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Global/micro-scale fine structure formation process of magnetic reconnection in high field plasma merging experiments

Hiroshi Tanabe[1], Qinghong Cao[2], Haruaki Tanaka[2], Tara Ahmadi[2], Moe Akimitsu[2], Ryo Someya[1], Mikhail Gryaznevich[3], Chio-Zong Cheng[1], Michiaki Inomoto[1] and Yasushi Ono[1]
[1] Graduate school of frontier sciences, university of Tokyo,
[2] Graduate school of engineering, university of Tokyo, [3] Tokamak Energy Ltd.
e-mail (speaker): tanabe@k.u-tokyo.ac.jp

Here we report our latest investigation of global/ micro-scale fine structure formation process of magnetic reconnection in the central solenoid (CS)-free merging spherical tokamak (ST) formation experiments on ST40 and TS-6 using our ultra-high resolution 2D ion Doppler tomography diagnostics (Fig.1). In addition to the previously reported high temperature plasma formation up to ~250eV in TS-3 and 1.2keV in MAST, global/ micro-scale fine structure formation process of magnetic reconnection under the influence of high guide field (toroidal field B_t) has been investigated: global ion heating in the downstream region, localized electron heating around the *X*-point and macro/microscopic fine structure formation due to the coupling of both global/local physics through transport process. Our high-resolution 2D imaging measurement clearly revealed that (i) magnetic reconnection initially forms localized hot spots around the diffusion region, (ii) the continuous accumulation of the heating coupled with transport process expands the high temperature region globally on the field line direction and (iii) the dynamic heat transport process is also affected by the polarity of toroidal magnetic field and forms poloidally tilted structure: Hall-effect when ion-electron mass ratio is high, while opposite polarity by transport process if mass-ratio is small. High temperature region formed by outflow heating initially has higher ion temperature gradient $|\nabla T_i|$ > 1keV/m but cross-field transport is strongly inhibited under the influence of high guide field because the ratio of parallel/perpendicular ion thermal conductivity satisfies $\kappa^i_{//}/\kappa^i_{\perp} = 2(\omega_{ci}\tau_{ii})^2 >> 1$. This performance is typically better in high field side and its propagation toward field line direction in microsecond time scale has experimentally detected for the first time in TS-6 with our full-2D imaging measurement of ion temperature profile. The maximum ion temperature achieved by reconnection heating increases as a function of reconnecting component of magnetic field ($\Delta T_i \propto B_{rec}^2 \sim B_p^2 \propto I_p^2$) and the extended performance was pioneered in the high field spherical tokamak ST40 with plasma current ~ 0.4MA (B_{rec} > 0.1T) and toroidal guide field B_t ~ 2T, leading to more heating performance than MAST ΔT_i > 2kV in 2018 and successful connection to steady scenario both with (in 2018) and without solenoid (in 2019: Fig. 2). The latest reports of the extended plasma performance and the achievement in 2020 will also be presented in the conference.

Acknowledgement
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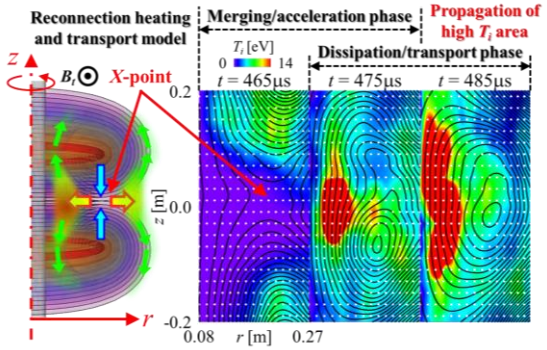

Figure 1 Full-2D imaging measurement of reconnection heating/transport process using ultra high-resolution ion Doppler tomography diagnostics in TS-6

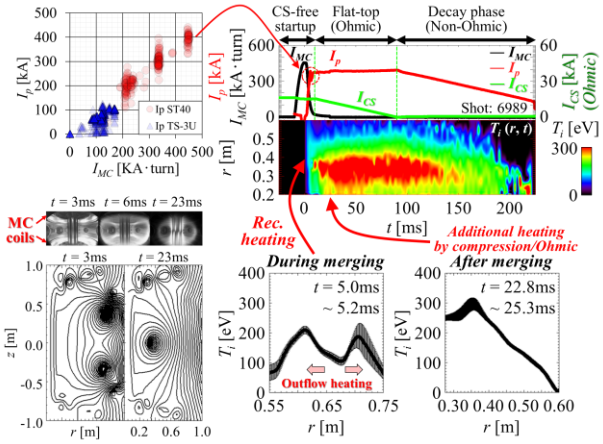

Figure 2 High field application of merging plasma startup in the ST40 spherical tokamak