Brandon Lee

Kearney, MO

Senior
Chemical Engineering; Physics

Faculty Mentor: Dr. Karl Hammond, Biomedical, Biological & Chemical Engineering

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Temperature Effects on the Relief Pressure of Helium Bubbles in Tungsten

Brandon F. Lee and Karl D. Hammond

Obtaining energy from nuclear fusion presents a significant materials engineering challenge. Tungsten, the current material of choice for the plasma-facing divertor of magnetic-confinement fusion reactors, is known to develop a network of microscopic tendrils, dubbed “fuzz,” when exposed to helium plasma. The mechanism behind fuzz formation is not well-understood, but the formation of helium bubbles below the surface is known to play a role. This study utilizes molecular dynamics to analyze the effects of temperature and surface proximity on the pressure at which helium bubble expansion and/or bursting occurs. As expected, raising the temperature lowers the pressure at which bubbles of a given size and depth will expand or burst, but the magnitude of the change decreases as the temperature increases. The relief pressure also falls off near the surface: the relief pressure at all tested temperatures is generally well-described by an empirical equation of the form $P_r = P_b\,(1 - e^{-Cd})$, where P_r is the relief pressure, P_b is the relief pressure in the bulk (far from the surface) at the same temperature, d is the depth of the bubble, and C is an adjustable parameter. The empirical correlation will be used in future simulations of helium bubbles in tungsten divertors at spatial and temporal scales comparable to the dimensions and operating windows of real devices, which are impossible to reach with atomic simulations.