Increased Plasma Performance with Liquid Lithium in Quasi Steady State HIDRA Plasmas

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Abstract

The former WEGA stellarator is now at the University of Illinois Urbana-Champaign and has been renamed the Hybrid Illinois Device for Research and Applications (HIDRA) [1]. One of the main motivations for HIDRA has been to have a dedicated PMI study and PFC technology development device especially for liquid metal technology. This is especially important as larger machines may not always have the time for a full dedicated PMI study. In particular Illinois specializes in liquid lithium and liquid metal for fusion applications research. HIDRA has now been operating for several years doing basic studies of the plasma parameters and shape using electron beam imaging [2-5] for liquid metal studies. To this end a material analysis test-stand (HIDRA-MAT) [6] has been built to expose materials to the steady state (up to 1000 s) HIDRA plasma with the capability to put a drop of lithium on to the surface as well via an injector [7]. HIDRA-MAT has in-vacuo capabilities with LIBS, LIDS and TDS to do some basic surface analysis without breaking vacuum. HIDRA is inherently a "dirty" machine with base pressure on the order of 10^{-7} torr. When running, spectroscopic measurements show a lot of hydrogen and oxygen due to water vapor trapped on the stainless-steel surfaces. Typical plasma parameters with 5 kW of ECRH heating are T_e = 15 - 25 eV, T_i = 2-3 eV and n_e = 1 - 3×10^{18} m^{-3}. In early 2021, the first lithium campaign was undertaken in HIDRA with a helium plasma. The main objective was to test some nano-porous tungsten samples with lithium in a helium plasma environment, however a surprising result was observed. In a 600 s discharge, 100 mg of lithium was evaporated into the plasma and interaction with the non-ionized and confined "recycling" gas, i.e. helium, hydrogen and oxygen saw a dramatic decrease in the recycling rate, over 90%. The effect on plasma performance was spectacular, with a sustained electron temperature of T_e = 45 eV over ***100 seconds***, while density reduced slightly to n_e = 2×10^{18} m^{-3}, most likely due to the hydrogen and oxygen impurities being removed. In November of 2021 a second set of lithium evaporation experiments (LEEX) was undertaken with the PFC samples at different position from the plasma. Again, the dramatic increase in plasma parameters was repeatably observed with T_e = 80 eV, T_i = 8 - 10 eV and n_e = 1 - 2×10^{18} m^{-3}. Along with this a strong increase in the toroidal magnetic field is observed indicating that there is a poloidal current flow that is being driven. This talk will present an overview of the HIDRA lithium results and some of the potential mechanisms that drive the increase in plasma performance and implications for future flowing liquid lithium PFC designs in stellarators.

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