

# MARC HODES

## PROFESSOR OF MECHANICAL ENGINEERING TUFTS UNIVERSITY

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### AREA OF INTEREST: TRANSPORT PHENOMENA

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- Momentum/Heat/Mass/Charge Transport Phenomena on Textured Surfaces.
- Mass Transfer in Supercritical Fluids.
- Heat Pipes and Heat Sinks.
- Thermoelectric Modules.

### EDUCATION

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**Massachusetts Institute of Technology** **Cambridge, MA**  
*PhD Mechanical Engineering (Chemical Engineering Minor)* 1998

- Thesis: *Measurements and Modeling of Deposition Rates from Near-Supercritical, Aqueous, Sodium Sulfate and Potassium Sulfate Solutions to a Heated Cylinder.*
- Advisor: Kenneth A. Smith, Emeritus Professor of Chemical Engineering. Co-Advisor: Peter Griffith, Emeritus Professor of Mechanical Engineering.

**University of Minnesota** **Minneapolis, MN**  
*MS Mechanical Engineering* 1994

- Thesis: *Gas Assisted Evaporative Cooling in Downflow through Vertical Channels.*
- Advisor: Avram Bar-Cohen, Distinguished University Professor of Mechanical Engineering at the University of Maryland (deceased).

**University of Pittsburgh** **Pittsburgh, PA**  
*BS Mechanical Engineering (magna cum laude)* 1990

### EXPERIENCE

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**Tufts University** **Medford, MA**  
*Professor of Mechanical Engineering & Director of Graduate Studies* Sept 2018-present  
*Associate Professor of Mechanical Engineering (tenured 5/19/14)* Aug 2008-Aug 2018

- Lead and directly contribute to research currently focused on analysis of convection in the presence of apparent slip, supercritical CO<sub>2</sub>-based drying of aerogels and thermal management of electronics. See <https://engineering.tufts.edu/me/research/hodes> for representative past and current research projects.
- Teach Statics, Fluid Mechanics and Heat Transfer at the undergraduate level and Thermal Management of Electronics, Applied Math for Engineers, Fluid Mechanics, Heat Transfer and Analytical Transport Phenomena at the graduate level.
- Service to the Department, University and Heat Transfer community.

**Transport Phenomena Technologies, LLC** – <http://www.tpotechcorp.com/> **Somerville, MA**  
*Co-Founder with Dr. Georgios Karamanis and Chief Technology Officer* 2017–present

- Technical and commercialization activities related to hybridization of computational fluid dynamics, flow network modeling, hardware-in-the-loop and multi-variable optimization to enable simultaneous optimization of the geometry and layout of arrays of heat sinks and the development of compliant vapor chambers as per Phases I and II NSF SBIR Program funding and State of Massachusetts Clean Energy Catalyst Program funding.
- Consulting on transport phenomena, including legal consulting.
- Located at Greentown Labs, the largest climatetech startup incubator in North America.

**Imperial College** **London, UK**  
*Academic Visitor in Department of Mathematics* Jan-July 2015, May-July 2016, May-July 2017, June-July 2018, ...

- Analysis of transport phenomena in the presence of apparent slip.
- Analysis of thermal contact resistance for rough surfaces.

**University of Limerick**

*E.T.S. Walton Award Visitor*

**Limerick, Ireland**

June 2012-Aug 2012

- Analysis of convection in the presence of apparent slip.

**Bell Laboratories**

*Manager (expatriate)*

**Murray Hill, NJ**

Oct 2006-Aug 2008

- Managed externally-funded Thermal Management Research Group at newly-founded Bell Labs Ireland.
- Participated in research on superhydrophobic nanostructured surfaces, “three-dimensional” heat sinks, etc.

*Member of Technical Staff*

July 1998-Sept 2006

- Developed algorithms to maximize the performance and efficiency of thermoelectric modules used for the precision temperature control of photonic components.
- Developed thermal management technologies, e.g., mechanical replacements for elastomeric gap fillers, for Lucent Technologies products.

*Postdoctoral Member of Technical Staff*

Aug 1998-July 2000

- Experiments on transient thermal management and analysis of multi-dimensional heat conduction.
- Developed numerical models for heat transfer in Lucent Technologies products, e.g., power conversion modules and handsets.

**Massachusetts Institute of Technology**

*Research Assistant in Department of Mechanical Engineering*

**Cambridge, MA**

Sept 1993-June 1998

- Modeled fouling due to precipitation of insoluble salts during Supercritical Water Oxidation (SCWO), an emerging technology to remediate hazardous organic wastes. Models predicted whether salts nucleated homogeneously or heterogeneously and rates of deposition of salt on walls of SCWO reactors by double-diffusive natural convection mass transfer.

**National Institute of Standards and Technology (NIST)**

*Visiting Scientist and NSF Fellow*

**Gaithersburg, MD**

Jan 1994-Aug 1997

- Performed solubility, deposition rate and nucleation experiments in salt-containing supercritical water.

**University of Minnesota**

*Research Assistant*

**Minneapolis, MN**

Sept 1990-Aug 1993

- Investigated transition to annular flow by addition of non-condensable gas to enhance evaporative cooling of microelectronics.
- Designed, constructed and commissioned  $\gamma$ -ray densitometer to identify two-phase flow regimes.

*Teaching Assistant*

Sept 1990-Aug 1993

- Teaching Assistant for Thermodynamics, Applied Thermodynamics, Heat Transfer and Boiling Heat Transfer and Multiphase Flow.

**Ford Motor Company**

*Summer Intern*

**Redford, MI**

Jun 1990-Aug 1990

- Performed simulations in Patran/Nastran to evaluate reliability of metal matrix composites in automobiles.

**University of Notre Dame**

*NSF REU Fellow*

**South Bend, IN**

Jun 1989-Aug 1989

- Experimental quantification of energy savings achievable in household refrigerators using Phase Change Material (PCM).

**AWARDS**

- 2014: IEEE SEMI-THERM Conference. Best Paper Award
- 2013: Tufts ASME Student Chapter. Award of Excellence
- 2012: Science Foundation Ireland. Walton Visitor Award
- 2011: ASME *Journal of Electronics Packaging*. Invited Contribution to Special Issue
- 2009: ASME InterPACK 2009. Best Poster Award in System Air and Liquid Cooling Track

- 2008: ASME ICNMMC 2008. Best Paper Nomination
- 2004: IEEE ITherm 2004. Best Paper Nomination
- 2002: Bell Laboratories. Teamwork Award
- 1997: NSF. NSF/NIST Graduate Student Fellowship
- 1994: MIT. Sigma Xi Honors Society
- 1989: NSF. REU Award to spend summer at University of Notre Dame
- 1989: University of Pittsburgh. Pi Tau Sigma Honors Society (Chapter President)

## JOURNAL EDITING

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- Associate Editor of *ASME Journal of Heat Transfer*, 2020-
- Associate Editor of *Journal of Mechanical Engineering Science*, 2019-
- Associate Editor of *IEEE Transactions on Components, Packaging and Manufacturing Technology*, 2013-
- Guest Editor of *IEEE Transactions on Components, Packaging and Manufacturing Technology*, 2010-13.

## REPRESENTATIVE PROFESSIONAL ACTIVITIES

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- External Examiner of undergraduate curriculum, Department of Mechanical, Aeronautical and Biomedical Engineering, University of Limerick, Limerick, Ireland, 2013-2017.
- Consultant on Thermal Management of DC-DC Power Converters, Altera Inc., San Jose, CA, 2012-13.

## JOURNAL PUBLICATIONS

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- [54] Moses, J., Hannon, J., Wilson, V., Dinh, H., Karamanis, G., Krishnamachari, V., Hodes, M., "Apparatus to Measure Density and Viscosity of Supercritical Carbon Dioxide-Alcohol Mixtures." Submitted to *Journal of Supercritical Fluids*.
- [53] Kadoko, J., Mayer, M. and Hodes, M., "Two-Dimensional Numerical Analysis of Gas Diffusion-Induced Cassie to Wenzel State Transition," 2021, *ASME J. Heat Transfer*. Invited contribution to a special issue in memory of Professor Ephraim Sparrow.
- [52] Hodes, M., Mahajan, R., Ruder, Z., Simon, T., Geisler, K., Ohadi, M., Mauer, J., Altman, D., Wilson, J., Ziskind, G., Spector, M., Catton, I., Dhir, V., Fisher, T., Ayyaswamy, P., Mikic, B., 2021, "In Memoriam: Professor Avram Bar-Cohen (1946-2020), Who Was Instrumental in Laying the Scientific Foundation for the Thermal Management of Electronics," *ASME J. Heat Transfer*, **143**(3).
- [51] Kirk, T., Karamanis, G., Crowdy, D., Hodes, M., 2020, "Thermocapillary Stress and Meniscus Curvature Effects on Slip Lengths in Ridged Microchannels," *J. Fluid Mech.* **894**.
- [50] Game, S., Hodes, M., Papageorgiou, D., 2019, "Effects of Slowly-Varying Meniscus Curvature on Internal Flows in the Cassie State," *J. Fluid Mech.*, **872**, pp. 272-307.
- [49] Karamanis, G., Hodes, M., 2019, "Conjugate Nusselt Numbers for Simultaneously-Developing Flow through Rectangular Ducts," *ASME J. Heat Transfer*, **141**.
- [48] Kane, D., Hodes, M., 2019, "Isoflux Nusselt Number Expression for Combined Poiseuille and Couette Flow Capturing Asymmetry and Slip," *Heat Transfer Research*, **50**(15).
- [47] Karamanis, G., Hodes, M., 2019, "Simultaneous Optimization of an Array of Heat Sinks," *ASME J. Electronic Packaging*, **141**(2).
- [46] Mayer, M., Hodes, M., Kirk, T., Crowdy, D., 2019, "Effect of Surface Curvature on Contact Resistance between Cylinders," *ASME J. Heat Transfer*, **141**.
- [45] Hodes, M., Kirk, T., Crowdy, D., 2018, "Thermal Spreading and Contact Resistance Formulae Capturing Boundary Curvature and Contact Distribution Effects," *ASME J. Heat Transfer*, **140**.
- [44] Game, S., Hodes, M., Kirk, T., Papageorgiou, D., 2018, "Nusselt Numbers for Poiseuille Flow over Isoflux Parallel Ridges for Arbitrary Meniscus Curvature." *ASME J. Heat Transfer*, **140**.
- [43] Karamanis, G., Hodes, M., Kirk, T., Papageorgiou, D., 2018, "Solution of the Extended Graetz-Nusselt Problem for Liquid Flow over Isothermal Parallel Ridges." *ASME J. Heat Transfer*, **140**.
- [42] Game, S., Hodes, M., Keavany, E., Papageorgiou, D., 2017, "Physical Mechanisms Relevant to Flow Resistance in Textured Microchannels." *Physical Review Fluids*, **2**.
- [41] Kadoko, J., Karamanis, G., Kirk, T., Hodes, M., 2017, "One-Dimensional Analysis of Gas Diffusion-Induced Cassie to Wenzel State Transition," *ASME J. Heat Transfer*, **139**.
- [40] Karamanis, G., Hodes, M., Kirk, T., Papageorgiou, D., 2017, "Solution of the Graetz-Nusselt Problem for Liquid Flow Over Isothermal Parallel Ridges," *ASME J. Heat Transfer*, **139**.

- [39] Hodes, M., Kirk, T., Karamanis, G., MacLachlan, S., 2017, "Effect of Thermocapillary Stress on Slip Length for a Channel Textured with Parallel Ridges" *J. Fluid Mech.*, **814**, pp. 301-324.
- [38] Kirk, T., Hodes, M., Papageorgiou, D., 2017, "Nusselt Numbers for Poiseuille Flow over Isoflux Parallel Ridges Accounting for Meniscus Curvature," *J. Fluid Mech.*, **811**, pp. 315-349.
- [37] Lam, L., Hodes, M., Karamanis, G., Kirk, T., MacLachlan, S., 2016, "Effect of Meniscus Curvature on Apparent Thermal Slip," *ASME J. Heat Transfer*, **138**.
- [36] Karamanis, G., Hodes, M., 2016, "Longitudinal-Fin Heat Sink Optimization Accounting for Non-Uniform Heat Transfer Coefficient under Fully-Developed Conditions," *ASME J. Thermal Sci. Eng. Appl.*, **8**.
- [35] Zhang, R., Hodes, M., Wilcoxon, R., Lower, N., 2015, "Water-Based Microchannel and Galinstan-Based Minichannel Cooling beyond 1000 W/cm<sup>2</sup> Heat Flux," *IEEE Trans. Compon., Packag., Manuf. Technol.*, **5**(6).
- [34] Lam, L., Hodes, M., and Enright, R., 2015, "Galinstan-Based Microgap Cooling Enhancement Using Structured Surfaces," *ASME J. Heat Transfer*, **137**.
- [33] Hodes, M., Lam, L., MacLachlan, S., and Enright, R., 2015, "Effect of Evaporation and Condensation at Menisci on Apparent Thermal Slip," *ASME J. Heat Transfer*, **137**.
- [32] Griffin, J., Mills, D., Cleary, M., Nelson, R., Manno, V., and Hodes, M., 2014, "Continuous Extraction Rate Measurements During Supercritical CO<sub>2</sub> Drying of Silica Alcolgel," *J. Supercritical Fluids*, **92**, pp. 38-47.
- [31] Brownell, E. and Hodes, M., 2014, "Optimal Design of Thermoelectric Generators Embedded in Thermal Resistance Networks," *IEEE Trans. Compon., Packag., Manuf. Technol.*, **4**(4), pp. 612-621.
- [30] Lam, L., Melnick, C., Hodes, M., Ziskind, G., and Enright, R., 2014, "Nusselt Numbers for Thermally Developing Couette Flow with Hydrodynamic and Thermal Slip," *ASME J. Heat Transfer*, **136**(5).
- [29] Enright, R., Hodes, M., Salamon, T., and Muzychka, Y., 2014, "Isoflux Nusselt Number and Slip Length Formulae for Superhydrophobic Microchannels," *ASME J. Heat Transfer*, **136**(1).
- [28] Hodes, M., Zhang, R., Lam, L., Wilcoxon, R., and Lower, N., 2014, "On the Potential of Galinstan-Based Minichannel and Minigap Cooling," *IEEE Trans. Compon., Packag., Manuf. Technol.*, **4**(1), pp. 46-56.
- [27] Cleary, M., Grimes, R., van Lieshout, M., Brooks, D., North, M. and Hodes, M., 2013, "Reduced Power Precision Temperature Control Using Variable Conductance Heat Pipes," *IEEE Trans. Compon., Packag., Manuf. Technol.*, **3**(12), pp. 2048-2058.
- [26] Mueller, S., Hodes, M. and Lyons, A., 2013, "A Capillary-Driven Evaporation-Enhanced Heat Sink," *IEEE Trans. Compon., Packag., Manuf. Technol.*, **3**(10), pp. 1683-1692.
- [25] Zhang, R., Hodes, M., Brooks, D., and Manno, V., 2012, "Optimized Thermoelectric Module-Heat Sink Assemblies for Precision Temperature Control." *ASME J. Electronic Packaging*, **134**.
- [24] Annapragada, R., Salamon, T., Kolodner, P., Hodes, M., and Garimella, S., 2012, "Determination of Electrical Contact Resistivity in Thermoelectric Modules (TEMs) from Module-Level Measurements," *IEEE Trans. Compon., Packag., Manuf. Technol.*, **2**(4), pp. 668-676.
- [23] Hodes, M., "Optimal Design of Thermoelectric Refrigerators Embedded in a Thermal Resistance Network," 2012, *IEEE Trans. Compon., Packag., Manuf. Technol.*, **2**(3), pp. 483-495.
- [22] Melnick, C., Hodes, M., Ziskind, G., Cleary, M., and Manno, V., 2012, "Thermoelectric Module-Variable Conductance Heat Pipe Assemblies for Reduced Power Temperature Control," *IEEE Trans. Compon., Packag., Manuf. Technol.*, **2**(3), pp. 474-482.
- [21] Krishnan, S., Hernon, D., Hodes, M., Mullins, J., and Lyons, A., 2012, "Design of Complex Structured Monolithic Heat Sinks for Enhanced Air Cooling" *IEEE Trans. Compon., Packag., Manuf. Technol.*, **2**(2), pp. 266-277.
- [20] Kumari, N., Bahadur, V., Hodes, M., Salamon, T., Lyons, A., Kolodner, P., and Garimella, S., 2010, "Analysis of Evaporating Mist Flow for Enhanced Convective Heat Transfer," *Int. J. Heat Mass Transfer*, **53**, pp. 3346-3356.
- [19] Hodes, M., 2010, "Optimal Pellet Geometries for Thermoelectric Power Generation," 2010, *IEEE Trans. Compon. Packag. Technol.*, **33**(2), pp. 307-318.
- [18] Hernon, D., Salamon, T., Kempers, R., Krishnan, S., Lyons, A., Hodes, M., Mullins, J., and McGarry, L., 2009, "Thermal Management: Enabling Enhanced Functionality and Reduced Carbon Footprint," *Bell Labs Technical Journal*, **14**(3), pp. 7-20.
- [17] Pettes, A., Hodes, M., and Goodson, K., 2009, "Optimized Thermoelectric Refrigeration in the Presence of Thermal Boundary Resistance," *IEEE Trans. Compon. Packag. Technol.*, **32**(2), pp. 423-430.
- [16] Kolodner, P., Hodes, M., Ewes, I., and Holmes, P., 2007, "Mechanical Gap Fillers: Concepts and Thermal Resistance Measurements," *IEEE Trans. Compon. Packag. Technol.*, **30**(4), pp. 813-823.

- [15] Krupenkin, T., Taylor, J. A., Wang, E., Kolodner, P., Hodes, M., and Salamon, T, 2007, "Reversible Wetting-Dewetting Transitions on Electrically Tunable Superhydrophobic Nanostructured Surfaces," *Langmuir*, **23**(18), pp. 9128-9133.
- [14] Hodes, M., Bolle, C., and Kolodner, P., 2007, "Efficient Cooling of Multiple Components in a Shielded Circuit Pack," *ASME J. Electronic Packaging*, **129**, pp. 216-218.
- [13] Hodes, M., 2007, "Optimal Pellet Geometries for Thermoelectric Refrigeration," *IEEE Trans. Compon. Packag. Technol.*, **30**(1), pp. 50-58.
- [12] Krupenkin, T., Taylor, J. A., Kolodner, P., and Hodes, M., 2005, "Electrically Tunable Superhydrophobic Nanostructured Surfaces," *Bell Labs Technical Journal*, **10**(3), pp. 161-170.
- [11] Hodes, M., "On One-dimensional Analysis of Thermoelectric Modules (TEMs)," 2005, *IEEE Trans. Compon. Packag. Technol.*, **28**(2), pp. 218-229.
- [10] Hodes, M., "Precision Temperature Control of an Optical Router," 2005, in *Handbook of Heat Transfer Calculations*. New York: McGraw-Hill.
- [9] Hodes, M., Smith, K.A., Hurst, W., Bower, Jr., W., Griffith, P., and Sako, K., 2004, "Salt Solubility and Deposition in High Temperature and Pressure Aqueous Solutions," *AIChE J.*, **50**(9), pp. 2038-2049.
- [8] Hodes, M., Marrone, P., Hong, G., Smith, K.A., and Tester, J., 2004, "Salt Precipitation and Scale Control in Applications of Supercritical Water Oxidation - Part A: Fundamentals and Research," *J. Supercritical Fluids*, **29**, pp. 265-288.
- [7] Marrone, P., Hodes, M., Smith, K.A., and Tester, J., 2004, "Salt Precipitation and Scale Control in Applications of Supercritical Water Oxidation - Part B: Engineering Approaches," *J. Supercritical Fluids*, **29**, pp. 289-312.
- [6] Hodes, M., Smith, K.A., and Griffith, P., 2003, "A Natural Convection Model for Deposition Rates in Aqueous Sulfate Solutions at Elevated Temperatures and Pressures," *ASME J. Heat Transfer*, **125**(6), pp. 1027-1037.
- [5] Hodes, M., Weinstein, R., Pence, S., Piccini, J., Manzione, L., and Chen, C., 2002, "Transient Thermal Management of a Handset using Phase Change Materials (PCMs)," *ASME J. Electronic Packaging*, **124**(4), pp.419-426.
- [4] Smith, K.A., Hodes, M., and Griffith, P., 2002, "On the Potential for Homogeneous Solution of Salt from Aqueous Solution in a Natural Convection Boundary Layer," *ASME J. Heat Transfer*, **124**(5), pp. 930-937.
- [3] Hurst, W., Hodes, M., Bowers, Jr., W., Bean, V., Maslar, J., Griffith, P., and Smith, K.A., 2001, "Optical Flow Cell and Apparatus for Solubility, Salt Deposition and Raman Spectroscopic Studies in Aqueous Solutions near the Water Critical Point," *J. Supercritical Fluids*, **22**(2), pp. 157-166.
- [2] Chen, C., Hodes, M., and Manzione, L., 2001, "Sizing of Heat Spreaders above Dielectric Layers" *ASME J. Electronic Packaging*, **123**, pp. 173-181.
- [1] Bar-Cohen, A., Sherwood, G., Hodes, M., and Solbrekken, G., 1995, "Gas-Assisted Evaporative Cooling of High Density Electronic Modules" *IEEE Tran. Compon., Packag., Manuf. Technol. A*, **18**(3), pp. 502-509.

## PATENTS

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### Filed

- [16] Hodes, M., Karamanis, G., 2016, "Hybrid Flow Evaluation and Optimization of Thermal Systems." Filed under International Publication Number WO 2017/120284 A1.

### Issued

- [15] Hodes, M., Lyons, A., Scofield, W., 2015, "Recirculating Gas Rack Cooling Architecture," US Patent. 9,025,330.
- [14] Hodes, M., 2014, "Stacked Thermoelectric Modules," EP 2 313 937 B1.
- [13] Hodes, M., Kolodner, P., Kroupenkine, T., Lyons, A., Mandich, and M. Taylor, A., 2012, "Method and Apparatus for Controlling the Flow Resistance of a Fluid on a Nanostructured or Microstructured Surface," US Patent. 8,187,894.
- [12] Fair, P., Hodes, M. Ling, W., Lyons, A., Messana, J., Rominski, P., Safavi, M., and Scofield, W., 2011, "Modular In-Frame Pumped Refrigerant Distribution and Heat Removal System," US Patent 7,905,105.
- [11] Basavanhally, N., Hodes, M., Kolodner, P., Kornblit, A., Krupenkine, T., Lee, W., Lyons, A., Salamon, T., and Vyas, B., 2010, "Thermal Energy Transfer Device," US Patent 7,832,462.
- [10] Hodes, M., Jones, C., Krishnan, S., and Malis, O., 2010, "Spreading Thermoelectric Coolers," US Patent 7,825,324.
- [9] Hodes, M., Kolodner, P., Krupenkine, T., Lyons, A., Mandich, M., Taylor, J., and Weiss, D., 2010, "Reserve Cell-Array Nanostructured Battery," US Patent 7,785,733.

- [8] Hodes, M., Kolodner, P., Krupenkine, T., Lyons, A., Mandich, M., Taylor, J., and Weiss, D., 2010, "Reversibly-Activated Nanostructured Battery," US Patent 7,749,646.
- [7] Hodes, M., Kolodner, P., Krupenkin, T., Salamon, T., and Taylor, A. 2010, "Closed Cell Surfaces with Enhanced Drag-Reduction Properties," US Patent 7,700,183.
- [6] Hodes, M., Kolodner, P., Krupenkine, T., Taylor, J., and Enright, R., 2008, "Structured Surfaces with Controlled Flow Resistance," U.S. Patent 7,412,938.
- [5] Bolle, C., Doerr, C., and Hodes, M., 2007, "Temperature Control of Thermo-optic Devices," U.S. Patent 7,299,859.
- [4] Bolle, C., Hodes, M., and Kolodner, P., 2007, "Thermal Management for Shielded Circuit Packs," U.S. Patent 7,254,034.
- [3] Bishop, D., Gates, J., Hodes, M., Kornblit, A., Pau, S., and Vyas, B., 2007, "Micro-channel Chemical Concentrator," U.S. Patent 7,220,388
- [2] Hodes, M., Kolodner, P., Krupenkine, T., Lee, W., Lyons, A., Salamon, T., Taylor, J., and Weiss, D., 2007, "Techniques for Microchannel Cooling," U.S. Patent 7,204,298.
- [1] Hodes, M. and Lyons, A., 2004, "Apparatus for Thermal Management in a Portable Electronics Device," U.S. Patent 6,724,626.

## CONFERENCE PUBLICATIONS

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- [38] Karamanis, G., Dinh, H., Waisbord, N., and Hodes, M., "Effects of Suction and Spillage on Supercritical Carbon Dioxide-Based Drying of Aerogels," *Proceedings of the 16<sup>th</sup> International Heat Transfer Conference*, Paper # IHTC16-24239.
- [37] Karamanis, G. and Hodes, M., "Algorithm for Simultaneous Optimization of an Array of Heat Sinks," *Proceedings of the 17<sup>th</sup> Intersociety Conference on Thermal and Thermomechanical Phenomena in Electronic Systems, ITherm 2018*.
- [36] Karamanis, G. and Hodes, M., "Optimal Design of Longitudinal-Fin Heat Sinks Accounting for Simultaneously Developing Flow and Conjugate Effects," *Proceedings of the 2nd Thermal and Fluids Engineering Conference, TFEC2017*, Paper # TFEC-IWHT2017-17556.
- [35] Kadoko, J., Karamanis, G., Kirk, T., and Hodes, M., "Analysis of Gas Diffusion-Induced Cassie to Wenzel State Transition on a Structured Surface," *Proc. 2016 ASME Heat Transfer Conference*, Paper # HT2016-7278.
- [34] Karamanis, G., Hodes, M., Kirk, T., and Papageorgiou, D. "Nusselt Numbers for Fully-Developed Flow Between Parallel Plates With One Plate Textured With Isothermal Parallel Ridges," *Proc. 2016 ASME Heat Transfer Conference*, Paper # HT2016-7262.
- [33] Hodes, M., Kirk, T., Karamanis, G., Lam, L., MacLachlan, S., Papageorgiou, D. "Conformal Map and Asymptotic Solutions for Apparent Slip Lengths in the Presence of Thermocapillary Stress," *Proc. First International ISHMT-ASTFE Conference (IHMTTC 2015)*, Paper #1254.
- [32] Hodes, M., Lam, L., Karamanis, G., and MacLachlan, S. "Effect of Thermocapillary Stress on Slip Length for Poiseuille Flow over Parallel Ridges," *Proc. ASTFE 2015*, Paper #12930.
- [31] Karamanis, G. and Hodes, M., "Optimal Fin Thickness and Spacing in Fully-Developed Flow Accounting for Non-Uniform Heat Transfer Coefficient," *Proc. ASTFE 2015*, Paper #12925.
- [30] Hodes, M., Lam, L., MacLachlan, S., Enright, E., "Effects of Evaporation and Condensation on Apparent Thermal Slip," *Proc. IHTC 2014*.
- [29] Zhang, R., Hodes, M., Wilcoxon, R., and Lower, N., "Thermo-fluid Characteristics of a Minichannel Heat Sink Cooled with Liquid Metal," *Proc. SEMI-THERM 2013*.
- [28] Lam, L., Hodes, M., and Enright, R., "Analysis of Galinstan-Based Microgap Cooling Enhancement Using Structured Surfaces," *Proc. NHTC 2013*.
- [27] Hodes, M., Zhang, R., Wilcoxon, R., and Lower, N., "On the Cooling Potential of Galinstan-Based Minichannel Heat Sinks," *Proc. ITherm 2012*.
- [26] Zhang, R., Hodes, M., Brooks, D., and Manno, V., "Optimized Thermoelectric Module-Heat Sink Assemblies for Precision Temperature Control," *Proc. InterPACK 2011*, Paper #52019.
- [25] Hwang, D., Manno, V., Hodes, M., and Chan, G., "Energy Savings Achievable Through Liquid Cooling: A Rack Level Case Study," *Proc. ITherm 2012*.
- [24] Anapragada, R., Salamon, T., Kolodner, P., and Hodes, M., 2010, "Determination of Electrical Contact Resistivity in Thermoelectric Modules from Module-Level Measurements." *Proc. ITherm 2010*.

- [23] Enright, R., Hodes, M., and Salamon, T., "Analysis and Simulation of Heat Transfer in a Superhydrophobic Microchannel," *Proc. 2010 Int. Heat Transfer Conf.*, Paper#14-22948.
- [22] Lyons, A., Krishnan, S., Mullins, J., Hodes, M., and Hernon, D., "Advanced Heat Sinks by Three-Dimensional Printing," *Proc. 2009 Freeform Fabrication Symposium*.
- [21] Hodes, M., 2009, "Optimal Pellet Geometries for Thermoelectric Refrigeration under Robin Boundary Conditions," *Proc. InterPACK 2009*.
- [20] Kumari, N., Bahadur, V., Hodes, M., Lyons, A., Salamon, T., Kolodner, P., and Garimella, S., 2009, "Numerical Analysis of Enhanced Thermal Management in Cabinets Using Mist Cooling," *Proc. InterPACK 2009*.
- [19] Cleary, M., Grimes, R., Hodes, M., and North, M., 2008, "PIV Measurements in the Condenser Region of a Gas Loaded Thermosyphons," *Proc. NHTC 2008*, Paper #56402.
- [18] Enright, R., Dalton, T., Krupenkin, T., Kolodner, P., Hodes, M., and Salamon, T., "Effect of Interfacial Position on Drag Reduction in a Superhydrophobic Microchannel." *Proc. ICNMM 2008*, Paper #62251.
- [17] Bahadur, V., Hodes, M., Lyons, A., Krishnan, S., and Garimella, S., 2008, "Enhanced Cooling Using an Evaporating and Condensing Dielectric Mist in a Sealed Cabinet." *Proc. ITherm 2008*.
- [16] Cleary, M., Grimes, R., Hodes, M., and North, M., 2007, "Characterization of a Variable Conductance Heat Pipe for a Photonics Applications," *Proc. NHTC 2007*, Paper #32623.
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- [7] Hodes, M., "Formula to Size Axisymmetric Heat Spreaders above Dielectric Layers," *Proc. ASME IMECE 2000*, Paper #2-16-2-12.
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- [2] Hodes, M., Smith, K.A., and Griffith, P., Hurst, W., and Bowers, W., "Measurements and Analyses of Solubilities and Deposition Rates of Salts in Near-Supercritical Water," *Proc. 1996 AIChE Conference*, Chicago, IL.
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FUNDED RESEARCH (PI OR INSTITUTIONAL PI AT TUFTS UNIVERSITY / SENIOR PERSONNEL AT TRANSPORT PHENOMENA TECHNOLOGIES, LLC)

- National Science Foundation grant #2122257 for “ STTR Phase I: Safe Disinfection and Oxygen-Level Enrichment in Recirculating Aquaculture Systems (RAS) Using Singlet Oxygen.” PI at Research Institute, July 2021-June 2022, \$255,999 (\$80,000 to Tufts University).
- National Science Foundation grant #2140033 for “ CBET-EPSRC: Analysis and Optical Control of Surfactant Effects for Increased Lubrication of Liquid Flows in the Cassie State.” PI, August 2021-July 2024, \$385,000.
- National Science Foundation grant #STTR-2014881 for “STTR Phase I: Continuous Manufacturing of Mechanically-Robust, Superinsulating Aerogel Monoliths and Thin Films via a New Ambient-Pressure Freeze Drying Technology.” PI at Research Institute. June 2020-June 2021, \$225,000 (\$112,500 to Tufts University).
- National Science Foundation grant #IIP-2025882 for “SBIR Phase II: Rapid and Accurate Multi-Variable Optimization Software for Arrays of Heat Sinks.” Senior Personnel at Transport Phenomena Technologies, LLC. September 2020-August 2022, \$986,321.
- Massachusetts Clean Energy Center (Catalyst Program) grant for “Compliant Vapor Chambers for Data Centers.” Senior Personnel at Transport Phenomena Technologies, LLC. August 2019-July 2020, \$65,000.
- Tufts University’s Tufts Collaborates Program for “Elimination of Surfactant-Induced Flow Resistance in Superhydrophobic Microchannels.” PI. July 2018-June 2019, \$30,500.
- National Science Foundation grant #CBET-1805179 for “Electrowetting-assisted Dropwise Condensation on Hybrid Superhydrophobic-Hydrophilic Surfaces.” Co-PI. September 2018-August 2021, \$354,742 (\$118,900 to Tufts University).
- National Science Foundation grant #IIP-1819580 for “SBIR Phase I: Rapid and Accurate Multi-Variable Optimization Software for Arrays of Heat Sinks.” Senior Personnel at Transport Phenomena Technologies, LLC. June 2018-May 2020, \$224,956 .
- Massachusetts Clean Energy Center (Catalyst Program) grant for “Heat Sink Optimization for Reduction of Energy Consumption in Data Centers.” PI. August 2016-July 2017, \$39,604.
- National Science Foundation grant #CMMI-1530603 for “SNM: Low-Cost, Large-Scale Nanomanufacturing of Superinsulating Aerogels and Lightweight, Mechanically-Strong Aerogels.” PI. January 2016-December 2019, \$1,536,268. (Includes supplement awarded through NSF INTERN program in 2019.)
- Google, Google Faculty Research Award for “Beyond 1 kW/cm<sup>2</sup> Microchannel Cooling of Microelectronics Enabled by Structured Surfaces and Liquid Metal.” PI. June 2015-July 2016, \$55,040.
- National Science Foundation grant #CBET-1402783 for “Analysis of Convection in the Presence of Apparent Thermal Slip.” PI. September 2014-August 2017, \$255,630.
- Futurewei Technologies, Inc. for “Low Flow Resistance 3D Heat Sinks for Enhanced Air Cooling of Telecommunications Equipment.” PI. July 2014-June 2015, \$106,620.
- Science Foundation Ireland grant #11/W.1I2072 for “Analytical Models Relevant to Evaporation-Induced Shear Stress-Driven Heat Spreaders.” PI. June 2012-August 2012. \$52,044.
- Byrne Thermodynamic Systems, LLC, for “A Calculation Model of a Thermosyphon Operating at -150°C for Attachment to a Cold Finger on a Stirling Cooler.” PI. January 2012 - April 2012, \$12,000.
- DARPA grant #W31P4Q-11-1-0011 for “Liquid Metal Cooling of Microelectronics.” PI. August 2011-August 2013. \$250,000.
- Wittich Energy Sustainability Research Initiation Fund Grant for “Thermoelectric Module-Liquid Metal Substrate Assemblies for Reduced Power Precision Temperature Control.” PI. June 2010-August 2011. \$57,771.
- Aspen Aerogel Inc. Subcontract #310264 from for “Aerogel Blanket Manufacture.” (DoE Contract DE-EE0000266 to Aspen Aerogel, Inc.). Institutional Co-PI in Year I and Institutional PI in Year 2. May 2009-May 2011. \$486,632.00.

## INVITED PRESENTATIONS & SHORT COURSES (2007-)

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- “Asymptotic Nusselt Numbers for Internal Flow in the Cassie State and Their Application to Thermal Management of Electronics,” Department of Mechanical Engineering, University of Southern California, 2020.
- “Eph Sparrow – A Tribute to a Lifetime of Remarkable Achievements from a Colleague and Students,” Sparrow Memorial Lecture (Part 2), Department of Mechanical Engineering, University of Minnesota. (with A. Bar-Cohen and M. Iyengar), 2020.
- “Diabatic Flow of Liquids in the Cassie State,” National Fuel Cell Research Center, University of California, Irvine, CA, 2019.



- “New Nusselt Number Expression for an Internal Liquid Flow in the Cassie State over Parallel Ridges,” Mini Symposium on Transport Phenomena and Textured Surfaces: Modeling and Applications, International Conference on Industrial and Applied Mathematics, Valencia, Spain, 2019 .
- “Diabatic, Internal Liquid Flow in the Cassie State,” the Mathematical Institute, University of Oxford, Oxford, UK, 2019 .
- “Modeling Transport Phenomena in Diabatic Internal Flows in the Cassie State,” ASME International Conference on Nanochannels, Microchannels and Minichannels (ICNMM) Keynote, St. Johns, Newfoundland, Canada, 2019.
- “Effect of Surface Curvature on Contact Resistance,” Department of Mechanical and Aerospace Engineering, Brunel University, London, UK, 2019.
- “Effect of Thermocapillary Stress and Meniscus Curvature on Internal Liquid Flows in the Cassie State,” Department of Mechanical Engineering, Purdue University, West Lafayette, IN, 2019.
- “Effect of Surface Curvature on Contact Resistance,” Department of Mechanics, Tianjin University, Tianjin, China, 2018.
- “Design and Optimization of Heat Sinks” Professional Development Course, Co-located IEEE Electronic Components & Technology Conference and Intersociety Thermal & Thermomechanical in Electronic Systems Conference, San Diego, CA, 2018. (with Georgios Karamanis)
- “Towards Rigorous Measurements and Modeling of Supercritical Carbon Dioxide Drying of Sol Gels ,” MRS Spring Meeting and Exhibit, Phoenix, AZ, 2017.
- “Effect of Thermocapillary Stress on Slip Length for a Channel Textured with Parallel Ridges ,” Condensed Matter Physics Seminar Series, Tufts University, Department of Physics, 2017.
- “Effect of Thermocapillary Stress on Slip Length for a Channel Textured with Parallel Ridges ,” *The Red Lotus Project Workshop* (Sponsored by the Royal Society), Chicheley, England, 2016.
- “Effect of Thermocapillary Stress on Slip Length for a Channel Textured with Parallel Ridges ,” Numerical Methods for Partial Differential Equations Seminar Series, Department of Mathematics, MIT, 2016.
- “Analysis of Convection in the Presence of Apparent Slip,” Department of Mechanical Engineering Seminar Series, IIT Bombay, 2015.
- “Analysis of Convection in the Presence of Apparent Slip,” Department of Mechanical Engineering Seminar Series, University of Connecticut, 2015.
- “Convection in the Presence of Apparent Slip and Its Implications on Microchannel Cooling,” Department of Mechanical Engineering Seminar Series, University College Dublin (UCD), 2015.
- “Effects of Evaporation and Condensation on Apparent Thermal Slip,” First International Applied and Computational Complex Analysis (ACCA) UK-JP Workshop, Imperial College London, 2015.
- “Analysis of Convection in the Presence of Apparent Slip,” Thermofluids Division Seminar Series, Department of Mechanical Engineering, Imperial College London, 2015.
- “3D Heat Sinks for Enhanced Air Cooling,” 6th International Electronic Cooling Technology Workshop, Yokohama, Japan, 2014.
- “Galinstan-Based Cooling of Microelectronics: Beyond Tuckerman and Pease?,” Keynote Lecture, Eurotherm Seminar 102, Limerick, Ireland, 2014.
- “Analysis of Convection in the Presence of Apparent Slip,” ACCA-UK Group, Imperial College, London, England, 2014.
- “Galinstan-Based Cooling of Microelectronics: Beyond Tuckerman and Pease?,” State of Maine IEEE Chapter, South Portland, ME, 2014.
- “Supercritical CO<sub>2</sub> Drying of Silica Alcolgel: State-of-the-Art and Outstanding Needs,” Invited Lecture, NSF Workshop on Supercritical Fluids, Campinas, Brazil, 2013.
- “Galinstan-Based Cooling of Microelectronics: Beyond Tuckerman and Pease?,” Keynote Lecture, Cooling Zone-13, eConference, 2013.
- “Galinstan-Based Liquid Cooling of RF MMIC PAs: Beyond Tuckerman and Pease?,” DARPA-organized Panel on “Embedded Thermal Management,” IEEE Compound Semiconductor IC Symposium, Monterey, CA, 2013.
- “Analysis of Convection in the Presence of Apparent Slip,” Mechanical Engineering Seminar Series, University of Houston, 2013.
- “Continuous Extraction Rate Measurements during Supercritical CO<sub>2</sub> Drying of Silica Alcolgel,” Empa Swiss Federal Laboratories for Materials Science and Technologies, Dübendorf, Switzerland, 2012.

- “Emerging Thermal Management Technologies,” University of Limerick, Limerick, Ireland, 2012.
- “Emerging Thermal Management Technologies,” ABB Inc., Zurich, Switzerland, 2012.
- “Ethanol Extraction Rates During Supercritical CO<sub>2</sub>-Based Drying of Alkogels,” Union College Aerogel Group, Schenectady, NY, 2011.
- “Reduced Power Consumption Precision Temperature Control of Photonic Components,” Lindbergh Lecture Series, Department of Mechanical Engineering, University of Wisconsin, Madison, WI, 2010
- “Thermoelectricity-Based Technologies for Thermal Management: Present and Future.” Keynote presentation at NSF Cooling Technologies Research Center/Huawei, Inc. Workshop on Thermal Management in Telecommunication Systems and Data Centers, Dallas, TX, 2010.
- “Thermoelectricity-Based Technologies for Thermal Management: Present and Future,” Thermal Management Seminar cum Panel Discussion, National University of Singapore, 2010.
- “Thermal Management of Electronics (Semester Long Course),” Lytron Inc., Woburn, MA, 2010.
- “Thermoelectric Modules: Principles and Research,” Guest lecture in ME597G (later ME51100) - Heat Transfer in Electronic Systems at Purdue University, West Lafayette, IN, 2006, 2008, 2019.
- “Thermoelectric Modules: Principles and Research,” short course at InterPACK 2005, 2007 and 2011 and ITherm 2006, 2008.
- “Optimized Pellet Geometry for Thermoelectric Power Generation,” University of Cardiff, Cardiff, Wales, 2007.

## PhD THESES EXTERNALLY EXAMINED

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- Samuel Tomlinson, 2021, *Superhydrophobic Surfaces: Their Hydrodynamic Stability, Thermal Resistance and Boundary Layers*, Imperial College London, Department of Mathematics.
- Eric Semples, 2020, *Optimization of Thermoelectric Generators for Low Temperature Waster Heat Recovery*, Université du Québec en Outaouais (UQO).
- Belal Al-Khamaiseh, 2018, *Analytical Solutions of 3D Heat Conduction in Flux Channels with Nonuniform Properties and Complex Structures*, Memorial University of Newfoundland.
- Seye Masood Razavi, 2016, *Advanced Thermal Analysis of Microelectronics Using Spreading Resistance Models*, Memorial University of Newfoundland.
- Mehdi Ghobadi, 2014, *Experimental Measurement and Modelling of Heat Transfer in Spiral and Curved Channels*, Memorial University of Newfoundland.
- Tamanna Alam, 2012, *Characteristics Investigation and Parametric Study of Flow Boiling in a Microgap Heat Sink*, National University of Singapore.
- Karthik Balasubramanian, 2012, *Experimental Study of Flow Boiling Characteristics and Instabilities in Straight, Expanding and Stepped Fin Microchannels*, National University of Singapore.
- Yong-Jiun Lee, 2011, *Enhanced Thermal Transport in Microchannel Heat Sink Using Oblique Fins*, National University of Singapore.
- David McGuire, 2006, *On the Interferometric Measurements of Convective Mass Transfer*, University of Limerick.
- Noel Sirr, 2008, *On Continuous Flow Discretized DNA Amplification*, University of Limerick.
- Cormac Eason, 2005, *Measurement of Pressure Drop and Heat Transfer Analysis of Microchannels*, University of Limerick.

## RESEARCH GROUP ALUMNI

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### Postdoctoral

- Martin Cleary, 2010-2011. Currently at GMZ Energy, Inc.

### PhD

- Georgios Karamanis, 2018, “Nusselt Numbers for Superhydrophobic Microchannels and Shrouded Longitudinal-Fin Heat Sinks.” Currently at Transport Phenomena Technologies, LLC.
- Lisa Lam, 2014, “Convection Heat Transfer in the Presence of Apparent Slip.”
- Rui Zhang, 2014, “Water-Based Microchannel and Galinstan-Based Minichannel Cooling.” Currently at ACS Material Inc.
- Martin Cleary, 2011, “An Experimental Investigation on the Operation of Variable Conductance Heat Pipes and Gas-Loaded Thermosyphons.” Co-advised with Dr. Ronan Grimes. Currently at Shell TechWorks.

### Master’s of Science

- Jonah Kadoko, 2018, "Analysis of Gas Diffusion-Induced Cassie to Wenzel State Transition."
- Michael Mayer, 2018, "Effect of Surface Curvature on Contact Resistance between Abutting Cylinders."
- Daniel Kane, 2017, "On Spreading Resistances and Apparent Slip Lengths for Rectangular and Elliptic Pillars," Currently an intern at Bell Labs Ireland.
- Georgios Karamanis, 2015, "Optimized Longitudinal-Fin Heat Sinks Accounting for Non-Uniform Heat Transfer Coefficient," Currently pursuing PhD at Tufts University.
- Ryan Nelson, 2014, "Effects of Pressure, Temperature, Solvent and Gel Thickness on the Kinetics of Supercritical CO<sub>2</sub> Drying of Silica Alcogel." Currently at Aerogel Technologies.
- Justin Griffin, 2013, "Continuous Extraction Rate Measurements During Supercritical CO<sub>2</sub> Drying of Silica Alcogels." Currently at Aerogel Technologies.
- Elizabeth Brownell, 2013, "Optimal Design of Thermoelectric Generators Embedded in a Thermal Resistance Network." Currently at Yankee Scientific.
- Rui Zhang, 2011, "Optimized Thermoelectric Module-Heat Sink Assemblies for Precision Temperature Control." Currently at ACS Material Inc.
- Drew Mills, 2011, "Apparatus to Measure Ethanol Extraction Rates During Supercritical CO<sub>2</sub>-Based Drying of Alcogels." Currently at Ocean Spray Inc.
- Yinzhen Liu, 2011, "Numerical Modeling of Peltier-Cooled Current Leads." Currently at American Chrome Company. Co-advised with Luisa Chiesa.
- Stuart Mueller, 2011, "Enhanced Heat Sink Performance Utilizing Capillary-Driven Evaporation." Currently at General Electric Company.
- David A. Brooks, 2011, "Experimental Characterization of Thermoelectric Module-Variable Conductance Heat Pipe Assemblies for Reduced Power Precision Temperature Control." Currently at Raytheon Corporation.
- George J. Chan, 2011, "Variable-Speed Compressor Enabled Energy Efficient Cooling of Blade Servers," Currently at General Electric Company.
- Douglas Hwang, 2009, "Data Center Power Consumption Reductions Achievable with Liquid Cooling: A Case Study." Currently at Etsy. Co-advised with Vincent Manno.

### Master's of Engineering

- Michael Eskowitz, 2014, "Optimal Design of Vapor Chamber-Heat Sink Assemblies." Currently at Lincoln Labs.

### HOBBIES

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- Reading, including the collected works of James A. Michener.
- Jogging, especially in newly-visited cities.
- Walking tours, including 216 through *London Walks*.
- Travel, including visiting all 7 continents in 2006 & 81 countries in total.
- Restaurants, from €5 meals at *Urbani* in the Jewish Ghetto in Rome to \$500 meals at *per se* in NYC.
- Films, especially at the *Film Forum* in Greenwich Village.
- Theatre, especially in the West End and elsewhere in London.
- Japan: language, travel, performing arts, arts, cuisine, etc.
- National Historic Sites, Parks, Monuments, etc. run by the National Park Service.