Physics of the edge plasma and first wall in fusion devices: Synergistic effects

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Over the years, and in particular with the beginning of the ITER era, it became clear that the fusion has, at least, two major issues: core plasma confinement and the performance of the edge plasma and the first wall. Different aspects of the core plasma confinement were the subjects of intense theoretical and experimental studies for a long time. On the contrary, the physics of the edge plasma and, in particular, the physics first wall in fusion devices have many unresolved issues and poor understanding. In most cases edge plasma and the first wall processes are treated separately from each other. For example, the first wall processes are often studied in linear plasma devices, where plasma properties (heating, turbulence, transport, etc.) are very different from fusion devices (e.g. tokamaks). Such approach, legitimate in many cases, fails when synergistic effects in edge plasma-first wall interactions in fusion devices become important.

Such effects are already observed in current experiments. For example [1, 2], uncontrollable release of hydrogen from the first wall, formation of the hot spots causing a strong influx of impurity, etc. significantly restrict operational domain or even terminate the discharge.

In this presentation we consider three examples of synergistic effects in edge plasma-first wall interactions. We analyze ELMy H-mode discharges from DIII-D with UEDGE-MB code coupled to the first wall model describing hydrogen absorption/desorption processes. We find that the pedestal crash in infrequent but large type-I ELMs is accompanied by the first wall absorption of plasma particle inventory expelled from the pedestal during the crash. As a result, the recovery of plasma density pedestal is virtually completely determined by the wall outgassing processes. Contrary to that, for the case of relatively small frequent ELMs, most of the plasma expelled from the pedestal resigns in the SOL and divertor regions, so that plasma particle pedestal recovery is controlled by plasma and neutral transport in the SOL and divertor.

Next we demonstrate that the interplay between secondary electron emission form the first wall material and non-Maxwellian features of electron distribution function, which is typical for the SOL plasma, can cause the bifurcation of the heat flux to the target. We notice that this effect is only possible for non-Maxwellian electron distribution function.

Finally, we consider coupled plasma particle and energy transport and hydrogen transport in and absorption/desorption in/from the wall material. We stress that in a standard conditions of a tokamak operation, the amount of hydrogen, stored in the wall material is often orders of magnitude larger than hydrogen inventory in tokamak plasma. In addition, hydrogen transport in the wall is rather sensitive for the wall temperature. We find that synergistic effects of edge plasma transport and wall processes can cause specific thermal instability resulting in uncontrollable and massive hydrogen injection into tokamak core, similar to that seen in some experiments.

[1] A. Ekedahl, et al., *Nucl. Fusion* **49**, 095010 (2009)
[2] E. M. Holmann, et al., *J. Nucl. Mater.* **390-391**, 601 (2009)