§4. Measurements of Reaction Rates and Tritium Production Rates in Li/V-alloy Assembly under 14 MeV Neutron Irradiation

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Neutronics studies on Flibe cooled and Li cooled advanced blanket systems have been conducted in the FFHR helical reactor design activity. In the studies, accuracies of neutronics calculations are required to be examined experimentally for validation of the calculation procedures and determination of the design margin. Irradiation experiments simulating the neutron environment in the Li/V-alloy (lithium/vanadium alloy) blanket system have been discussed and planned in the present collaborative study.[1)]

A 14 MeV neutron irradiation experiment on a Li/V-alloy assembly has been performed at the FNS facility in JAEA to examine the impact of the V-alloy structural material on the neutron transport and tritium production in the Li breeder/coolant layers. The Li/V-alloy assembly with dimensions of 45 x 50 x 50 cm^3 was constructed using metal Li blocks (Fig. 1). A vanadium alloy (V-4Cr-4Ti) layer with dimensions of 23 x 24 x 5 cm^3 was installed in the assembly at the position of 15 cm from the front surface. Activation foils of Nb, Ni and In were set in the assembly for examination of neutron transport and 3 hours irradiation was performed with a neutron generation rate of 9 x 10^{10} n/s. After the irradiation, reaction rates of the ^{93}Nb(n,2n)^{92m}Nb, ^{58}Ni(n,p)^{58}Co and ^{115}In(n,n')^{115m}In reactions were obtained from gamma-ray measurements of the activated foils. Irradiations of ~30 minutes were also repeated with neutron generation rates of 0.9-3 x 10^9 n/s for measurements of tritium production rates through the ^{6}Li(n,α)T reaction. A Li glass scintillation detector, which can detect charged particles from the ^{6}Li(n,α)T reaction, was inserted in a detector hole of 2 cm in diameter and a distribution of the tritium production rates was obtained by changing the detector position. The results of these reaction rate and tritium production rate measurements were compared with those calculated by using the Monte Carlo transport code MCNP5 and nuclear data library JENDL-3.3.

Figure 2 shows an example of reaction rate measurements. Since the threshold neutron energy of ^{93}Nb(n,2n)^{92m}Nb reaction is 9.0 MeV, the result corresponds to examination of fast neutron transport in the Li/V-alloy assembly. The measured and calculated reaction rates were consistent within 3%. Similar comparisons were performed for the ^{58}Ni(n,p)^{58}Co and ^{115}In(n,n')^{115m}In reactions whose threshold energies are 0.72 MeV and 0.34 MeV. Differences between the measured and calculated reaction rates were almost <3 % and <5 %, respectively. These results indicate that the accuracies of transport calculation for the Li/V-alloy assembly are smaller than ~5% for neutrons of > ~0.5 MeV.

The preliminary result of the tritium production rate measurement with the Li glass scintillation detector is shown in Fig. 3. Counts of the ^{6}Li(n,α)T reaction in the detector was converted to the tritium production rate using the chemical composition of the Li glass scintillator provided from the detector supplier. The measured distribution represents the enhancement of the tritium production rates around the V-alloy layer. The enhancement is considered to be attributed to the elastic scattering, inelastic scattering and (n,2n) reaction in the V-alloy layer. The maximum difference between the measured and calculated results was ~25 %. Acquisition of the detection efficiency and response characteristic of the detector with a monoenergetic neutron source is planned for more accurate evaluations. The possibility that the difference between experimental and calculated results comes from the nuclear data of vanadium is also under examination by literature search of previous studies.[2)]

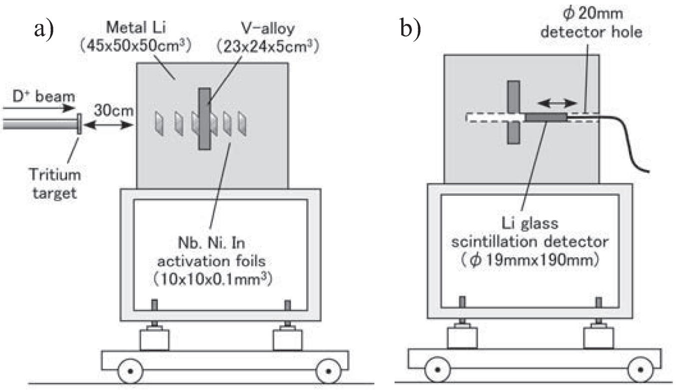

Fig. 1. Schematic drawing of a) reaction rate and b) tritium production rate measurements in Li/V-alloy assembly.

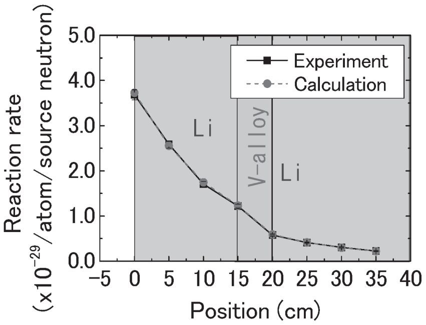

Fig. 2. Comparison between measured and calculated reaction rates for ^{93}Nb(n,2n)^{92m}Nb reaction.

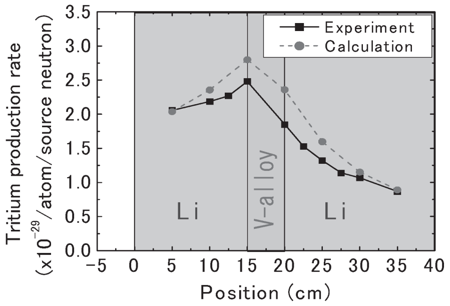

Fig. 3. Preliminary result of tritium production rate measurement with Li glass scintillation detector.

1) T. Iida *et al.*, NIFS annual report April 2005 - March 2006, p. 261.
2) F. Maekawa *et al.*, Fusion Technology 34 (1998) pp. 1018-1022.