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MECHANICAL ENGINEERING
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Energy applications of thermal switches and diodes

Prof. Chris Dames
Department Chair and Howard Penn Brown Professor, Department of Mechanical Engineering,
University of California at Berkeley

Mechanical Faculty Scientist/Engineer, Materials Sciences Division, Lawrence Berkeley National Laboratory

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ABSTRACT

This talk will begin with a brief survey of physical mechanisms which can be used to create thermal switches, regulators, and diodes [1]. The heart of the talk will then present three energy applications of these nonlinear thermal phenomena:

(a). A thermal regulator can passively stabilize the temperature of lithium ion batteries over a wide range of operating conditions and external temperatures, which helps with the battery capacity, safety, and lifetime [2].

(b). A temperature doubler thermal circuit, inspired by an analogous electrical H-bridge rectifier, uses thermal diodes and capacitances to convert an AC thermal resource into a quasi-DC temperature difference across a heat engine [3]. This gives approximately 4x higher power output than traditional approaches to energy scavenging from such a resource.

(c). A bi-stable thermal switch, which consumes no power at steady state, has been optimized for thermal management of building walls [4]. This calls for very low effective thermal conductivity in the off state ($k_{Off} \approx 0.04$ W/m-K), which was not readily available in existing thermal switch mechanisms.

[1]. G. Wehmeyer, T. Yabuki, C. Monachon, J. Wu, and C. Dames, "Thermal diodes, regulators, and switches: Physical mechanisms and potential applications," Applied Physics Reviews 4, 041304 (2017).

[2]. M. Hao, J. Li, S. Park, S. Moura, and C. Dames, "Efficient thermal management of Li-ion batteries with a passive interfacial thermal regulator based on a shape memory alloy," Nature Energy 3, 899-906 (2018).

[3]. M. Westwood, X. Zhao, Z. Chen, and C. Dames, "4-fold enhancement in energy scavenging from fluctuating thermal resources using a temperature-doubler circuit", Joule https://doi.org/10.1016/j.joule.2021.06.007 (in press, 2021)

[4]. R. Miao, R. Kishore, S. Kaur, R. Prasher, C. Dames, et al., "Active Thermal Switch for Building Energy Savings Based on a Shape Memory Alloy" (in preparation, 2021).

ABOUT THE SPEAKER

Chris Dames' research focuses on fundamental studies of thermal transport at the nanoscale and other challenging regimes. He earned his PhD from MIT in 2006 under Gang Chen, following a BS and MS (under Arun Majumdar) from UC Berkeley. He was previously an Assistant Professor at UC Riverside before joining UC Berkeley in 2011, and since 2013 he has also held a joint appointment at the Lawrence Berkeley National Laboratory (LBNL) in the Materials Science Division. PhD alumni from his research group have moved on to positions in academia, industry, and national labs. Prof. Dames' honors include an NSF CAREER Award, DARPA Young Faculty Award, Viskanta Fellowship and heat transfer lectureship at Purdue University, and selection to the Faculty Leadership Academy at UC Berkeley. He has been serving as Chair of the Department of Mechanical Engineering at UC Berkeley since July 2021.

Session chair: Prof. R. V. Ravikrishna, mecheng @ IISc