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Experimental Study of Solar Flare Mechanism by Use of Torus Plasma Merging

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We experimentally investigate the mechanism of the flux-merging-type flare by using torus plasma merging experiments in our TS-6 device focusing on its micro- and macro-scale processes. For micro-scale process, we discuss that the sheet ejection and the anomalous resistivity mainly accelerate the magnetic reconnection, which plays the major role in the development of solar flare. For the macro-scale process, we discussed the destabilization mechanism of merging coronal loops. We have found that the following instabilities: the torus instability, the current-driven instability, and the pressure-driven instability mainly caused the expansion of the merging flux tube.

Solar flares are driven by magnetic reconnection and involve both micro-scale processes which govern the onset and speed of flares, and macro-scale processes which destabilize coronal loops leading to eruptions. While the standard flare model suggests that eruptions originate from a single coronal loop losing force balance [1], recent studies indicate that some flares are caused by the merging of multiple coronal loops. Kusano et al. (2012) proposed that solar eruptions occur when a small, reversed-polarity magnetic flux loop merges with a major magnetic field through reconnection [2].

For the micro-scale process, we investigated how the current sheet dynamics accelerate reconnection. Using high-resolution Printed-Circuit-Board (PCB) coils, we measured detailed *r-z* 2D magnetic field profiles during the high-guide-field flux tube merging. Setting two separation lengths of acceleration coils (427 mm & 700 mm), we changed the inflow speed/sheet compression to study its effect on the current sheet structure. We defined the merging ratio as the ratio of the reconnected poloidal flux at X-point (common flux) to the peak flux of a torus plasma before merging (private flux + common flux) to investigate the influence of the dynamic current sheet structure on the reconnection speed. As shown in Figure 1 and Figure 2, our results show that the reconnection speed increases in two stages, along with toroidal current density *Jt*, toroidal electric field *Et*, and effective resistivity η at the X-point. These accelerations are caused by mass ejection from the current sheet which drives the inflow via mass conservation, and by anomalous resistivity induced by current sheet compression to the ion Larmor radius.

For the macro-scale process, we investigated the destabilization mechanism of merging coronal loops during reversed polarity spheromak merging. We measured the toroidal mode by using r-θ 2D magnetic field measurement probes, and evaluated the instabilities with the following parameters: decay index n_{decay}, plasma beta β, toroidal mode number n, and safety factor q. We have found that the merging spheromak-type flux tubes expand mainly due to three mechanisms: Torus instability caused by the increased decay index n_{decay}, pressure-driven instability caused by the increase in plasma beta β, and current-driven instability caused by the decrease in safety factor q after merging. These findings experimentally explain the flux-merging-type solar flare models, highlighting how current sheet dynamics accelerate reconnection and how the merging process destabilizes the coronal loop followed by its eruptions. Now, we try to include the influence of the foot-points of coronal loops using half-torus flux tubes on conductors.

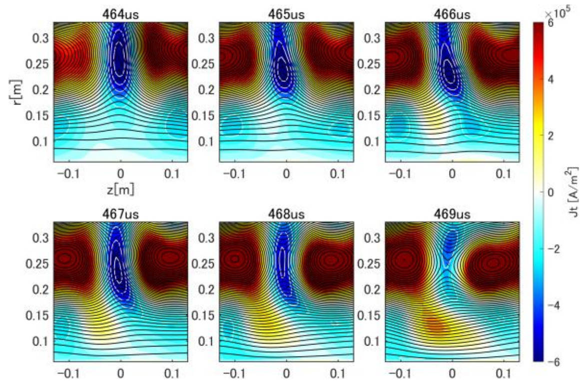

Figure 1 The magnetic profiles when the separation length of the acceleration coils is 427 mm. *R-Z* contours of the poloidal flux (color contour: toroidal current density *Jt*, black lines: poloidal flux lines, 0.25 mWb spacing, white lines: contour line of toroidal current density *Jt*, 10^5 A/m^2 spacing).

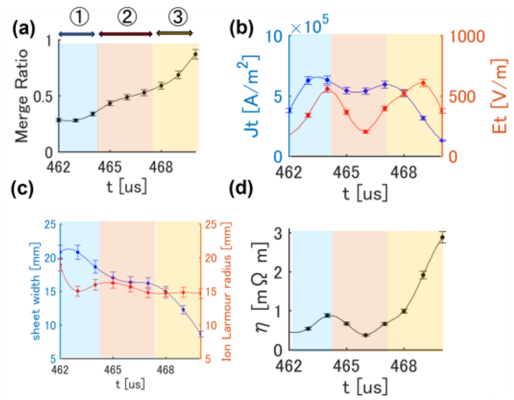

Figure 2 Time evolutions of (a) merge ratio α, (b) toroidal current density *Jt*, toroidal electric field *Et*, at X-point (c) effective resistivity at X-point, and (d) sheet thickness and ion Larmour radius.

References
[1] S. Masuda et al., Nature, Vol.271, 495-497, 1994
[2] K. Kusano et al., Astrophysical Journal, Vol. 760, p. 31, 20