Fluence Monitor Design for Irradiation Test at CT and IP hole of HANARO

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1. Introduction

For neutron dose assessment for specimens in material/fuel irradiation tests at HANARO research reactor, neutron fluence evaluation have been performed using two methods: Monte Carlo N-Particle (MCNP) code calculations and, measurements utilizing fluence monitors (FMs). The difference of results between measurements and calculations had been shown to be around ±10~20% for CT and OR holes.

In 2024, new irradiation tests for nuclear fusion reactor materials and, validation of the quantitative analysis of elements for non-proliferation are scheduled at HANARO. FMs such as Ni, Fe, Nb and Co wire for thermal and fast neutron measurements was addressed for these tests. In this presentation, the process of producing the FMs was introduced. Based on the production process and preliminary assessment results, we will endeavor to enhance the precision of evaluations, thus facilitating qualitative improvements in HANARO irradiation tests.

2. Methods and Results

2.1 Irradiation Tests with FM application

FM has been designed and fabricated for the following two irradiation tests: "ARAA test" for evaluation of neutron irradiation characteristics of the Advanced Reduced Activation Alloy (ARAA) [1], and "Fuel & Graphite test" for empirical testing of the Graphite Isotope Ratio Method (GIRM) [2]. For both tests, the assigned capsule names are 23M-01F and 22F-01U, respectively. 23M-01F is scheduled to be inserted into the CT hole, while 22F-01U has been inserted into the IP11 hole. Fig. 1 shows summary of the tests.

2.2 Material Determination

Ti, Ni, and Fe are commonly used as FMs in material irradiation tests at HANARO. They were utilized in investigation capsules 09M-02K, 10M-01K, 10M-15K, and 11M-03K in the past. In the cases, the irradiation period ranged from 84 hours to 25 days, and the measured doses were recorded to have an error of less than 20% compared to calculations. In addition to the existing FM metals, it has been decided to introduce Co for thermal neutron measurements and Nb for fast neutron measurements in this case.

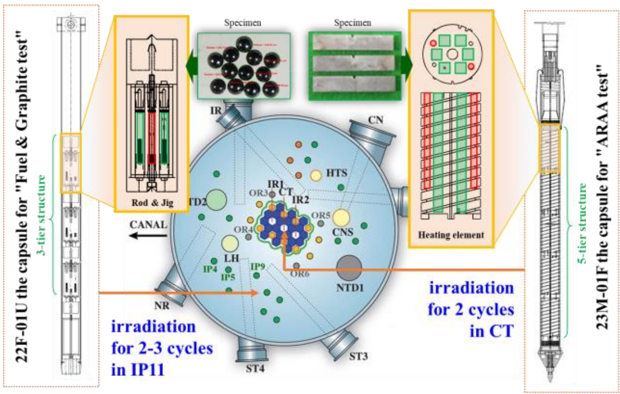

Fig. 1. Irradiation tests with FM application.

The determination of FM weight should consider radiation safety for the retrieving worker and gamma detection efficiency. Based on the preliminary assessment results (Fig. 2), the weight of each FM was determined to ensure that the dose rate is below several tens of μSv/hr, and the cps to be around 10 for the 7.4 cmϕ high purity Ge detector located 17 cm away from the source. As a result, the weight of the fabricated FMs ranged from 200 to 400 μg.

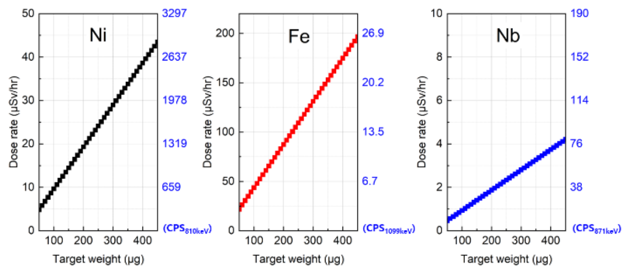

Fig. 2. Dose rate and expected cps based on FM weight. NAAPro [3] was used in the calculation. Irradiation and cooling period was set to be 56 days and 1 year respectively.

The neutron flux assumed in the calculation are as follows:

Table I: Irradiation hole condition used in the calculation

Hole	Neutron flux (n/cm^2/sec)		
	Thermal	Epithermal	Fast
CT	3.20E+14	1.72E+14	3.01E+14
IP11	9.95E+13	2.65E+12	4.98E+11

2.3 Container Design

The FM container has mainly utilized aluminum alloys. In this case, considering potential material changes (such as eutectic reactions) during long-term irradiation, low-reactivity quartz was introduced as the container material. The container was sealed under a vacuum condition (approximately 0.001 Torr) to minimize unwanted activation. Fig. 3 shows the quartz containers containing the FM material. The outer diameter of the containers is 3 mm (approximately 1 mm inner diameter), with a length of about 2.5 cm. Each specimen is distinguished by a pattern engraved on the surface of the container through slight abrasion.

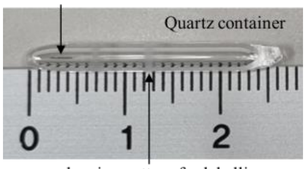

Fig. 3. Fabricated FM element using quartz container.

2.4 FM positioning and flux evaluation method

The tier structure of the two irradiation test capsules is shown in Fig. 1. The shaded red area indicates the location where the FM will be placed. For the “Fuel & Graphite test,” FMs were inserted on the 2nd and 3rd tiers, while for the “ARAA test,” FMs were inserted into heating elements on all tiers. The FM using the existing aluminum container was also used.

After the irradiation, neutron fluence at each position will be calculated based on activity measurement results and the method outlined in ASTM E261 [4]. The method includes following factors:

- Fluctuations in neutron fluence due to reactor power variations
- Losses due to reactions between the product and neutrons (burn-up)
- Depletion of target atoms

3. Conclusions

We have fabricated FMs for irradiation test capsules newly loaded into the HANARO reactor in 2024. Through ongoing experiments using various metals, we plan to enhance the accuracy of characterization of HANARO irradiation holes and performance evaluation of irradiation test in the future.

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