A Liquid Metal PFC Initiative

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A number of community strategic planning studies have identified control of the plasma-material interface as a critical area for realization of power production. Solid plasma-facing components (PFCs) have been viewed as the leading candidates for future devices, and predominantly serve as the PFCs for present devices. ITER is relying on metallic PFCs, namely W in the divertor and Be on the first wall. While ITER's scenarios have been designed to work with these PFC materials, there is little safety margin on heat flux removal capability. The power exhaust challenge for reactors the size of ITER is substantially harder, requiring substantially higher amounts of core and divertor radiation[1]. Moreover, studies performed over the last 5 years since the ReNeW study have shown that both the steady heat exhaust and transient exhaust, during e.g. edge-localized modes (ELMs), is more challenging, owing in part to the narrowness of the scrape-off layer power flux footprint with increasing midplane poloidal field[2-7].

Liquid metals (LM) flowing PFCs have some attractive features that could remove some of the restrictions of solid PFCs. The typical erosion and PFC performance degradation of solid PFCs can be obviated with self-healing surfaces; the challenge shifts to controlling core impurity content. Similarly LM PFCs are also tolerant to neutron damage. Under the right conditions LM PFCs can exhaust very high steady and transient heat flux. Finally liquid lithium PFCs can provide access to low recycling, high confinement regimes[8], e.g. at $\geq$ 2 times H-mode scaling laws, around which attractive core and pedestal plasma scenarios can be based. The knowledge gaps for LM PFCs include keeping the surfaces clean for reliable flow, counteracting MHD mass ejection forces, determining operating temperature windows, and demonstrating He ash exhaust.

The proposed LM PFC initiative consists of three thrusts:

1. Developing the LM PFC science and technology in flowing, self-cooled and externally cooled systems in non-confinement devices (M. Jaworski abstract)
2. Conducting fundamental LM surface science studies, both in technology development and in confinement devices (J.P. Allain abstract)
3. Deployment in high power, long pulse confinement devices, e.g. NSTX-U and EAST, complementing studies in smaller devices, e.g. LTX and FTU; an element of this is to look at compatibility with very high confinement scenarios

With the rest of the world fusion community focusing on evaluating and trying to extend the capabilities of solid PFCs, the development of flowing LM PFC is a transformative area in which the US can provide world leadership toward fusion power realization.

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