

§48. Active Particle Control in the Compact Spherical Tokamak CPD by a Li-gettered Poloidal Limiter

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It is widely recognized in the magnetic fusion community that high-performance core plasmas often favor reduced particle recycling in the edge areas. Therefore, a variety of wall conditioning techniques such as boronization have been developed to achieve reduced recycling as well as impurity-controlled conditions.

However, due to the surface saturation with absorbed and/or implanted particles, the efficacy of wall conditioning by any technique has a finite lifetime, necessitating re-conditioning after a certain number of discharges. Clearly, this is not desirable from the point of view of operating future steady state fusion power reactors. To resolve this steady state issue, essentially all the imaginable PFC concepts have been proposed over the past decade. Most of these concepts employ some self-replenishing surface component, either solid or liquid, to provide “active” wall pumping. One such concept proposed by Hirooka et al. [2] features a moving-belt made of SiC-SiC fiber fabrics with an in-line getter film deposition system. A series of PoP (for proof-of-principle) experiments have been conducted on this concept with the moving-belt simplified by a laboratory-scale rotating drum [3]. Results indicate that not only hydrogen but also helium recycling can be reduced to levels significantly lower than 100% even at steady state, so long as the rotating drum surface is gettered with lithium.

Encouraged by these successful laboratory-scale PoP experiments, a similar but custom-designed rotating drum setup has been constructed to be used as a poloidal limiter in a compact spherical tokamak: CPD (for the Compact Plasma-wall interactions research Device). Active wall pumping effects observed on global particle recycling, impurity control, and core plasma properties have been presented at the 18th PSI-conference in 2008 [4].

As shown in Fig. 1, it has reproducibly been observed that, as soon as the rotating surface is gettered with lithium, hydrogen recycling, i.e. H_α intensity, decreases by a factor of 2-3 not only near the gettered surface but also in the center stack bumper limiter region. Along with reduced edge recycling, the core oxygen impurity level measured with O-II spectroscopy is reduced by a factor of 2-3. More importantly, while the flat-top density barely changes a few percent, the core electron temperature has been found to jump from $\sim 7\text{eV}$ to $\sim 20\text{eV}$, i.e. a significant increase in plasma pressure, having resulted in a factor of 2-3 increase in toroidal plasma current, as illustrated in Fig. 1.

After-the-fact depth profiling analysis with SIMS, using an O_2^+ probe beam, has been conducted, cutting two pieces of specimen out of the plasma-exposed rotating drum; one from the center and the other from an off-center area, as illustrated in Fig. 2-(a). Shown in Figs. 2-(b) and (c) are the secondary ion intensities of Li^+ , Fe^+ , H^+ , W^+ ,

C^+ and LiH^+ , all normalized by the O^+ intensity. Notice that the Li^+ intensities with $m/e=6$ and 7 taken from the off-center area (Fig. 2-(c)) decrease more rapidly with increasing depth than those from the center (Fig. 2-(b)). It follows immediately from these data that the drum center is deposited with more lithium than the off-center area, corroborating the discoloration seen in Fig. 2-(a).

It is noteworthy that both H^+ and LiH^+ exhibit the same trend as Li^+ in depth distribution. This implies that lithium was hydrogenated as soon as it was deposited for gettering. Also, judging from their depth distributions, Fe^+ and C^+ are considered to be plasma impurities gettered in lithium deposits.

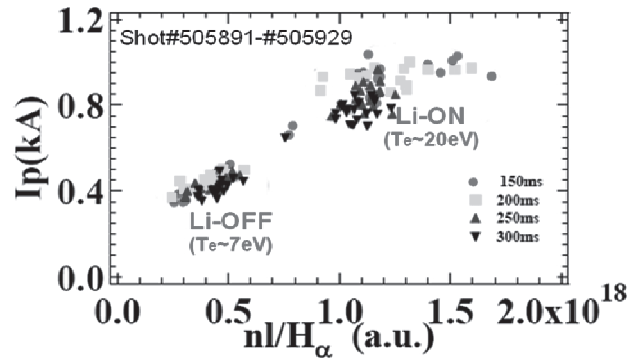


Fig. 1 Flat-top toroidal current vs. nl/H_α relationship.

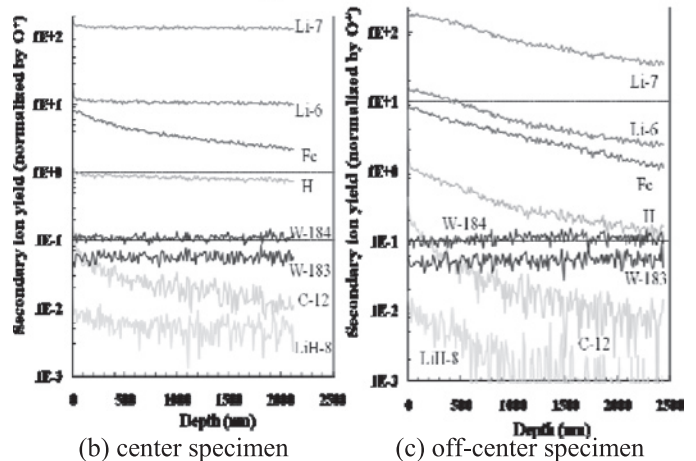
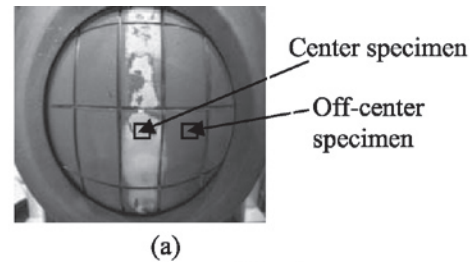


Fig. 2 Surface analysis of the lithium-gettered drum.

- 1) Mansfield, D. K. et al., Phys. Plasmas 3(1996)1982 .
- 2) Hirooka, Y. et al., Proc. 17th IEEE-SOFE, San Diego, Oct. 6th -10th, 1997, pp.906.
- 3) Hirooka, Y et al., J. Nucl. Mater. **363-365** (2007)775.
- 4) Hirooka, Y et al., J. Nucl. Mater. **390-391** (2009)502.