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Operation of Alcator C-Mod with high-Z plasma facing components and implications

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High-Z Plasma Facing Components (PFCs) are likely necessary for a tokamak reactor due to their low tritium (T) retention, capability to handle high heat fluxes with low erosion, and robustness to nuclear damage and activation. ITER is considering using all high-Z PFCs to reduce the T retention projected from current carbon PFC experiments. Recent C-Mod experiments, utilizing molybdenum PFCs, provide unique experience regarding the effect of high-Z PFCs on: 1) plasma performance; 2) necessity of a low-Z wall-coating (boronization); & 3) hydrogenic retention. After boron was removed from vessel & molybdenum PFC surfaces RF-heated H-modes were readily achieved although the resultant enhancement in energy confinement was small (H89 $\sim$ 1). Particle confinement was 'good,' causing core Mo radiation to rapidly rise after the H-mode transition, cooling the plasma, reducing confinement and/or causing a back H/L transition. Ohmic H-modes had better confinement (H89 $\sim$ 1.5). Post-boronization the situation was changed; Mo sources and core levels were reduced $\sim$ x10 with H89 reaching 2. Under these conditions a world-record volume-average plasma pressure of 1.8 atmospheres at 5.4 T was achieved at the ITER β_N. The positive effects of boronization are found to last a limited time, correlated with the input energy. Intra- and inter-shot boronization techniques were developed with the latter being the most successful. Wall fuel retention was significant (up to 50% of D_2 pulsed in) both for boronized and un-boronized PFCs. Scaling fuel retention to an ITER-size device gives of order 50g/pulse. Planned, localized disruptions were developed to thermally desorb the retained H/D from PFC surfaces. This initial comparison indicates that high-Z operation, without boronization, carries some risk for poor confinement performance and implies that boronization (or other low-Z wall coating), not presently planned for ITER, might be required for high-Z PFCs. With or without boronization, the H/D retention could be large; but disruptive techniques to remove the D/T show promise.