Irradiation of Polyimide and Neutron Poison Materials by Using a HANARO Capsule

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1. Introduction

A material capsule system has been developed for an irradiation test of non-fissile materials in HANARO (High flux Advanced Neutron Application ReactOr) [1]. This capsule system has been actively utilized for the various material irradiation tests requested by users from research institutes, universities, and the industries [2]. The capsules were mainly designed for an irradiation of the RPV (Reactor Pressure Vessel) and reactor core materials, and Zr-based alloys of parts of nuclear fuel assembly.

Recently, irradiation tests of neutron poison materials and Polyimide were requested by Westinghouse Electric Company (WEC) and Hanyang University, respectively. As a candidate material of control rod of AP1000 reactor, Ag and Ag-In-Cd alloys were requested to be irradiated in HANARO by WEC [3]. Polyimide has been studied as a shielding material against thermal and fast neutrons [4].

The irradiation of these new materials which might affect the safety of a reactor was carried out for the first time in HANARO. As a preliminary test, small amount of these materials were determined to be inserted in a KNF (Korea Nuclear Fuel) irradiation capsule of 07M-13N [5]. Due to the new materials, the irradiation test of the 07M-13N capsule was examined and approved by the "HANARO Safety Review Committee".

The 07M-13N capsule was safely irradiated for 95.19 days (4 cycles) in the CT test hole of HANARO of a 30MW thermal output at 230 ~ 420 ℃. The specimens of these new materials were irradiated up to a maximum fast neutron fluence of 1.13×10^{21}(n/cm^2) (E>1.0MeV) and the dpa of the irradiated specimens were evaluated as 1.87.

2. Irradiation of Neutron Poison Materials

Westinghouse/KAERI/KNF agreed to perform an irradiation test in the HANARO reactor to obtain irradiation data on the new grey rods that will be a part of an AP1000 system [6]. As a preliminary test, two samples containing pure Ag (Reference) and Ag-In-Cd materials provided by WEC were inserted in a KNF irradiation capsule of 07M-13N.

The irradiation of a high neutron absorption material which might affect the safety of a reactor was carried out for the first time in HANARO. Therefore, the irradiation of the WEC samples in the 07M-13N capsule was examined to attain an admission of the 'Reactor Safety Review Committee of HANARO' based on the capsule design and safety analysis. In the exanimation, the reactor reactivity change, the capsule structural safety by the WEC specimens, and the effect on other specimens were checked and proved to be negligible [5].

Based on the design recommendations of KAERI, three different kinds of WEC samples were inserted into the specimen containers. One type is a stainless sleeved silver wire, the second is a bare silver wire of the same diameter as the sleeved silver, and the third is an AIC (silver-indium-cadmium) sample of the same dimensions as the bare silver wire. In the specimen configuration of the 07M-13N capsule, one Ag specimen (divided into 2 pieces) is located in the #1 hole and another Ag-In-Cd specimen is located #3 hole of Al1050 holder in the Stage 2 (Figure 1 and 2).

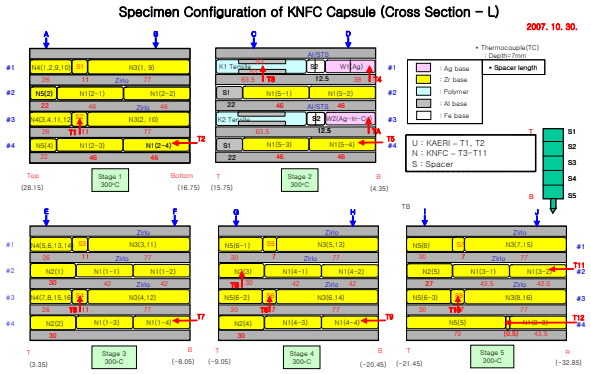


Figure 1. Specimen configuration in the 07M-13N capsule

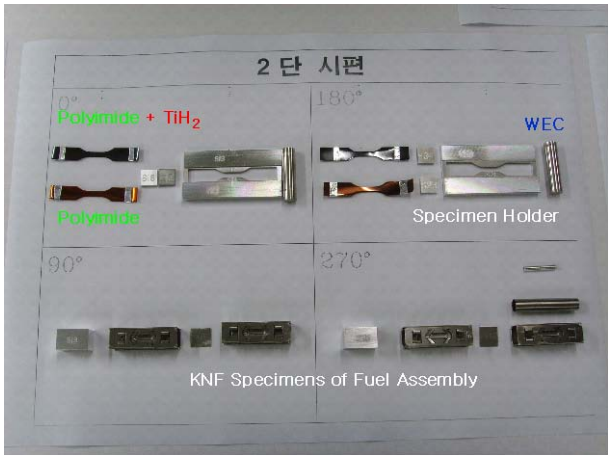


Figure 2. Polyimide and WEC specimens in the 2nd stage of the 07M-13N capsule

The WEC specimens were irradiated for 95.19days (4 cycles) in the CT test hole of the HANARO of a 30MW thermal output to have a fast neutron fluence of

1.13×10^{21}(n/cm^2) (E>1.0MeV). During the entire irradiation, the measured temperatures of the Ag and AIC specimens are consistently maintained in the range of 240 ± 10℃ and 245 ± 10℃, respectively. The measured temperatures of the specimens showed a large difference from the original target temperature of 370-480℃. The difference between the calculated and measured temperatures of the specimens seems to be mostly related to an incorrect location of a thermocouple. Based on the X-ray film of a thermocouple and a temperature profile of the WEC samples calculated by ANSYS code, the measured temperatures were attributed to indicate the interface region's temperatures between the specimen container and Al holder rather than the specimen's core temperatures.

3. Irradiation of Polyimide

As a part of the 2007 project for an active utilization of HANARO, Polyimide specimens were required to be irradiated in HANARO by Hanyang University. Polyimide has a chemical structure as shown in Figure 3 and is composed of more than 69% carbon (C), 20% oxygen (O), 7% nitrogen (N), and 2.6% hydrogen (H). Generally, Polyimide is well known as an organic chemical having several good properties for industrial applications. Especially, Polyimide containing metallic hydride such as HfH_2 is known to be an effective light-weight shielding material both for thermal and fast neutrons [4]. In the present work, the resistance of Polyimide against a neutron irradiation was investigated by using an irradiation capsule.

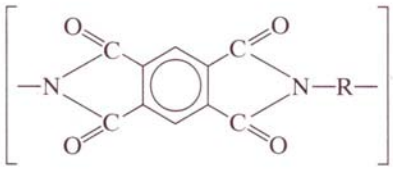
Chemical	Chemical Structure
Polyimide	

Figure 3. Chemical structure of Polyimide

Two kinds of Polyimide, pure and containing TiO_2 hydride, provided by Hanyang University were inserted in a KNF irradiation capsule of 07M-13N. Polyimide is prepared as thin films and designed as plate tensile specimens. TiH_2 is used in this test instead of HfH_2 in a point view of the reactor safety. The irradiation of Polyimide was carried out for the first time in HANARO. Therefore, the irradiation of the Polyimide samples in the 07M-13N capsule was also examined to attain an admission of the 'Reactor Safety Review Committee of HANARO' based on the capsule design and safety analysis.

Because organic materials are generally known to be decomposed by neutron irradiation, the radioactivity due to the expected gases was proven to be negligible during the irradiation test.

The Polyimide specimens were successfully irradiated for 95.19days (4 cycles) in the CT test hole of the HANARO of a 30MW thermal output to have a fast neutron fluence of 1.04×10^{21}(n/cm^2) (E>1.0MeV). During the entire irradiation, the measured temperatures of the specimens are consistently maintained in the range of 230±20℃.

3. Conclusion

The neutron poison materials (Ag and Ag-In-Cd alloys) and Polyimide containing TiH_2 were successfully irradiated for the first time in HANARO. Based on the preliminary test, main irradiation tests involving an increased amount of specimens are under discussion with the users. Although additional analysis on the safety of the irradiation test should be performed based on a specified specimen specification, the irradiation data of the 07M-13N capsule will be crucial for the committee's judgment.

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