Accuracy of Helium Accumulation Fluence Monitor for Fast Reactor Dosimetry

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A helium (He) accumulation fluence monitor (HAFM) has been developed for fast reactor dosimetry. In order to evaluate the measurement accuracy of neutron fluence by the HAFM method, the HAFMs of enriched boron (B) and beryllium (Be) were irradiated in the Fast Neutron Source Reactor "YAYOI". The number of He atoms produced in the HAFMs were measured and compared with the calculated values. As a result of this study, it was confirmed that the neutron fluence could be measured within 5 % by the HAFM method, and that met the required accuracy for fast reactor dosimetry.

1. Introduction

A He accumulation fluence monitor[1] (HAFM) has been developed for fast reactor dosimetry in various irradiation tests and material surveillance tests. The He production rate is measured by counting He atoms accumulated in the HAFM and the neutron fluence is then obtained using measured He production rates in the same way as employed for the foil activation method. Another application of the HAFM is expected for the direct measurement of He production in the structural component materials of fast reactors.

The calibration of the HAFM measurement system as to counting He atoms in the HAFM materials was carried out using the He ions implanted samples in the previous study, and the counting error was evaluated to be approximately 5 %[2].

Based on the last study, the accuracy of measuring neutron fluence by the HAFM method was evaluated. As the measurement accuracy of neutron fluence was determined by that of He production rates during irradiation, HAFMs were irradiated in the well characterized fast neutron spectrum field of the Fast Neutron Source Reactor "YAYOI"[3] of the University of Tokyo. The accuracy of measuring neutron fluence was evaluated by comparing the measured He production with calculated values using the neutron flux and He production cross section.

2. HAFM Measurement System

2.1 System Outline

The HAFM measurement system is illustrated in Fig. 1. An electric furnace is used to melt the HAFM materials, and the released He atoms were counted by means of a magnetic type gas mass spectrometer. The number of He atoms which can be measured in this system ranged $10^{12} \sim 10^{19}$. This range covers the expected number of He atoms when the HAFM is used in a typical fast reactor irradiation field.

2.2 Calibration

The calibration of the HAFM measurement system has already been performed using the He implanted samples. The samples of copper, aluminum and vanadium chips contained He ions of $10^{13} \sim 10^{15}$ which had been implanted by the ion source and the accelerator of Kyushu University. The relation between the number of He atoms and the mass spectrometer output indicated good linearity as shown in Fig. 1. The counting error of He atoms was evaluated to be approximately 5 % in this system.

3. Experiments

3.1 Irradiation

The specifications of HAFMs and their irradiation conditions are summarized in Table 3. The HAFMs of 93 % enriched B were irradiated at three locations: those are reactor core center (Glory hole: Gy), under the leakage neutron field from the reactor core (Fast column: FC) and at an experimental hole through the blanket surrounding the core (BLK) to total fluences of $10^{15} \sim 10^{17}$ n/cm^2. At BLK, the HAFMs of Be were also irradiated to test the applicability for fast neutron monitoring.

The He production rate spectra in each irradiation position are shown in Fig. 3. Considering each neutron spectrum, the He production in B type HAFM occurred with neutron of which energy ranged 10 keV ∼ 1 MeV at Gy and BLK, and with neutron less than 10 keV at FC. As to Be type HAFM, the He was produced with neutron over 1 MeV at BLK.

3.2 Measurement and Calculation

The number of He atoms produced in the irradiated HAFMs was counted by the HAFM measurement system. Some of the irradiated HAFMs were measured independently by the system[4] of Kyushu University to secure the reliability of this experiments.

The He production rate was calculated with the neutron flux and He production cross sections processed from the JENDL-3.2 cross section library[5] [6]. The neutron spectra were determined based on the foil activation method.

4. Results

The measured (M) and calculated (C) number of He atoms are shown in Figs. 4 to 7. The average value of M/C ranged 0.98 ∼ 1.03 for the B type HAFMs and was 0.96 for the Be type HAFMs as shown in Table 2.

It was found that the differences of He production between the calculated and measured values were as follows: it was less than 5 % for the B type HAFM at Gy, BLK and FC, and it was also less than 5 % for the Be type HAFM at BLK. This result indicated that the Be type HAFM could be applied for fast neutron measurement over 1 MeV.

The differences of the measured values between our results and those by Kyushu University were less than the experimental error, that means the measured values were reliable.

5. Conclusion

In order to evaluate the measurement accuracy of neutron fluence by the HAFM method, the B and Be type HAFMs were irradiated in "YAYOI". The number of He atoms in the irradiated HAFMs were measured and compared with the calculated values. As a result, it was confirmed that the neutron fluence could be measured within 5 % by the HAFM method, and that met the required accuracy for fast reactor dosimetry. This result indicates that the HAFM can be applicable to monitor neutron fluences for various irradiation tests and material surveillance tests conducted in fast reactors.

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