THE CHALLENGES OF HIGH HEAT FLUX COMPONENTS IN FUSION REACTORS WITH RESPECT TO MATERIAL SELECTION

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Present design concepts for future inertial as well as magnetic fusion reactors include high heat flux components (HHFC) which have to be operated at extreme physical conditions. Even though the exact in-service conditions are unknown today, it is clear that heat, neutron, and particle fluxes will exceed those of experimental near-term concepts like ITER. A comprising and sufficient knowledge of all plasma-surface interactions and their implications is presently not available. Also the extent of possible control instruments or prediction capabilities of off-normal plasma events like disruptions and the appearance of localized modes is not known yet. Anyway, even based on non-conservative estimations and extrapolations of possible operation conditions, material selection in the designs for HHFC, such as blankets and in particular divertors, is a very complex problem.

In principle, the most delicate design components are (1) plasma facing shields, (2) cooling structures, and (3) backbone/support structures. Of course, the in-service temperature of the involved parts is a mayor design criterion and depends strongly on the underlying cooling concept (water, gas, or liquid metal). Thermal load, heat conductivity, or recrystallization, however, are typical properties which restrict the design significantly on the upper temperature limit while brittleness, irradiation damage, or tritium retention considerations narrow the materials of question on the low-temperature range. Moreover, specific defect processes such as helium bubbles, swelling, new kind of surface reactions, or crack formation have to be considered for the use of shield materials and for the application of possible coatings and protection layers.

There are divertor design studies on characteristic length scales of 1, 10, and 100 cm which demonstrate the importance of efficiency, on the one hand, but also show the difficulties connected with fabrication issues on the other. Processability, joining, and compatibility are just a few key words related to component production and assembly. Finally, there are natural criteria like the availability and there are environmental criteria like low-activation which rule out a significant number of possible elements.

This paper maps where we are with materials for HHFC and where we need to be for their application in fusion reactors. The challenges to get there will be outlined by describing and structuring the complex interrelation of design goals, material properties, and operation conditions.