The Chodura sheath for angles of a few degrees between the magnetic field and the surface of divertor targets and limiters

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Abstract. To achieve low deposited power flux density to solid surfaces in magnetic fusion devices, very small values of α are required, where α is the angle between $\boldsymbol{B}$ and the surface tangent. For an oblique magnetic field, there exists in front of the solid surface a Chodura sheath (CS) of thickness several ρ_i, the ion larmor radius. The standard assumption is that the CS is additional to the Debye sheath (DS) of thickness several λ_D, the Debye length. Simple fluid modeling for collisionless CS conditions gives the drop in normalized electrostatic potential across the CS as $e\Delta\phi_{CS} / kT_e = \ln(\sin\alpha)$. For an electrically floating wall there is the separate constraint of ambipolar flow to the wall $e\Delta\phi_{floating} / kT_e = 0.5\ln\left[(2\pi m_e / m_i)(1+T_i / T_e)\right]$, where $\Delta\phi_{floating} = \Delta\phi_{CS} + \Delta\phi_{DS}$. For the case of a deuterium plasma and $T_i = T_e$, $|e\Delta\phi_{floating} / kT_e| = 2.84$. For $\alpha \le 3.35^\circ$, $|e\Delta\phi_{CS} / kT_e|$ exceeds 2.84 which evidently implies that the DS ceases to exist for such values of α and the entire potential drop would then occur across the CS. New analysis of the CS provides solutions for a number of quantities of practical importance, which improve on the solutions presently in use in models and edge impurity codes. Compared with the latter, the results of the present analysis indicate that (i) ion impact angles on the surface are more glancing, (ii) the E-field directed toward the solid surface is stronger, (iii) the plasma flow speed toward the solid surface is higher, and (iv) the plasma density drops more rapidly approaching the solid surface. The effect of (i) is to increase impurity sputtering yields. The effects of (ii) and (iii) increase the probability of prompt local deposition of sputtered particles, while (iv) has the opposite effect.

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