



MECHANICAL ENGINEERING SEMINAR

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Multiscale Study of Micro- and Nanoscale Interfacial Flows

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Interfacial flows at the micro- and nanoscale, such as those involving bubbles and liquid films, play a vital role in the energy transition and advanced manufacturing. For example, during water electrolysis, tiny bubbles that form on electrodes can hinder electrolyte access to the electrode surfaces, reducing the effective reaction area and overall efficiency. Understanding why these bubbles remain attached to the electrodes and how to detach them is key to improving hydrogen production. In immersion lithography, the high scanning speed of the wafer can entrain water into ultrathin liquid films. These films may rupture due to microscale and nanoscale effects, potentially damaging the wafer. Understanding the mechanisms underlying liquid film instability is therefore crucial for preventing film rupture and enabling higher scanning speeds.

In this talk, I will present a multiscale simulation framework that combines molecular dynamics simulations with continuum numerical simulations to investigate flow processes at the micro- and nanoscale and their connections to macroscopic flows. Our findings reveal that nanobubble coalescence can trigger detachment from electrodes, driven by the release of pressure energy rather than surface energy, as previously thought. This finding establishes a unified mechanism for coalescence-induced bubble detachment across length scales. We also identify a threshold current above which nanobubbles become unstable and grow uncontrollably to larger scales. Finally, I will discuss how small-scale effects, including thermal fluctuations, van der Waals forces, and liquid–solid slip, interact to determine the stability of micro- and nanoscale liquid films. By developing stochastic lubrication equations under different slip conditions, our work provides new physical insights into thin-film stability at small scales and offers guidance for controlling it.

Dr. Yixin Zhang is currently a postdoctoral researcher in the Department of Mathematics at the University of Warwick. He previously conducted postdoctoral research at the University of Twente. He received his B.Sc. (2015) and M.Sc. (2017) degrees from Harbin Institute of Technology and obtained his Ph.D. in fluid mechanics from the University of Warwick in 2021. His research focuses on micro- and nanoscale interfacial flows. He has published 13 first-author papers in international journals, including leading journals such as Proceedings of the National Academy of Sciences, Physical Review Letters, and Journal of Fluid Mechanics.