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Liquid Lithium/Metal Research for Fusion at the University of Illinois

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The Center for Plasma Material Interactions (CPMI) at the University of Illinois specializes in understanding the science behind plasma material interactions and development of technologies behind plasma facing components. It is a multi-plasma disciplined laboratory that covers low temperature plasmas such as processing plasmas and atmospheric plasmas as some examples. However, it is also one of the leading fusion PMI laboratories specializing in using liquid metals, in particular liquid lithium, as the first wall and divertor material that is seen by the plasma. There is much evidence that lithium can improve the performance of a fusion reactor by stabilizing instabilities such as EM and disruptions, through flattening of the temperature profile and significantly reducing recycling. This leads to an increase in the stored plasma energy for the same amount of input power if there is no lithium. This eventually has the potential to reduce the size of a fusion machine, making them more attractive financially to build. CPMI in particular has a focus on developing and understanding liquid lithium and other liquid metal technology in the context of how it can be best used in these fusion devices. The lab not only does the science behind why a liquid metal can work, but it also one of the few labs doing concise studies of t7he engineering required for a flowing LM system. This talk will provide a summary and present some of the most important results from CPMI's comprehensive liquid metal program. This includes some of the results from CPMI's recently acquired toroidal fusion device HIDRA[1-3]. HIDRA (Hybrid Illinois Device for Research and Applications) is the former WEGA stellarator that was located at the Max-Planck Institute for Plasma Physics, Greifswald, where it was a development test bed for some of the W7-X systems. In 2014 it was moved to the University of Illinois and will become a technology testbed for many of the LM systems and also be a dedicated toroidal device for PMI studies with a dedicated test-stand, HIDRA-MAT. The design of HIDRA is such that it can operate as a l = 2, m = 5 classical stellarator and has steady state performance. It also has a tokamak core from its initial days as a tokamak in Grenoble and so eventually will be utilized to test high energy transient events on PFC's. UIUC's PFC design results will also presented in particular the latest results on the lithium-metal infused trenches. Full-size LiMIT[4,5] limiter plates have been built and are being tested in HIDRA. LiMIT flows the LM over the surface and uses what the plasma gives you, namely a heat flux and magnetic field, to generate a thermo-electric magneto-hydrodynamic flow (TEMHD) to remove heat and collected impurities. Concurrently plans are underway to fabricate and install in HIDRA a FLiLi limiter plate which is a design for a flowing LM system by PPPL[6]. The LiMIT and FLiLi are two concepts to flow lithium down the front face; and due to HIDRA's five-fold symmetry, a direct comparison between the two plated can be performed. Different aspects of these technologies will be tested for reliability before or in parallel with full deployment in future EAST. However, in the meantime, in July of 2019 gen-3 LiMIT and FLiLi plates are being tested in EAST as part of their summer campaign. These versions of LiMIT and FLiLi are being manufactured from molybdenum. For these limiters to work a fundamental understanding of the wetting[7] and thermoelectric[8,9] and corrosion[10-11] properties of liquid lithium with Mo (and other fusion relevant materials) have been performed. These are in collaboration with ASIPP[10-11] and PPPL. Also, Results from the first active lithium hydrogen/deuterium (LiHD) distillation system will be shown. LiHD will eventually be part of a fully integrated liquid lithium loop system being proposed at CPMI to study not only the recycling effects of lithium, but also the absorption rates and the technology needed to retrieve hydrogenic species (e.g. deuterium and tritium which are reactor fuel) and re-use back in the device. Finally, results from an alternate liquid metal, tin-lithium (Sn-Li), will be presented where one of the first thorough studies of Sn-Li properties is being undertaken.

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