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Progress in European research towards efficient Plasma-Facing Components for ITER and DEMO

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This paper presents advances in the physics program of EUROfusion with respect to plasma-facing components (PFC) research, which addresses mainly Mission 2 (Heat-exhaust systems) of the EFDA Fusion Electricity Roadmap [1].

The research for efficient PFC operation for ITER and DEMO is focused on the erosion, transport and deposition of wall materials, as well as the resulting material mixing and fuel retention. These effects are studied from an atomistic level up to large-scale experiments with ITER- and DEMO-relevance [2].

The paper overviews the work in this area over the last 4 years and highlights the latest results:

In the area of material qualification, systematic studies of ITER-grade tungsten samples under sequential and/or parallel plasma-, particle- and heat-loading in different plasma and accelerator facilities were performed. From these studies, synergistic effects of different exposure parameters were identified. This allowed for new and improved predictions of material properties and damage thresholds in the tokamak divertor environment, as opposed to studies of just one parameter at a time.

Nonetheless, experimental results from tokamaks are of great importance for the validation of these findings. For this purpose, the WEST tokamak was integrated in the EUROfusion program as a facility dedicated specifically for plasma-wall-interaction research [3]. The WEST research program on plasma-wall-interaction, together with first results of the EUROfusion experiments, which are expected in 2018, are presented here as well.

Similarly, synergistic effects have also been identified in the area of fuel retention studies. Among others, exposures of samples to mixed plasmas (hydrogen/deuterium + (intrinsic) impurities like helium), as well as simultaneous self-ion implementation and deuterium beam loading, were performed. Again, these experiments lead to better predictions of the behavior in the tokamak environment, and also allow for a better understanding of the fundamental processes causing the observed effects.

The experiments are supported by modelling activities, with models ranging from molecular dynamics- (MD) up to tokamak-modelling with global erosion-deposition codes. The progress in the model development and application was most significant in the areas of fuel retention, where first principle methods were used to explain the fuel retention in tungsten / beryllium on a atomistic level; as well as the modelling of W erosion, deposition and transport in tokamaks.

The EUROfusion PFC research focusses on tungsten and beryllium, but also includes advanced materials like Eurofer or fiber-reinforced tungsten. Here, comparisons with the conventional materials with regard to erosion, surface properties and fuel retention, as well as investigations on material-specific properties, like the preferential sputtering of Eurofer steel surfaces, are investigated.

Also, a special focus lies on liquid metal materials. Whilst tungsten PFCs are the baseline for European DEMO design, research on liquid metal divertors is pursued as a risk mitigation strategy. In 2018, the work on liquid metals was restructured inside EUROfusion. Europe is now looking to develop at least one pre-conceptual design of a full liquid metal divertor for fusion reactors [4]. This would be the first necessary step for the realization of a proven liquid metal divertor concept for the DEMO design. The work consists of investigating open physics questions, as well as covering all engineering aspects which have to be considered during the design and integration of a liquid metal divertor into the DEMO design. The strategy will be presented along with the first results on the material selection and qualification, as well as the first concepts of divertor designs.

References

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