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Fluid-Structure Interactions: From Controlled Drug Release to Micro-Robotics

ABSTRACT:

A fascinating class of problems in contemporary fluid mechanics and transport phenomena involves the interplay between dynamic boundaries and fluid flows. These problems are of paramount importance in many engineering, biological, and biomedical contexts. In this talk, I will focus on two of such problems motivated, respectively, by the drug release from micro-capsules during volume transitions and the design of self-propelled miniature robots that surf at liquid-gas interfaces. First, I will discuss the release of nanoparticles and linear macromolecules from microgel capsules that swell and de-swell in response to external stimuli. Our meso-scale numerical simulations reveal that not only swelling, but also de-swelling of hollow micro-capsules can be harnessed for controlled release, and that the release mechanisms for these two scenarios are different. The release from swelling capsules is relatively slow, controlled by particle diffusion through the capsule shell. The release from de-swelling capsules, on the other hand, is burst-like and is driven by the expulsion of the encapsulated solvent during capsule contraction. The de-swelling induced release can be regulated by introducing micrometer-sized rods inside the capsule that prevent early membrane sealing. This method can be harnessed for designing advanced drug delivery and release systems using stimuli-responsive micro-carriers. Next, I will discuss the Marangoni surfing of active particles located at a liquid-gas interface atop a liquid layer of finite depth. The particles are sources of either an insoluble chemical species or heat. The self-induced scalar field (i.e. concentration of species or temperature field) locally changes the surface tension and the consequent gradients in the surface tension lead to the propulsion of the particle. It is natural to surmise that Marangoni surfers are pulled towards the higher surface tension direction. Contrary to this common instinct, our theoretical calculations indicate that the surfers may propel in the lower surface tension direction depending on their geometry and proximity to the bottom of the liquid layer. This and other findings that will be presented in this talk pave the way for designing programmable micro-surfers capable of operating in bounded environments.

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BIOGRAPHY:

Hassan Masoud is an assistant professor in the Department of Mechanical Engineering at the University of Nevada, Reno. Prior to that, he was a lecturer at Princeton University and a post-doctoral fellow working jointly with Howard Stone in the Department of Mechanical and Aerospace Engineering at Princeton University and Michael Shelley at the Courant Institute of Mathematical Sciences. Hassan received his Ph.D. in Mechanical Engineering from the Georgia Institute of Technology in 2012. He uses the tools of applied mathematics and high-performance computing to solve state-of-the-art problems in fluid mechanics, transport phenomena, and hydrodynamics of soft and active matter. Hassan's research findings have been published in journals such as Nat. Commun., ACS Nano, Phys. Rev. Lett., Macromolecules, Soft Matter, J Fluid Mech., and Phys. Fluids. They have been also featured by several academic publications and news media outlets including the National Science Foundation News, U.S. News & World Report, Science Daily, and Futurity Magazine. Furthermore, Hassan is the recipient of several awards and honors including the Institute for Complex Adaptive Matter Post-doctoral Fellowship, Materials Research Society Graduate Student Silver Award, Society of Engineering Science Graduate Student Presentation Award, Georgia Tech GTRIC Fellowship, and Sharif University of Technology Outstanding Undergraduate Student Award.