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Development of Cr Electroplated Cladding Tube for preventing Fuel-Cladding Chemical Interaction (FCCI)

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1. Introduction

A Sodium-cooled Fast Reactor (SFR) has been considered as one of the most probable reactors for the next-generation power plant in Korea because of its ability to maximize fuel utilization by recycling light water reactor (LWR) spent fuel. Metal fuel has been selected as a candidate fuel in the SFR because of its superior thermal conductivity as well as enhanced proliferation resistance in connection with the pyroprocessing. However, metal fuel suffers eutectic reaction (Fuel Cladding Chemical Interaction, FCCI) with the fuel cladding made of stainless steel at reactor operating temperature so that cladding thickness gradually reduces to endanger reactor safety. In order to mitigate FCCI, barrier concept has been proposed between the fuel and the cladding in designing fuel rod. Regarding this, KAERI has initiated barrier cladding development to prevent interdiffusion process as well as enhance the SFR fuel performance. Previous study revealed that Cr electroplating has been selected as one of the most promising options because of its technical and economic viability [1]. This paper describes the development status of the Cr electroplating technology for the usage of fuel rod in SFR.

2. Development of Cr Electroplating Technology

2.1. Parametrical Studies

Preliminary electroplating has been tried using Sargent bath. Parametrical studies like current density and bath temperature have been scoped over HT9 coupon. Specimen plated as 50^{o}C in temperature and 35A/dm^2 in current density (Hard Cr) revealed to generate numerous cracks across thickness so that uranium penetrated through a certain depth after the diffusion couple study in U-10Zr, as shown in Fig.1(a). Although altering plating condition like 80^{o}C in bath temperature and 56A/dm^2 in current density significantly reduced the number of crack, still it did not eliminate cracks totally.

2.2. Optimization

During plating process, Cr atoms were deposited at the cathode and formed into Cr grain. As the thickness of plating increases, residual stress would generate so that it acts as a driving force to generate crack between Cr grains [2]. In this regards, it has been tried to reduce the crack by alleviating internal stress. Pulse plating as well as post-heat treatment has been tried over the plated specimen and showed that they have a positive effect on the plating performance as shown in Fig. 1(b) [3].

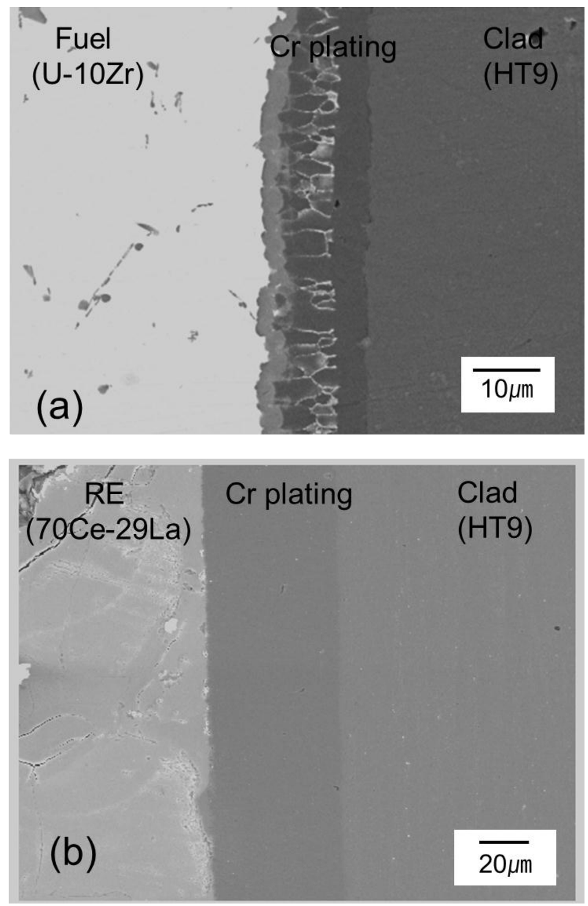

Fig. 1 Performance of the Cr electroplating after diffusion couple study (a) Hard Cr, (b) Post-heat treatment after plating

3. Application to Cladding Inner Surface

3.1. Manufacture of Cr-plated cladding tube

Application to the inner surface of the cladding has been tried by using electroplating technology. Anode wire has been inserted at the center of cladding tube which is used as cathode, while electrolyte has been continuously circulated through the cladding inner surface. Periodic flow reversal and tube rotation has been applied to secure the uniformity of the plating thickness along the axial direction. Cr plating was successfully carried out at the inner surface of Gr.92 tube having 4.6mm inner diameter and 170mm length to coat 20μm thickness, as shown in Fig. 2. It has been prepared as the cladding tube for HANARO irradiation.

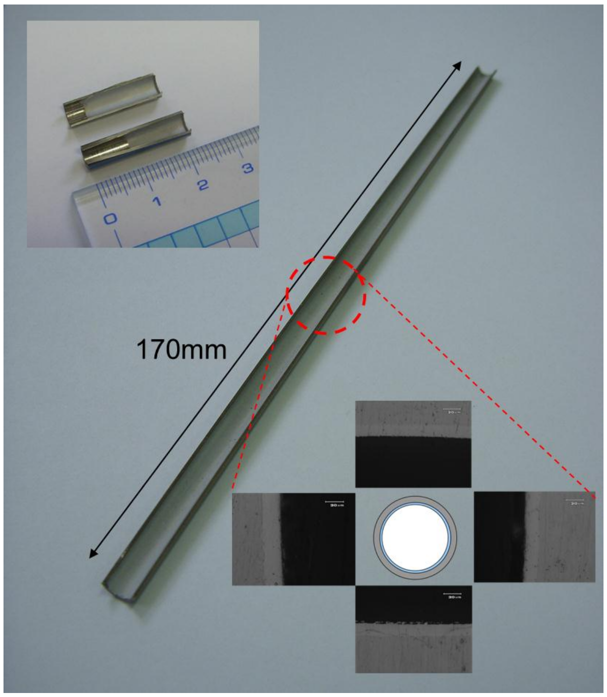

Fig. 2 Manufacture of Cr electroplated tube coated at the inner surface

3.2. In-pile property

Irradiation at HANARO reactor has been conducted in order to verify the performance of KAERI-developed metal fuel. Test performed at the OR-5 irradiation site, which ran for 182EFPD. Maximum burnup was achieved at 3at%, where cladding inner wall temperature was calculated to be around at 600^{o}C. Microstructural observation of the irradiated fuel rod revealed that Cr was effective in preventing interdiffusion between fuel and cladding, as shown in Fig. 3. Optimized plating process developed at the previous coupon study will be introduced at the next irradiation test.

4. Conclusion

This paper summarizes the status of Cr electroplating technology to prevent FCCI in metal fuel rod. It has been selected for the ease of practical application at the tube inner surface. Technical scoping, performance evaluation and optimization have been carried out. Application to the tube inner surface and in-pile test were conducted which revealed as effective. Further study will be focused on the optimization of the Cr plating to the tube geometry, mechanical compatibility between barrier and cladding.

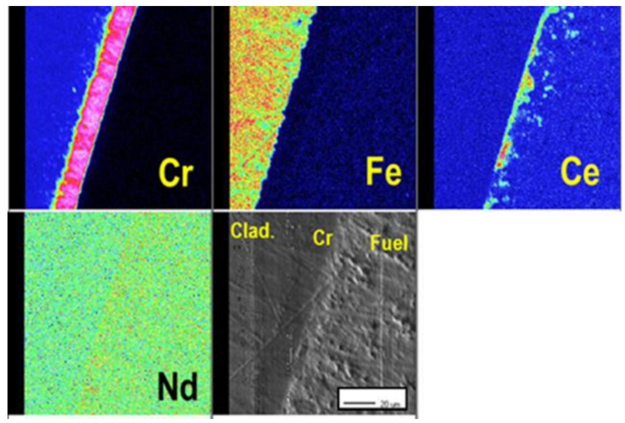

Fig. 3 Microstructure of the Cr electroplating after irradiation in HANARO for 3at%

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