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EME International Seminar Series

Investigation of Thermal Conductance at Nanoscale Solid/Fluid Interfaces

Dr. Rohit Pillai
Senior lecturer in Mechanical Engineering
The University of Edinburgh, UK

Abstract:

Escalating transistor densities are forcing power-device hotspots above 1 kW cm^{-2}, a regime where interfacial phenomena, along than bulk boiling or convection conductance, can bottleneck the performance of two-phase cooling devices. The heat flux across a solid/liquid (SL) boundary is limited by the interfacial thermal conductance G, which in turn depends on how the solid and the adjacent nanoscale liquid layers exchange energy. This energy exchange occurs via thermal waves across the nanoscale-thick interfacial region, making it challenging to study experimentally. We use high-fidelity molecular-dynamics (MD) simulations to investigate thermal conductance three progressively more realistic systems: (a) a simple Lennard-Jones (LJ) SL interface [1], (b) the same LJ interface confined by a nanochannel that incorporates a liquid meniscus [2], and (c) metal/water interfaces whose wettability can be tuned by surface chemistry. In all three cases, our simulations enable new insights on interfacial thermal transport. Our results are relevant to rationally engineered thermal interfaces for next-generation electronics, plasmonic devices and other high-heat-flux technologies.

[1] A. El-Rifai, S. Perumanath, M. K. Borg, and R. Pillai, "Unraveling the Regimes of Interfacial Thermal Conductance at a Solid/Liquid Interface," J. Phys. Chem. C, vol. 128, pp. 8408–8417, 2024.
[2] A. El-Rifai, L. Klochko, S. Perumanath, D. Lacroix, R. Pillai, and M. Isaiev, "Spectral Mechanisms of Solid/Liquid Interfacial Heat Transfer in the Presence of a Meniscus," Phys. Chem. Chem. Phys. (accepted/in press), 2025.

Tuesday, June 17, 2025 16:30 – 17:30 p.m. JST
@3E301 (On-site only)

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Bio:

Dr. Pillai is a Senior Lecturer (equivalent to Associate Professor) in Mechanical Engineering at the University of Edinburgh, and leads a computational research group (multiscaleflowx.githib.io) working on a range of problems across the thermofluid sciences, with a focus on nanoscale heat transfer and phase change. He was awarded his PhD from the University of Melbourne in 2017, appointed as Lecturer in Edinburgh less than a year later, and promoted to Senior Lecturer in 2023. His research has featured in prominent top-quality journals (such as Physical Review Letters and Nano Letters), the press (BBC, Times, Metro), and led to a radio interview on BBC Newsnight Scotland. He has supervised 5 PhD students as primary/secondary supervisor, and 2 PDRAs (both of whom have gone onto permanent academic roles). He has recently won a €1.5M ERC Starting Grant (NANO-COOL, 2024-2029) aimed at developing a new computational toolkit to design nanomaterial-enhanced cooling technologies, which forms the focus of his current research work.

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