Multiple plasmoid formation and flux closure during transient-CHI start-up process on HIST

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The transient-Coaxial Helicity Injection (T-CHI) current drive without requiring for dynamo is a promising candidate for the non-inductive plasma start-up on Spherical Torus (ST). So far, the T-CHI method was successfully applied for HIT-II, NSTX and HIST devices[1, 2]. The flux closure during the short-time T-CHI process in ST is one of significant research issues that connect with the physics of fast magnetic reconnection. The recent MHD simulation[3] on T-CHI for NSTX predicts the formation and breakup of an elongated Sweet-Parker (S-P) current sheet and a transient to plasmoid instability. According to this simulation, the reconnection rate based on the plasmoid instability is faster than that by the S-P model and becomes nearly independent of the Lundquist number *S*. In this workshop, we will report the formation of multiple X-points (plasmoids) in the elongated current sheet has been observed in the T-CHI start-up on HIST.

The flux closure of T-CHI plasmas in the presence of the toroidal (guide) field have been measured by using the 2D internal magnetic probe arrays. The stronger toroidal magnetic field makes plasma less compressible and ion sound gyro-radius smaller, leading to slower reconnection time and longer current sheet even if the plasma resistivity is high. The long and thin current sheet in large size systems is unstable to the tearing mode. Recent experimental observation shows that two or three plasmoids are generated in the elongated current sheet with the narrow width comparable to the ion skin depth or the ion sound gyro-radius. We have measured the electron density and temperature profiles inside the current sheet by using the double electrostatic probes in order to estimate the *S* value. The one of plasmoids develops to a large-scale flux structure (closed flux) during the decay phase because the injected current diffuses into the plasmoid from the edge of the central open flux column. These findings indicate that the plasmoid instability in the elongated current layer in the presence of the guide field allows the formation of X-points and the fast flux closure via fast magnetic reconnection during the T-CHI start-up.

1) R. Raman *et al*., Phys. Rev. Lett. **104**, 095003 (2010).
2) T. Hanao *et al*., Plasma and Fusion Research **11**, 1402001 (2016).
3) F. Ebrahimi and R. Raman, Phys. Rev. Lett. **114**, 205003 (2015).