

A study of Microstructure and Electrochemical Properties of Neutron Absorber

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1. Introduction

A dense storage rack is installed in 16 domestic nuclear power plants and the Spent Nuclear Fuel (SNF) is under wet storage. In a SNF pool, fission products are generated by nuclear fission at uranium fueled nuclear reactors. Therefore, neutrons are so unstable so that they must be absorbed. Especially, the materials used as the neutron absorber are sandwiched shape between Boron-Carbide and Aluminum. In this situation, neutron absorbers have been used to inhibit neutronic coupling between fuel assemblies. Degradation phenomena of neutron absorbers are observed in monitoring specimens through-out the world at present, which is a risk factor in changing and transferring criticality. If degradation persists, pitting corrosion is observed, which means that there is a risk of boric acid leakage and fragmentation. [1,2]

When the corrosion in the neutron absorbers occurs under radiation and high temperature condition, it will negatively affect the surface and cross-section of the neutron absorber. It affects the density and properties of intermetallic particles, which weakens storage stability and causes public perception of nuclear safety.

For neutron absorber materials that can be used for a long term, it is necessary to study the degradation mechanism of material performance due to environmental corrosion.

During normal operation, when it is considered the structure of the neutron absorber, the core part (Aluminum 1070 + Boron-Carbide) may be exposed to the water, so further determination of the corrosion behavior is necessary.

The main cause of the corrosion behavior about neutron absorber is believed to be Helium gas generation by the neutron absorption reaction of Boron-Carbide, however, it is also important to determine the corrosion behavior due to the fundamental corrosion.

In this study, it is investigated the degradation behavior of Aluminum and Boron-Carbide corrosion. Corrosion behavior is analyzed through electrochemical techniques such as Open Circuit Potential (OCP) and Potentiodynamic Electro-polarization (PE). And its microstructure and chemistry are analyzed by Scanning Electron Microscopy (SEM).

2. Experimental

2.1 Material Preparation

For electrochemical experiments, the specimen geometry is presented in the Figure 1., and its dimension was 2.54 cm * 5.1 cm * 0.7cm respectively. The sample consists of Aluminum 5052 outer clad tightly to an inner core of Aluminum 1070 with Boron-Carbide, it is composed of sandwiched shape as described in introduction part. It is confirmed that the Aluminum 5052 cladding material is about 150 μm through figure 1 by SEM.

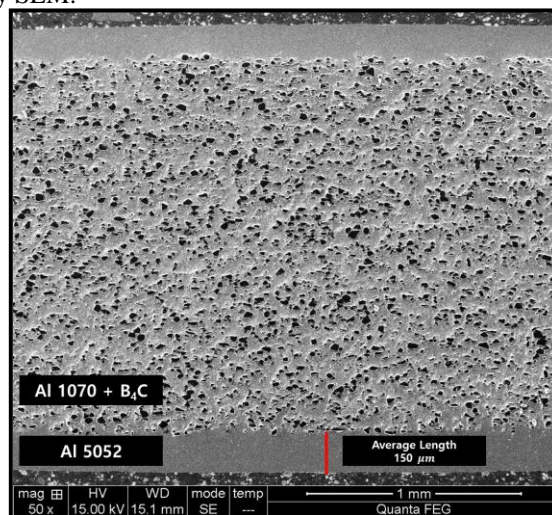


Figure 1. Cross section results about neutron-absorber

For the electrochemical experiments, the cross section of specimen is prepared to investigate the galvanic corrosion and pitting corrosion between outer clad and the inner core, Boron-Carbide surrounded Aluminum 1070 respectively. Before the electrochemical experiments, the cross section of the composite was polished with 320, 400, 600, and 800 grit Si-C papers and 0.25 μm diamond suspension.

2.2 Electrochemical Experiments

Initial corrosion behavior is important to analysis the pitting corrosion, it can be confirmed by using PE and OCP measurement. PE is a method of controlling potential and current. This combines the potential and

current relationship to erosion cells operating over a wide range of oxidation conditions and produces a polarization curve that represents an electrochemical reaction.

The specimens for electrochemical experiments were positioned into an electrochemical cell with 1.0cm² surface immersed in air saturated and 3.5 wt.% NaCl solution for 3600 seconds to measure OCP and PE.

For PE, it was conducted by the potential at open-circuit with a scan rate of 0.1667 mVs⁻¹ from -0.5 V to 1.5V (vs S.C.E).

The potentiodynamic polarization curves were plotted with potential vs current density for experiments, and they were performed in neutron absorber's cross section and surface respectively.

After electrochemical analysis, the microstructure was analyzed using SEM for the surface and cross section of the specimens.

3. Results and Discussion

3.1 OCP and PE results of Neutron Absorber

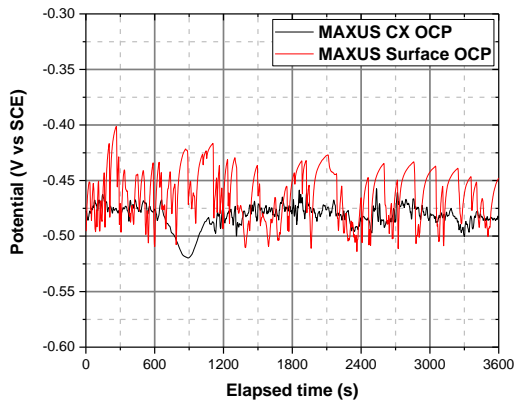


Figure 2. OCP result of Neutron Absorber

In figure 2, it can be confirmed the OCP result of neutron absorber. Experiments were performed at 3.5 wt.% NaCl solution. The OCP potential is the potential value of the working electrode for the reference electrode when the potential or current is not subject to corrosion. Values for OCP are not stabilized on both surfaces and cross-section as it can be seen in Figure 2. Unstable OCP curves are associated with pitting corrosion and galvanic corrosion.

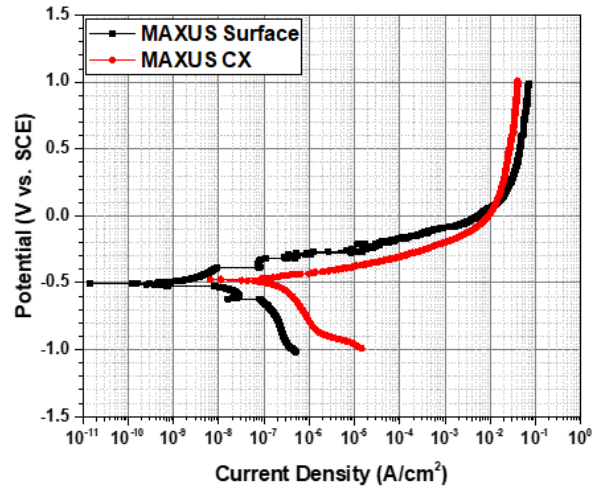


Figure 3. PE result of Neutron Absorber

The potentiodynamic polarization curves result of the specimen surfaces and cross-section are presented in Figure 3. Some of the passive regions were short in the polarization curves performed on the surface. This passivity property appears to be lost due to pitting corrosion of surface Aluminum 5052 cladding.

3.2 Cross section of Neutron absorber, after electrochemical test

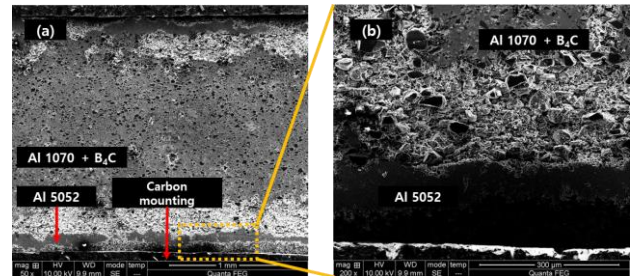


Figure 4. After PE experiments
(a) Cross section and (b) Magnified cross section

Before the PE experiment, in figure 1., the specimen section clearly distinguished that the Aluminum 5052 cladding material, Boron-Carbide and Aluminum 1070 matrix.

After the electrochemical experiment, Aluminum and Boron Carbide corrosion has been actively occurred near Aluminum cladding. In figure 4., mainly Aluminum was oxidized, Boron-Carbide was not oxidized. As this result, it can be seemed occurrence galvanic corrosion between Aluminum 1070 and Aluminum 5052.

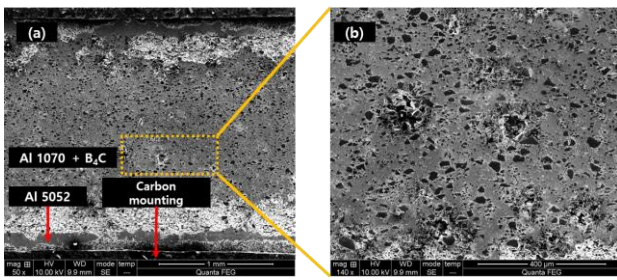


Figure 5. Possible pitting corrosion on specimen's edge

In figure 5., SEM image shows the regions that are believed to cause pitting corrosion. [4] The corrosion diameter estimated by pitting corrosion is 50 μm .

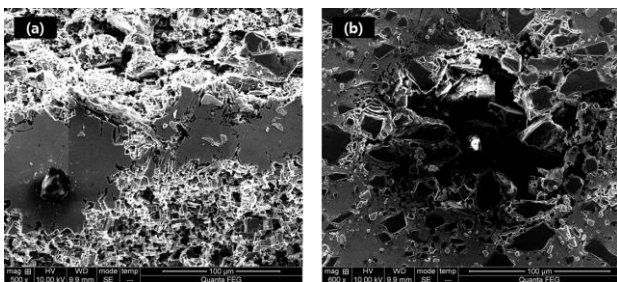


Figure 6. Possible pitting corrosion penetration

By figure 6., possible pitting corrosion is observed. The Boron-Carbide does not disappear but falls out. And if pitting penetrates the core, the neutron absorption performance could be affected, but this does not mean that the material will no longer act as a neutron absorber because Boron-Carbide will remain. [5]

4. Summary

In this stud, neutron absorbers shows pitting corrosion and galvanic corrosion between Aluminum cladding and inner core in 3.5 wt.% NaCl solution. Galvanic corrosion was observed between Aluminum 5052 and Aluminum 1070. Possible pitting corrosion was observed around Boron-Carbide in inner core. When pitting corrosion penetrates the core, neutron absorber performance could be affected. Degradation of neutron absorber due to corrosion behavior and accumulation of irradiation damage and/or high temperature condition may weaken spent fuel storage safety. It may lead to deterioration of public perception of nuclear safety.

Acknowledgement

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