

## Electrodeposition of chromium on ferritic/martensitic steel (FMS) for a fuel cladding chemical interaction (FCCI) barrier coating

Seong Woo Yang\*, Ho Jin Ryu, Jun Hwan Kim, Byoung Oon Lee, Chan Bok Lee  
Recycled Fuel Development Division, Korea Atomic Energy Research Institute, Yuseong, Daejeon, 305-353  
\*Corresponding author: swyang@kaeri.re.kr

### 1. Introduction

Sodium-cooled fast reactor (SFR) is being developed for an efficient use of U resources and an actinide management. Metallic fuel is considered to be used in a SFR because of its good thermal conductivity, proliferation resistance, compatibility with sodium, etc., unlike ceramic fuel. However some weak points exist and the main one is a fuel cladding chemical interaction (FCCI) because eutectic melting occurs by a chemical interaction between components of a fuel and a cladding.

Diffusion barrier concept was proposed in order to prevent this interaction. Ryu et al. observed the performance of some barrier materials in out-of-pile tests, with Zr, Nb, Cr, V, Mo, Ti, and Ta foils [1]. In his study, Cr and V show a good performance as barrier materials.

To form barrier materials on the surface of ferritic/martensitic steel (FMS), as a representative proposed cladding material, various methods can be used. Among them, an electrodeposition is very cheap and easy. Electrodeposition of Cr is used widely in automotive, aerospace, mining and general engineering, etc [2]. On the other hand, electrodeposition of V needs a high energy and complex equipments due to the need of a molten salt [3].

In this study, electrodeposition behavior of Cr on the surface of FMS was investigated by controlling the current density and deposition time. Cr-deposited FMS disks were used for interaction tests with U-10Zr to evaluate the diffusion barrier performance.

### 2. Experimentals

#### 2.1 Cr deposition

Cr deposition was prepared in a Sargent bath containing 250 g/l of chromic acid and 2.5 g/l of sulfuric acid at a temperature of 50°C. Current density and deposition time was controlled to search for the optimum condition. The apparatus was composed of power supply, a stirring and a heating system as shown in Fig. 1. The anode metal is Pb-Sn alloy. The electrolyte was circulated by a magnetic stirrer bar.

The target materials (cathode) were HT9 disks. Diameter and thickness were 8 and 1.5 mm, respectively. Before an electrodeposition, it was polished, pickled and cleaned. After an electrodeposition of Cr, thickness was observed by an optical microscopy (OM). Scanning electron microscopy (SEM) and energy dispersive X-ray spectroscopy (EDX) were used for a detailed observation.

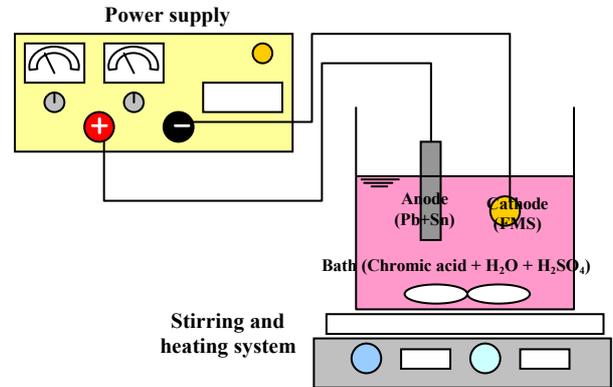


Fig. 1. Apparatus for Cr deposition on FMS

#### 2.2 Interaction test

U-10Zr was used to simulate the SFR fuel material. Both Cr-deposited HT9 and U-10Zr were stuck to each other by a fitting. Interaction test was carried out in a heat treatment furnace under a vacuum atmosphere,  $10^{-4}$ ~ $10^{-5}$  Pa range. Interaction temperature and time were 800 °C, 25 hours.

After a test, the specimen was cooled by water to room temperature. Adhered specimen was cut, mounted, polished for SEM-EDX observation.

### 3. Results and Discussions

#### 3.1 Deposited Cr

The current density was controlled from 15 to 177 A/dm<sup>2</sup> and the deposit time was 10 min to seek the best deposition condition. Below 25 A/dm<sup>2</sup>, Cr was hardly plated on the surface of HT9. Fig. 2 show the comparison of deposited Cr layer between 70 and 177 A/dm<sup>2</sup>. As the current density was large, the thickness of plated Cr was thick, but the difference of thickness between the edge and central area was big due to the existence of current gradient. Therefore the low current density was profitable to form uniform Cr layers. In this study, the current density of 35 A/dm<sup>2</sup> was used to prepare the interaction test specimen.

Fig. 3 shows the linear mapping result of Cr and Fe formed at 35 A/dm<sup>2</sup> and 10 min by SEM/EDX. The fine Cr layer of 3~4 μm was formed in this condition. In order to undertake the interaction test, Cr deposited HT9 disks of 10, 20, 30 μm (30, 60, 90 min deposition, respectively) in thickness were prepared.

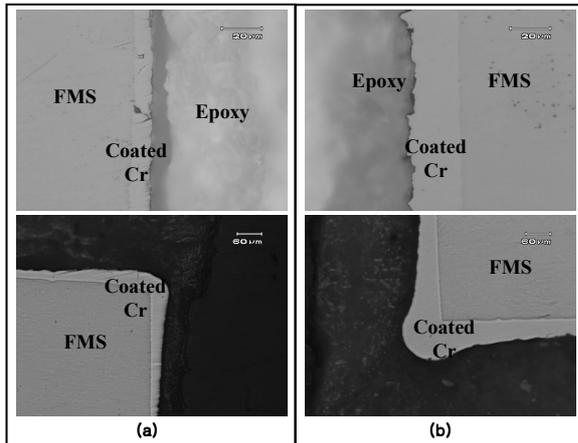


Fig. 2. Comparison of formed Cr layer (10 min)  
 (a) 70 A/dm<sup>2</sup> (b) 177 A/dm<sup>2</sup>

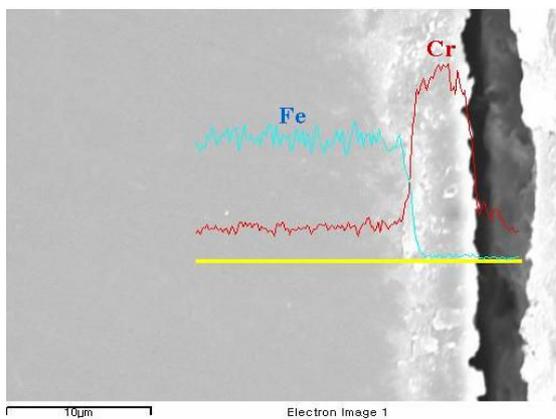


Fig. 3. Deposited Cr layer (35 A/dm<sup>2</sup>, 10 min)

### 3.2 Interaction test with U-10Zr

The interaction test was carried out between Cr-deposited HT9 and U-10Zr at 800°C under a vacuum. Fig. 4 shows the SEM/EDX image of the interaction test between U-10Zr and Cr-deposited HT9 (90 min deposition). Although the annealing temperature was well above the eutectic melting temperature (~725°C) for the diffusion couple, no interaction was observed due to the presence of a Cr layer between the U-10Zr and HT9. U was not detected inside the Cr layer. However, U penetrated into the Cr layer along the boundary of the Cr layer and cracks. A similar result was observed in another Cr-deposited HT9. Because a penetration of U can cause a eutectic melting of a FMS cladding, a supplementary treatment is necessary in order to remove the cracks and boundaries.

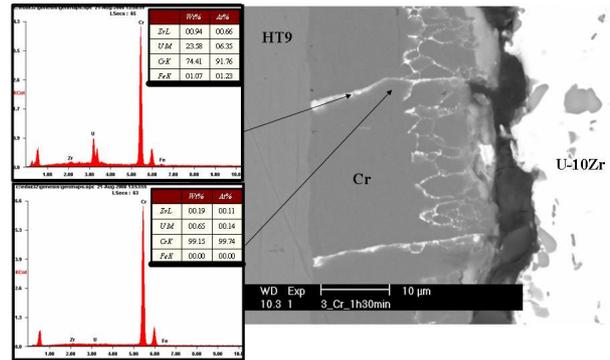


Fig. 4. Interaction between formed Cr layer on surface of HT9 (90 min deposition) and U-10Zr

## 4. Conclusions

Electrodeposition of Cr on FMS (HT9) was carried out and the optimum condition was acquired. Although electrodeposited Cr layer prohibit an eutectic melting of a U-10Zr vs. FMS diffusion couple at 800°C, an additional heat treatment is needed to accomplish the role of FCCI barrier materials due to the vertical cracks through the coated layer.

## ACKNOWLEDGEMENTS

This study was supported by the National Nuclear R&D Program of the Ministry of Education, Science and Technology (MEST) of Korea.

## REFERENCES

- [1] H. J. Ryu, B. O. Lee, S. J. Oh, J. H. Kim, and C. B. Lee, Performance of FCCI Barrier Foils for U-Zr-X Metallic Fuel, Proceedings of the Nuclear Fuels and Structural Materials for the Next Generation Nuclear Reactors (NFSM-2008), Jun. 8-12, 2008, Anaheim, CA.
- [2] C. Fontanesi, R. Giovanardi, M. Cannio, and E. Soragni, Chromium electrodeposition from Cr (VI) low concentration solutions, Journal of Applied Electrochemistry, vol.38, p.425, 2008
- [3] P. K. Tripathy, J. C. Sehra, D. K. Bose, and R. P. Singh, Electrodeposition of vanadium from a molten salt bath, Journal of Applied Electrochemistry, vol.26, p.887, 1996