DESIGN AND CHALLENGE FOR ITER DIVERTOR LANGMUIR PROBE

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According to the ITER project requirements and diagnostics system requirements document, the contribution of the Divertor Langmuir Probe (DLP) system is to provide the electron temperature and density as well as the ion saturation current for advanced control, and the supplementary contribution to basic control is to measure the plasma position and shape at the divertor targets. Meanwhile, it will also be used for future physics analysis. The DLP system consists of two components: 1) a total of 400 probe sensors bonding on the side of 5 divertor cassettes with the corresponding tail; 2) the back-end electronics, which includes 200 All-in-one power supplies and instrumentation & control (I&C) system.

The ITER operation environment gives the DLP sensor very high load requirements. The probes are subjected to the demanding and complex challenge including very high, steady-state heat loads from plasma flux, photon irradiation, and energetic neutrals from charge exchange reactions, which are a new issue with respect to existing tokamaks such as DIII-D [1], JET[2], and JT60-SA[3]. The total heat load is 10MW/m^2 in the steady state and 20MW/m^2 in about 10 seconds' transient state [4]. It should also resist the effect of dust and coating, which can destroy the insulating property of the probe sensor.

After three iterations of design, a full-tungsten probe sensor was developed. It consists of a 2-mm-diameter tungsten probe, a complex shaped tungsten shield, and a 0.4mm alumina layer, as an electrical insulator between the tungsten probe and shield. All components are bonded together to make a high thermal transfer capacity in order to reduce the temperature of the probe. And the top of electrical insulator is designed as step-like structure to reduce the impact of coating. The relevant manufacturing technology, machining, sintering, and brazing are being developed at Xia Men Tungsten Company, Ltd., China (XTC). Combining the above heat loads, cooling condition, and emission, the complete boundary conditions for thermal simulation are determined. In addition, the properties of the materials used for the thermal analysis are from the ITER material handbook or measurements taken at XTC. The thermal analysis results show that the maximum temperatures of the probe body and alumina are lower than 1200°C and 700°C, respectively, at the heat load of 10MW/m^2 heat load [5,6].

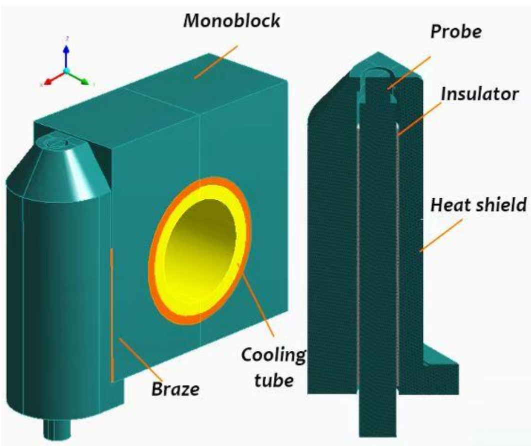

Fig. 1 The design of full-tungsten probe sensor

Two important tests were conducted for DLP sensor, the first one is the high heat flux test by electron beam device. Three probe sensor prototypes, with resistance between probe tip and heat shield above 3GΩ, were tested through

20MW/m^2&300 cycles test, 10MW/m^2&5000 cycles test and 10MW/m^2&6000 seconds steady state test. Though the electrical resistance of these prototypes has been dropped after the test, the minimum resistance is still larger than 3MΩ in 150V voltage， which meets the ITER measurement requirement. The second test is the long plus plasma test. It focuses on the effect of dust and coating only and was done in EAST tokamaks. Six samples were installed in the lower vertical divertor target and operated in more than 9700 discharges, for a total of about 90,000 seconds, and experienced boron coating many times which is also ITER wall conditioning method. The results show the measured signals of DLP sensor are similar with EAST probe at first, but the resistance and the signal of some samples fluctuated and deteriorated after the 3000 discharges. The preliminary analysis implies that the dust accumulated in the gap between the probe and the heat shield affected the insulation resistance. This is another challenge for probe sensor. A possible solution, which uses a transient current in the probe tip has been proposed, and will be test soon.

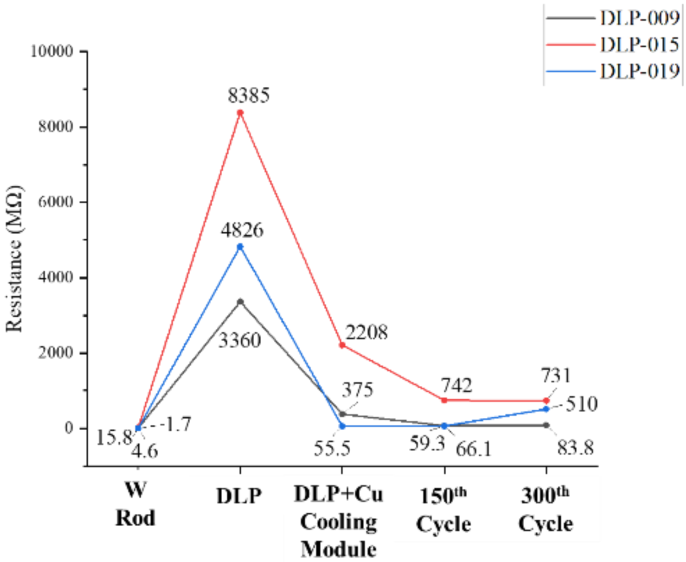

Fig. 2 The resistance evolution of DLP sensor during 20MW/m^2&300cycles electron beam test

For the back-end electronics design, we are integrating the function of power supply, mode switching and signal conditioning into one chassis, called All-in-one power supply. This new power supply has already reached the final design and tests in HL-3 and EAST tokamak show very good results. The I&C system has been developed to provide voltage driving waveform for power supply and send the probe characteristics to CODAC for calculation of measurement parameters.

In conclusion, most of the final design work of DLP is complete. However, the dust effect remains a key issue. A solution has already been proposed and testing is being prepared. The system is scheduled for its final design review at the end of 2025.

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