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Strategies for Enhancement of Two-Phase Immersion Cooling for High-Power AI Chips

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4:00 PM to 5:00 PM
Room 2540 GGB

ME Seminar Link
Passcode: 845686

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Abstract:
Two-phase immersion cooling is promising for passive, power-dense thermal management of electronics to address the challenges associated with rapid increases in thermal design power for AI computing applications. However, the required dielectric coolants have boiling performance and heat flux dissipation limitations that require use of boiling surface enhancements to meet these goals. Our recent research efforts in the Cooling Technologies Research Center (CTRC) at Purdue University have explored various routes for boiling enhancement, from microstructured surfaces that aim to enhance liquid delivery to the surface, to physicochemical modifications that tune the fluid-surface interactions to aid in bubble nucleation and departure. Nevertheless, the longstanding approach of using heat sinks with extended fins has the potential to most substantially increase the heat dissipation during two-phase immersion cooling, especially if deployed in conjunction with the aforementioned surface enhancements. However, predicting pool boiling from a heat sink is challenging due to multiple boiling regimes that can occur at different locations along the fin height. One recent breakthrough in our research has been to demonstrate an approach predicting two-phase immersion heat sink performance by applying superheat-dependent heat transfer coefficient within a fin analysis. Our approach also uniquely considers interaction between the vapor and fins, such that the predictions are valid at characteristic dimensions both below and above the capillary length scale, which has been shown key to achieving experimental validation. This modeling approach has been recently coupled with a topology optimization algorithm that optimizes the geometry of a two-phase immersion heat sink to minimize thermal resistance, while implicitly considering critical heat flux limitations, providing a first-of-its-kind design tool for two-phase immersion heat sinks.

Bio:
Justin A. Weibel is a Professor of the School of Mechanical Engineering at Purdue University and Director of the Cooling Technologies Research Center (CTRC), a graduated NSF I/UCRC that addresses research and development needs of companies and organizations in the area of high-performance heat removal from compact spaces. He received his PhD in 2012 and BSME in 2007, both from Purdue University. Dr. Weibel's research group explores methodologies for prediction and control of heat transport to enhance the performance and efficiency of thermal management technologies and energy transfer processes. He has been a key contributor to the development of transformative cooling technologies supported by the DARPA TGP (2008-2012), DARPA ICECool (2013-2017), NAVSEA NEEC (2016-2018), ONR NEPTUNE (2015-2021), SRC CHIRP (2019-), ARPA-E ASCEND (2021-), ARPA-E COOLERCHIPS (2023-), and ONR MURI (2024-) programs, in addition to numerous sponsored research projects that transition these technologies to industry. Dr. Weibel has supervised 39 PhD and 16 MS students, current and former, co-authored over 200 refereed journal and conference papers (h-index of 45). He has been recognized as an Outstanding Engineering Teacher and Outstanding Faculty Mentor in the College of Engineering at Purdue University. He received the 2020 ASME Electronic & Photonic Packaging Division (EPPD) Young Engineer Award, 2021 ASME K-16 Outstanding Early Faculty Career in Thermal Management Award, and in 2023 was elected a Fellow of the ASME. Dr. Weibel is on the IEEE ITherm Executive Committee (Conference General Chair in 2021) and is Associate Editor of the IEEE Transactions on Components Packaging and Manufacturing Technology.