

DIONISOS: A new experiment on the dynamics of plasma-surface interactions

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The plasma-surface interface composes one of the most interesting and important fields of study in plasma physics, and in the application of plasma physics to magnetic confinement fusion research. Both the plasma and the material surface simultaneously change characteristics due to their interaction, and affect each other in a complex, non-linear manner. This dynamic interaction leads to several effects, such as net erosion of plasma-facing surfaces, tritium retention in deposit layers and plasma impurity contamination, which are all estimated to limit the viability of long-pulse plasma fusion devices. However, in general, these phenomena remain relatively poorly understood, primarily due to the lack of proper plasma-surface diagnosis.

A new experimental facility DIONISOS (Dynamics of ION Sputtering and Implantation On Surfaces) is described. The innovative feature of the facility is its ability to measure accurately the real-time response of the material surface to the plasma bombardment using in situ high-energy ion beam analysis. The facility couples a dual-source 1.7 MV tandem ion accelerator to a plasma exposure chamber. A high current ($\sim 100 \mu\text{A}$) sputtering negative ion source on the accelerator allows for in-situ implantation of surface and for the simulation of energetic particle damage found in a fusion reactor environment. A low current ($\sim 1 \mu\text{A}$) RF ion source provides He ion beams for in-situ ion beam surface analysis (IBA). The IBA measures depth-resolved elemental composition, including hydrogen isotopes, in the first few μm of the surface, which is the region of interest for plasma-surface interactions. The facility incorporates flexible plasma/beam exposure geometry to provide spatially and temporally resolved measurements of net erosion rates, film growth and hydrogen trapping. The IBA is complemented by local plasma optical emission diagnostics that relate the material efflux to the net erosion.

Initial operation will use a helicon plasma source to provide steady-state plasma exposure over a wide range of plasma densities. The use of pulsed plasma guns are also planned to study transient effects on the material surface. Active heating and cooling of the sample will control temperature during plasma exposures.

We will briefly describe specific research topics

- The effect of ionization mean-free path on net erosion rates.
- The dynamics of hydrogenic/tritium fuel trapping in plasma-deposited films, for single or multiple species materials.
- Mixing and erosion of tungsten / carbon plasma-facing surfaces.
- The dynamic release of fuel and impurity particles from surfaces exposed to transient, high-density plasmas.