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7. Developments of Measurement Technique

7.1 Micro Fission Chamber for the ITER Neutron Monitor

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7.1.1 Introduction

Micro-fission chamber is a candidate diagnostic device to measure the fusion power, which is one of the basic control parameters. In present large tokamak facilities such as JET, TFTR or JT-60U, the neutron yield measurement has been carried out using ^{235}U or ^{238}U fission chambers installed outside the vacuum vessel [1-3]. Detection efficiencies in this method are easily affected by surrounding equipment such as other diagnostics or heating systems. Moreover, ITER has thick components as blanket and vacuum vessel that disturb clear signal to arrive there. Therefore, detectors outside the vacuum vessel cannot measure the neutron source intensity with sufficient accuracy. Thus, micro-fission chambers, which are pencil size gas counters with fissile material inside, has been developed as neutron flux monitors in the vacuum vessel of ITER [4-8]. Installing a pair of a ^{235}U micro-fission chamber and a "blank" detector behind the shielding blanket module is proposed. The "blank" detector is a fissile-material-free detector to identify noise issues such as those from gamma-rays. Pulse counting mode and Campbelling mode [9] in the electronics were employed to meet the ITER requirement with respect to the temporal resolution and the dynamic range.

This paper describes the design and the fabrication of a prototype micro-fission chamber and test results under ITER relevant conditions including wide neutron spectrum and intense gamma-rays, and the performance as a ITER power monitor is discussed.

7.1.2 Design of Micro-Fission Chamber

Figure 7.1-1 shows the schematics of a typical micro-fission chamber with wide dynamic range, which is designed for the ITER. In this detector, UO_2 is coated on the outer cylindrical electrode with a coating density of 0.6 mg/cm^2. The active length is 76 mm, and the total amount of UO_2 is 12 mg. The enrichment of ^{235}U is 90%. Thus, the total amount of ^{235}U is about 10 mg. This detector is filled with Ar and 5% N_2 gas at 14.6 atm. The housing material is stainless steel 316L. Electric insulator is alumina (Al_2O_3).

A full body drawing of the fabricated micro-fission chamber and the MI cable is also shown in Fig.7.1-1. Double coaxial MI (mineral insulated) cable is welded directly to the fission chamber. The cable uses SiO_2 as electric insulator with a packing density of 30%. It is filled with Ar at 14.6 atm. The center conductor is insulated not only with the SiO_2 powder but also Ar gas. In case of cracking at the alumina insulator in the detector due to swelling, the Ar gas in the MI cable will prevent the leak of detector gas into the MI cable. The dummy chamber has the same structure as the micro-fission chamber, except no uranium coating on the electrode.

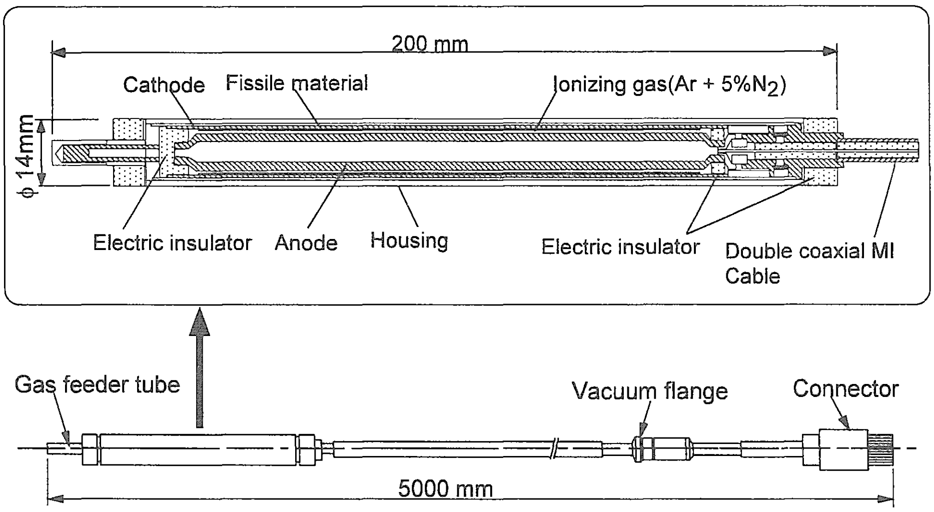

Fig. 7.1-1 Schematics of the structure and the full body of micro-fission chamber and MI cable.

7.1.3 Performance Test

1) Basic Performance

The dummy chamber with MI cable was tested for vacuum leaks at room temperature. We confirmed that the helium leak rate was less than the detection limit, 1×10^{-8} cc/s. In the acceleration test for mechanical shocks, the micro-fission chamber was set on a weighted free-fall table. When the table hit the floor, the acceleration for 30 ms reached 50G at maximum. The test was repeated 10 times. Although a few counts were observed during each mechanical shock, no change appeared in the Campbelling output signal. Neither did in resistance, dimension and vacuum leaks. The resistance between the center conductor and the outer sheath was measured in the range from room temperature (20°C) to 350°C with an impedance analyser. Both detector heads of the micro-fission chamber and the dummy chamber were heated up by a heating apparatus. Although the conductivity is increased by the ionization of alpha particle emitted from the alpha decay of the uranium at low temperature, the change of measured resistances are within the acceptable range for the micro-fission chamber performance.

2) Response for 14 MeV neutrons

The performance tests under 14 MeV neutrons were performed with the target of 80° beam line at FNS. It produces 14 MeV neutrons up to 3×10^{11} n/s. For the sensitivity and linearity measurements, the micro-fission chamber and the dummy chamber were installed just in front of the target as shown in Fig.7.1-2. Both chambers were heated by a ribbon heater from R.T to 250°C.

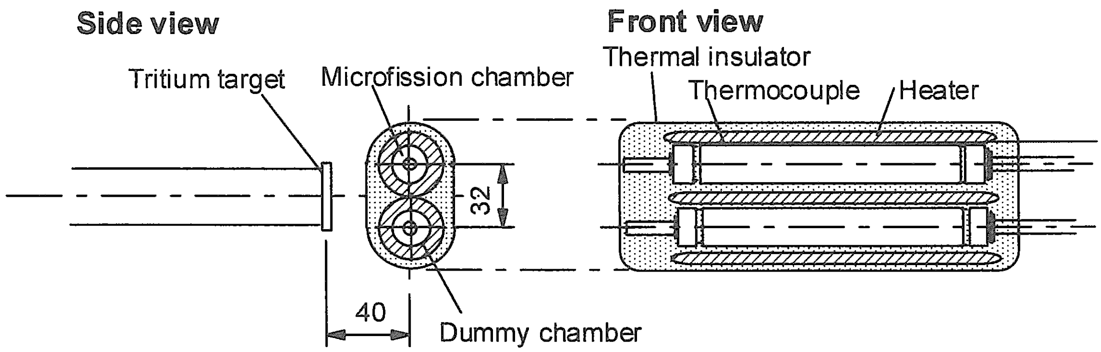

Fig. 7.1-2 Experimental setup of the 14 MeV neutron response measurement at FNS.

The pulse height distributions were measured with a discrimination level of -150 mV. The output voltage of the Campbelling amplifier and the output current of the high voltage power supply were also monitored.

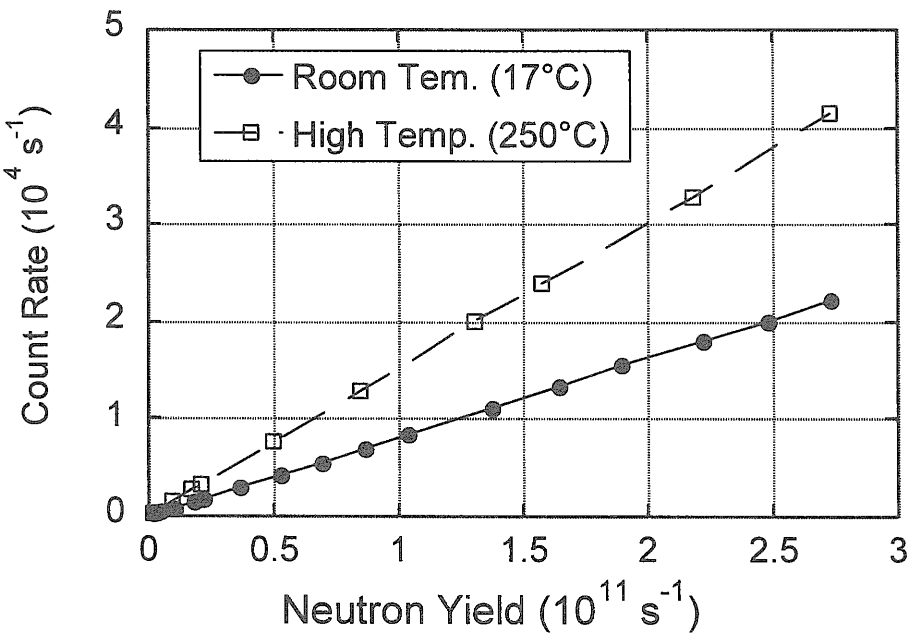

Fig. 7.1-3 Pulse count rates of the micro-fission chamber as a function of the neutron yields.

In the pulse height distributions, shifts of the peak position were observed when the temperature of the chamber was changed. Although the discrimination level was adjusted to minimize the effect of the peak shift, the temperature-dependence could not be avoided in the present study. The relation between pulse count rates of the micro-fission chamber and neutron yields measured by alpha monitor is shown in Fig.7.1-3. An excellent linearity is observed up to the neutron yield of about 3×10^{11} n/s.

The relation between the squares of the Campbelling output voltages and neutron yields measured by alpha monitor is shown in Fig.7.1-4. An excellent linearity is also observed. The temporal response is shown in Fig.7.1-5. When a neutron pulse in 1ms duration was generated, the squares of the Campbelling output voltage made a curve with 0.98 ms time constant, which means 1 ms temporal resolution could be attained.

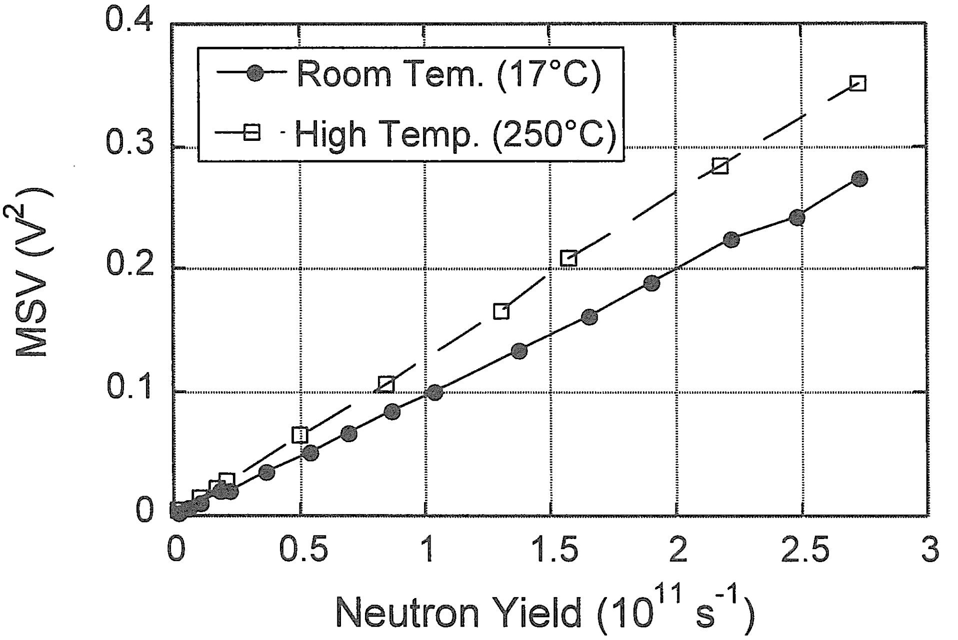

Fig. 7.1-4 Campbelling output voltages of the micro-fission chamber as a function of the neutron yields.

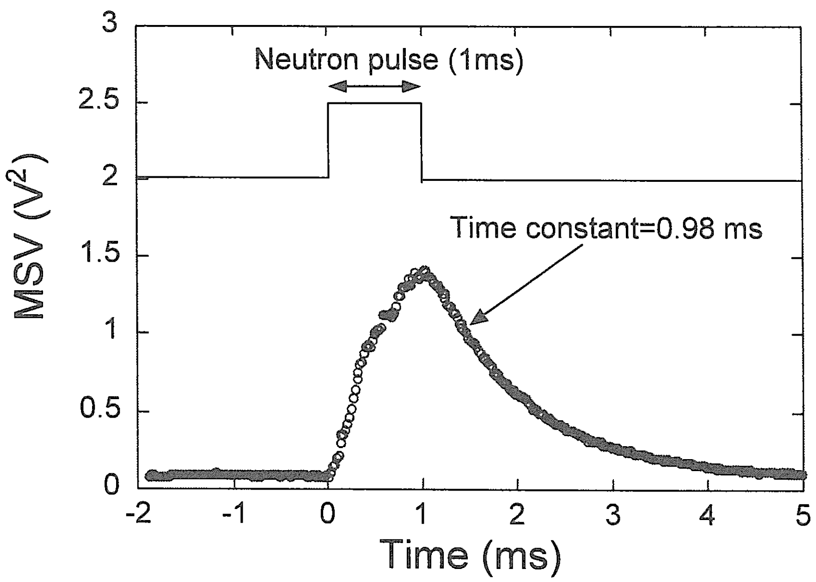

Fig. 7.1-5 Temporal curve of squared Campbelling output response for the 1 ms neutron pulse.

3) Response for gamma-rays

This micro-fission chamber can be operated both in the pulse counting and the Campbelling modes. In the pulse counting mode, current pulse generated by the fission fragments or gamma reaction in the ionizing gas is measured. When a fission reaction releases ~170 MeV as kinetic energy of fission fragments, average energy deposited in the ionization gas is 70 - 100 MeV, while the gamma-ray energy is less than 10 MeV in the chamber. In addition, the Campbell mode is less sensitive to gamma-rays. Therefore, the dummy chamber was employed not only for the gamma-ray compensation but also identification of noise events and radiation induced events such as RIEMF (Radiation Induced Electrical Motive Force).

The dummy chamber was irradiated at the ^{60}Co gamma-ray irradiation facility of JAERI-Takasaki. The gamma-ray dose rate was 4.7Gy/s at the dummy chamber location, which is almost equivalent to the dose rate between the shielding blanket module and the vacuum vessel in ITER, where the micro-fission chambers will be installed. The dummy chamber was irradiated for 19.1 hours, which resulted in the total dose of 0.32 MGy. Compared with the sensitivity for neutrons, gamma-ray sensitivity in Campbelling mode was estimated to be less than 0.1 %.

7.1.4 Conclusion

A micro-fission chamber with 12 mg UO_2 and a dummy chamber without uranium were designed and fabricated for the in-vessel neutron flux monitoring of ITER. The measurement ability was tested with the FNS facility for 14 MeV neutrons and the ^{60}Co gamma-ray irradiation facility at JAERI-Takasaki. Employing the Campbelling mode in the electronics, the ITER requirement for the temporal resolution was satisfied. The excellent linearity of the detector output versus the neutron flux was confirmed in the temperature range from 20°C to 250°. As a result, it was concluded that the developed micro-fission chamber is applicable for ITER.

References

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