Effects of Inverse Sheaths on the Plasma-Surface Interactions in Magnetic Fusion Research Areas

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At the 2018 instance of this conference, we showed that surfaces with strong electron emission float above plasma potential and form an inverse sheath [1]. Inverse sheaths make the plasma-surface interaction very different from the classical or space-charge limited sheaths long assumed [2] to form at emitting surfaces in magnetic fusion devices. More recently, we show in kinetic simulations that inverse sheaths cause an extreme local cooling of the plasma near the surface [3]. This presentation will focus on ongoing new work [4] aiming to quantify the degree of cooling that could be expected in a tokamak scrape-off layer (SOL). Our calculations predict that for the same SOL input power that leads to a tens-or-hundreds-of-eV target plasma in a classical sheath operating regime, a few-eV or sub-eV target plasma will generally form if there is an inverse sheath. As a consequence, we propose that a cold enough target plasma for detachment is achievable using thermonic divertor plates as an alternative to the standard cooling method of injecting neutrals (which tends to compromise core plasma performance). Other expected advantages [4] of operating with inverse sheaths over conventional sheaths include (a) ion impact energies are as low as possible, thereby minimizing sputtering and tritium implantation, (b) surface recombination heat flux is reduced due to ion confinement, and (c) damaging arcs are inhibited due to the reversed sign of the surface electric field. We estimate the critical thermonic flux required to sustain an inverse sheath in tokamaks and analyze what thermonic materials are capable of providing it.

Other inverse sheath applications to magnetic fusion motivating ongoing research will be discussed. For example, when a negatively biased thermonic cathode forms an inverse sheath, the interior plasma potential collapses over an extended distance [5]. We show this may enable inducing large-scale perturbations or convection in the SOL using biased emissive target segments or inserted hot filaments. Zhang et al. [6] found that the same processes responsible for inverse sheath formation at electron-emitting surfaces [1] carry over to H- emission. They showed in simulations that inverse sheaths can transform the plasma to an ion-ion plasma (dominated by H+ and H-, with negligible e- density), which can alter the operation of negative ion sources designed for neutral beam injection in tokamaks including ITER.


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