Preliminary Evaluation on Reaction Loss Rate of $NdYO_3$ Plasma-spray Coated Crucible

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1. Introduction

U-TRU-Zr-RE metal fuel slugs have been fabricated with injection casting process operating under atmospheric pressure [1]. TRU is transuranium element, which refers to radioactive materials that are heavier than uranium. RE is composed of rare-earth elements consisting of 53wt.%Nd, 25wt.%Ce, 16wt.%Pr, 6wt.% La. Metal fuel has been melted in graphite crucible plasma-spray coated with Y_2O_3 to prevent melt/material interactions [2]. Since reactive RE is included during pyro-processing process, coated Y_2O_3 layer is reacted with RE in metal fuel and forms reaction products of RE-Y-O system, producing considerable amount of fuel loss and large amounts of radioactive crucible waste.

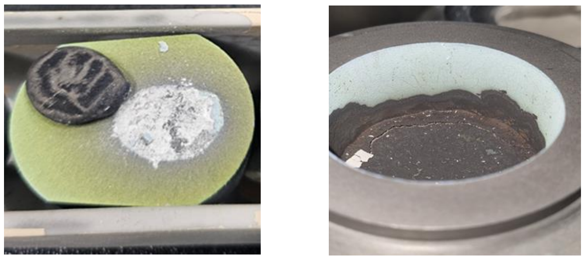
In this study, alternative $NdYO_3$ has been introduced as a promising candidate material for plasma-spray coating on a graphite crucible [3]. $NdYO_3$ coatings were prepared and characterized related to interaction with U-10wt.%Zr-5wt.%RE alloy at elevated temperature. Reaction loss rate during melting process has been evaluated, based on interaction study between U-10Zr-5RE and coating layer.

2. Methods and Results

A plasma-spray coating methods were applied to graphite coupon with a diameter of 30 mm and graphite crucible with a diameter of 70 mm, respectively. Nd_2O_3-50mol.%Y_2O_3 powders, ranging from 20 µm to 80 µm in size, were coated onto graphite crucible materials. A coating approximately 250 µm thick was deposited using a torch input power of approximately 15 kW, an arc current of approximately 750 A, and a plasma gas of a mixture of argon and helium. Sessile drop test and melting test of U-10Zr-5RE alloy on $NdYO_3$ plasma-spray coated crucible materials were performed as shown in Table 1 and Fig. 1. In order to demonstrate the reaction characteristics with U-10Zr-5RE melt at elevated temperature, the graphite coupons coated with $NdYO_3$ were investigated through sessile drop test at 1500 °C. U-10Zr-5RE alloy was melted in the graphite crucible coated with $NdYO_3$ at 1470 °C under an inert

Table I. Conditions of melting test at elevated temperature

Experiment parameter \ Test method	Sessile Drop Test	Melting Reaction Test
Alloy composition (wt.%)	U-10Zr-5RE	
Melt mass (g)	3	740
Melting temp. (°C)/ holding time (min)	1500/10	1470/10
Atmospheric pressure (Torr)	760	360
Substrate materials/type	Graphite/ coupon	Graphite/ crucible
Coating method/material/ thickness (㎛)	Plasma-spray coating/ $NdYO_3$/250	



(a) (b)

Fig. 1. Images of $NdYO_3$ plasma-spray coated graphite materials after melting test: (a) coupon and (b) crucible.

atmosphere with the same condition with actual melting condition. The microstructure of the plasma-sprayed $NdYO_3$ crucible materials after sessile drop test and melting test was investigated by scanning electron microscopy (SEM) combined with energy dispersive spectroscopy (EDS).

After sessile drop test and melting test of U–10Zr-5RE alloy, alternative $NdYO_3$ coated materials, composed of Nd_2O_3-50Y_2O_3, was shown with a discrete coating interface between $NdYO_3$ coating layer and U-10Zr-5RE alloy. Some penetration layer of U-10Zr-5RE melt with a thickness of about 12 ㎛ was formed along grain boundaries. Conventional Y_2O_3 layer coated on graphite materials, indicated a significant penetration layer of U-10Zr-5RE melt with the thickness ranging from 46 ㎛ to 100 ㎛ formed along grain boundaries [4].

After melt reaction test, the penetration depth of U-10Zr-5RE alloy was reduced by about 81%, compared to conventional Y_2O_3 coating layer. Hence, the $NdYO_3$

coating showed a promising performance in the reduction of the fuel loss during fabrication of metal fuel.

Table II. Preliminary results on reaction loss rate of $NdYO_3$ plasma-spray coated specimens, compared to Y_2O_3 plasma-spray coated specimens [4]

Test method / Result	Sessile Drop Test		Melting Reaction Test	
Type	Coupon		Crucible	
Coating material	(Conventional) Y_2O_3	(Alternative) $NdYO_3$	(Conventional) Y_2O_3	(Alternative) $NdYO_3$
Average Reaction thickness (μm)	74	12	73	13
Reaction reduction rate (%)	-	82	-	81

3. Conclusions

Alternative $NdYO_3$ plasma-spray coated layer was introduced on the graphite crucible materials to control the loss rate due to interaction between U-10Zr-RE alloy and melting crucible during fabrication of metal fuel. After sessile drop test and melting test of U-10Zr-5RE alloy at elevated temperature, alternative $NdYO_3$ plasma-spray coated materials, composed of Nd_2O_3-$50Y_2O_3$, was shown with a discrete coating interface between $NdYO_3$ coating layer and U-10Zr-5RE alloy. The penetration depth of U-10Zr-5RE alloy was reduced by 81.5%, compared to conventional Y_2O_3 coating layer. Hence, alternative $NdYO_3$ plasma-spray coated layer showed promising performance in the reduction of fuel loss during fabrication of the metal fuel.

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