Licence to freeze: understanding and controlling ice formation on surfaces

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Abstract

Icing has long been recognized as a serious hazard for safety and for functioning of systems in diverse areas such as transportation, power and communication systems, infrastructures, and even domestic or commercial appliances. The control of water behavior at the interface through the tailoring of surface wetting properties represents a great scientific and technological challenge and opportunity, which can be used as a strategy to control and mitigate ice formation on surfaces. During the lecture, Dr. Antonini will present his research activities focused on understanding the interaction mechanism between liquid and solid surfaces in freezing conditions. Focus will be given to the effects of surface wetting and topography on ice nucleation, to the wetting behavior of superhydrophobic surfaces in icing conditions, and to ice adhesion, highlighting the role of environmental conditions where relevant. A brief discussion of practical issues, challenges, and innovations in using non-wetting coatings will also presented.

Short Bio

Dr. Carlo Antonini received the BSc in Aerospace Engineering (2004) and the MSc in Aeronautical Engineering (2007), from Politecnico di Milano, Italy, and the PhD in Technologies for Energy and Environment from University of Bergamo (2011), Italy, with a thesis titled "Superhydrophobicity as a strategy against icing". In 2012, Dr. Antonini received support from the European Research Council (ERC) to join ETH Zurich, Switzerland, as a Marie Curie Fellow; he worked in the Laboratory of Thermodynamics in Emerging Technologies on the project "ICE^2: ICEphobicity for severe ICing Environments". Since March 2015, Dr. Antonini joined EMPA – Swiss Federeal Laboratory for Material Science and Technology – as scientist, focusing on the control of surface wetting properties of cellulose-based materials for various engineering applications, ranging from liquid separation (oil remediation) to thermal insulation. One of his current projects include ice templating as a technique to fabricate ultra-porous foams from nanofibrillated cellulose. In 2017 he started the consulting company "Antonini R&D and Innovation Consulting", to support innovation in SMEs.

Links

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What is the optimum wettability of a pool boiling heater ?

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Abstract

Pool boiling is a complex transport process involving dynamic deformations of multiple interfaces between solids, liquids and vapors. Here, a roadmap to enhance pool boiling is formulated on the general hypothesis that an optimal heater for phase change heat transfer should match the features of phase change heat transfer in the same way as a key matches a lock. Indeed, boiling has better efficiency and performance when both the liquid and vapor phases are in contact with the solid surface transferring heat. This situation is promoted by surfaces with spatial biphilicity, which juxtapose hydrophilic and hydrophobic regions. These surfaces have demonstrated significant enhancements of critical heat flux and efficiency in phase change heat transfer. We then investigate temporal biphilicity, with functional surfaces that vary their wettability between hydrophilic and hydrophobic upon sequential application of stimuli. These surfaces have enhanced hydrophobicity at low heat fluxes, to promote nucleation, and enhanced hydrophilicity at high heat flux, to promote wicking and prevent critical heat flux.

Short Bio

Attinger is an Associate Professor in the Mechanical Engineering Department at Iowa State University. His scholarship is in thermofluids and complex fluids, with applications in energy technologies and bloodstain pattern analysis. He has co-authored more than 80 peer-reviewed articles, edited four books, and written several book chapters and critical reviews. He has given ten keynote lectures at international conferences, and 80 invited talks in the Americas, Asia and Europe. He is the recipient of a 2001 medal for outstanding Ph.D. thesis at ETH Zurich, a US National Science Foundation CAREER award, the 2012 ASME ICNMM Outstanding Researcher Award, the 2014 Professor of the Year award in his Department, and a 2016 JSPE Research Fellowship. He is the co-inventor of four US and international patents and a Fellow of the ASME.

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Droplet Wetting and Evaporation: From Pure to Complex Fluids

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Abstract

In the early 1800s, Thomas Young and Pierre-Simon Laplace conducted the first investigations on the wetting of droplets. They investigated the wetting issues, the role of the contact angle and the liquid/solid coupling nature driving the droplet problems. While a sessile droplet is a simple geometry, it is also a complex system to solve for real life situations (metallic inks for inkjet printing, spreading of pesticides on leaves, drops of whole blood or blood serum spreading and drying for medical applications). By taking into account its wetting and then its evaporation, this simple case becomes a very complex problem that is researched by several teams worldwide. The complexity is mainly due to the physics involved, the full coupling with the substrate on which the drop sits (the Latin root of the word sessile means "on which one can sit"), the atmosphere and the fluid nature (pure fluid, bi- or multi-phases or even containing colloids). In the keynote, I will present the different research topics dealing with droplets that have been studied and which are right now studied in different teams worldwide. I will focus the main part of my keynote on complex fluids such as blood and nanofluids.

Short Bio

David Brutin received his M.Sc. / Engineering diploma in mechanical engineering in 2000 with a semester spent at the University of Iowa, College of Engineering. In 2003 he obtained his Ph.D. degree in mechanical engineering at the University of Provence, France. He became Assistant Professor at Aix-Marseille University, France in 2005, and Associate Professor 2009, after completing his Habilitation. In 2015, he were promoted Full Professor at Aix-Marseille University, Polytech' Marseille and got also an excellency fellowship from the "Institut Universitaire de France ». His work focuses on phase change heat transfer, pure and complex fluids physics (refrigerants, blood, nanofluids), soft matter, with applications in space science, aeronautics, biomedical, forensic science, and printing technology. He is author of 50 papers in peer reviewed journals, member of the editorial board of "Colloids and Interface Science Communications" published by Elsevier and « Interfacial Phenomena and Heat Transfer » published by Begell House. He is editor of a collaborative book, « Droplet Spreading and Evaporation » published by Elsevier in 2015.

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Heat transfer enhancement during condensation over wettability-control surfaces

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Abstract

Condensation occurs in many engineering applications. A solution to enhance the condensation heat transfer is to promote and maintain dropwise condensation instead of the usual filmwise condensation. This needs surfaces that repel water. Theoretically, to increase the performance of the condensation, the number of the nucleation sites and the mobility of the droplets should be increased, thus, surfaces with low surface energy and high roughness should be required. But the mechanism is highly affected by the fluid. The talk will be focused on the effect of wettability during condensation of steam over metallic surfaces.

Short Bio

Davide Del Col is associate professor at the University of Padova, Italy. He was visiting scholar at Pennsylvania State University, USA. He took his PhD on Energy Engineering at the University of Padova.

Member and Secretary of Commission B1 (Thermodynamics & transfer processes), IIR, Paris; Secretary of UIT (Italian Union of Thermal-Fluidynamics) and member of the Steering Committee of UIT; Associate of INFN (Istituto Nazionale di Fisica Nucleare) in the framework of the Program ALICE (A Large Ion Collider Experiment) for the project on sensor cooling at CERN, Geneve. Member of Committee K-13 (Multiphase Heat Transfer), ASME.

Scientific coordinator of the international ESA project on Condensation in microgravity (16 partners from Europe and Canada). Leader of the Laboratory of Sustainable Thermal Energy Technologies at the Department of Industrial Engineering of University of Padova. This lab is active in the fields of two-phase heat transfer, refrigerants and refrigeration technologies, solar energy conversion.

He has authored more than 200 scientific publications, with 115 documents cited in Scopus.

Wettability, gravity and electric field effects on local heat flux at triple line

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Abstract

The local distribution of heat flux underneath a droplet evaporating on a heated surface is of great interest to understand the ruling physical phenomena. To investigate the topic, a water droplet was evaporated on heated thin laminas of different wettability, at different values of gravity acceleration and applied electric field. The electric field was intended both as a force replacing gravity and a mean to enhance evaporation. The temperature distribution underneath the droplet was detected with an infrared camera, and the local value of heat flux was evaluated with a dedicated software. The results showed that in all the investigated configurations the heat flux distribution has a peak in correspondence of the three-phase contact line, regardless of wettability, gravity level and applied electric force. The amplitude of the peak is influenced to a different extent by the applied field forces. Results from literature show that such a behavior is common also for growing bubbles. The physical mechanisms underlying this feature are still subject of debate among the scientific community, and will be discussed during the presentation.

Short Bio

Paolo Di Marco is full Professor of Engineering Thermodynamics and Heat Transfer, DESTEC, School of Engineering, University of Pisa. He obtained a Ph.D. in "Nuclear Engineering Safety" at University of Pisa in 1989. His investigation field include Single-Phase and Boiling Heat Transfer, Bubble Dynamics, Heat Transfer in Microgravity, Effect of Electric Fields on Heat Transfer, Drops and spray dynamics, Instability in Boiling Loops, Two-Phase Flow Measurements, Drying techniques, Heat Pipes and Thermosyphons, Solar and Wind Energy, Biomass gassification. In particular, he accumulated a wide experience in experimentation in microgravity on two-phase flow with and without electric fields, including ten parabolic flights campaigns, two droptower campaigns in JAMIC (Japan), two sounding rocket campaigns (MASER 7 and 8), one unmanned orbital flight (FOTON-M2).

He is author of about 60 papers in refereed international journals, 12 invited/keynote papers in international conferences, about 10 invited presentations in foreign universities, over 100 papers in international conference proceedings (about 40 fully refereed), 10 book chapters.

He is currently president EUROTHERM, elected member of Executive Committee of ICHMT, Associate Editor of International Journal of Multiphase Flow, and member of ESA Topical Team on Boiling Heat Transfer since foundation.

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Evaporation effect on the contact angle and contact line dynamics

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Abstract

I will discuss the theory of increase of the macroscopically observed contact angle in the presence of evaporation. Two limiting cases of evaporation will be considered. The first case is the fast evaporation into the pure vapor controlled by the liquid heat conduction (like bubble growth in boiling). The second case is the slow evaporation into the atmosphere of neutral gases. It is limited by vapor diffusion (like drop drying in the open air). The impact of wetting properties is analyzed. Implications of the evaporation-induced contact angle increase for the contact line motion are discussed. Experimental results on the capillary dewetting caused by evaporation are also described.

Short Bio

Dr. Vadim S. Nikolayev graduated from the Radio-Physics Department of Kiev State University (Ukraine, ex-USSR at the time) in 1985 and received his Ph.D. degree in Physics in 1989. He has defended his habilitation thesis in 2005. He was a staff researcher at the Institute for Theoretical Physics in Kiev in 1988-1999. He took visiting positions in France and USA. Since 1999 he works as a staff researcher at the French Alternative Energies and Atomic Energy Commission (CEA). As a member of the Team of supercritical fluids for environment, materials and space (ESEME) created jointly by CEA, CNRS and ESPCI (1999-2013), he was based at several laboratories: Laboratory of low temperatures (SBT) at Grenoble (1999-2000), ICMCB/CNRS at Bordeaux (2000-2004), PMMH/ESPCI at Paris (2004-2013). He is currently based at the Laboratory of Condensed Matter Physics (SPEC) at the Paris-Saclay campus. His fields of interest include the physics and fluid mechanics associated with phase changes in fluids (evaporation, condensation, boiling, triple contact line dynamics), theory and experiments under reduced gravity conditions with pure fluids near their liquid-vapor critical point. Last years he directs a research program on the experiments and modeling of the pulsating heat pipes carried out at CEA. He is the author of more than 50 papers in the refereed journals.

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Kinetic Effects in Interfacial Flows

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Abstract

Understanding the behaviour of liquid-gas interfaces at the micro and nano scale is key to a myriad of phenomena, ranging from the formation of clouds through to the performance of next-generation evaporative cooling devices. Accurate experimental observation of these phenomena is complex due to the small spatio-temporal scales or interest and, consequently, mathematical modelling and computational simulation become key tools with which to probe such flows. In such flows, the characteristic scales of interest can become comparable to the mean free path in the gas, so that the Navier-Stokes-Fourier (NSF) paradigm no longer provides an accurate description of the physics in the gas, whilst it remains valid in the liquid.

In this talk I will consider modelling approaches that can be deployed on such flows, focussing on the interaction of liquid drops with solid surfaces and phase change driven phenomena. It will be shown that NSF is inadequate for the gas flow and that kinetic effects via the Boltzmann equation must be deployed. It will be shown that when thin gas films dictate the dynamics of drops this can be relatively easily achieved within a lubrication framework whereas for generic geometries moment methods can be utilised to develop an efficient computational framework.

Short Bio

James Sprittles is an Associate Professor in the Mathematics Institute at the University of Warwick, a former EPSRC Postdoctoral Research Fellow and Junior Research Fellow at Oxford University. His background is in the mathematical modelling and computational simulation of complex multiscale interfacial flows including dynamic wetting, coalescence and breakup phenomena. Alongside Duncan Lockerby, he runs the Micro & Nano Flow group in Warwick (~15 Masters, PhD & PDRAs), whose research focusses on going beyond classical modelling approaches that are inaccurate at small-scales. The new models and efficient simulation techniques developed allow us to gain new insight into technologically relevant flows and have led to numerous collaborations with industrial partners, e.g. on phase-change driven thermal management solutions with Bell Labs.

Sprittles' research has been published in many prestigious journals, including *Physical Review Letters,* where his is recent work on kinetic effects in dynamic wetting was published. He has given invited talks across the world and in 2015 was awarded a Wellcome Trust 'Frontier Innovator' prize.

Link

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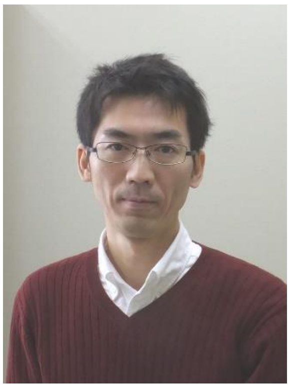
Multi-scale Multiphase Flow Gas-Liquid-Solid Interfacial Equation Based on Thermodynamic and Mathematical Approaches

Prof. Yukihiro Yonemoto



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Abstract

A gas-liquid interface involves complex physics along with unknown phenomena related to thermodynamics, electromagnetics, hydrodynamics, and heat and mass transfer. Each phenomenon has various characteristic temporal and spatial scales, which makes detailed understanding of the interfacial phenomena very complex. Therefore, modeling the gas-liquid interface is a key issue for numerical research on multiphase flow. In this lecture, we show a new gas-liquid interfacial model based on thermodynamics via a mathematical approach, assuming that the interface has a finite thickness like a thin fluid membrane. In particular, free energy, including an electrostatic potential due to the contamination at the interface, is derived based on a lattice gas model. Free energy is incorporated into the conventional Navier-Stokes equation as new terms using Chapman-Enskog expansion based on the multiscale concept. Using the Navier-Stokes equation with the free energy terms, we derived a new governing equation of fluid motion that characterizes mesoscopic scale phenomena. The developed equation is expanded to the macroscopic interfacial equation where the interface has no thickness (mathematical surface). Then, we try to consider possibility of the expansion of the macroscopic interfacial equation to wettability problem.

Short Bio

Education and professional experience

Education

2002 B.S., Department of Energy Science and Engineering, Kyushu University, Fukuoka, Japan.
2004 MSc (Engineering), Advanced Energy Engineering Science, Interdisciplinary Graduate School of Engineering Science, Kyushu University, Fukuoka, Japan.
2008 Ph. D. (Engineering), Department of Nuclear Engineering, Kyoto University, Kyoto, Japan.
Postdoctoral Training, Faculty Academic Appointments, Other Professional Positions
2008-2010: Assistant Professor, Department of Applied Electronics, Tokyo University of Science, Chiba, Japan.
2010-2012: Researcher, Japan Atomic Energy Agency, Fukui, Japan.
2012-2013: Researcher, Institute of Nuclear Safety System, Incorporated, Fukui, Japan.
2013-2017: Tenure Track Assistant Professor, Priority Organization for Innovation and Excellence, Kumamoto University, Kumamoto, Japan.

2018-Present: Associate Professor, Advanced Thermal and Fluid Energy System, Division of Energy Science, Faculty of Advanced Science and Technology, Kumamoto University, Kumamoto, Japan.
Research interests
My research interests lie in the multiphase flow and interfacial phenomena.

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