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§24. Experimental Study on Heat Flux of Divertor Plasma (Measurement of Fluctuation and Heat Transport in the Edge Plasma of Heliotron J Device)

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In 2010FY experiment, a new hybrid probe was constructed and tested with Heliotron J edge plasma for the first time. Its body is made of boron nitride (BN) and equipped with four conventional Langmuir probe tips and a temperature gradient type thermal probe (GTP) tip made of copper (Cu).[1] The size of Cu tip is set as small as possible to improve time response. So its fabrication was very difficult task and the setting of GTP tip is possible only along the axial direction of a large probe head, since GTP tip is connected to a long heat sink to establish the temperature gradient along the probe axis. Whole probe system was connected to the driving system at the port 8.5 in order to study the edge plasma around X-point of the last closed flux surface of Heliotron J. But this makes plasma electrons difficult to reach GTP tip under the strong magnetic field. So thermocouple signal shows much noise and no temperature increase even when BN cover suffers heat damage.

In order to overcome this problem, small GTPs must be designed to set at the side area of the hybrid probe head. Figure 1 shows calculation result of temperature response of a Cu GTP tip without the heat sink. Plasma heat pulse is assumed to be 2MW $\times$ 1s. Three curves correspond to the signal at 1, 5, 9mm from the irradiation surface. It is confirmed that, even with this temperature data, heat flux evolution can be reconstructed by the conventional GTP model with a heat sink.[2] In order to demonstrate this, a prototype GTP is constructed with pylex glass and tested for low density glow plasma.

Figure 2 shows the basic design of this heat isolation type probe tip. Its thickness is 5mm and plasma irradiation area is $0.5 \times 1[\mathrm{cm}^2]$. Both area is covered with thin Ar film to prevent from temperature nonhomogeneity and to fix the junction point of Type-K thermocouple. This make it possible to describe the heat transfer in the tip with one dimensional heat conduction model. Figure 3 shows the raw data of both side temperature. Since the heat flux density of the glow plasma is very small ($\sim 10[\mathrm{W/m}^2]$), temperature gradient across the probe tip is hardly measured. But estimated heat flux does not contradict with those obtained with conventional thermal probes and old GTP with the heat sink. On the contrary to Fig. 1, measured temperature shows saturation during the discharge. This is due to the convective cooling of the probe tip side area by residual neutral gas, whose estimation and correction were already reported in [2]. In Heliotorn J experimental condition, this effect can be negligible completely.

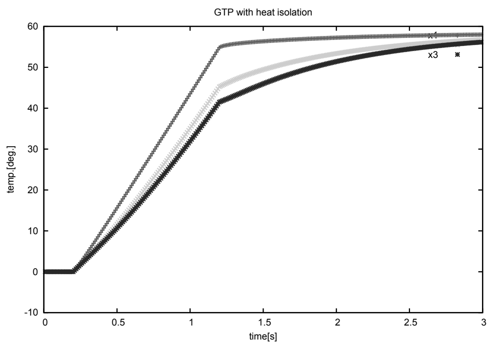

Fig. 1: Calculation of temperature response of a Cu GTP tip without the heat sink.

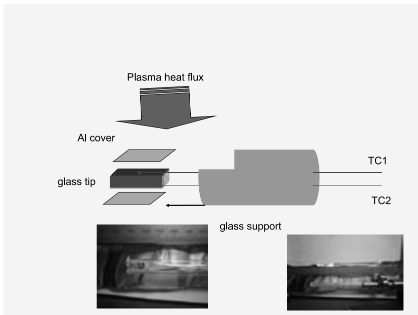

Fig. 2: Basic design of glass GTP tip. Both area is covered with thin Ar film and connected with the junction point of Type-K thermocouple.

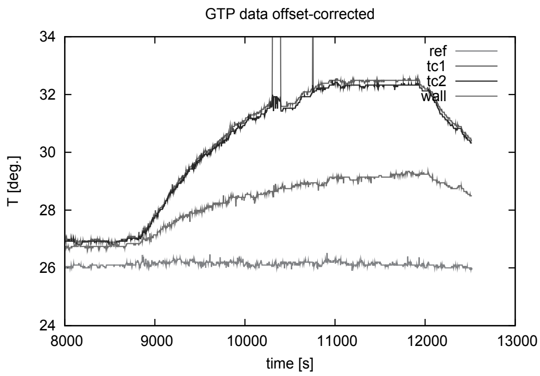

Fig. 3: Raw data of GTP thermocouple (front: red solid line, back: blue dotted line). The offset of these signals are corrected. Reference signals for room temperature and chamber wall temperature are also plotted.

1) H.Matsuura *et al.*, Ann. Rep. NIFS, Apr.2012-Mar.2013(2013)526.

2) H.Matsuura *et al.*, Japanese Journal of Applied Physics 49 (2010) 08JD03.