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Global observation and potential effects of arc traces in fusion devices

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Unipolar arcing has been a long-standing issue for nuclear fusion devices since it was found in tokamak devices [1]. The arcing erodes and emits the plasma-facing materials (PFMs) toward the core plasma region, acting as an impurity source as well as an erosion source of PFMs. Both should be suppressed for sustainable plasma operations of the fusion reactors.

Since unipolar arcing occurs randomly, both temporally and spatially, it is difficult to predict or observe its occurrence, especially in large fusion devices. For this reason, systematic evaluations of the occurrence and effects of arcing in large devices have not been conducted enough. This study introduces an attempt to summarize arcing occurrences found over several years in two large-scale devices, Wendelstein 7-X (W7-X) and Large Helical Device (LHD), with the aim of obtaining information on the frequency, distribution, and timing of arcing in large fusion devices and its potential impact.

The in-vessel inspection was primarily conducted by entering the vacuum vessel of each device between experimental campaigns and observing the arc traces left on the inner walls using a digital optical microscope and a digital camera.

The in-vessel inspection of W7-X has been conducted twice since 2019, after the end of the operation phase (OP) 1.2b [2] and OP2.1 [3]. The surfaces inspected include stainless-steel (SUS) first wall panels, in-vessel ports for diagnostics, and the graphite test divertor units (TDUs) for OP1.2b and CFC high heat flux divertor for OP2.1, the heat shields and baffles made of graphite, and heat sinks of the baffles made of CuCrZr plates and inboard-side vacuum vessel surfaces behind the heat shield and baffles.

Arc traces were found on various surfaces of the in-vessel components. Before OP2.1, 288 trails were found in total [2]. After OP2.1, a total of 105 new traces were recorded on the in-vessel surfaces. Among 105 traces, 5% formed on carbon surfaces. It was found that the number of arc traces are accumulated as the plasma operation proceeds, and the locations do not show any preference. Arc occurrence on divertor tiles was first observed after OP2.1. The shape of trace showed straight linear propagation of arcing, suggesting that the arcing occurred in a high magnetic field condition [3].

In LHD, three observations have been conducted after 22nd, 23rd, 24th operation cycles. Unlike in W7-X, the number of arc traces were relatively small, 23 traces in total. On the other hand, more than 50% formed on carbon surfaces, likely due to enhanced deposition at the closed divertor configurations of LHD. After the 22nd operation cycle, some of divertor tiles were taken out for analysis. Figure 1 shows cross-sectional energy-dispersive X-ray spectroscopy (EDS) mapping of an arc trace found on the backside of the divertor tile. From the element components of the arc trace with its bottom layer being removed as seen in Figure 1(a), it can be conjectured that the arc ignition on this tile occurred at least one operation campaign earlier.

In addition, we present summarized arc observation results of the two devices and draw potential effects of arcing in fusion devices.

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References

[1] G. McCracken and D. Goodall, Nucl. Fusion **18** (1978) 537.

[2] D. Hwangbo et al., Plasma Fusion Res. **15** (2020) 2402012.

[3] D. Hwangbo et al., Nucl. Mater. Energy (2024) submitted.

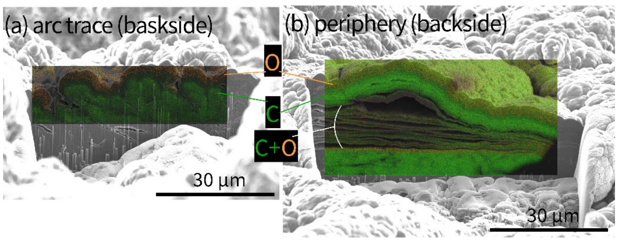

Figure 1 Cross-sectional EDS mapping of (a) an arc trace and (b) its periphery recorded on the backside of a divertor tile of LHD.