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Fast Magnetic Field Penetration into Low Resistivity Plasma

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Magnetic field penetration, much faster than expected by resistive diffusion, is observed in pulsed-power experiments for three decades [1]. The fast penetration is explained as a Hall-induced penetration that occurs when the Hall electric field becomes inductive due to non-uniformity of the plasma [2]. Large deviations from the frozen-in law in low-resistivity plasma have been explained by the formation of a shock with a narrow current layer. Despite the dominant role of the Hall penetration, basic issues remained unsolved. The magnetic field penetration is predicted by the theory to occur only if the current-carrying electron flows in the direction of the gradient of the electron density. In the opposite polarity, magnetic field expulsion out of the plasma instead of penetration is predicted. Such asymmetry in the penetration has not been observed. Moreover, the penetration seems to occur also in plasmas in which the initial density non-uniformity was small [3]. Energy conservation requires large magnetic field energy dissipation. The fate of the dissipated energy is not clear, however, as electron heating is small. An additional unexpected process of simultaneous magnetic field penetration and ion separation was discovered [4]. The ion separation was shown to consist of light-ion plasma being pushed ahead of, while heavy-ion plasma lags behind the magnetic piston. A model will be described that explains the combined fast magnetic field penetration and ion separation. With all the experimental and theoretical progress, this fast magnetic field penetration into low-resistivity plasma is only partially understood and is a puzzle that remains to be solved.

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