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Edge and divertor plasma: detachment, stability, and plasma-wall interactions

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The processes involving edge plasma and plasma-material interactions in magnetic fusion devices are very multifaceted and include a wide spectrum of phenomena ranging from plasma turbulence and meso-scale stability, recycling and transport processes of hydrogen species in the wall material, to the modification of wall material properties. In many cases these processes are strongly coupled and exhibit synergistic effects. Here we present the results of our studies of a wide range of edge plasma related issues: Our numerical simulations solve a long standing dispute on the roles of impurity radiation loss, plasma volumetric recombination, and ion-neutral friction in the rollover of the plasma flux to the target, which is the manifestation of detachment. We show that the rollover is caused by the increase of the impurity radiation loss and volumetric plasma recombination while the ion-neutral friction, although important for establishing necessary edge plasma conditions, does not contribute per se . With numerical modeling and theoretical analysis we consider stability of detachment and show that the absorption/desorption of hydrogen and impurity species from the wall can be crucial for a global stability of detached plasma. We also identify different mechanisms of meso-scale thermal instabilities driven by impurity radiation and resulting in a self-sustained oscillations of edge plasma parameters. We consider a trapping of He, which is an intrinsic impurity of fusion plasmas, in the first wall tungsten material. Our newly developed model, accounting for the generation of additional He traps caused by He bubble growth, fits all available experimental data on the layer of nano-bubbles observed in W under irradiation of low energy He plasma. Finally, we report on an impact of sheared magnetic field on the dynamics of blobs and ELM filaments playing an important role in edge and SOL plasma transport. This material is based upon work supported by the U.S. Department of Energy, Office of Science, Office of Fusion Energy Sciences under Award Numbers DE-FG02-04ER54739, DE-FG02-06ER54852, DE-SC0010413, and through the Scientific Discovery through Advanced Computing (SciDAC) program on Plasma Surface Interactions, funded by U. S. Department of Energy, Office of Science, Advanced Scientific Computing Research and Fusion Energy Sciences under Award Number DE-SC0008660.

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