COLLEGE OF ENGINEERING AND COMPUTER SCIENCE
FLORIDA ATLANTIC UNIVERSITY

Announces the Ph.D. Dissertation Defense of

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for the degree of Doctor of Philosophy (Ph.D.)

"Aqueous Microdroplet Generation in Oil-Free Environments"

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Engineering West, Room 187
777 Glades Road
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DEPARTMENT:
Ocean and Mechanical Engineering

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ABSTRACT OF DISSERTATION
Aqueous Microdroplet Generation in Oil-Free Environments
Droplet microfluidics generates and manipulates microdroplets in microfluidic devices at high manufacturing efficiency and controllability. Microdroplets have proven effective in biomedical applications such as single-cell analysis, DNA sequencing, protein partitioning and drug delivery. Conventionally, a series of aqueous microdroplets containing biosamples is generated and controlled in an oil environment. One of the critical challenges in this system is that recovery of the aqueous samples from the oil phase is very difficult and often requires expensive and cumbersome post-processing. Also, the low Reynolds (*Re*) number characteristic of this system results in low throughput of droplet generation. To circumvent challenges and fully utilize microdroplets for practical clinical applications, this research aims to unpack the fundamental physics that governs droplet generation in oil-free systems including an aqueous two-phase system (ATPS) and a high inertial liquid-gas system. We experimentally and numerically studied the droplet morphology, droplet breakup mechanisms, droplet generation frequency, monodispersity and different flow regimes of droplet generation in ATPS and high inertial water-in-air (W/A) system. We passively produced ATPS droplets with a wide range of droplet size and high production rate (~ 300 Hz) without the involvement of an oil phase and external forces. For the first time, we reported important information of the

flow rate and Capillary (*Ca*) number for passive, oil-free ATPS droplet generation. In addition, passive generation of salt-based ATPS microdroplets for cell encapsulation and their biocompatibility test were studied. On the other hand, aqueous microdroplet generation in the W/A system in microfluidic flow-focusing and T-junction geometries was studied numerically. At various *Re* and *Ca* numbers, several flow regimes were identified including squeezing, dripping, unstable dripping, plugging, stratified flow, multi-satellite droplet formation, and unstable jetting. Unstable dripping, multi-satellite droplet formation, and unstable jetting have been observed as new flow regimes in our study which have not been previously reported. The maximum generation frequency of ~ 2K Hz was obtained under the unstable dripping regime in the flow-focusing geometry. It was found that increasing *Re* number results in droplet size reduction, while higher *Ca* number leads to bigger droplets.

BIOGRAPHICAL SKETCH

Born in Sabzevar, Iran

B.S., Azad University, Science and Research Branch, Tehran, Iran, 2007

M.S., Urmia University of Technology, Urmia, Iran, 2011

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CONCERNING PERIOD OF PREPARATION
& QUALIFYING EXAMINATION

Time in Preparation: 2015-2019

Qualifying Examination Passed: Spring 2016

Published Papers:

1) M. Mastiani, N. Firoozi, N. Petrozzi, S. Seo, M. Kim, “Polymer-Salt Aqueous Two-Phase System (ATPS) Micro-Droplets for Cell Encapsulation”, Lab on a Chip, (Under review).
2) M. Mastiani, S. Seo, B. Riou, M. Kim, “High Inertial Microfluidics for Droplet Generation in a Flow-Focusing Geometry”, Biomedical Microdevices, (2019) 21(3) (In press).
3) M. Mastiani, S. Seo, B. Mosavati, M. Kim, “High-Throughput Aqueous Two-Phase System Droplet Generation by Oil-Free Passive Microfluidics”, ACS Omega, (2018) 3(8) 9296-9302.
4) M. Mastiani, B. Mosavati, M.M. Kim, “Numerical Simulation of High Inertial Liquid-in-Gas Droplet in a T-Junction Microchannel”, RSC Advances, (2017) 7 48512 - 48525.
5) M. Mastiani, S. Seo, S.M. Jimenez, N. Petrozzi, M.M. Kim, “Flow Regime Mapping of Aqueous Two-Phase System Droplets in Flow-Focusing Geometries”, Colloids and Surfaces A: Physicochemical and Engineering Aspects, (2017) 531 111-120.
6) M. Mastiani, M.M. Kim, A Nematollahi, “Density Maximum Effects on Mixed Convection in a Square Lid-Driven Enclosure Filled with Cu-Water Nanofluids”, Advanced Powder Technology, (2017) 28(1) 197-214.
7) S. Seo, M. Mastiani, M. Hafez, G. Kunkel, C.G. Asfour, K.I. Garcia-Ocampo, N. Linares, C. Saldana, K. Yang, M. Kim, “In-situ injection of CO2 microbubbles into deep saline aquifers for carbon sequestration”, International Journal of Greenhouse Gas Control, (2019) 83, 256-264.
8) S. Seo, M. Mastiani, B. Mosavati, D.M. Peters, P. Mandin, M. Kim, “Performance Evaluation of Environmentally Benign Nonionic Biosurfactant for Enhanced Oil Recovery”, Fuel, (2018) 234 48-55.
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10) M. Kim, A. Giry, M. Mastiani, G.O. Rodrigues, A. Reis, P. Mandin, “Microscale Thermometry: A Review”, Microelectronic Engineering, (2015) 148 129-142.
11) M. Mastiani, S. Seo, B. Mosavati, M. Kim, “Oil-Free Passive Generation of Aqueous Two-Phase System Micro Droplets”, 71st Annual Meeting of the APS Division of Fluid Dynamics, Nov. 18–20, 2018, Atlanta, Georgia, USA.
12) M. Mastiani, S. Seo, S. Jimenez, N. Petrozzi, M. Kim, “Understanding Fundamental Physics of Aqueous Droplet Generation Mechanisms in the Aqueous Environment”, ASME International Mechanical Engineering Congress & Exposition (IMECE), Nov. 3–9, 2017, Tampa, Florida, USA.
13) M. Mastiani, S. Seo, M.M. Kim, “Aqueous Droplet Generation in High Inertial Air Flow”, ASME International Mechanical Engineering Congress & Exposition (IMECE), Nov. 3–9, 2017, Tampa, Florida, USA.
14) M. Mastiani, S. Seo, M.M. Kim, “Water-in-Water Droplet Generation using Pressure Driven Flow”, 3rd Thermal and Fluids Engineering Conference (TFEC), March 4–7, 2018, Fort Lauderdale, Florida, USA.
15) M. Mastiani, S. Seo, M.M. Kim, “Water-in-Air Droplet Generation in a T-Junction Geometry”, 3rd Thermal and Fluids Engineering Conference (TFEC), March 4–7, 2018, Fort Lauderdale, Florida, USA.
16) S. Seo, M. Mastiani, C. Saldana, M.M. Kim, “Porous Photobioreactor for Improved Biofuel Production by Microalgae”, ASME International Mechanical Engineering Congress & Exposition (IMECE), Nov. 3–9, 2017, Tampa, Florida, USA.
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21) S. Seo, M. Mastiani, K. Garcia, M.M. Kim, “Dynamics of Water Evaporation and Salt Precipitation during CO2 Injection to Microfluidic Chips”, 3rd Thermal and Fluids Engineering Conference (TFEC), March 4–7, 2018, Fort Lauderdale, Florida, USA.