"Overview of the ALPS Program"[1]

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The US Advanced Limiter-divertor Plasma-facing Systems (ALPS) program is working to develop the science of liquid metal coated divertors for near and long term tokamaks. These systems may help solve the very demanding heat removal, particle removal, and erosion issues of fusion plasma/surface interactions. We are designing both static and flowing liquid lithium divertors for the National Spherical Torus Experiment (NSTX) at Princeton. We are also studying lithium, tin, and gallium divertors for future D-T machines, with emphasis on key science/engineering issues.

ALPS combines tokamak experiments, lab experiments, and modeling. Lab experiments PISCES(UCSD), IIAX(UIUC), ARIES(SNL), PRIME(ANL) show strong deuterium pumping by liquid lithium, enhanced but stable D and self-sputter yields up to surface temperatures of ~450°C, and are providing data on lithium on graphite substrate performance. CDX-U(PPPL) tokamak experiments show good plasma performance using a full liquid lithium limiter. DIII-D (GA) experiments with a small DiMES probe have provided key data on Li sputtering, transport, and disruption/operational limits.

Molecular dynamic modeling of D and He transport in liquid metals is being used to understand diffusion, trapping, and temperature enhanced sputtering. There is some indication that lithium may be able to pump helium via trapped bubbles—if true, an important advantage for future D-T device application.

The two proposed systems for NSTX are a static pre-shot deposited ~300 nm liquid Li divertor coating, and a 10 m/s in-shot injected flowing system. Both systems are predicted—via detailed coupled code/data analysis—to strongly pump D^+ resulting in a low-recycle high plasma temperature (~200-400 eV), low density, edge/SOL regime, with potentially major advantages for the NSTX physics mission. The static system has acceptable net sputter erosion and low core plasma contamination, and has little or no MHD issues. The more complex flowing system would be even more capable (higher power handling) but needs critical MHD evaluation, currently underway via experiments LIMITS(SNL), MTOR(UCLA), and code work.

Modeling of reactor grade systems indicates that tin and possibly gallium coated divertors would operate in a "conventional" high recycle regime with good power handling capability and very low sputter erosion/plasma-contamination. Whereas evaporation/sheath-superheat analysis shows acceptable Li operation up to about 500 °C, much higher limits, ~1200 °C, obtain for Sn and Ga, however sputter yield increase with surface temperature may impose lower limits. (In general, the strong plasma flow to the *divertor* substantially eases evaporation and other concerns, compared to e.g., a liquid *first wall* system). Supporting lab experiments are being conducted on critical issues of temperature-dependent particle/surface interactions in liquid tin and gallium.

Erosion due to ELMs and other transients is being examined with the HEIGHTS code package. There is erosion/contamination concern for all materials examined, solid and liquid, but with the obvious advantage for the liquids of being able to replenish the surface via flow.

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