7th Asia-Pacific Conference on Plasma Physics, 12-17 Nov, 2023 at Port Messe Nagoya

Progress in the development of a compact D-T neutron spectrometer based on a single-crystal chemical vapor deposition diamond stack for fusion plasma diagnostic

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In a future D-T fusion reactor, neutron diagnostic will be one of the key diagnostics because the neutron has information for the birth profile of alpha particles, fuel ion density ratio, and fuel ion temperature if the plasma is Maxwellian. Diamond detectors are very promising candidates for neutron diagnostics in the harsh radiation environment of a fusion reactor because of their high radiation tolerance and compactness. The neutron diagnostic based on a natural diamond was developed and has been used since the 1990s for 14 MeV D-T neutron measurements in large Tokamaks, such as TFTR [1], JET [2], and JT-60U [3]. Recently, with the development of the diamond produced by chemical vapor deposition, high-quality artificial diamond detector becomes available at relatively low cost.

We are developing a novel compact D-T neutron spectrometer based on a single-crystal chemical vapor deposition (s-CVD) diamond stack (B14 diamond telescope detector, CIVIDEC Instrumentation GmbH). Figure 1 shows the measurement principle of a compact neutron spectrometer (a) and the parameters of the diamond telescope detector (b). A neutron to proton converter was installed in front of the detector. The detector consists of one thin and two thick s-CVD diamond sensors. This spectrometer was designed for the detection of 3 MeV to 17 MeV neutrons. The incident fast neutron creates a recoiled proton inside the converter. The forward scattering recoiled proton deposits the energy into the s-CVD diamond sensors. The pulse signals of three sensors are acquired individually. The neutron spectrum is obtained by coincidence analysis in which the gamma background can be rejected. Here, the thickness of the converter should be chosen according to the neutron flux and energy resolution requirement. An increase in the thickness of the converter enhances the detection efficiency but causes low energy resolution because the deposition energy of the proton inside the converter is unmeasurable.

We surveyed the effect of the converter thickness on energy resolution and detection efficiency using 0.025 to 2.3 mm thick polyethylene films. We first tested the spectrometer with a ^{252}Cf neutron source. Then, the D-D, D-T, and D-Li experiments were performed using the accelerator-based neutron sources OKTAVIAN in Osaka University and the Fast Neutron Laboratory in Tohoku University. The detail of the compact D-T neutron spectrometer as well as the effect of polyethylene converter thickness on energy resolution and detection efficiency will be presented.

References

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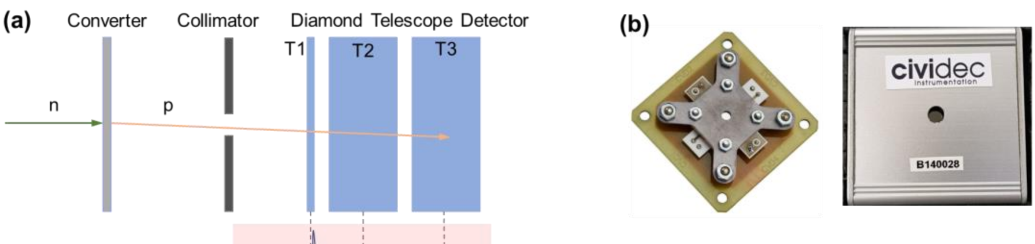

Box size (mm)	55 × 55 × 24
Box material	Aluminum
Number of sensors	3
Sensor material	sCVD diamond
Sensor active area	4 mm × 4 mm
△E-sensor: T1	50 μm
E-sensors: T2, T3	500 μm

Figure 1. (a) The measurement principle of a compact neutron spectrometer. (b) The parameters of the diamond telescope detector.