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“Evaluation of Materials Deposited by a Novel Electrothermal Plasma Technique”

Abstract

Advanced fusion energy systems require the development of materials able to resist high operating temperatures, high neutron irradiation, and high thermomechanical stresses. Additional requirements for fusion materials include low absorption cross-sections, high thermal conductivity, and minimal swelling. Graphite, beryllium, lithium, stainless steel, tungsten, copper, and molybdenum are among the materials and alloy/ceramic components proposed for use in fusion reactors. Even with advances in the reliability of non-disruptive plasma systems, plasma-facing components, such as the diverter and first wall, must withstand abnormal hard disruption events as well as normal operational conditions. Sustained operation of fusion devices necessitates understanding long-term effects of materials response to high heat fluxes experienced during disruptions. The high heat flux effects on fusion reactor suitable materials is investigated herein by simulating heat flux deposition to materials of the interior liners inside electrothermal (ET) plasma sources, which produce high-density ($10^{23}-10^{27}$/m$^3$) plasmas with heat fluxes of up to 125 GW/m$^2$ over a period of 100μs relevant to expected heat fluxes during hard disruptions.

Radiative heat flux to the inner wall of the ET source ablates the wall material, forming a dense vapor of excited atoms or molecules dissociated from the wall, followed by their ionization. The ETFLOW is a 1D time dependent code which models ET sources, the plasma formation and flow inside the source. Additionally, it calculates the incident and deposited heat flux, the amount of ablated mass, the pressure, velocity and number densities of the species. Erosion of selected materials has been studied over a range of heat fluxes comparable to expected heat fluxes during hard disruptions in future tokamaks.

Computational experiments using heat fluxes between 10GW/m$^2$ and 125 GW/m$^2$ have shown low total erosion for low-z materials (Li, Be, C) and higher erosion for high-z materials (Fe, Cu, Mo, W). The time rate of material erosion for various ranges of heat fluxes shows increased erosion with time evolution over the 150 ms pulse length of the simulated disruption event. At the highest values of heat flux simulated, low-z materials were found to ablate almost identically. At all simulated values of heat flux, the ablation of high-z materials correlated positively with z-number.

Biosketch

John Echols received his undergraduate degree in Physics from Virginia Tech in 2011. He studies under Dr. Leigh Winfrey and his research interests include first-wall and structural materials for fusion reactors, plasma-based deposition systems, and package coating for high-level nuclear waste. In addition, John Echols practices gourmet molecular gastronomy in his spare time.