Abstract for an Invited Paper
for the DPP06 Meeting of
The American Physical Society

Achievement of Low Recycling and High Power Density Handling in CDX-U with Lithium Plasma-Facing Components[1]

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The CDX-U spherical tokamak research program has focused on lithium as a large area plasma-facing component (PFC). The CDX-U experiments have used a toroidal lithium limiter and evaporated lithium wall coatings up to 100 nm thick. Under these conditions, a particle pumping rate of 1 - 2 x 10^{21} particles/second was achieved from an active wall area of 0.4 m^2. The energy confinement times deduced from plasma equilibrium reconstructions showed a nearly six-fold improvement over discharges without lithium PFC's. This was an increase of up to a factor three over ITER98P(y,1) scaling, and reflect the largest enhancement in confinement ever seen in Ohmic plasmas. Recycling coefficients (R) of 0.3 or below were deduced from spectroscopic measurements. These are the lowest values of R observed to date in magnetically-confined plasmas, and for the first time, the wall was not the dominant source of fueling. The process of generating lithium evaporative coatings also showed the effectiveness of liquid lithium in redistributing heat loads at extremely high power densities. An electron beam was used to deposit about 1.5 kW of power on a 6 mm spot on the toroidal lithium limiter. Lithium evaporation was not localized to this spot, but occurred only after the entire volume of lithium was raised to the evaporation temperature. Infrared camera images showed that even with a lithium depth of 3 mm, convection due to the Marangoni effect was able to distribute a heat load of about 50 MW/m^2 for the 240 second duration of the electron beam pulse. This could have significant consequences for PFC's in burning plasma devices, where high power densities are a concern.

[1]Supported by US DOE contract #DE-AC02-76CH-03073

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