature for MOD Er_2O_3 Coating Fabrication on JLF-1

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Reduced activation ferritic/martensitic (RAFM) steels developed as a candidate structural material for a fusion blanket have high hydrogen permeability at high temperature. Therefore, suppression of tritium fuel permeation through RAFM steel walls will be required especially in blanket systems adopting a coolant of Flibe, Flinak, Li-Pb etc. with low hydrogen solubility. Coating of ceramic layers on the RAFM steel walls is considered to be one of solutions for the issue. Among the various ceramic materials, a small Er_2O_3 coated RAFM steel disc fabricated by the filtered arc deposition method showed a high performance in suppression of hydrogen permeation.[1)] In the present study, fabrication of Er_2O_3 coating layers by the metal organic decomposition (MOD) process has been studied aiming for large area coating on large blanket components. In the MOD process, a substrate plate is immersed in organic liquid containing Er and baked after withdrawal. The baking process in oxidation atmosphere is indispensable for the MOD coating fabrication for removal of organic components and production of oxide coatings on a substrate. However, in our previous studies, it has been found that the surface of the RAFM steel substrate is easily oxidized by baking process in air and thick oxidation layer has been produced between the substrate and Er_2O_3 coating layer. The thick oxidized layer was Fe_2O_3 whose thermal expansion coefficient is significantly larger than that of Er_2O_3 and it is considered that production of this layer degraded the coating performance as a hydrogen permeation barrier[2)] and chemical stability in a blanket coolant[3)] in our previous studies. These performances have been improved by reducing O_2 partial pressure in the baking process. Fig. 1 shows a change of the oxidized layer on a substrate surface. A thinner Cr_2O_3 layer, which has a thermal expansion coefficient close to that of Er_2O_3, was produced by baking with a low O_2 partial pressure.[2,3)]

Ranges of the baking temperature and O_2 partial pressure to suppress the production of Fe_2O_3 oxidized layer, i.e. condition to produce a thin Cr_2O_3 layer, have been examined by controlling the O_2 pressure in Ar gas flow. The result of the examination is shown in Fig. 2. The ranges have been examined for RAFM steel JLF-1 (Fe-9Cr-2W) and also for commercial ferritic steel SUS430. The minimum baking temperature for decomposition and removal of the organic components is ~450 ^oC. The maximum temperature for JLF-1 should be ~700 ^oC for avoiding changes of the property optimized as a blanket material.

The result indicates that the production of Fe_2O_3 oxidized layer on a SUS430 substrate could be suppressed even in air at temperature of >600 ^oC. In case of a JLF-1 substrate, reduction of O_2 partial pressure to ~1 Pa was required for suppression of the Fe_2O_3 layer. The baking temperature of >650 ^oC was also required for JLF-1. The distribution of the plots in Fig. 2 indicates that the temperature is important factors for suppression of the Fe_2O_3 layer in addition to O_2 partial pressure control. In the element depth profile of Er_2O_3-coated JLF-1 plate measured with XPS, large increase of the Cr concentration can be observed at the substrate surface (Fig. 1 (b)). It is considered that diffusion of Cr from inside of ferritic steel substrate to the surface is significantly important for control of the surface oxidation. The high temperature baking condition is required for enhancement of the fast Cr diffusion.

Since the preferable fabrication condition to suppress the influence of substrate surface oxidation has been made clear by the present result, the study on the MOD coating fabrication can proceed into demonstration of coating fabrication on tubes and examination of the performance as a hydrogen permeation barrier. The MOD method can also be applied for fabrication of other candidate oxide coatings of ZrO_2, Y_2O_3 etc. proposed for hydrogen permeation barrier and electrical insulation in a fusion blanket.

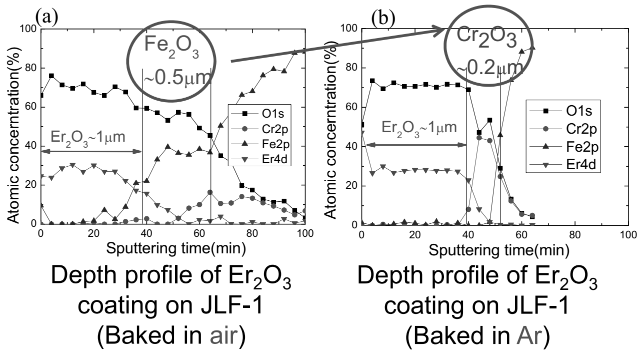

Fig. 1 Element depth profiles of Er_2O_3-coated JLF-1 plates. (a) Baked in air. (b) Baked in Ar (O_2: ~1 ppm as impurity) .

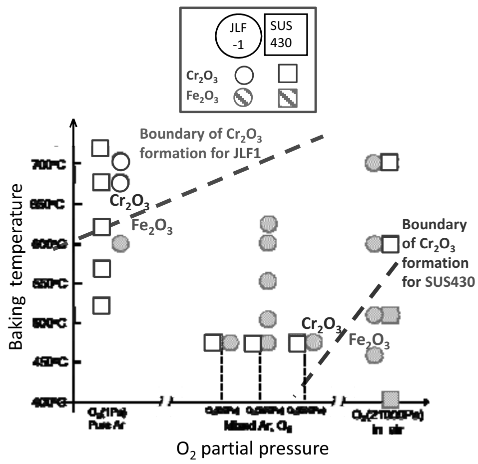

Fig. 2 Influence of baking temperature and O_2 partial pressure on the oxidized composition.

1) Chikada,T. et al. Nucl. Fusion **51** (2011) 063023.
2) Zhang, D.X. et al.: Fus. Sci. Technol, **60**(2011)1579.
3) Zhang, D.X. et al.: Fusion Eng. Des. **86**(2011)2508.