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Plasmoid Formation and Ejection in TS-3U Merging Tokamaks Experiment

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Multiple blob/plasmoid structures were measured for the first time in current sheet of merging spherical tokamak(ST) plasmas in TS-3U, using high-resolution and high-accuracy print-circuit-board (PCB) type magnetic probe array. We found (i) formation of multiple current sheet blobs: initially one, finally three or four partly due to current sheet deformation by Hall effect, (ii) merging of the multiple blobs into a single blob, (iii) existence of small plasmoid (=magnetic island) inside the blobs of current density, (iv) increase in reconnection electric field E_t due to plasmoid ejection from the X-point region. The plasmoid ejection with large mass ejection from X-point area, increases E_t, suggesting large increase in reconnection heating power for the burning ST plasma formation.

We have been investigating on reconnection heating characteristics of merging ST plasmas for direct access to burning plasma without using any additional heating like NBI[1]. The reconnection heating depends on the current sheet structure which is left unsolved for a long time due to lack of high-resolution and high-accuracy magnetic field measurement. As shown in Fig. 1(a), we developed the PCB type magnetic probe array with 5mm-resolution[2], whose accuracy is about 0.1%. It made clear formation of a single plasmoid and multiple blobs in the current sheet of merging STs in Fig. 1(b) and Figs. 2(a)(b), respectively.

In Figs. 2(a)(b), the current sheet initially appears, then peaks at two positions and splits into three and/or four blobs. The magnetic field lines deformed by the tilt motion looks promoting the current sheet splitting. The Hall current density deform/rotate the current sheets clockwise in Fig. 2(a) or counter-clockwise in Fig. 2(b),

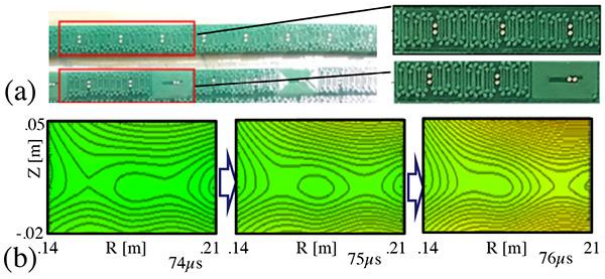

Fig. 1 (a) High-density (5mm) magnetic probe arrays made from Print Circuit Board (PCB) technique and (b) 2D contours of poloidal flux around the X-point regions of two merging tokamak plasmas in TS-3U.

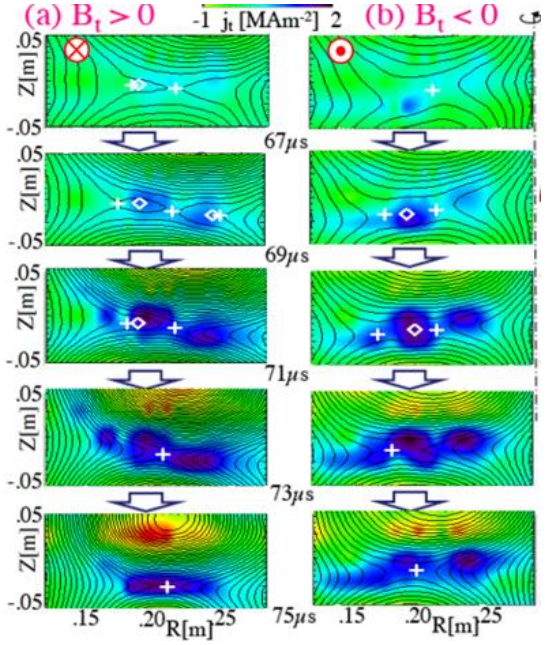

Fig. 2 (a)(b) R-Z contours of poloidal flux (solid lines: 0.1mWb spacing) and toroidal current density jt (color) of two merging STs for (a) positive and (b) negative toroidal magnetic field B_t in TS-3U (white symbols: ◊ and + indicate O-point and X-point positions, respectively)

depending on polarity of applied toroidal field B_t shown by red arrows:⊙,⊗ Since electrons move along magnetic field lines much faster than ions, the current sheet always has radial Hall current j_{Hall} flowing toward the X-point. It also produces negative and positive potential wells for ion acceleration The $j_{Hall} \times B_t$ force rotates the current sheet, deforming the magnetic field lines (at 73μs), promoting multiple blob formations. Then, the four blobs merge and finally relax into a single blob.

References

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