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Surface Characteristics of Metal Fuel Rod Prepared by Using Quartz and Graphite Molds

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1. Introduction

In the production of metal fuel rod with U-Zr as a basic composition, manufacturing methods are selected according to the characteristics of each country taking into consideration the advantages and disadvantages of each casting method [1-3]. The metal fuel fabrication is progress in which raw materials are melted in a crucible with high-temperature vacuum atmosphere, this melt is injected into a casting mold, cooled in a furnace, and then withdrawn from the furnace. In this study, quartz and graphite molds were manufactured as molds used in the fabrication of metal fuel rod, and a metal fuel having the composition of U-10Zr-5RE was prepared by using them. And the reaction characteristics on the surface of the prepared metal fuel rods was observed and analyzed.

2. Experimental and Analysis

The quartz and graphite molds used in the metal fuel rod manufacturing process are in contact with the metal melt for about 7 to 8 seconds at a high temperature of about 1500°C for a short time [4]. A reaction preventive coating layer is adhered to the inner surface of the quartz and graphite mold to prevent the Si or C element from eluting of quartz or graphite material [5], respectively. In this process, a ceramic slurry solution having a very low reactivity with the hot melt is applied as a protecting layer. In this study, an yttria slurry solution was used. SEM and EDS were used for the surface analysis of metal fuel rod, and the reaction characteristics at the contact surface after rod withdrawal were analyzed. Experimental progress for metal fuel rod fabrication is shown in Fig.1.

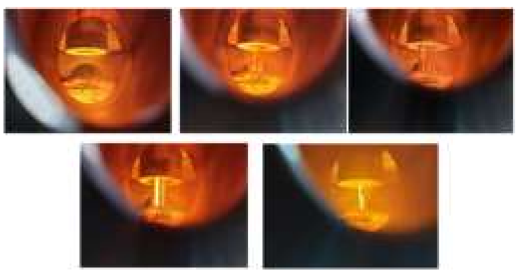

Fig.1. Fabrication procedure of U-10wt.%Zr-5wt.% RE's composition metal fuel rod.

3. Fuel Rod Fabrication and Surface Characteristics

Fig.2 briefly shows the separation of the fuel rod from the mold assembly after manufacturing the metal fuel. The upper of the figure shows the shape of a metal fuel rod manufactured using a quartz mold, and the lower part shows the fuel rod obtained from the graphite mold. Before manufacturing a metal fuel slug using a quartz mold or a graphite mold, in order to prevent the reaction between the molten metal and the mold material, internally coat and dry were progressed with the Y_2O_3 slurry solution at each mold inside, beforehand.

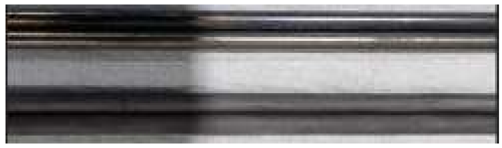

Fig.2. Metal fuel rods fabricated from quartz mold and prototype graphite mold.

In the case of a metal fuel slug made from a quartz mold, the luster of the fuel rod surface was observed as a metallic luster color than that of a fuel rod made from a graphite mold. The fuel rod surface obtained from the graphite mold seems to have fine black particles attached to the surface in general. In order to determine the surface characteristics of the metal fuel rod manufactured above, the middle portion of metal fuel rod was cut.

After preparing the specimens for surface analysis, they were mounted and polished using with epoxy resin, and then observe the surface using SEM. Also, elemental analysis was performed on the surface using the EDS function of SEM. The following Fig.3 shows the SEM photographs of the surface of the metal fuel rods prepared of quartz and graphite molds.

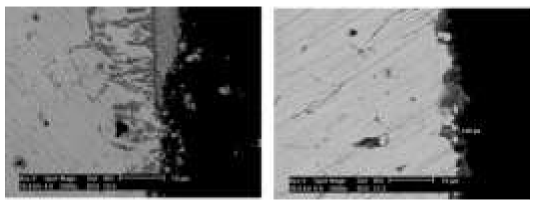

Fig.3. SEM photographs of metal fuel rod fabricated from quartz and graphite molds

The left of Fig. 3 shows the surface of a metal fuel rod made using a quartz mold, and the right is a case where a graphite mold is used. When the surface of the metal fuel rod is enlarged by 2000 times, the Y_2O_3 coating layer used as a reaction protection barrier exist fine on the surface of the fuel rod made from a quartz mold. But the reaction protection layer does not exist on the metal fuel rod surface made from the graphite mold.

The surface roughness of the metal fuel rod was observed to show a lower value in the case of the quartz mold. In the case of the graphite mold, the size of the surface roughness was observed to be about 5㎛ thick, and it is thinner than that of graphite mold. In order to understand the properties of the mold material, a constituent analysis was performed based on the data obtained in Fig. 3. In the case of quartz mold, only the data for Si and Y elements, and for the graphite mold were selected for C and Y elements. The intensity that appeared at each analysis point was simply shown in Fig. 4.

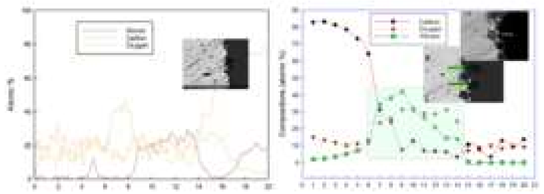

Fig. 4. SEM-EDS point analysis profiles and atomic % compositions at analysis points.

The left picture of Fig. 4 is a picture that analyzes the composition of Si, C, O elements, which are elements related to the mold, in atomic% by performing elemental analysis on the surface of a metal fuel rod manufactured using a quartz mold. The right picture is a plot of the analysis results for C, O, and Y elements in the composition elements related to graphite mold. The analysis thickness is about 5 μm, and on the surface of the fuel rod made of a quartz mold, Si, the main component of quartz, was observed on the surface. In the case of the graphite mold, C appeared on the surface of the fuel rod, but its depth was judged to be insignificant.

4. Conclusions

The yttria slurry solution used as a reaction barrier was replaced with yttria spray aerosol and applied to quartz and graphite molds to manufacture metal fuel rod. After manufacturing the metal fuel rod, it was easier to separate the metal fuel rods and recycle them. U-10Zr-3RE composition showed the possibility of reuse for coating the inside of the quartz tube with spray coating solution about three times, while graphite molds were separable, but natural separation was difficult because the graphite-type geometries were slightly different from quartz molding. For graphite molds, further research on inner flatness improvement and prevention of leakage at prefabricated connections will be needed.

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