Transactions of the Korean Nuclear Society Autumn Meeting
Yeosu, Korea, October 25-26, 2018

Screening test of candidate CRUD reduction materials

Jin-Ho Jeong*, Kwang-Ho Lee
Korea Hydro & Nuclear Power Co., Ltd., Central Research Institute, Daejeon, 34101, Republic of Korea
**Corresponding author: jinho.jeong@khnp.co.kr*

1. Introduction

Recent few years, operation environment of nuclear power plants has been much influenced by crud due to extended life cycle and high burnup operation. Crud, corrosion products made up of oxide of Fe, Ni, Cr, is produced from steam generator tube and pipes, etc. Crud is migrated to reactor core through primary system coolant. This crud is deposited on upper fuel cladding where sub-cooled nucleate boiling is occurred which shown in Fig. 1

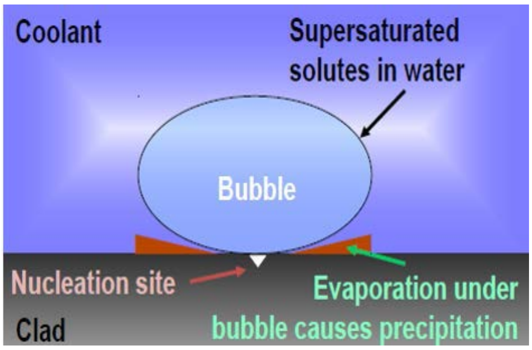


Fig. 1 Proposed mechanism for crud's initial formation on fuel cladding [1]

Crud raise cladding surface temperature and accelerate the oxidation due to its low thermal conductivity. In addition, if soluble boron is accumulated to its porous structure, this cause crud induced power shift (CIPS) [2].

Because crud influenced to safety operation, most of nuclear power plant conduct chemical cleaning operation and ultrasonic fuel cleaning to remove the crud in reactor coolant system and fuel.

In recent, EPRI and MIT conducted the research about special coating materials which prevent deposition of crud to block the fundamental reason [1, 3]. EPRI evaluated crud reduction ability of various material under atmospheric pressure and PWR chemical conditions. They selected the ZrC, ZrN, TiC and TiN as candidate coating materials.

In Korea, Korea Atomic Energy Research Institute (KAERI) developed CrAl coating of accident tolerance fuel concept [4]. They also conducted crud deposition test of this coating materials under PWR chemistry conditions.

In this study, we made two coating cladding, CrAl, TiN concerning manufacturing problem and evaluated coating stability to consider the possibility of manufacturing and application.

2. Experimental

CrAl and TiN were coated on zircaloy-4 base material using arc ion coating methods (Fig. 2). Each specimens were coated with 10 microns of thickness. Specimens were cut with 3 mm using accurate specimen cutting machine for microscopy and ring tensile test.

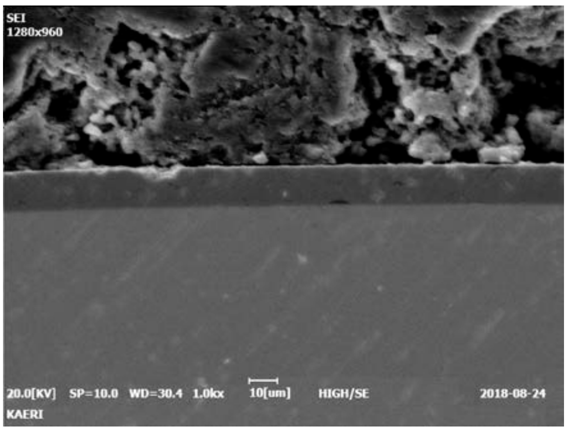
Fig. 2 Arc ion plating apparatus (developed by KAERI)

Specimens for scanning electron microscopy (SEM) were mounted by resin to confirm the coating quality

Methods to confirm bonding stability of coated material are scratch test and ring tensile test. In this study, we conducted ring tensile test and observed fracture surface of each coated specimens. Instron 3367 universal material test machine was used for ring tensile test and strain rate was set with 0.1mm/min. Each tests were repeated three times.

3. Results

Fig. 3 showed boundary of coated specimens. This showed that bonding stability of each specimens made by arc ion plating method was well bonded.



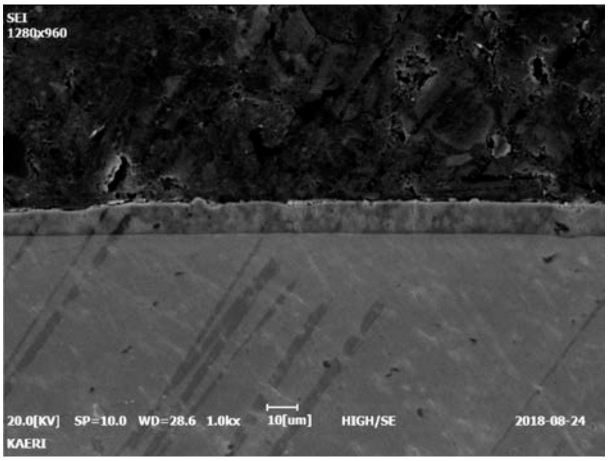


Fig. 3 SEM images of CrAl coated specimen (upper) and TiN coated specimen (lower)

Fig. 4 showed fracture surface after ring tensile test. In case of CrAl coated specimens, coating material was perfectly bonded on base material even after specimen underwent fracture. In case of TiN, however, coating material is hardly seen near the fracture surface. Only some fragments were observed. This meant that coated material might peel out when certain tensile stress were loaded.

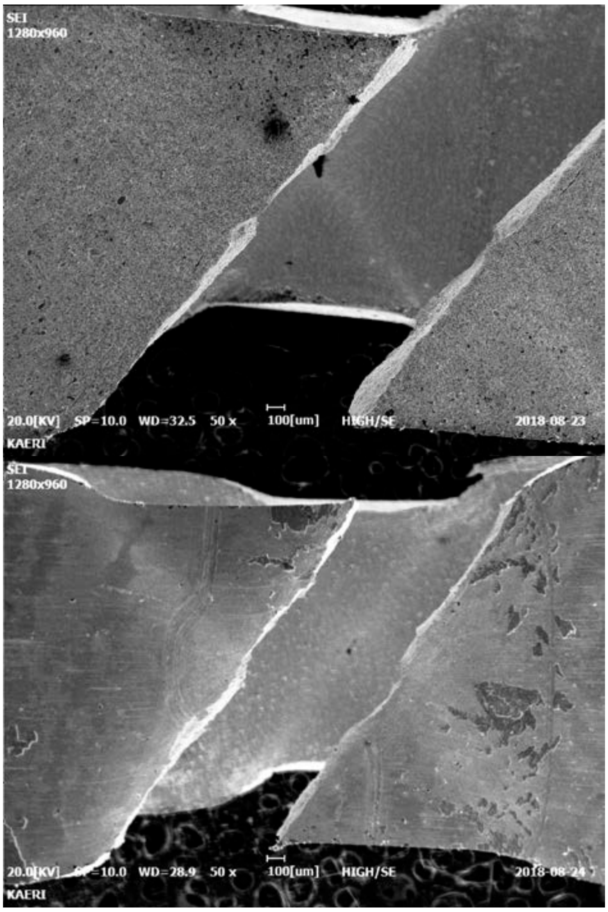


Fig. 4 SEM images after ring tensile test of CrAl (upper) and TiN (Lower)

Because CrAl coating is metal, it has enough ductility even though specimen underwent fractured. However TiN is ceramic material, it is more brittle than CrAl. It could cause the separation of coated material when tensile stress is applied such as thermal cycling or internal pressure rise, etc. Of course, base material is not damaged even if coated material is separated entirely. So, fuel reliability was not affected although all of coated material were lost. But it might affect chemical conditions of reactor coolant system and may burden chemical and volume control system or shutdown chemistry system to remove separated coating materials. Therefore, TiN is not suitable coating material to apply NPPs according to ring tensile test under room temperature.

4. Conclusions and Future plan

In this study, we made coated cladding samples and conducted bonding stability test to screen candidate crud reduction materials. According to ring tensile tests, TiN coating has potential risk of peeling out the coated material. Of course, additional tests will be conducted to screening the candidate materials. In the future, the other material, ZrN, also will be examined. In addition, heat treatment test under 500 ^{o}C and ring tensile test under reactor operation temperature. We will select the final candidate material and conduct simulated crud deposition loop test after summarize these screening test results.

Acknowledgments

This work was supported by the research and development program of National Research Foundation (NRF) grant funded by the Ministry of Science and ICT (NRF-2018M2A8A5013698)

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