Department of Mechanical Engineering Distinguished Colloquium
Thursday, January 26, 2017 4:00pm ESB2012

Fog, Feathers and Fluid Friction Reduction using Omniphobic Surfaces: Biomimetic Inspiration and Engineering Realization

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with K.-C.Park[1], J. Kleingartner[2], S. Srinivasan[2], R.E. Cohen[2]

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Abstract:
A plethora of microstructured surfaces with a wide range of surface chemistries and topographies have been investigated for controlling the wetting (or non-wetting) properties of a fluid/solid interface. Experimental advances in nanofabrication have led to the ability to achieve unprecedented control over the micro- and nano-texture of a substrate and this can result in almost perfect superhydrophobicity. Outstanding challenges include scalability, robustness and super-oleophobicity; i.e. resistance to wetting by low interfacial tension liquids such as hydrocarbons. Fluorinated silsesquioxanes are nanometer-scale caged molecules that can be heavily fluorinated and molecularly dispersed in a range of polymers to systematically control both the hydrophobicity and oleophobicity (oil-repellency) of substrates. Microtextured re-entrant structures coated with FluoroPOSS are the most oleophobic surfaces produced to date, with alkane contact angles greater than 160˚ and low wetting hysteresis. We have also developed single-step dip-coating and spray-coating processes for applying such omniphobic coatings to a wide-range of substrates. We use dip-coated feathers as natural microstructured and re-entrant structures to illustrate the systematic changes in thermodynamic stability against wetting by water and oil that can be achieved through nanodispersed surface chemical treatments. Real-world applications of these multiscale structured coatings include fabrics with enhanced solvent/oil resistance, efficient separation processes for oil/water dispersions, reduction of ice- and gas hydrate adhesion in deep-sea oil/gas exploration as well as 'fog-harvesting surfaces' that greatly enhance our ability to collect solar-desalinated water from wind-borne fog, and 'spray-on' coatings for reducing frictional drag through modification of the no-slip boundary condition. We demonstrate drag reduction on these surfaces of up to 20%, corresponding to effective slip lengths of approximately 20 μm, at Reynolds numbers $Re \leq 80{,}000$. By using active replenishment of the air layer we can increase this drag reduction to greater than 80% friction reduction.

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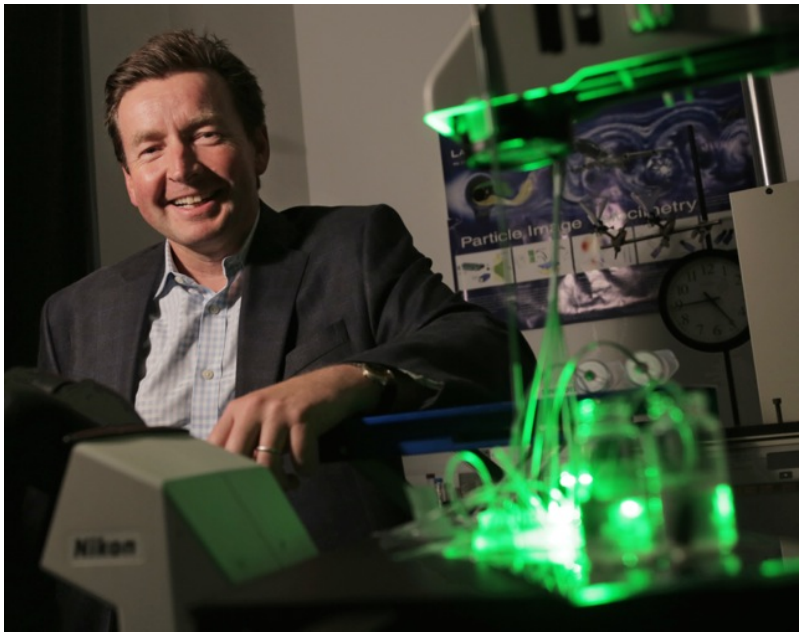

Bio:

Gareth H. McKinley is the *School of Engineering Professor of Teaching Innovation* within the Department of Mechanical Engineering at MIT. He received his BA (1985) and M.Eng (1986) degrees from the University of Cambridge and his Ph.D (1991) from the Chemical Engineering department at MIT. He taught in the Division of Engineering and Applied Science at Harvard from 1991-1997 and was an NSF Presidential Faculty Fellow from 1995-1997. He won the Annual Award of the British Society of Rheology in 1995 and the Frenkiel Award (with J. P. Rothstein) from the APS Division of Fluid Dynamics in 2001. He served as Executive Editor of the *Journal of Non-Newtonian Fluid Mechanics* from 1999 to 2009 and as Associate Editor of Journal of Fluid Mechanics from 2007-2009. He is presently a member of the Editorial Board of the *Journal of Rheology*, *Rheologica Acta* and *Applied Rheology*. He most recently served as the Associate Dept. Head for Research of the Mechanical Engineering Department at MIT from 2008-2013. He is also a co-founder and member of the Board of Directors of Cambridge Polymer Group. His current research interests include extensional rheology of complex fluids, non-Newtonian fluid dynamics, microrheology & microfluidics, field-responsive fluids, super-hydrophobicity, wetting of nanostructured surfaces and the development of nanocomposite materials.

He is the author of over 250 technical publications and was one of the winners of the 2007 Publication Award of the Society of Rheology. He is a Fellow of the *American Physical Society* and vice-president of the US *National Committee of Theoretical and Applied Mechanics* (USNC/TAM). He was the recipient of the 2013 Bingham Medal of the Society of Rheology and the 2014 Gold Medal of the British Society of Rheology. He presently serves as the President of the Society of Rheology.