Advances in energy storage and manufacturing for novel building energy systems

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Abstract

As the globe progresses towards increased electrification and renewable energy penetration in buildings, several key challenges must be addressed. Particularly, the integration of renewable energy resources into building energy systems is often limited by both system inefficiencies and renewable energy intermittency. A selection of strategies to overcome these challenges is presented here. To mitigate the intermittency of renewable energy resources, energy storage is critical. Latent thermal storage in phase change materials (PCMs) is one such attractive method; however, it suffers from low power density due to the increased thermal resistance as the phase front migrates away from the heat source/sink. Here, a solution for PCM thermal storage, termed "dynamic" phase change materials, is introduced, wherein an external driving force promotes drainage of the molten PCM layer to maintain close contact between the heat source and sink. This approach shows the potential for >10× enhancement in power density compared to the state of the art in PCM thermal storage. The underlying physics, experimental validation, and fundamental limits are presented, and a new direction in adapting the dynamic PCM system for cold storage in ice is discussed. Applications of new advances in metal additive manufacturing are also discussed, showing the potential of this technology to enable high-resolution topology optimization for cold plates, and, scalable metal and polymer additive manufacturing techniques are discussed that can allow for advanced heat exchangers for building applications, as well as for chipset thermal management across a variety of different architectures. Ultimately, the work presented here can pave the way for a lower-carbon future by enabling more efficient building systems and more effective multiscale energy storage.

Bio

Vivek Garimella is an Assistant Professor in the Department of Mechanical Engineering at Rice University in Houston, TX. He received his PhD in Mechanical Engineering in 2026 from the University of Illinois Urbana-Champaign and his Bachelor of Science in 2021 from the Georgia Institute of Technology. His research focuses on advanced thermal management and energy storage systems, specifically in building- and grid-scale energy storage, design and manufacturing of data center cooling systems, and efficiency enhancements in HVAC&R systems. He is the recipient of the Mechanical Science and Engineering Distinguished Fellowship and the Mechanical Science and Engineering Teaching Fellowship from the University of Illinois.