SDSU | College of Engineering Mechanical Engineering

Mechanical Engineering Seminar Series

November 24, 2026, 11:00AM

Dean's Conference Room, E 203E

Title: Real-Time Powder Injection for Wall Conditioning and Impurity Control in Fusion Reactors

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Abstract: Long-pulse operation of ITER and future fusion reactors requires control of plasma-material interactions (PMI), including erosion of plasma-facing components (PFCs), impurity contamination, and fuel retention. Wall conditioning modifies plasma-facing surfaces through thin protective coatings to reduce impurity release and plasma recycling. Conventional techniques typically require interruptions of plasma operation, motivating real-time conditioning and in-situ replenishment of boron (B)- and lithium (Li)-rich coatings using low-Z powder injection.
This talk presents recent experimental and modeling advances in DIII-D and KSTAR. In DIII-D, B injection reduces carbon and oxygen emission, enhances B deposition, and lowers tungsten (W) accumulation on remote collector probes by 25–50%. Boron nitride (BN) injection provides additional impurity control through radiative divertor cooling. In KSTAR, B injection improves wall conditions, while Li injection reduces W line emission by up to 30%. Surface characterization using spectroscopy and microscopy reveals mixed B–C coatings whose composition and thickness depend on deposition conditions. Fuel-retention studies highlight the roles of B–C–D bonding and Li–D co-deposition. Integrated modeling couples three-dimensional plasma-fluid and kinetic-neutral transport (EMC3-EIRENE), particle dynamics and ablation (DIS), and mixed-material erosion, redeposition, and surface evolution (WallDYN3D). Comparisons with laser-induced breakdown spectroscopy (LIBS) measurements constrain predictions of B migration and coating distributions. ITER simulations predict particle-size-dependent B source localization, with characteristic penetration thresholds of approximately 100–600 μm across different plasma scenarios. Implications for solid boron injector design and real-time coating replenishment in future fusion devices will be discussed.

Bio: Florian Effenberg is a Staff Research Physicist at the Princeton Plasma Physics Laboratory (PPPL), based at the DIII-D National Fusion Facility in San Diego. He serves as Deputy U.S. Tokamak Research Coordinator for Plasma-Material Interactions and leads a multi-institutional research program developing real-time wall conditioning and coating technologies for ITER and future fusion devices. He received his Ph.D. in Nuclear Engineering and Engineering Physics from the University of Wisconsin–Madison. His doctoral and postdoctoral research included three-dimensional plasma edge transport modeling and the first demonstration of impurity-seeded radiative power exhaust at the W7-X stellarator. His current research combines experiments, advanced diagnostics, and integrated modeling to investigate impurity transport, plasma-facing surface evolution, and fuel retention.