

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

10X GENOMICS, INC.
Petitioner,

v.

BIO-RAD LABORATORIES, INC.
Patent Owner

Case IPR2020-00086
U.S. Patent No. 9,562,837

DECLARATION OF SHELLEY ANNA, Ph.D.

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I. INTRODUCTION

1. I have been retained by Bio-Rad Laboratories, Inc. (“Bio-Rad” or “Patent Owner”) to provide my expert opinions as to the validity of certain claims of U.S. Patent Nos. 9,562,837 (“the '837 patent”) in light of the Petition for *Inter Partes*, IPR2020-00086 (“the 086 Petition”) filed by 10X Genomics, Inc. (“10X” or “Petitioner”).

II. BACKGROUND AND QUALIFICATIONS

A. Education and Expertise

2. I attach a true and correct *curriculum vitae*, which includes a complete list of my qualifications, as Exhibit A.

3. I am a professor of chemical engineering at Carnegie Mellon University with extensive experience with microfluidics. I have been a professor at CMU since 2003 and was granted indefinite tenure and promotion to full professor as of July 1, 2013. I have been retained by Bio-Rad Laboratories, Inc.

4. My education, training, and work in the field of microfluidics dates back to my time as a Ph.D. student at Harvard University, between 1996 and 2000. As a Ph.D. student, I applied the knowledge of fluid dynamics that I had learned while working toward my Bachelor of Science degree in Physics at CMU (earned 1995) and my Master of Science degree in Engineering Sciences at Harvard (earned 1996) to conduct thesis research on the rheology of polymer solutions. The experiments for which I built equipment and conducted measurements

involved observations of stretching liquid filaments, which are small-scale free surface flows that are in the sub-millimeter scale (i.e., less than 1000 microns).

See, e.g., Anna et al., An Interlaboratory Comparison of Measurements from Filament-Stretching Rheometers Using Common Test Fluids, 45 J. Rheology 83, 96, tbl. III (2001) (Ex. 2027); Shelley L. Anna & Gareth H. McKinley, *Elasto-Capillary Thinning and Breakup of Model Elastic Liquids*, 45 J. Rheology 115, 120, fig. 4 (2001) (Ex. 2028)

5. After I earned my Ph.D. in June 2000, I was employed at Solutia, Inc., a company that manufactured adhesive and polymer coatings. As the result of my thesis research, I was the company's expert in rheology. I conducted experiments related to the small-scale flows of particulate and polymeric fluids in thin film coatings. In each of these early experiences I gained further knowledge and training in the physical phenomena that govern fluid flow at a wide range of length scales, including the millimeter scale, the micrometer scale, and below. Because I worked in the analytical division, I saw products (adhesives, emulsions, polymer films) at various stages of development. I also have interacted with companies through my current research, including conducting joint research projects, holding workshops and consulting. I am thus familiar with product development from the perspective of both a commercial company and academia. My research contributions during this time and the education and training that led up to them

provided me with the needed expertise to begin a postdoctoral fellowship conducting research in the area of microfluidics in October 2001.

6. From 2001 to 2003, I was a Postdoctoral Fellow in Fluid Dynamics and Complex Fluids at Harvard University. My fellowship entailed significant ground-breaking work in the field of microfluidics. Among other things, I designed a novel “flow-focusing” microfluidic device to synthesize monodisperse emulsion droplets (which resulted in a patent); established an operating diagram organizing fundamental modes of droplet formation; and modeled scaling conditions for splitting a droplet at a T-shaped microfluidic junction. Overall, my work during this period contributed significantly to the rapidly growing field of droplet-based microfluidic technologies.

7. After my Harvard fellowship concluded, I joined CMU's Department of Mechanical Engineering in 2003. I took a joint appointment in Chemical Engineering beginning in July 2009, and in July 2017 I converted to a full faculty appointment in Chemical Engineering. Since joining CMU, the focus of my teaching and research efforts has been on microfluidics. I have taught numerous courses in fluid dynamics, microfluidics, and transport phenomena to hundreds of graduate and undergraduate students. In fact, I developed, implemented, and created materials for an interdisciplinary course for graduate and undergraduate students dedicated to microfluidics at CMU. The course focuses on developing

students' knowledge of the ongoing academic and commercial work in microfluidics as well as providing experience in developing engineering solutions to cutting edge problems in microfluidics. My teaching at all levels receives high evaluations from students. I have also advised at least 38 Masters and Ph.D. students working on advanced microfluidics research.

8. In fact, since 2003, I have headed a fluid dynamics research laboratory composed of between five to six Ph.D. students as well as two to three Masters students each year. One of the principal focuses of my lab has been and continues to be cutting-edge microfluidics research. Specifically, my group has focused on developing innovative, microscale experimental methods to probe and control liquid-fluid interfaces, using scaling analysis, theory, and numerical simulations as tools to complement our experiments. In particular, by developing strategies for relevant processes, we have achieved advances in the fundamental engineering science relating to multiphase flows.

9. A major contribution of my research has been to show that uniform submicron droplets can be produced robustly and continuously in a microfluidic flow-focusing device using a fluid dynamical phenomenon called "tipstreaming." By submicron I mean that the diameters of the droplets produced are less than one micrometer and the volumes are less than one half of one femtoliter (10 to the minus 15 liters). My group has used experiments and dimensional analysis to

establish design rules for droplet-based processes in microfluidic devices, including droplet formation, coalescence, splitting, and packing of concentrated emulsions. We wrote a review article on droplet production for Journal of Physics D in 2007, and another review article on “Droplets and Bubbles in Microfluidics” for Annual Review of Fluid Mechanics in 2016. All in all, I have been working with droplets for more than nineteen years.

10. My work is routinely cited in the academic literature, with two publications from my postdoctoral work having more than 3600 citations altogether, and all of my publications having more than 8300 total citations.

11. In addition to these teaching and research activities, I am also a member of the faculty in the Center for Complex Fluids Engineering at CMU (“CCFE”). CCFE is an interdisciplinary research and education effort involving faculty and students from the science and engineering colleges at CMU. Participants conduct research in the formulation and processing of materials based on complex fluids. CCFE facilitates collaborative research among faculty, education of Ph.D. students in complex fluids experimentation through the PPG Industries Colloids, Polymers, and Surfaces Laboratory, and outreach and interaction with industrial scientists and engineers.

12. I was the co-Chair (together with Jonathan Posner of the University of Washington) of the 2015 Gordon Research Conference (“GRC”) on Physics &

Chemistry of Microfluidics. This GRC is held every two years, and the co-Chair is an elected position that is voted on by the participants at each Gordon Research Conference. I was elected co-Vice Chair along with Dr. Posner at the 2011 meeting. My co-Vice Chair and I served in this position for the 2013 GRC meeting, and we automatically became co-Chairs of the 2015 meeting. Our responsibilities for the 2015 meeting included selecting and inviting speakers to create a dynamic program focusing on current trends in the area of microfluidics, encouraging free, unhampered discussion of this research, and promoting younger scientists and students.

13. In November 2018, I became Vice-Chair of the Division of Fluid Dynamics (DFD) of the American Physical Society. This is a position elected by the membership of the DFD and in this role I am one of four primary leaders of the Division (the “Chair line”). Upon serving as Vice-Chair for one year, I then rotated to become Chair-Elect beginning in November 2019. I will rotate to become Chair beginning in November 2020, and then Past Chair beginning in November 2021. As a member of the Chair line of the DFD, I serve in various capacities to select Fellows of the DFD, to solicit and select invited speakers and focus sessions at our annual fluid dynamics meeting, to plan the annual fluid dynamics meeting, and to address other major issues of concern to the DFD membership such as meeting

safety and harassment, media coverage of our science, diversity equity and inclusion, and division finances.

14. I have also taught several workshops and short courses in the area of microfluidics, each of which entailed developing course and tutorial materials and delivering one to three hours of lecture on the subject. For example, I served as a lecturer on microfluidics at the European School on Rheology in Belgium in September 2011, teaching industrial scientists and engineers about the uses of microfluidics for characterizing rheological properties of complex fluids. I also taught a tutorial lecture on an introduction to multiphase flows in microfluidics at the Institute for Mathematics and Its Applications Workshop on Microfluidics: Electrokinetic and Interfacial Phenomena at the University of Minnesota in December 2009. In 2012, I held an Industry-Academia workshop at CMU on Transport and Mechanics at Fluid-Fluid Interfaces.

15. I have published numerous articles relating to microfluidics, including a seminal paper “Formation of dispersions using 'flow focusing' in microchannels,” which was published in 2003 in the journal Applied Physics Letters and has received over 2400 citations in the academic literature to date.

16. On the basis of my contributions to research in the area of microfluidics, I have been awarded a National Science Foundation CAREER Award, and an Honorable Mention in the category of Emerging Female Scientist of

the Carnegie Science Awards. I was also given two awards at CMU, including the George Tallman Ladd Research Award from the College of Engineering, and the Russell V. Trader Career Faculty Fellowship in the Department of Mechanical Engineering. In 2014, I was inducted as a Fellow of the American Physical Society in part for my contributions in droplet microfluidics and surfactant effects.

B. Prior Expert Experience

17. In the prior 4 years, I have provided a declaration(s) and/or testimony on behalf of Bio-Rad in *Bio-Rad Laboratories, Inc. and Bio-Rad QL, Inc., v. Benjamin Hindson, Kevin Ness, and Serge Saxonov*, Case No. 01-14-0001-5239 (American Arbitration Assoc.); IPR No. 2015-00009 (*Bio-Rad Laboratories v. California Institute of Technology*) (U.S. Patent No. 7,294,503); IPR No. 2015-00010 (*Bio-Rad Laboratories v. California Institute of Technology*) (U.S. Patent No. 8,252,539); *In the Matter of Certain Microfluidic Devices*, Inv. No. 337-TA-1068 (Int'l Trade Comm'n) and *Bio-Rad Laboratories, Inc. v. 10X Genomics, Inc.*, Civil Action No. 18-1679 (D. Del.).

C. Compensation

18. I am being compensated at a rate of \$350 per hour for consulting work on this case and \$525 per hour for deposition and trial testimony. This compensation is not contingent upon my performance, the opinions expressed or

facts stated herein or during any testimony, the outcome of this case, or any issues involved in or related to this case.

D. Materials Reviewed

19. In preparing this declaration, I have considered the claims, specifications and prosecution file histories for U.S. Patent Nos. 9,562,837 (“the ‘837 patent”) and 9,896,722 (“the ‘722 patent”) (collectively, “the patents-in-suit” or “the Link Patents”) from the vantage point of one of ordinary skill in the art. I have also reviewed the Petition for *Inter Partes* Review of the ‘837 patent, IPR2020-00086 (“the 086 Petition”), the Declaration of Richard B. Fair, Ph.D. filed in support of the 086 Petition and the Decision Granting Institution of the 086 Petition by the Patent Trial and Appeal Board (“the Board”), and all cited exhibits therein.

20. I reserve the right to modify or supplement my opinions or the bases for my opinions in light of any additional documents, depositions and other testimony, or other evidence that may become available as the 086 Petition progresses. I may supplement Exhibit 2 to incorporate such additional materials. I also may be asked to respond to any declarations or testimony submitted on behalf of Patent Owner concerning the patents-in-suit, state of the art or other matters, and reserve the right to do so.

III. BACKGROUND

A. The '837 Patent

21. The '837 patent is entitled "Systems for Handling Microfluidic Droplets" and issued on February 7, 2017. The '837 patent was filed on April 2, 2013, and claims priority to several provisional applications, the earliest of which (Provisional Application Nos. 60/799,833 and 60/799,834) were filed on May 11, 2006.

22. The '837 patent is directed generally to assemblies for forming, separating and collecting emulsion droplets.

23. The '837 specification explains that the use of microfluidics to partition a sample into droplets offers improvements over the prior art by reducing sample contamination, sample loss, and sample handling in several different ways: (1) by limiting operator handling of the sample during partitioning, addition of reagents, and displacement of droplets for analysis; (2) by isolating small amounts of sample in closed droplet partitions that are fully sealed off from other droplet partitions and from the environment; (3) by preventing a contaminant that is present in one partition from contaminating reactions in other partitions and potentially overwhelming the detection of a rare sample in a high background of contaminant. *See, e.g., '837 Patent, col. 2:4-31, 40-53; 52:27-37.*

24. The '837 patent describes problems with sample contamination in the prior art resulting from operator handling of samples, leading to repeated exposure of a sample to the outside environment:

A significant problem with PCR is sample contamination from non-target nucleic acid. Conventional PCR typically includes numerous handling steps that expose the sample to the outside environment, all [of] which may introduce contamination into the sample. For example, a sample may be transferred by manual pipette from an open container where the sample was isolated to a PCR tube where amplification will occur. Although the tube may be closed after the addition of the sample, the PCR tube is then reopened to add the necessary reagents for amplification, again typically by manual pipette. The PCR tube is then closed and transferred to a thermocycler for the amplification process. After numerous cycles of heating and cooling, the PCR tube is removed from the thermocycler, whereupon the tube is reopened in order to remove and analyze the amplified product. Aside from exposing the sample to the outside environment whenever the container holding the sample is opened, the manual handling of the sample that occurs during the opening or closing of the tube, or during the process of manual pipetting, only increases the risk of contamination.

('837 patent at 2:4-23).

25. The '837 specification explains that the problem of contamination in reactions such as PCR reactions is particularly acute where the sample is present only in a very small amount. Because the reaction proceeds in exponential fashion, starting molecules compete for reagents present in the reaction, causing molecules present in relatively small amounts initially to be out-competed during the reaction.

As a result, rare molecules may be present only in such small relative amounts at the end of the amplification reaction that they are not detectable in a background of amplified contaminant:

Since the PCR reaction is so efficient, the contaminant nucleic acid may be amplified during the PCR reaction, thus leading to biased or incorrect assay results. Contamination is especially problematic when the target nucleic acid is present in very small amounts, because the contaminant nucleic acid may easily out-compete the target nucleic acid during amplification, and thus the target nucleic acid will not be detected after the amplification reaction.

('837 patent at 2:24-31).

26. The '837 patent expressly states that the methods of the invention offer an improvement over the prior art through the use of microfluidic assemblies to partition the sample into droplets, which are then displaced for analysis in a manner that minimizes operator handling and exposure of the sample to the environment:

The invention provides systems and methods that are designed to minimize sample contact and exposure of the sample to the surrounding environment, thereby minimizing or eliminating the introduction of contaminants into an amplification reaction. Aspects of the invention are accomplished using microfluidic assemblies. A sample including nucleic acid is loaded into a first microfluidic assembly that is used to partition the sample into partitioned portions using an immiscible fluid. Reagents for the amplification reaction are introduced to the partitioned portions, and the partitioned portions are flowed in the immiscible fluid to a chamber. The sample

fluid and the immiscible fluid are of different densities, such that upon entry into the chamber, the density difference in the fluids is utilized to displace the partitioned portions from the chamber while the immiscible fluid remains in the chamber. The displaced sample portions are collected in a vessel that is sealed and transferred to a thermocycler for amplification of the nucleic acid in the partitioned portions.

('837 patent at 2:40-53).

27. Notably, in the methods of the claimed invention, each droplet serves as an isolated reaction chamber, sealed off from every other droplet reaction chamber, in which PCR amplification occurs. I note that the parties' agreed construction of the term “droplet” in the parallel Delaware Litigation, which is taken directly from the '837 specification (*see, e.g.*, '837 patent at 15:1-3) is: “an *isolated* portion of a first fluid that is completely surrounded by a second fluid” (emphasis added).

28. The '837 specification stresses that the methods of the invention reduce operator handling of sample droplets, maintaining isolation of the sample from the environment in each individual droplet:

The methods and assemblies described herein use immiscible fluids of certain densities to displace sample droplets from one location to another without the need for operator handling. Accordingly, the risk of contamination associated with such handling is eliminated.

('837 patent at 52:33-37).

29. The '837 patent has 1 independent claim and 19 dependent claims.

Independent claim 1 recites:

1. An assembly, the assembly comprising:

a microchannel in a horizontal plane;

at least one droplet formation module comprising a sample inlet, an immiscible fluid inlet, and a junction, wherein the junction is located between the sample inlet and the microchannel and the droplet formation module is configured to produce droplets comprising the sample surrounded by the immiscible fluid; and

at least one downstream separation chamber comprising a droplet receiving chamber inlet and at least one droplet receiving outlet, wherein the separation chamber is upright to the microchannel and out of the horizontal plane;

wherein the droplet formation module and the separation chamber are in fluid communication with each other via the microchannel; and wherein the separation chamber has a wider cross-section than the microchannel cross-section to accumulate a plurality of droplets comprising the sample and is of a volume sufficient to separate the plurality of droplets comprising the sample from the immiscible fluid within the separation chamber.

30. As recited in claim 1, the '837 patent covers systems for generating sample-containing droplets, or emulsions, through the use of “a microchannel in a horizontal plane” with “at least one droplet formation module.” Emulsions are formed when the instrument drives fluids through the microchannel into a droplet formation module that contains both a “sample inlet” and an “immiscible fluid inlet” to a “junction” that creates droplets comprising the sample fluid surrounded

by the immiscible fluid. The '837 patent further teaches the use of a novel “separation chamber” that is “out of the horizontal plane” of the microchannel and has a wider cross-section than the microchannel cross-section. The “separation chamber” is designed to be of a volume “sufficient to separate the plurality of droplets comprising the sample from the immiscible fluid.”

B. Ismagilov

31. Ismagilov is titled “Device and Methods for Pressure-Driven Plug Transport and Reaction.”

32. The Abstract teaches that the invention disclosed “provides microfabricated substrates and methods of conducting reactions within these substrates.”

33. There are 45 figures (many of which include sub-figures) in Ismagilov, all of which focus on the configuration of channels within the substrate in order to prepare droplets or plugs, and conduct the reactions being described.

34. What is not disclosed in any detail in the figures, or anywhere else in the specification, is the configuration, structure, or design of the outlet in any of the devices.

35. In my opinion, the references to “outlet ports” or “wells or reservoirs” that are relied upon by Petitioner in the 086 Petition are not disclosing any new design or configuration, but are merely referencing commonly known elements of

microfluidic devices from the time of the disclosed invention in the early 2000's that I describe below. This is evidenced by the reference to the use of cork borers or syringe needles to cut holes into the PDMS when preparing the devices. (Ex. 1004 at 16:35-36).

36. In my opinion, a POSA would understand that to the extent Ismagilov provided any description of the outlets that were employed in the devices, the reference was merely describing standard off-the-shelf techniques that were well known in the art.

C. Quake

37. Quake discloses "a chip with an inlet channel and reservoir, a detection region a branch point, and two outlet channels and reservoirs."

38. Quake further discloses that the apparatus embodying this configuration "is mounted on an inverted microscope for optical detection" and that "[e]lectrodes are used to direct virons or cells in response to the microscope detection."

39. It is my understanding that during his deposition, Dr. Fair admitted that "Quake did not use droplets, he injected dye, which then he sorted based upon red or green. And this is not a droplet-based system." (Ex. 2017 at 141:12-142:2).

40. Dr. Fair's testimony is consistent with the described use case of the device shown Figures 6 and 8 in Quake, which makes clear that the device was

used to conduct “Sorting Experiments” where “[t]hree platinum electrodes were each inserted into separate wells” and then the device “was used to sort fluorescent beads of different emission wavelengths in different ratios up to 33,000 beads per hour.” (Ex. 1006 at ¶¶ 192-214).

IV. LEGAL STANDARDS

A. Claim Construction

41. I understand that the claims should be construed from the standpoint of a hypothetical person of ordinary skill in the art as of the invention date of the asserted patent. I understand that the following factors are relevant to determining the level of ordinary skill in the art: (a) type of problems encountered in the art, (b) prior art solutions to those problems, (c) rapidity with which innovations are made, (d) sophistication of the technology, and (e) educational level of active workers in the field.

42. I understand that the claims of a patent define its scope, and the construction of claim terms is a question of law. I also understand that claim construction is a process that begins with the claims of the patent that define the invention. The claims are given their ordinary and customary meaning as understood by a person of ordinary skill in the art when read in the context of the specification and prosecution history. In determining the proper construction of the claims, courts apply a hierarchy of intrinsic record: (1) the claim language, (2)

the specification, and (3) the prosecution history. It is my understanding that extrinsic evidence, such as expert testimony, dictionaries, and learned treatises, can be used if claim terms remain ambiguous but extrinsic evidence cannot be used to contradict the intrinsic evidence.

43. I understand that the written description of the invention in the patent specification is of paramount importance in construing the claims. The specification is the single best guide to the meaning of a disputed term and is usually dispositive. While the specification is a guide when construing claims, specific embodiments should not be read into claims.

44. I understand that an inventor may act as his or her own lexicographer and provide definitions for terms used in a patent. I also understand that when the specification shows that the inventors gave a special definition to a claim term that differs from the meaning it would otherwise possess, that definition controls the meaning of the term.

45. I understand that a claim construction should give meaning to all of the terms in the claim. Constructions that render a claim term(s) superfluous are generally rejected. Each claim term is also presumed to have a different meaning and scope.

46. I understand that an element in a claim for a combination may be expressed as a means or step for performing a specified function (“means plus

function”) without the recital of structure, material, or acts in support thereof, and such claim shall be construed to cover the corresponding structure, material, or acts described in the specification and equivalents thereof.

47. I also understand that there is a rebuttable presumption afforded the patent drafter that claim language is not “means plus function” if it does not include the word “means.” I also understand that the presumption can be overcome only if the challenger demonstrates that the claim term fails to recite sufficiently definite structure or else recites function without reciting sufficient structure for performing that function. In such cases, a substitute term acts a generic placeholder (or so-called “nonce” word) for the term “means.” I understand that the standard is whether a person of ordinary skill in the art would understand the claim language to refer to structure, assessed in light of the presumption that flows from the drafter's choice not to employ the word “means.”

B. Anticipation

48. I understand that a claim is anticipated only if each and every element as set forth in the claim is found, either expressly or inherently described, in a single prior art reference.

49. I understand that inherency may not be established by probabilities or possibilities, and the mere fact that a certain thing *may* result from a given set of circumstances is not sufficient.

50. I understand that to serve as an anticipating reference, the reference must enable that which it is asserted to anticipate. I further understand that a claimed invention cannot be anticipated by a prior art reference if the allegedly anticipatory disclosures cited as prior art are not enabled. I further understand that enablement requires that the prior art reference must teach one of ordinary skill in the art to make or carry out the claimed invention without undue experimentation.

51. I understand that determination of whether the requisite amount of experimentation is undue may include consideration of several factors (known as the *Wands* factors). Those factors include: (1) the quantity of experimentation necessary, (2) the amount of direction or guidance presented, (3) the presence or absence of working examples, (4) the nature of the invention, (5) the state of the prior art, (6) the relative skill of those in the art, (7) the predictability or unpredictability of the art, and (8) the breadth of the claims.

C. Obviousness

52. I understand that an analysis of obviousness must include an analysis of (1) the scope and content of the prior art; (2) the differences between the prior art and the claims at issue; (3) the level of ordinary skill in the art at the time the invention was made; and (4) objective evidence of nonobviousness, if any.

53. I further understand that there must be some articulated reasoning with some rational underpinning to support the legal conclusion of obviousness. I

further understand that the patent challenger must demonstrate a “reasonable expectation of success” of combining the prior art references to achieve the claimed invention.

54. I also understand that a patent can be obvious in light of a single prior art reference if it would have been obvious to modify that reference to arrive at the patented invention.

55. I understand that in evaluating prior art, a person of ordinary skill in the art (“POSA”) must avoid the trap of hindsight. I further understand that even an obvious solution does not render an invention obvious if the problem solved was previously unknown.

56. I further understand that a reference that teaches away cannot serve as a basis for obviousness. I further understand that a reference may be said to teach away when a person of ordinary skill, upon reading the reference, would be discouraged from following the path set out in the reference, or would be led in a direction divergent from the path that was taken by the applicant.

57. I further understand that evidence of “secondary considerations” when present must always be considered in a determination of obviousness. I understand that these objective considerations, when considered with the balance of the obviousness evidence in the record, guard as a check against hindsight bias.

V. STATE OF THE ART

58. Biomedical applications are increasingly reliant on high throughput assays of sample material under study combined with reagents. An example of this in research and clinical applications is high throughput genetic tests that may use reagents to provide high-quality information about samples for drug discovery, biomarker discovery and clinical diagnostics among other things. A specific example in the realm of infectious disease screening is to examine a sample for multiple genetic targets to determine which organism is causing the infection.

59. Often in research, large volumes of materials to be studied are not available. This has created a trend toward methods of analysis which can use smaller volumes yet detect significant numbers of targets. Mixing and creating very small volumes of materials can be time consuming, labor intensive, and error prone. Detecting target molecules may require specialized instrumentation which is expensive and require large sample volumes for accuracy, especially with rare target molecules. This trade-off created a need for improved technology to permit large sample numbers to be studied using small volumes of sample and reagent at high speed, low cost, with high accuracy and with reduced instrument and workflow complexity.

60. Emulsions have substantial promise for revolutionizing the field of high throughput assays. Emulsification can create tens to hundreds of thousands of

aqueous droplets. The aqueous droplets are formed from a water based substance surrounded by a continuous phase fluid such as oil that is immiscible with the water. Each tiny droplet within the oil acts as an individual, enclosed “test tube” in which reactions can occur.

61. The field of microfluidics includes devices and instruments that can reproducibly and reliably generate uniform emulsion droplets with very small volumes. These devices are commonly referred to as “chips” or “microfluidic chips.” They typically have a number of wells or reservoirs to hold fluids and channels that allow the fluid to travel to particular locations on the chip. The chips are typically made of glass, silicon or a polymer such as polydimethylsiloxane (“PDMS”).

62. As explained above, the technology at issue in the ‘837 patent involves microfluidic chips with a “separation chamber” that facilitates the collection and transfer of droplets for further “off chip” processing. By substantially separating the droplets from the immiscible carrier fluid and directing them to a desired location, the novel chips of the ‘837 patent make collection of the droplets much easier to avoid contamination that can corrupt further downstream processing.

63. During the timeframe prior to May 11, 2007, microfluidics researchers were largely focused on two major aspects of on-chip emulsification:

(i) best methods of formation of uniformly-sized droplets of a desired size, frequency, and number; and (ii) using droplets as in-line reactors in which samples and reagents could be visualized. The collection of droplets after formation for further processing or analysis was not a common focus, and the separation of droplets from the surrounding oil fluid was also not widely reported or considered.

64. Although emulsification outside microfluidic devices has been well studied for decades, emulsification in microfluidic devices did not gain popularity until the early 2000's when several academic research groups developed methods for forming uniform droplets in microfluidic chips. Thorsen presented a method using two channels oriented perpendicular to one another to shear off droplets of one immiscible liquid into a surrounding liquid. (Ex. 2040, Chapter 3). Anna, Bontoux and Stone presented a different method for breaking off droplets using a "flow focusing" method that draws a narrow jet of one immiscible liquid into an accelerating stream of a surrounding liquid. (Ex. 2031). Other methods of droplet formation were also presented in the literature around that time, and many were summarized in a review article that was published shortly after the stated priority date (Christopher and Anna, Journal of Physics D: Applied Physics, "Microfluidic Methods for Generating Continuous Droplet Streams" published Sept 1, 2007 (Ex. 2029)).

65. In many of the examples of microfluidic droplet formation in that time period, microfluidic devices were fabricated using a standard rapid prototyping method called soft lithography (J. Cooper McDonald et al., Fabrication of Microfluidic Systems in Poly(Dimethylsiloxane), 21 Electrophoresis 27 (2000) (Ex. 2039)). This involved creating a raised stamp from a two dimensional design of interconnected channels that were typically tens of micrometers in width and millimeters to centimeters in length. Channels of rectangular cross-section were created with a depth determined by the depth of the stamp or mold, and this depth could be a few to tens of micrometers.

66. PDMS and other elastomers used for soft lithography typically created hydrophobic surfaces, which promoted the formation of aqueous droplets surrounded by an immiscible oil.

67. In order to generate flow in microfluidic devices, fluid needed to be introduced via an external pumping mechanism, and fluid also needed to be able to exit the channels. This is necessary because of the basic physical principle of conservation of mass: in a channel with a single inlet and a single outlet, what goes in must come out.

68. To create inlets and outlets, it was common at the time to punch a hole through the PDMS at the ends of the channels where fluid was desired to be introduced and to exit. (Samuel K. Sia & George M. Whitesides, Microfluidic

Devices Fabricated in Poly(Dimethylsiloxane) for Biological Studies, 24

Electrophoresis 3563, 3564 (2003) (Ex. 2033)) These holes were commonly punched using sharpened syringe needles. This was sufficient to press fit a piece of flexible tubing into the punched hole, allowing for fluid to be directed into the channel at the entrance, or diverted away from the channel at the exit.

69. In addition to forming droplets and characterizing their size and formation frequency, researchers were also using droplets at that time as on-chip vessels for generating and monitoring reactions. It was common to use long segments of microchannels to generate many sequential droplets and observe reactions within them as they travel along the length of the channel. Examples of this type of application are described in a review article published in 2006 (Ex. 2035)

70. In the time period prior to the priority date of the patent there was not a focus on collecting and separating droplets formed in microfluidic devices.

71. Most droplet microfluidic applications focused on in-line production and manipulation of droplets, without considering removal of the droplets from the chip.

VI. PERSON OF ORDINARY SKILL IN THE ART

72. It is my opinion that a POSA at the time of the priority date of the '837 patent¹ would have had at least the equivalent of a Bachelor's degree in engineering, physics, or chemistry and two years of academic, research, or industry experience related to fluid mechanics, fluid dynamics, or microfluidics. Additional training or study could substitute for work experience and additional work experience or training could substitute for formal education.

73. Dr. Fair proposes a different level of skill for the person of ordinary skill in the art, including (1) a Ph.D. and one year of experience, (2) a Bachelor's Degree with four years of experience or (3) a higher level of education with less relevant experience or more relevant experience but less education. He also proposes that the person of ordinary skill might have been part of a group of workers, which includes workers with additional skills, for example, in the biological, chemical, or engineering sciences.

74. I disagree with Dr. Fair's definition of a POSA because I do not believe that a Ph.D. or a Bachelor's Degree and four years of experience are necessary for a person of ordinary skill in the art. I also disagree that the skills of an entire team are relevant or necessary to the consideration of a POSA. However,

¹ It is my understanding that the priority date of the Asserted Patents is no later than May 11, 2007.

should the Board adopt Dr. Fair's definition of the POSA instead of my own, my opinions as set out herein would not change.

VII. CLAIM CONSTRUCTION

A. “separation chamber” (all Challenged Claims)

75. In my opinion, the claim term “separation chamber” means “a chamber sized to accommodate multiple droplets and an immiscible fluid in separated form.”

76. In my opinion, the intrinsic evidence, including the claim, the specification, and the file history, fully supports this proposed construction of the term “separation chamber.”

77. The term “separation chamber” involves two concepts that are central to the claimed assemblies of the '837 patent – the idea of “separation” of droplets, for example, based on differential density, and the idea of a “chamber” or vessel. In my opinion, Bio-Rad's proposed construction gives meaning to both words in the term.

78. The claims require the separation chamber to be large enough to allow droplets to separate from the surrounding immiscible fluid. For example, claim 1 of the '837 Patent includes the following “wherein” clause: “wherein the separation chamber has a wider cross-section than the microchannel cross-section to accumulate a plurality of droplets comprising the sample and *is of a volume*

sufficient to separate the plurality of droplets comprising the sample from the immiscible fluid within the separation chamber.” (‘837 Patent, col. 88:18-23 (emphasis added)).

79. The ‘837 specification similarly explains that the function of the chamber is to receive and *separate* droplets (“partitioned portions”) from the surrounding immiscible fluid based on differences in density:

“The sample fluid and the immiscible fluid are of different densities, *such that upon entry into the chamber, the density difference in the fluids is utilized to displace the partitioned portions from the chamber while the immiscible fluid remains in the chamber.*”

(‘837 patent at 2:45-50).

80. Similar descriptions are present throughout the specifications, explaining the function of the chamber to collect and separate the droplets:

The assembly also includes at least one chamber equipped with an outlet. *The partitioned portions and immiscible fluid flow into the chamber. The partitioned portions and the immiscible fluid are of different densities.* In certain embodiments, the partitioned portions are of a greater density than the immiscible fluid, *so the partitioned portions sink within the chamber while the immiscible fluid rises.* In other embodiments, the immiscible fluid is of a greater density than the partitioned portions, *so the partitioned portions rise within the chamber while the immiscible fluid sinks.*

(‘837 Patent, col. 3:37-46 (emphases added)).

81. As another example, the specifications state:

The chamber is configured to receive droplets and an immiscible fluid from the droplet formation module. . . . As immiscible fluid continues to flow into the chamber, the immiscible fluid displaces the droplet from the chamber into the outlet due to the difference in density. . . . As the immiscible fluid displaces the droplets towards the outlet, the majority of the immiscible fluid remains inside the chamber, leaving substantially only droplets to exit the chamber.

('837 Patent, col. 53:22-35 (emphases added)).

82. The prosecution histories of the Asserted Patents also support Bio-Rad's proposed construction. For example, the inventors explained during prosecution that the claimed separation chamber was an improvement over the prior art because it allowed separation of multiple droplets from the surrounding immiscible fluid. In the following passage from the prosecution history, the inventors are explaining the difference between their invention and a prior art reference ("Lee"):

Lee's conduit differs from the claimed chamber because Lee's conduit accommodates *only one droplet across its width at a time*. In contrast, *the width of the claimed chamber is sized to accommodate multiple droplets which allows for droplet concentration and removal of carrier fluid from between the droplets*.

See, e.g., Ex. 1002 at 1114 (emphases added).

83. They similarly stated during prosecution:

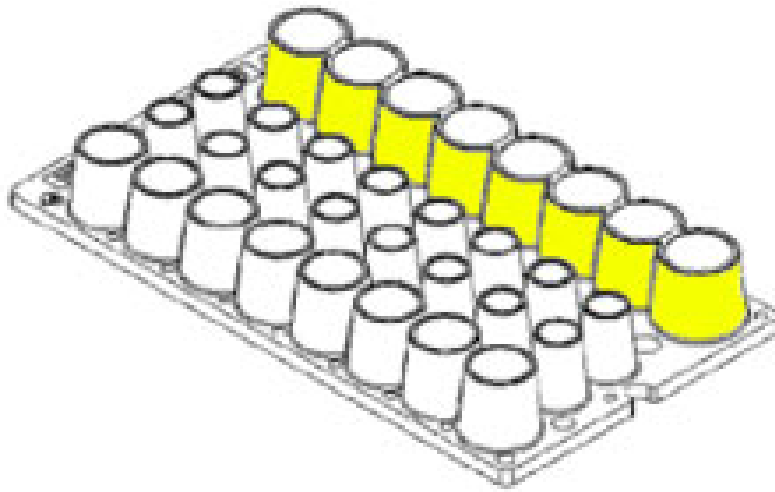
As acknowledged by the Examiner . . . Lee's cross-intersection is different from the separation chamber in amended claim 1 because Lee's cross-intersection is not a

vertical chamber to separate droplets from an immiscible fluid carrier fluid. ***Nor does Lee's cross-intersection . . . accumulate droplets in an immiscible fluid or have a specific volume to separate droplets from an immiscible fluid.***

Id. at Ex. 1002 at 1168-69 (emphasis added).

84. I understand that Petitioner argues that Bio-Rad's interpretation of this term must be "broad enough to encompass an open well." (Pet. at 19). I also understand that this argument and reference to Bio-Rad's interpretation is based on the Infringement Contentions that were served in the parallel Delaware Litigation. (Ex. 1026). In my opinion this an overly broad reading of Bio-Rad's infringement contentions, and as a result is not an accurate reading of the scope of this limitation.

85. Patent Owner's Infringement Contentions from the Delaware Litigation assert that the open-top chamber from the 10X Accused Device infringes the '722 patent. For ease of reference, I have reproduced the image of the 10X Accused Device from Patent Owner's Infringement Contentions below, with the chambers highlighted in yellow:



86. As the image shows, the open top chambers in the 10X Accused Device meet the requirements of a “separation chamber” because they are “chambers sized to accommodate multiple droplets and an immiscible fluid in separated form.”

87. While I agree that some “open wells” (like those of the structures found on the 10X Accused Device) may satisfy that limitation, others will not, and thus a construction of this limitation that allows for simply any open well is not correct.

88. Petitioner’s alternative proposed construction ignores the word “separation” in the term and strips it of any meaning. Petitioner’s proposed construction also imports the limitation “substantially enclosed” into the term, contradicting the descriptions of various “chambers” in the specifications of the Asserted Patents.

89. I disagree with Dr. Fair (¶ 86) that a person of ordinary skill in the art would understand the plain meaning of “chamber” to be a “space that is substantially enclosed.” In my opinion, a person of ordinary skill in the art would not interpret the word “chamber” in this fashion. I note that Dr. Fair supports his opinion with extrinsic evidence, such as dictionaries. (Fair Decl. ¶ 86). I also note that none of these dictionaries address the meaning of terms in the context of microfluidics. Instead, they relate to anatomy (a “chamber of the heart”), or to machines, or simply to general usage. *See id.*

90. Dr. Fair argues (¶¶ 87-88), that the goal of reducing sample contamination supports 10X's proposed construction requiring “substantial enclosure” for the separation chamber. I believe that Dr. Fair's interpretation of the goals of the inventions is incorrect. Reducing sample contamination, sample loss, and sample handling in the methods and apparatuses of the invention, is accomplished primarily through partitioning of a sample into droplets, isolated microreactors, and then separating those droplets from the surrounding immiscible fluid in a separation chamber by, for example, density differentials. This is in contrast to the prior art, where multiple handling steps were used to transfer a sample from one bulk container to another, exposing it to the atmosphere.

91. Pursuant to the invention, whether or not the separation chamber is “substantially closed,” the sample is isolated in individual partitions, as I discussed

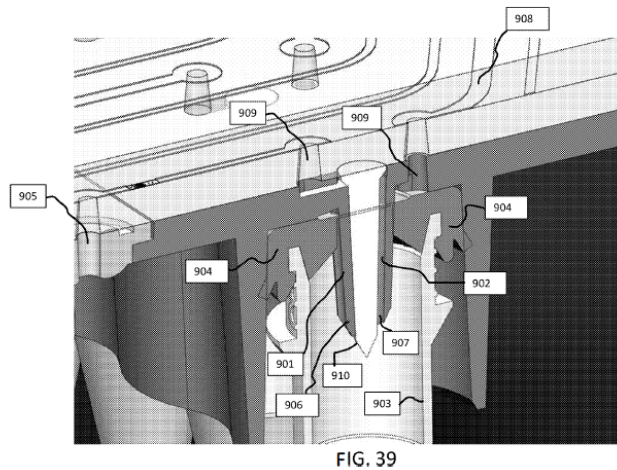
above, that are maintained intact during subsequent steps such as separation in the separation chamber and analysis, for example, through heating on a thermocycler:

The sample fluid and the immiscible fluid are of different densities, such that upon entry into the chamber, *the density difference in the fluids is utilized to displace the partitioned portions from the chamber while the immiscible fluid remains in the chamber. The displaced sample portions are collected in a vessel that is sealed and transferred to a thermocycler* for amplification of the nucleic acid in the partitioned portions.

('837 Patent, col. 2:45-53 (emphasis added)). I note that when the inventors wished to specify that a collection vessel must be sealed, or “substantially enclosed,” they did so, as the above passage demonstrates, which states that the sample portions “are collected *in a vessel that is sealed*” after they have been separated in the chamber. The separation chamber, however, is not described as enclosed, partly, substantially, or otherwise.

92. Dr. Fair does not explain how the use of a separation chamber that is not “substantially enclosed” will increase the risk of sample contamination. Given that the droplets isolate the sample from the environment, Dr. Fair has not presented any mechanism by which contaminants will enter the isolated droplet microreactors. Because the droplets protect and isolate the sample from contaminants in the outside environment, the method of the invention reduces contamination compared to the prior art and the separation chamber does not need to be substantially enclosed to do that and to provide substantial protection.

93. Dr. Fair also opines (Fair Decl. ¶ 89) that because certain embodiments in the specification show a “sealable connection” from the separation chamber to other assemblies, the “separation chamber” itself must be “substantially enclosed.” This argument is inconsistent with the description of the figure that Dr. Fair relies on, Figure 39:



94. According to the specification, vessel **903** in the figure is the separation chamber where droplets are separated from surrounding immiscible fluid. *See, e.g.*, '837 Patent, col. 56:8-10 (“As the oil fills the vessel **903**, the oil displaces the droplets inside the vessel due to the density difference between the droplets and the oil”). The specification expressly states that the sealable connection to vessel **903** is optional: “In addition, the assembly *may include* devices configured to sealably connect the vessel **903** to the assembly.” '837 Patent, col. 55:55-57 (emphasis added). Therefore, this figure and the description

of the figure in the specifications actually contradict 10X's proposed construction that the separation chamber must be “substantially enclosed.”

95. I note also that Figure 38 of the Asserted Patents shows an assembly that includes a “slide,” indicated as structure **806** in the figure:

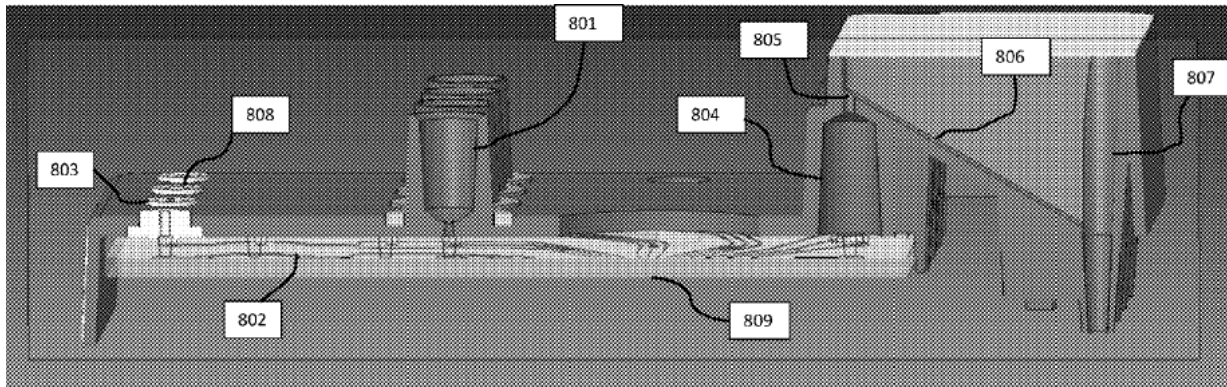


FIG. 38

(‘837 Patent, Fig. 38). The ‘837 Patent describes the figure as follows:

In certain embodiments, the outlet is connected to a slide **806**. The slide **806** includes a proximal end connected to the outlet **805** and a distal end. In certain embodiments, the proximal end of the slide **806** is higher than the distal end. *The outlet 805 is in fluid communication with the slide 806 such that droplets exiting the chamber 804 through the outlet 805 will enter into the slide 806. The droplets travel from the higher positioned proximal end of the slide 806 to the lower distal end where they are collected.* To further facilitate the collection of droplets, the slide may be connected to an output nozzle **807**.

(‘837 Patent, col. 54:47-47 (emphases added)). I note further that in this figure, structure **804** is a separation chamber, and structure **805** is an outlet from the separation chamber. (See ‘837 Patent, col. 54:34-46).

96. A person of ordinary skill in the art would understand the term “slide” to indicate an open structure – *i.e.*, a surface that is angled relative to gravity. In my opinion, if it were closed in some way, a person of ordinary skill in the art would refer to it as a channel or a tube, as the inventors do at '837 Patent Col. 53:42-46 (describing a “channel” attached to the outlet to transport droplets from the outlet to a collection vessel), and would not use the term “slide.” Therefore, the Asserted Patents expressly include at least one embodiment in which the droplets are exposed to the outside environment on the slide. This intrinsic evidence contradicts Dr. Fair's arguments that the separation chamber—and, for that matter, everything holding or transporting droplets—needs to be “substantially enclosed” to avoid exposing the sample to the outside environment and contaminating it. It would be pointless to enclose the separation chamber to avoid exposing the droplets to the environment and then to remove them from the outlet via a slide that is open to the air.

B. “droplet receiving outlet” (all Challenged Claims)

97. In my opinion, the claim term “droplet receiving outlet” should be construed as a “portion of the separation chamber where droplets are collected,” which is consistent with the intrinsic record.

98. The '837 specification explains that the “droplet receiving outlet” is part of the separation chamber. ('837 patent 3:48-51 (“The outlet may be

positioned at any place in the chamber and it is positioned based upon the densities of the partitioned portions and the immiscible fluid.”).

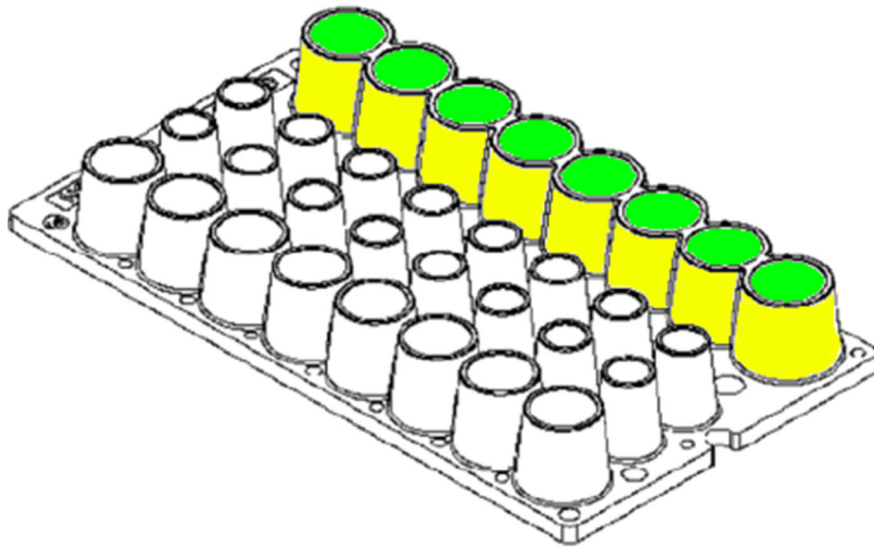
99. The ‘837 specification also discusses specific locations of the “droplet receiving outlet” within the chamber. For example, the ‘837 specification explains that when the droplets are less dense than the immiscible fluid, they rise, and the “droplet receiving outlet” may be located at the top of the separation chamber. *Id.* Col. 3:51-58 (“[I]n certain embodiments, [the outlet] is positioned in a top portion of the chamber. In this embodiment, the partitioned portions and immiscible fluid flow into the chamber. The immiscible fluid is of a greater density than the partitioned portions and the partitioned portions rise in the chamber while the immiscible fluid sinks. The partitioned portions then flow into the outlet.”); *id.* Col. 4:12-13 (“Accordingly, an outlet for collecting the displaced droplets can be positioned at the top of the chamber.”). When the droplets are more dense than the immiscible fluid, they fall, and the “droplet receiving outlet” may be located at the bottom of the chamber. *Id.* Col. 4:12-16 (“In another example, aqueous droplets placed in a chamber of certain mineral oils will tend to sink due to their greater density. Accordingly, an outlet for collecting the displaced droplets can be positioned at the bottom of the chamber.”). The ‘837 specification also explains that the “droplet receiving outlet” may be placed in between the top and bottom of

the chamber. *Id.* Col. 3:51-58 (“The outlet may be at the top, middle, or bottom of the chamber . . .”).

100. The ‘837 specification also explains that, wherever located, the “droplet receiving outlet” is the place in the separation chamber where droplets are collected. *Id.* Col. 3:46-48 (“The chamber includes an outlet that is positioned to receive substantially only the partitioned portions of sample.”); *id.* Col. 53:28-29 (“The outlet can be positioned accordingly to collect the droplets.”).

101. I understand that Petitioner argues that “Bio-Rad’s interpretation of this term must be broad enough to include the opening at the top of an open well.” (Pet. at 19). I also understand that this argument and reference to Bio-Rad’s interpretation is based on the Infringement Contentions that were served in the parallel Delaware Litigation. (Ex. 1026). In my opinion this an overly broad reading of Bio-Rad’s infringement contentions, and as a result is not an accurate reading of the scope of this limitation.

102. Patent Owner’s Infringement Contentions from the Delaware Litigation assert that the open tops of the chambers that sit atop the 10X Accused Device are “droplet receiving outlets.” For ease of reference, I have reproduced the image of the 10X Accused Device from Patent Owner’s Infringement Contentions below, with the chambers highlighted in yellow and the open tops highlighted in green.



103. As the image shows, the open tops of the chambers in the 10X Accused Device are “droplet receiving outlets” because they are the “portion of a separation chamber where droplets are collected.”

104. While I agree that some open tops of some open wells (like those of the 10X Accused Device pictured here) may satisfy these requirements, others will not, and thus a construction of this limitation that allows for simply the opening at the top of any open well is not correct.

105. In support of Petitioner’s alternative claim construction proposals, Dr. Fair argues that a person of ordinary skill in the art would not understand the term “droplet receiving outlet” to describe a structure in the '837 Patent. (Fair Decl. ¶ 80). I disagree with Dr. Fair that the droplet receiving outlet is a generic term to describe a function, rather than a structural element of the claimed assemblies. As the passages from the specification that I discussed above demonstrate, the droplet

receiving outlet is a specific structural feature of the claimed assembly, which is described in the specification as being the structural feature of the separation chamber where droplets are collected depending on the relative densities of the droplets and surrounding immiscible fluid inside the separation chamber.

106. The '837 Patent also describes examples of how a “droplet receiving outlet” is connected to and interacts with other structural features of the overall assembly. For example, dependent claim 7 recites that the “droplet receiving outlet” is “coupled to a vessel,” and the specification describes in detail how such coupling might occur. *See, e.g.*, '837 Patent, col. 53:42-46 (the outlet is connected to a channel that allows droplets to be collected in a vessel); col. 54:47-67 (a proximal end of a slide is connected to the outlet and the distal end may lead to a vessel for collecting droplets).

107. Dr. Fair ignores the repeated descriptions of outlets as the structural feature of the separation chamber where droplets are collected in the specification, focusing exclusively on descriptions of the function of the outlets. (Fair Decl. ¶ 81).

108. It is also my opinion that the alternative proposed construction discussed by Dr. Fair (¶¶ 82-83) is not supported by the intrinsic evidence. As I have explained above, the droplet receiving outlet is a part of the separation chamber where droplets collect and can be positioned in the separation chamber

according to the relative densities of the droplets and surrounding immiscible fluid. There is no requirement in the '837 Patent that the droplet receiving outlet must be connected to the “interior space of the chamber” or that it may only collect droplets “exiting the chamber.”

C. “coupled” (dependent claims 7 and 9)

109. In my opinion, the claim term “coupled” should be construed as a “operably linked,” which is supported by both intrinsic and extrinsic evidence.

110. The term “coupled” arises in two dependent claims where one states that the droplet receiving outlet of the separation chamber is coupled to a vessel (claim 7) and the other says it is sealably coupled to the vessel (claim 8).

111. The specification explains that the “coupling” between the droplet receiving outlet and the vessel is to effectuate transfer of droplets from the separation chamber to the vessel. (*See, e.g.*, ‘837 Patent Col. 4:17-36).

112. Under this description in the specification, one method of coupling to connect a slide sloping downward from the top separation chamber, where the droplet outlet is, to a “second location,” which could be a vessel. Droplets flow downward to the vessel, which can be any vessel known in the art, such as PCR tubes, test tubes, vials, Eppendorf tubes, and the like. (*Id.* Col. 4:17-29). This slide example illustrates a vessel coupled to the outlet even though there was no physical or mechanical connection between them. The inventors also offered another

example of the vessel being coupled to an outlet without the slide to facilitate droplet collection. (*Id.* Col. 4:27-29).

113. In my opinion, the conventional use of the term as it has been construed in the past, also supports this construction.

VIII. ANALYSIS OF PETITIONER’S GROUNDS FOR *INTER PARTES* REVIEW

A. A. Ground 1: Ismagilov Anticipation

114. In Ground 1, Petitioner alleges that claims 1-2, 4, 10, 13 and 19-20 are anticipated by Ismagilov. As explained in detail below, it is my opinion that Ismagilov is missing critical elements of the Challenged Claims.

1. “at least one downstream separation chamber comprising a droplet receiving inlet and at least one droplet receiving outlet”

115. Petitioner misinterprets and conflates several separate disclosures in Ismagilov that discuss an “outlet port,” “wells or reservoirs” and “manifold outlets” in asserting that Ismagilov teaches a “separation chamber” and a “droplet receiving outlet.”

116. As I discussed above, Petitioner also applies improperly broad constructions of “separation chamber” and “droplet receiving outlet,” and uses those overly broad constructions in order to stretch the description of the device in Ismagilov to teach the claimed “separation chamber comprising a droplet receiving inlet and at least one droplet receiving outlet.”

117. In my opinion, the separate sections of the specification that Petitioner cites from Ismagilov do not clearly connect to one another in any discernable arrangement or configuration that would be considered a “separation chamber” as that term is properly construed.

118. I disagree with Petitioner’s argument that the “outlet port . . . that *collects* or dispenses the plug fluid” teaches a separation chamber. (Pet. at 36 (citing Ismagilov, 9:5-8) (emphasis in original).) Absent from this disclosure in Ismagilov is any description of a “well or reservoir” as part of the “collection” process at the outlet port.

119. I also note that in the same section of the specification Ismagilov explains that the “*inlet port* may contain an inlet channel, *a well or reservoir*, an opening, and other features *that facilitate the entry of chemicals into the substrate.*” (Ex. 1004 at 8:41-44).

120. In my opinion, a POSA reading these two definitional descriptions of the inlet and outlet ports of the device in Ismagilov would not automatically assume that fluids were being accumulated in a well or reservoir at the outlet port, or that a well or reservoir would even necessarily exist at the outlet port of the device.

121. To the contrary, given the separate disclosure of wells or reservoirs facilitating the introduction of fluids at the inlet port, I believe that had the

inventors of the Ismagilov patent intended to describe a “well or reservoir” that would facilitate the accumulation of fluids at the outlet port they clearly would have been able to do so. In my opinion, the absence of wells and reservoirs from the definition of outlet port, when they are included in the definition of an inlet port just a few paragraphs earlier, indicates to a POSA that they are not part of the outlet port.

122. Petitioner also points to a separate disclosure in Ismagilov describing that the outlet port “may also communicate with a well or reservoir.” (Pet. 36 (citing Ex. 1004 at 14:36-38)). However, in my opinion this separate disclosure does not teach that the “well or reservoir”—which *may* be in communication with an outlet port—is functioning as a separation chamber at the outlet of the device.

123. I also do not believe that this section of the specification, or any other portion of the specification, provides a description of the structure, function, or operation of any wells or reservoirs that may communicate with an outlet port.

124. In addition, like the definitions of inlet and outlet ports discussed above, this portion of the specification includes additional functional description of the inlet port, but not the outlet port. (Ex. 1004 at 14:41-42 (“Fluids can be *introduced* into the channels *via the inlet* by any means.”)).

125. A POSA reading this disclosure would therefore understand there to be a specific intended function of introducing fluids at the *inlet* well or reservoir,

but no clear intended function at the *outlet*, as Petitioner contends. And again, had the inventors intended there to be a specific function for a well or reservoir at the outlet, namely to accumulate fluids in any manner rather than to simply facilitate movement of fluids out of the device using the standard customary techniques known in the art that I described above, they clearly could have done so.

126. Petitioner then relies on another separate disclosure in Ismagilov explaining “the outlet can be adapted for receiving, for example, a segment of tubing or a sample tube” or, alternatively, a “micropipette.” (Pet. at 36). I do not believe that this section of the specification describes a “separation chamber” or a “droplet receiving outlet.”

127. I disagree with Dr. Fair’s assumption, made without any citation to support in Ismagilov, that the devices in Ismagilov that include these manifolds would necessarily include a “collection well.” (Fair ¶¶ 129-132).

128. Nowhere in this section discussing this particular “solution outlet” at the end of the group of manifolds is there any reference to the previously disclosed “outlet port” or to “wells or reservoirs,” and there is also no further discussion of the “solution outlet” of the manifold anywhere in the specification. (Ex. 1004 at 17:18-30).

129. I believe that Petitioner is improperly equating the term “outlet,” i.e., “manifold outlet” with Ismagilov’s prior disclosure of an “outlet port” even though

Ismagilov does not actually refer to the “manifold outlet” as a “port” of any kind.

As Ismagilov states, the “manifold outlet” is only described as “facilitating the movement of plugs” from different analysis units. (Ismagilov at 17:18-22). In other words, the “outlet ports” of Ismagilov typically act as the standard conduits I described above that allow for collection of the entirety of the “solution” outside of the device following analysis within the manifolds, not as a “chamber” that maintains the entirety of the solution contents in a well or reservoir. The “manifold outlet” is never described as equivalent to an “outlet port,” and Petitioner did not cite anything from Ismagilov describing the “manifold outlet” as a structure for collecting multiple droplets or immiscible fluid.

130. I also do not agree with Petitioner’s and Dr. Fair’s assumption that collection “using micropipettes” requires a certain volume of fluid in an open port that is present in Ismagilov. In the section that discusses “collection” using “micropipettes” Ismagilov does not describe creating a collection well, or any type of well, after the manifold outlet to facilitate the use of micropipettes, and Petitioner cited nothing from Ismagilov that shows otherwise. It is also my understanding that while Petitioner relies entirely upon Dr. Fair’s declaration for this particular argument, Dr. Fair also testified that he has never actually collected plug fluid from a device using a pipette:

Q. When is the first time you used a pipette to remove a droplet from a chip and move it off chip?

A. I don't think I've done that.
Q. You've never done that?
A. Not on electrowetting chips, no.
Q. On any other chips?
A. Not that I can recall.

(Ex. 2017 at 43:9-16). Given Dr. Fair's testimony, I do not believe he would have a basis for his assumptions concerning what structure or volume would be present in any well or reservoir in Ismagilov, or what would have even been a necessary volume to facilitate collection using a micropipettes.

131. Furthermore, in order for such a collection to be possible in the first place a micropipette tip would need to fit inside the punch holes as Ismagilov explains they would be created. Although Dr. Fair shows an image of a micropipette in his declaration, he never discloses the size of the "polypropylene disposable tip" or discusses whether it would fit into the outlet openings of the Ismagilov that Petitioner asserts to be the "separation chamber." Nor do the brochures of the micropipette attached to Dr. Fair's declaration disclose these dimensions.

132. I understand that during his deposition Dr. Fair conceded that the smallest micropipette is 1 mm (1000 μ m), which is consistent with my personal understanding of the sizes of micropipettes that are available. (Ex. 2017 at 159:13-16 ("Q. What is the minimum dimension of a micropipette? A. The ones we have, which are the smallest, are 1 millimeter.")). A diameter of 1 mm would generally

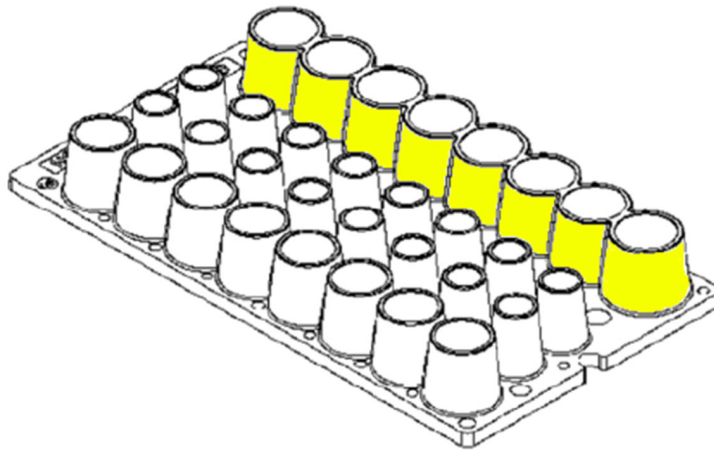
be the same size or larger than the size of a punch hole created by the standard techniques from that timeframe disclosed in Ismagilov using a syringe needle or cork borer. It is therefore my opinion that there is no evidence showing whether the criteria Dr. Fair laid out in his declaration for the volume necessary to collect droplets via a micropipette is actually satisfied by the “outlet port” or “wells or reservoirs” in Ismagilov.

133. There is simply no disclosure in Ismagilov that teaches any chamber with the dimensions and configuration claimed in the ‘837 patent, which is unsurprising given that the only functionality disclosed for the “outlet ports” is solution extraction, as I explained above.

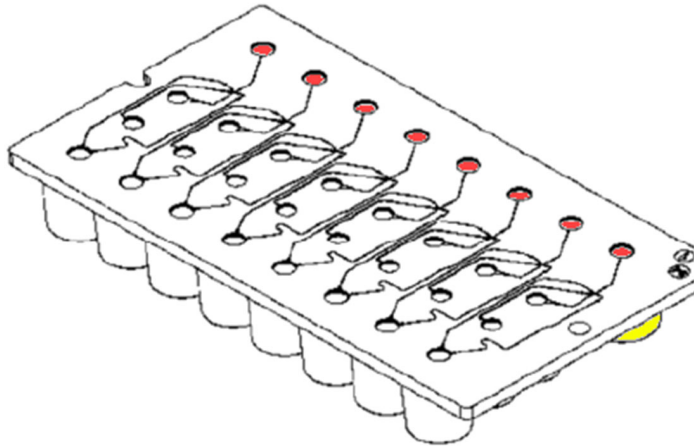
134. To the extent any such collection would have even been feasible given the limitations of the punch holes I explained above, a POSA knowledgeable about the state of the art from this time frame would have understood Ismagilov to be describing a micropipette tip that could be placed in much smaller diameter holes, such as those described in Ismagilov as being created by syringe needles and cork borers, at the end of the chip to collect the “slugs” directly through the tip region of the micropipette, as shown by other references to the use of a pipette from the same timeframe, including an article written by Ismagilov. Ex. 2020, 2021.

135. I disagree with Petitioner’s argument that Ismagilov “discloses the separation chamber . . . under Bio-Rad’s interpretations by disclosing a well or

reservoir . . . [and] a well with an opening into which a pipette can be inserted meets this limitation.” (Pet. at 36-37). To illustrate why I disagree with this assertion I have included color-annotated images from the infringement contentions that were cited by Petitioner. It is my understanding that Petitioner argues that if the 10X chambers highlighted in yellow in the image below constitute “separation chambers” within the meaning of the ‘837 patent, then so too must the “outlet ports,” “wells or reservoirs,” or “solution outlet” allegedly disclosed in Ismagilov:



136. However, the portion of the accused device that Petitioner pointed to does not tell the full story of the configuration of this device. Specifically, the yellow highlighted chamber in the image above sits atop a “hole punched” outlet well. This “hole punch” is not shown in the above image of the **top** of the 10X device, but it is highlighted in red in the below image of the **bottom** of the 10X device:



137. While there is no image of the “outlet ports” or “wells or reservoirs” referenced in Ismagilov, a POSA reading the explanation that “[h]oles may be cut into the PDMS [substrate] using, for example, a tool such as a cork borer or a syringe needle” would understand the structures being fabricated in Ismagilov would simply include the red “hole punches” in the 10X Accused Device that would have been well known to a POSA at the time, not the yellow accused “separation chamber.”

138. In sum, it is my opinion that the 086 Petition is based on an incomplete depiction of Bio-Rad’s Infringement Contentions from the Delaware Litigation. It is my understanding that Bio-Rad is not arguing in the Delaware Litigation that the “hole punches” in the 10X Accused Device are “separation chambers.” Rather, it is my understanding that Bio-Rad is arguing that the separate yellow chamber that 10X places atop the standard “hole punch” is a “separation chamber.” While the additional structure that functions as a separation chamber

would facilitate separation and collection of its droplets while minimizing contamination, i.e. the same problem addressed in the '837 patent, the smaller hole punches would not.

2. “wherein the separation chamber is upright to the microchannel and out of the horizontal plane”

139. As I set forth above, Petitioner has not identified a separation chamber in Ismagilov. Petitioner cites to disclosures of an “outlet port” that can “collect,” but does not cite to any disclosures actually showing a “well or reservoir” in Ismagilov collecting anything. Nevertheless, according to Petitioner, “[b]ecause Ismagilov describes forming the substrate and closing the channels with a glass coverslip, the well or reservoir would extend up and out of the plane of the microchannels.” (Pet. at 40-41). Petitioner is again mixing and matching different disclosures from the reference in order to construct a separation chamber that would meet this limitation where none is disclosed in Ismagilov.

140. Petitioner also assumes that collecting with a micropipette requires a “well or reservoir” extending “out of the horizontal plane.” (Pet. at 41). Again relying instead on the same disclosure concerning the collection by pipette at the “manifold outlet” and arguing that this disclosure requires a “volume . . . deep enough for a pipette to extent into it, and so the wells or reservoirs will extend out of the horizontal plane to permit that.” (Pet. at 40-41). However, of the 45+ figures in Ismagilov, none show a well or reservoir upright to the microchannel or

out of the horizontal plane. There are simply no disclosures supporting Petitioner's assumptions that undisclosed vertical wells or reservoirs must necessarily exist in the devices disclosed in Ismagilov.

141. If anything can be gleaned about the device outlets in Ismagilov from the figures provided, it would appear that "outlet port" is actually considered to be in the horizontal plane. (Ismagilov at 39:53-40:2; Figure 22D). A POSA would therefore just as easily understand the disclosure Petitioner relies on to be describing a "sample tube," "centrifuge tube," or "micropipette" inserted into the end of the outlet port in the horizontal plane.

142. The disclosure of wells or reservoirs alone does not lend itself to the sole conclusion that they would extend upright and out of the horizontal plane in the device. For example, I understand that Dr. Fair explained it was not necessary for a well or reservoir to extend out of the horizontal plane, and that, in fact, he had designed and used wells in the same plane as the microchannels in his own devices. I agree with Dr. Fair's testimony that when the well is in the same plane as the microchannel, the droplet will not separate from the surrounding oil:

Q. If I asked you to design a system where the outlet well was in the same plane as the channel, could you do that?

A. You could you do that, but if the collection well that you're describing has the same height as the channel, then it would be very difficult to do separation of oil and liquid and droplets. So the early waste reservoirs that we built were, in fact, designed to have the same height as the channels in our devices. And they were just holding –

they just were there to hold the droplets, not to separate from the oil.

Q. You did not put the outlet wells vertical to the channel until you decided you wanted to separate?

A. That's correct.

143. Petitioner also assumes that a well or reservoir must have a volume that “permit[s] collecting multiple droplets” because the channels do not have a “cross-section that can accommodate multiple droplets.” (Pet. at 41). As with Petitioner’s other unsupported assumptions, here too this assumption has no support in Ismagilov. A POSA would not assume that such a volume was necessary at an outlet well, and would just as easily understand that droplets can be collected by inserting “sample tube,” “centrifuge tube,” or “micropipette” inserted into the end of the outlet port in the horizontal plane as I discussed above.

3. “wherein the droplet formation module and the separation chamber are in fluid communication with each other via the microchannels” (all challenged claims)

144. The Challenged Claims require that the “droplet formation module” is in “fluid communication” with a “separation chamber” via “microchannels” in the device. For the same reasons discussed above that Ismagilov does not disclose a separation chamber as that term is properly construed, it is my opinion that Ismagilov also does not disclose that the non-existent separation chamber is in fluid communication with any other aspect of Ismagilov.

4. “and wherein the separation chamber has a wider cross-section than the microchannel cross-section to accumulate a

plurality of droplets comprising the sample and is of a volume sufficient to separate the plurality of droplets comprising the sample from the immiscible fluid within the separation chamber”

145. It is my opinion that the limitation requiring that the “separation chamber” is “of a volume sufficient to separate the plurality of droplets comprising the sample from the immiscible fluid within the separation chamber” is missing from Ismagilov for the reasons discussed above relating to the other limitations relating to a “separation chamber” in claim 1.

146. As noted above, Ismagilov has no disclosure that discusses separating droplets from the immiscible fluid in wells, reservoirs, outlet ports, or anywhere else on the device.

147. I understand that Petitioner also includes an argument based on the legal doctrine of inherency for this limitation that the outlets in Ismagilov, which again are not described in any detail or shown in any figures in Ismagilov, would nevertheless be used to separate droplets from immiscible fluid because the droplets and oil will necessarily separate because of their different densities. (See Pet. at 46 (“[T]he droplets floating or sinking relative to the oil is at least inherent because it necessarily occur with liquids of different densities”)).

148. However, depending on the density of the particular oil, the droplets will not always separate. Ismagilov only explains that “[s]uitable carrier fluids include oils, preferably fluorinated oils.” (Ismagilov at 20:37-38). If the selected

oil has substantially the same density as water, the droplets will be mixed with the oil as they are dispersed throughout the reservoir.

5. “wherein an aqueous fluid from the sample inlet is segmented with an immiscible fluid from the immiscible fluid inlet at the junction” (dependent claim 2)

149. For the same reasons discussed above in Section V(A)(1)(a)-(e), it is my opinion that Ismagilov does not include all of the limitations of claim 2 of the ‘837 patent.

6. “wherein at least one droplet receiving outlet is located on the upper portion of the separation chamber” (dependent claim 4)

150. For the same reasons discussed above in Section V(A)(1)(a)-(e), it is my opinion that Ismagilov does not include all of the limitations of claim 4 of the ‘837 patent.

7. “wherein the droplet receiving outlet receives substantially one or more droplets” (dependent claim 10)

151. For the same reasons discussed above in Section V(A)(1)(a)-(e), it is my opinion that Ismagilov does not include all of the limitations of claim 10 of the ‘837 patent.

8. “wherein the reagent inlet is in fluid communication with the junction or the microchannel” (dependent claim 11)

152. For the same reasons discussed above in Section V(A)(1)(a)-(e), it is my opinion that Ismagilov does not include all of the limitations of claim 11 of the ‘837 patent.

9. “wherein the reagent inlet introduces one or more amplification reagents to the junction or the microchannel” (dependent claim 12)

153. For the same reasons discussed above in Section V(A)(1)(a)-(e), it is my opinion that Ismagilov does not include all of the limitations of claim 12 of the ‘837 patent.

10. “wherein the one or more amplification reagents are for a polymerase chain reaction” (dependent claim 13)

154. For the same reasons discussed above in Section V(A)(1)(a)-(e), it is my opinion that Ismagilov does not include all of the limitations of claim 13 of the ‘837 patent.

11. “a sorting module to direct the flow of droplets, wherein the sorting module is located between the droplet formation module and the separation chamber” (dependent claim 19)

155. For the same reasons discussed above in Section V(A)(1)(a)-(e), it is my opinion that Ismagilov does not include all of the limitations of claim 19 of the ‘837 patent.

12. “wherein the sorting module comprises an apparatus to generate an electric force” (dependent claim 20)

156. For the same reasons discussed above in Section V(A)(1)(a)-(e), it is my opinion that Ismagilov does not include all of the limitations of claim 20 of the ‘837 patent.

B. Ground 2: Ismagilov and Quake Obviousness

157. In Ground 2, Petitioner argues that Ismagilov and Quake combined render claims 1-2, 4, 7, 9-13, and 19-20 of the ‘837 patent obvious. (Pet. at 24).

158. However, in my opinion Petitioner has not identified a sufficient motivation to combine Ismagilov and Quake, which are directed to two entirely different systems.

159. Moreover, as noted above there are critical differences between Ismagilov and the Challenged Claims, and Quake cannot be used to fill those gaps.

1. A POSA Would Not Have Had a Motivation to Combine Ismagilov and Quake

160. As I explained above, the Ismagilov reference is focused on microfabricated substrates for forming droplets or “plugs”. (See Ex. 1004 at Abstract). The examples of Quake on which Petitioner relies, on the other hand, were focused on cell sorting and did not use droplets or “plugs.” (Ex. 1006 at ¶31).

161. Petitioner also argues that a POSA would have been motivated to combine Ismagilov with Quake because “[t]he differences between Ismagilov and Quake are minor and relate to additional structural details provided by Quake.” (Pet. at 39). However, the differences between the two disclosures are not “minor” but actually relate to two completely different structures and assemblies with two completely different intended uses. Figures 6 and 8 of Quake are not droplet formation devices at all. Rather, Figures 6 and 8 disclose a “cell-sorting device.” (Ex. 1006 at ¶197). I agree with Dr. Fair’s testimony from his deposition that

“Quake did not use droplets And this is not a droplet-based system.” (Fair. Dep. Tr. 141:12-142:2).

162. There is nothing in Quake’s sorting embodiment depicted in Figures 6 and 8 described as an “extrusion region,” which is what Quake calls the place where droplets are formed. (*Id.* at ¶¶ 29, 70). Quake actually states that in the sorting embodiment utilizing the devices disclosed in Figures 6 and 8, the first step is filling one of the wells with buffer, allowing that buffer to fill “all the channels . . . to avoid the formation of air pockets,” and then filling each of the wells with buffer. (*Id.* at ¶ 220). In performing the steps outlined in Quake, the “input or sample well is typically loaded last” and the “flow of material” is “driven by the electrodes.” *Id.* There are no disclosures of forming droplets or of an “extrusion region” and these droplet sorting embodiments are not relevant to forming droplets. I therefore do not believe that a POSA would look to the wells utilized in the sorting embodiment in Quake in order to construct the wells in the droplet formation devices of Ismagilov where hole punches were described as being created with syringes or cork borers.

163. Petitioner also fails to explain how a POSA would go about combining the disparate elements of the references, or what modifications a POSA would necessarily have made in order to combine the disparate elements.

164. I also understand that Dr. Fair testified in his deposition that he “started with looking at the claim language” and then “found appropriate references to cite in an invalidity analysis.” (Fair Dep. Tr. at 53:5-8). It is my understanding that this hindsight-based reconstruction of the claim elements in the ‘837 patent is an improper methodology for asserting invalidity based on obviousness.

2. Differences Between the Combination of Ismagilov and Quake and the Challenged Claims

(a) “separation chamber” (and related limitations from all challenged claims)

165. I disagree with Petitioner’s argument that because Figures 6 and 8 show “wells or reservoirs as large, open structures” they are necessarily operating as a “separation chamber.” (Pet. at 38-40). I believe that Petitioner is misreading the disclosures, and Quake does not disclose a “separation chamber” and the related limitations in claim 1.

166. Petitioner cites paragraphs 198-200 as disclosing wells intended for separation, but this portion of Quake teaches nothing of the sort. The “wells” in Quake are used for “sorting experiments” where “cells can be directed to either side of the ‘T’ channels depending upon the voltage potential settings” created by inserting platinum electrodes into the disclosed “wells.” (Ex. 1006 at ¶¶197-198; Figure 6 and 8). While Figure 6 includes “collection wells,” there are no

disclosures of separating droplets and immiscible fluid in these wells. (*Id.* at ¶197).

Thus, even if a POSA were motivated to combine Ismagilov with Quake, which I do not believe Petitioner has established, the combination would still fail to teach the claimed separation chamber and related limitations of the '837 patent.

(b) “wherein an aqueous fluid from the sample inlet is segmented with an immiscible fluid from the immiscible fluid inlet at the junction” (dependent claim 2)

167. Petitioner presents no analysis of dependent claim 2 under Ground 2 separate from its analysis under Ground 1, and therefore for the same reasons discussed above, it is my opinion that dependent claim 2 is also non-obvious in light of the combination of Ismagilov and Quake. Should Petitioner or Dr. Fair at any point be permitted in the future to provide a separate analysis of this limitation for Ground 2, I reserve the right to respond further at such time.

(c) “wherein at least one droplet receiving outlet is located on the upper portion of the separation chamber” (dependent claim 4)

168. Petitioner presents no analysis of dependent claim 4 under Ground 2 separate from its analysis under Ground 1, and therefore for the same reasons discussed above, it is my opinion that dependent claim 4 is also non-obvious in light of the combination of Ismagilov and Quake. Should Petitioner or Dr. Fair at any point be permitted in the future to provide a separate analysis of this limitation for Ground 2, I reserve the right to respond further at such time.

(d) “wherein the droplet receiving outlet is coupled to a vessel” (dependent claim 7)

169. Claim 7 of the ‘837 patent depends from and includes all of the same limitations as claim 1, plus the additional limitation that “the droplet receiving outlet is coupled to a vessel.” I disagree with Petitioner’s assertion that it would be “obvious to a POSA that droplets collected from a well by pipette would be transferred to another vessel for downstream use, and such vessels were well known.” For the same reasons discussed above in Section V(B)(1)(e), it is my opinion that a POSA would not have been motivated to move collected droplets using a micropipette.

(e) “wherein the vessel is a PCR tube or a test tube” (dependent claim 9)

170. Claim 9 of the ‘837 patent depends from and includes all of the same limitations as claim 7, plus the additional limitation that “the vessel is a PCR tube or a test tube.” It is my understanding that Petitioner’s arguments concerning this additional limitation are the same as dependent claim 7, and for the same reasons discussed above in Section V(B)(1)(i), it is my opinion that the combination of Ismagilov with Quake does not render obvious dependent claim 9.

(f) “wherein the droplet receiving outlet receives substantially one or more droplets” (dependent claim 10)

171. Petitioner presents no analysis of dependent claim 10 under Ground 2 separate from its analysis under Ground 1, and therefore for the same reasons

discussed above, it is my opinion that dependent claim 10 is also non-obvious in light of the combination of Ismagilov and Quake. Should Petitioner or Dr. Fair at any point be permitted in the future to provide a separate analysis of this limitation for Ground 2, I reserve the right to respond further at such time.

(g) “wherein the reagent inlet is in fluid communication with the junction or the microchannel” (dependent claim 11)

172. Petitioner presents no analysis of dependent claim 11 under Ground 2 separate from its analysis under Ground 1, and therefore for the same reasons discussed above, it is my opinion that dependent claim 11 is also non-obvious in light of the combination of Ismagilov and Quake. Should Petitioner or Dr. Fair at any point be permitted in the future to provide a separate analysis of this limitation for Ground 2, I reserve the right to respond further at such time.

(h) “wherein the reagent inlet introduces one or more amplification reagents to the junction or the microchannel” (dependent claim 12)

173. Petitioner presents no analysis of dependent claim 12 under Ground 2 separate from its analysis under Ground 1, and therefore for the same reasons discussed above, it is my opinion that dependent claim 12 is also non-obvious in light of the combination of Ismagilov and Quake. Should Petitioner or Dr. Fair at any point be permitted in the future to provide a separate analysis of this limitation for Ground 2, I reserve the right to respond further at such time.

- (i) **“wherein the one or more amplification reagents are for a polymerase chain reaction” (dependent claim 13)**

174. Petitioner presents no analysis of dependent claim 13 under Ground 2 separate from its analysis under Ground 1, and therefore for the same reasons discussed above, it is my opinion that dependent claim 13 is also non-obvious in light of the combination of Ismagilov and Quake. Should Petitioner or Dr. Fair at any point be permitted in the future to provide a separate analysis of this limitation for Ground 2, I reserve the right to respond further at such time.

- (j) **“a sorting module to direct the flow of droplets, wherein the sorting module is located between the droplet formation module and the separation chamber” (dependent claim 19)**

175. While the Petition includes separate sub-sections for Grounds 1 and 2 for this limitation, Petitioner presents no analysis of dependent claim 19 under Ground 2 separate from its analysis under Ground 1, and therefore for the same reasons discussed above, it is my opinion that dependent claim 19 is also non-obvious in light of the combination of Ismagilov and Quake. Should Petitioner or Dr. Fair at any point be permitted in the future to provide a separate analysis of this limitation for Ground 2, I reserve the right to respond further at such time.

- (k) **“wherein the sorting module comprises an apparatus to generate an electric force” (dependent claim 20)**

176. Petitioner presents no analysis of dependent claim 13 under Ground 2 separate from its analysis under Ground 1, and therefore for the same reasons

discussed above, it is my opinion that dependent claim 13 is also non-obvious in light of the combination of Ismagilov and Quake. Should Petitioner or Dr. Fair at any point be permitted in the future to provide a separate analysis of this limitation for Ground 2, I reserve the right to respond further at such time.

3. Several Secondary Considerations Support a Finding of Non-obviousness

177. I have also considered several secondary considerations that, in my opinion, weigh in favor of a finding of nonobviousness of the '837 claims, including long-felt need, commercial success, praise, and acquiescence and licensing.

178. For example, I understand that Patent Owner acquired RainDance Technologies, Inc. ("Raindance") and all of its intellectual property, including the '837 patent, in January 2017. In my opinion, this demonstrates the value that has been placed on the protected features of the '837 patent. (*See, e.g.*, Ex. 2014, Bio-Rad to *Acquire RainDance Technologies*, *genomeweb* (Jan. 16, 2017), <https://www.genomeweb.com/pcr/bio-rad-acquire-raindance-technologies>).

179. I understand that the terms and conditions of Patent Owner's ddPCR™ platform – including the QX100 and QX200 Droplet Digital PCR systems and AutoDG Droplet Generator – state that this platform is protected by several patents, including the '837 patent. (Ex. 2022 at 2 ("The Bio-Rad Digital PCR Systems and/or their use is covered by claims of U.S. patents, and/or pending

U.S. and non-U.S. patent applications owned by or under license to Bio-Rad Laboratories, Inc., including, but not limited to, U.S. Patent Nos. 9,089,844; 9,126,160; 9,216,392; 9,347,059; 9,500,664; 9,562,837; 9,636,682; 9,649,635; and 9,896,722.”).

180. In my opinion, Patent Owner’s ddPCR™ platform – including the QX100 and QX200 Droplet Digital PCR systems and AutoDG Droplet Generator – practices the ‘837 patent. The novel features of the ‘837 patent are repeatedly referenced in Patent Owner’s instruction manuals and are critical to the products’ workflows. (*See, e.g.*, Ex. 2010, ddSEQ™ Single-Cell Isolator, Instruction Manual, at 18 (instructing users on how to transfer droplets out of the separation chamber of the ddSEQ cartridge); Ex. 2011, QX200™ Droplet Generator, Instruction Manual, at 18 (instructing users on how to transfer droplets out of the separation chamber of the DG8 cartridge)).

181. For all of these reasons, it is my opinion that the secondary considerations cited herein related to Patent Owner’s products have a direct nexus to the ‘837 claims.

(a) Long-Felt Need

182. In my opinion, RainDance helped transform disease research by making innovative tools using its proprietary technologies that simplify complex genetic analysis. RainDance’s patented droplet system, which included features

embodied in the '837 patent, fundamentally enhances the way researchers and scientists study cell-based and cell-free biomarkers in cancer, infectious disease, and inherited disorders. The '837 patent includes numerous novel elements, including multi-step processes designed to improve the ability to easily and reliably remove the droplets from the separation chamber while minimizing the removal of unwanted continuous phase fluid. This ability is facilitated by a particular orientation for the separation chamber (one that is upright or perpendicular to the microchannel) of a certain width. This design is used to enhance separation and collection of the sample-containing droplets.

183. Patent Owner's ddPCR™ platform was a breakthrough that greatly advanced the capabilities of PCR. Shortly after its launch, Patent Owner's first-generation ddPCR™ product, the QX100, was widely acknowledged as an innovative design that contributed to the progression of PCR technology. The new product was an easy-to-use alternative to the existing technology, such as real-time or quantitative digital PCR, for users looking for more precise and accurate methods of detecting rare mutations and small copy number variations. (*See, e.g., Ex. 2001, Erica Mazaika & Jason Homsy, Digital Droplet PCR: CNV Analysis and Other Applications, 82 Current Protocols in Hum. Genetics 7.24.1 (2014)*).

184. Patent Owner's ddPCR™ products were rapidly adopted in the industry and led to an explosion of research. Just one year after the QX100 launch,

the number of cancer research papers citing ddPCR™ nearly quintupled. (Ex. 2002, Press Release, Bio-Rad, Bio-Rad's Droplet Digital™ PCR Technology Highlighted at the 2014 AACR Annual Meeting (Apr. 5, 2014), https://www.bio-rad.com/en-us/life-science-research/news/bio-rads-droplet-digital-pcr-technology-highlighted-at-2014-aacr-annual-meeting?ID=Bio-Rad-s-Droplet-Di_1396030479). Since launching Bio-Rad's ddPCR™ platform, there have been more than 4,400 published studies describing research breakthroughs using this technology, including 1034 publications in 2019. (See Ex. 2003, *Droplet Digital Polymerase Chain Reaction Publication*, Bio-Rad, <https://www.bio-rad.com/ddPCR/publications> (last visited Jan. 28, 2020)).

185. With the help of ddPCR™, researchers were able to detect rare targets with a level of precision that was just not possible with previous technologies. (See, e.g., Ex. 2004, Droplet Digital™ PCR (ddPCR™) Technology, Bio-Rad, <https://www.bio-rad.com/en-us/applications-technologies/droplet-digital-pcr-ddpcr-technology?ID=MDV31M4VY> (last visited Jan. 28, 2020)).

186. For all of these reasons, in my opinion, the inventions of the '837 patent fulfilled a long-term need for a means of isolating sample from the surrounding environment for further analysis using microfluidic droplets by means of the claimed separation chamber.

(b) Commercial Success

187. 187.

In my opinion, Patent Owner's

products that embody the '837 patent have also been a commercial success, with the inventions disclosed in the '837 patent contributing to this success. They allow for the utilization of differences in density of the different fluids to concentrate the droplets in a particular part of the chamber. This greatly improved the ability to easily and reliably remove the droplets from the separation chamber while minimizing the removal of unwanted continuous phase fluid. These developments represented a significant improvement on the prior art that greatly advanced the capability of PCR and NGS. (See, e.g., R&D 100 Archive of Winners (2012), <https://www.rdworldonline.com/rd-100-archive/2012> (Ex. 2005); Bio-Rad's QX100™ Droplet Digital PCR System Wins 2012 Laboratory Equipment Readers' Choice Award (Ex. 2006); Bio-Rad's QX200™ Droplet Digital PCR System Wins the SelectScience Scientists' Choice Award for Best New Life Sciences Product of 2013 at AACR (Ex. 2007); Frost & Sullivan Recognizes Bio-Rad's Digital PCR Platform, the QX200™ AutoDGT™ Droplet Digital™ PCR System for New Product Innovation (Ex. 2008); Editorial Article: Winners of the 2018 Scientists' Choice Awards for Life Sciences Announced at AACR (Ex. 2009)).

188. Similarly, Petitioner's products embodying the invention have been a commercial success. (See, e.g., Ex. 2012, 10X Genomics, *Prospectus: 10,000*

Shares Class A Common Stock at 75-76 (Sept. 11, 2019),

<https://investors.10xgenomics.com/static-files/ad03dcbd-2c62-49f8-916b-917918056567> (“Since launching our first product in mid-2015, and as of June 30, 2019, we have sold 1,284 instruments to customers around the world, including 93 of the top 100 global research institutions by publications, and 13 of the top 15 global pharmaceutical companies by 2018 revenue. . . . Revenue increased 106% to \$146.3 million in the year ended December 31, 2018 as compared to \$71.1 million in the prior year, and increased 85% to \$109.4 million for the six months ended June 30, 2019 as compared to \$59.2 million for the six months ended June 30, 2018, primarily due to the adoption of our platform by customers as reflected by the doubling in size of our installed base to more than 1,000 instruments as of December 31, 2018 and more than 1,280 instruments as of June 30, 2019, and the associated consumables pull-through on those instruments.”)).

(c) Praise by Others

189. Patent Owner’s innovative ddPCR™ products have also received repeated accolades for their contributions to the field. In 2012, just one year after its launch, the QX100 ddPCR™ product was awarded *R&D Magazine*’s 100 Award, which is given to the 100 most technologically significant products introduced into the marketplace over the past year. (Ex. 2005).

190. The QX100 ddPCR™ product was also awarded the *Laboratory Equipment Readers' Choice Award* in the biotech category, which is given to celebrate excellence in product design and performance for the tools and materials used by scientists and engineers in research laboratories. (*See Ex. 2006*).

191. Similarly, the QX200 ddPCR™ product – Patent Owner's second-generation ddPCR™ system – received the Scientists' Choice Award for Best New Life Sciences Product of 2013 from *SelectScience* because of its significant contribution in 2013. (*See Ex. 2007*).

192. The following year, the QX200 ddPCR™ product received the 2014 Frost & Sullivan New Product Innovation Award for the Digital PCR Market in recognition of its innovation, value-added features/benefits, and the return on investment to customers. (*See Ex. 2008*).

193. Similarly, prior to its acquisition by Patent Owner, Raindance received praise from the industry for its own systems that incorporated the patented features of the '837 patent. (Exs. 2023, 2024, 2025, 2026).

194. Patent Owner's investment and development efforts led to a new generation of products to be used in the preparatory steps of creating thousands of microdroplets that are then evaluated in Next Generation Sequencing ("NGS") applications, such as in those provided by Illumina Corporation. Patent Owner's next generation product that is used in NGS is called the ddSEQ™ system. It was

launched in January 2017 and it consists of both a newly-optimized microfluidic device (cartridge/chip) and a droplet generator instrument. As with its prior droplet products, the ddSEQ™ system has also received wide acclaim. (*See, e.g.*, Ex. 2009).

195. Both Patent Owner's and Petitioner's products have received praise because of their turn-key, easy-to-use workflows. (*See, e.g.*, Ex. 2013, Sonia Nicholas, *Editorial Article: Technology Showcase: How to Use Bio-Rad's Droplet Digital PCR* (May 12, 2017), <https://www.selectscience.net/editorial-articles/technology-showcase-how-to-use-bio-rads-droplet-digital-pcr/?artID=43650> (customer reviews noting the ease-of-use of the QX200)). The patented inventions allow users to easily remove the droplets by collecting them on the microfluidic chip, where they can separate from the continuous fluid. This feature allows users to more efficiently and easily subject the contents of the droplets to further downstream reactions and analysis.

IX. CONCLUSION

220. For all of the reasons set forth above, it is my opinion that the Challenged Claims of the '837 patent are novel and nonobvious over the prior art.

221. I hereby declare under penalty of perjury that all statements made herein of my own knowledge are true and correct, and that all statements made on information and belief are believed to be true and correct.

Date: August 11, 2020

A handwritten signature in black ink that reads "Shelley Anna". The script is cursive and fluid, with the first letters of each name being capitalized and prominent.

Shelley Anna, Ph.D.

Exhibit A

Shelley Lynn Anna

Professor of Chemical Engineering
Carnegie Mellon University
Pittsburgh, Pennsylvania
sanna@cmu.edu
<http://annalab.org>

Education

Degree	Discipline	University	Date
B.S.	Physics <i>University and College Honors</i>	Carnegie Mellon University	1995
M.S.	Engineering Sciences	Harvard University	1996
Ph.D.	Engineering Sciences <i>Fannie and John Hertz Foundation Graduate Fellowship</i>	Harvard University	2000

Leadership Positions

Associate Dean for Graduate and Faculty Affairs College of Engineering, Carnegie Mellon University	Jan 2019 to Jun 2020
Acting Director, Center for Faculty Success College of Engineering, Carnegie Mellon University	Dec 2019 to Jun 2020

Academic and Professional Positions

2017-present

Professor, Department of Chemical Engineering, Carnegie Mellon University,
Pittsburgh, Pennsylvania

Courtesy Faculty, Department of Physics and Department of Mechanical Engineering

2013-2017

Professor, Department of Mechanical Engineering, Carnegie Mellon University,
Pittsburgh, Pennsylvania (50% Appointment)

Professor, Department of Chemical Engineering, Carnegie Mellon University,
Pittsburgh, Pennsylvania (50% Appointment)

Courtesy Faculty, Department of Physics

Faculty in the Center for Complex Fluids Engineering

2009-2013

Associate Professor, Department of Mechanical Engineering, Carnegie Mellon University, Pittsburgh, Pennsylvania (50% Appointment)

Associate Professor, Department of Chemical Engineering, Carnegie Mellon University, Pittsburgh, Pennsylvania (50% Appointment)

Courtesy Faculty, Department of Physics

Faculty in the Center for Complex Fluids Engineering

2003-2009

Assistant Professor, Department of Mechanical Engineering, Carnegie Mellon University, Pittsburgh, Pennsylvania (50% Appointment since 9/2008)

Assistant Professor, Department of Chemical Engineering, Carnegie Mellon University, Pittsburgh, Pennsylvania (50% Appointment since 9/2008)

Courtesy Faculty, Department of Physics

Faculty in the Center for Complex Fluids Engineering

Institute Fellow, NETL – Institute for Advanced Energy Solutions

2001-2003

Postdoctoral Fellow in Fluid Dynamics and Complex Fluids, Harvard University, Cambridge, Massachusetts. *Advisor*: Howard Stone, *Sponsor*: Unilever Research.

- Designed novel ‘flow-focusing’ microfluidic device to synthesize monodisperse emulsion droplets via elongational flow.
- Established operating diagram organizing fundamental modes of drop formation.
- Developed physical model for critical scaling conditions for splitting a droplet at a T-shaped microfluidic junction.
- Contributed significant early work in the rapidly growing area of droplet-based microfluidic technologies.

2000-2001

Senior Research Engineer, Solutia, Inc., Springfield, Massachusetts

- Corporate rheology expert.
- Designed rheological test methods for developing and improving Solutia’s adhesives, coatings, and films products.
- Collaborated with analytical chemists to develop combined techniques to relate microstructural properties to processing flow behavior.
- Rheology/NMR studies of curing industrial coatings led to measurement of kinetic rate constants while tracking evolution of coating mechanical properties.

- Emphasized systematic development of new products via quantitative structure-property-performance relationships in place of empirical correlations.

Consulting Assignments

August 2014 to present

Bio-Rad Laboratories, Inc. Client: Josh Shinoff, Ph.D., Director, Life Sciences Business Development, Digital Biology Center.

Consulting on droplet microfluidics technologies.

September 2012 to December 2013

Consumer Specialties, Evonik Industries AG, Goldschmidtstrasse 100, 45127 Essen Germany. Client: Dr. Joachim Venzmer, Head of Research, Interfacial Technology.

Characterized interfacial dynamics of emulsifiers for “leave on” technology using microtensiometer apparatus.

January 2012

Consumer Products Processing Group, P&G Chemicals, Cincinnati, Ohio. Client: Dr. Will Hartt, Senior Research Engineer.

Worked together with Prof. Lynn Walker to analyze surface tension in high internal phase emulsion products and oil-water emulsions relevant for laundry rinse aids.

December 2010

ASML Netherlands B.V., De Run 601, 5504 DR, Veldhoven, Netherlands. Client: Dr. Ramin Badie, Senior Manager Research Immersion, and Dr. Michel Riepen, Senior Scientist Research Immersion.

Worked together with Prof. Steve Garoff to analyze air entrainment issues in high-resolution lithography imaging processes.

September 2007

ICx Agentase, 2240 William Pitt Way, Pittsburgh, PA 15238. Client: Dr. Marcus Erbelinger, Senior Research Engineer.

Participated in the design review process as a microfluidics expert for a prototype wearable badge device designed to detect hazardous chemicals and wirelessly communicate a detected event.

September 2005

Cytec Industries, Indian Orchard, 730 Worcester Street, Springfield, Massachusetts 01151. Client: Dr. Jong Guo.

Advised on the role of extensional viscosity of adhesive emulsions on the curtain coating process.

August 2005

MSA Instrument Division, 1100 Cranberry Woods Drive, Cranberry Township, Pennsylvania 16066. Clients: Zane Frund and Rick Katz.

Analysis of flow instabilities in a self-contained breathing apparatus at cold temperatures leading to undesirable low pressures inside the face mask.

July 1999

Cambridge Polymer Group, 52-R Roland Street, Boston, Massachusetts 02129. Client: Dr. Stephen Spiegelberg, President.

Wrote a user's guide to filament stretching rheometry.

June 1998

Cambridge Polymer Group, 52-R Roland Street, Boston, Massachusetts 02129. Client: Dr. Stephen Spiegelberg, President.

Measured filament stretching and breakup behavior of industrial samples.

Teaching and Education

Courses Taught at CMU

	Course Title	Units	Class	Offered	Number Enrolled	Number Response	FCE Course	FCE Instructor
24-739B	Special Topics: ^(a) Interfacial Fluid Mechanics	12	Gr	F 03	13	8	4.00	4.50
24-711	Fluid Mechanics I	12	Gr	F 04	18	17	3.94	4.35
24-739	Special Topics: Interfacial Fluid Mechanics	12	Gr	S 05	6	6	4.67	4.67
24-711	Fluid Mechanics I	12	Gr	F 05	18	12	3.92	4.17
24-500 ^(b)	Microfluidics ^(a)	9/12	Jr/Sr/Gr	S 06	15	8	3.80	4.50
42-507 ^(b)	Microfluidics ^(a)	9	Jr/Sr/Gr	S 06	5	3	4.30	4.30
06-500 ^(b)	Microfluidics ^(a)	9	Jr/Sr/Gr	S 06	6	N/A ^(c)	N/A ^(c)	N/A ^(c)
24-500 ^(b)	Microfluidics	9/12	Jr/Sr/Gr	S 07	10	5	4.00	4.20
42-507 ^(b)	Microfluidics	9	Jr/Sr	S 07	2	1	4.00	5.00
42-707 ^(b)	Microfluidics	12	Gr	S 07	2	1	5.00	5.00
24-711	Fluid Mechanics I	12	Gr	F 07	18	17	4.24	4.59
24-231	Fluid Mechanics	10	So	S 08	108	47	3.55	3.26

24-711	Fluid Mechanics I	12	Gr	F 08	14	11	4.6	4.9
24-231	Fluid Mechanics	10	So	S 09	109	98	3.97	3.94
06-703	Adv. Fluid Dyn.	12	Gr	F 09	25	18	4.31	4.65
24-231	Fluid Mechanics	10	So	S 10	112	79	3.14	3.18

	Course Title	Units	Class	Offered	Number Enrolled	Number Response	FCE Course	FCE Instructor
06-703	Adv. Fluid Dyn. ^(d)	12	Gr	F 10	45	32	4.25	4.63
24-231	Fluid Mechanics	10	So	S 11	100	69	3.32	3.29
06-323	Heat&Mass Trans.	9	Jr	F 11	66	45	4.02	4.07
24-231	Fluid Mechanics	10	So	S 12	145	134	4.05	4.23
06-323	Heat&Mass Trans. ^(e)	9	Jr	F 12	72	44	4.43	4.70
24-615 ^(b)	Microfluidics	12	Gr	S13	18	14	3.85	4.07
06-615 ^(b)	Microfluidics	12	Gr	S13	9	6	4.33	4.67
42-643 ^(b)	Microfluidics	12	Gr	S13	5	4	3.25	3.75
06-610	Rheo Str Cmplx	9	Gr	F13	9	4	4.75	4.75
24-615 ^(b)	Microfluidics	12	Gr	S14	12	10	3.9	3.9
06-615 ^(b)	Microfluidics	12	Gr	S14	3	3	5	5
42-643 ^(b)	Microfluidics	12	Gr	S14	3	3	4.67	5
24-701 ^(b)	Math Techn. Engr.	12	Gr	F14	39	25	3.88	4.21
12-701 ^(b)	Math Techn. Engr.	12	Gr	F14	4	3	4.67	4.67
06-704	Adv. Heat Mass.	12	Gr	S15	9	7	4.11	4.22
24-701 ^(b)	Math Techn. Engr.	12	Gr	F15	30	24	4.21	4.33
12-701 ^(b)	Math Techn. Engr.	12	Gr	F15	4	4	5.00	5.00
06-704	Adv. Heat Mass.	12	Gr	S16	13	6	4.83	4.83
24-701 ^(b)	Math Techn. Engr.	12	Gr	F16	13	8	4.88	5.00
12-701 ^(b)	Math Techn. Engr.	12	Gr	F16	3	3	5.00	5.00
06-704	Adv. Heat Mass.	12	Gr	S17	8	8	4.12	4.38
06-703	Adv. Fluid Dyn.	12	Gr	F17	29	22	4.77	4.81
06-261	Fluid Mechanics	9	So	S18	53	40	4.7	4.72
06-703	Adv. Fluid Dyn.	12	Gr	F18	15	12	4.58	4.58
06-261	Fluid Mechanics	9	So	S19	51	21	4.48	4.67
06-615 ^(b)	Microfluidics	12	Gr	S20	7			
24-615 ^(b)	Microfluidics	12	Gr	S20	6			

42-643^(b) Microfluidics 12 Gr S20 6

(a) New course

(b) Cross-listed with other courses the same semester.

(c) This course number was excluded from the FCE evaluations.

(d) This course co-taught with A. Khair.

(e) This course co-taught with S. Stepan.

Student Projects

Undergraduate Projects

48. Augustine Duffy (CHE, Class of 2021), “DropSeq Method for Microbial DNA,” AY 2019-20. SURG Grant for S20.
47. Jacob Rushkoff (CHE, Class of 2020), “Stable Capsules with Magnetic Interfaces,” Summer 2018 and AY 2018-19. SURA and SURG Programs.
46. John Hoagland (CHE, Class of 2020), “Mixing of Viscous Droplets in Static Arrays,” Summer 2018. ChESS Program.
45. Trevor Russell (PHY, Class of 2021), “DNA Sequencing in Microfluidic Droplets,” Summer 2018.
44. Matthew Carroll (PHY, Class of 2018), “Statistics of Co-crystallization Processes in Microscale Batch Reactors,” Summer 2016.
43. Daniel Ah Tou (CHE, Class of 2017), “Capsule Generation in Microfluidic Channels,” Spring 2016 and AY 2016-17.
42. Isabel Roscoe (MEG, Class of 2018), “Design Second Generation Microtensiometer,” AY 2015-2016.
41. Jyo Lyn Hor (CHE, Class of 2013), “Crystallization of Active Pharmaceutical Ingredients in Droplets,” CIT Honors Research, AY 2012-2013.
40. Malavika Thottappillil (CHE, Class of 2015), “Design of Multi-channel Pumping System for Microfluidics,” AY 2012-2013.
39. Sarah McCormick (CHE, Class of 2013), “Encapsulation of Living Organisms in Microfluidic Droplets,” Summer 2012, AY 2012-2013.
38. Michael Pavilonis (CHE, Univ. California – Berkeley, Class of 2014), “Adsorption of Nanoparticles at Interfaces in Microfluidic Channels,” Summer 2012.
37. Richa Khosla (CHE, Class of 2013), “COMSOL Simulations of Microfluidic Flows,” Summer 2012.

36. Edward Smongeski (CHE, Class of 2013), "Generating Armored Drops in a Flow Focusing Device," Spring 2012.
35. Coilin Richards (Chemistry, Class of 2013), "Multiplexed Assays in a Sessile Drop Based Biosensor," Spring and Summer 2012. Jointly advised with S. Garoff.
34. Svetlana Romanova (PHY, Class of 2012), "Total Protein Assay in a Sessile Drop Based Biosensor," Summer 2011. Jointly advised with S. Garoff.
33. Christopher Crawford (MEG, Cal State Univ. Northridge, Class of 2013), "Stability of Foams in Particle-Surfactant Mixtures," Summer 2011. Jointly advised with L. Walker.
32. Jonathan Michel (PHY, Class of 2012), "Virology in Single Cells Using Microfluidic Drops," Summer 2011. Jointly advised with A. Evilevitch.
31. Andrew Kojzar (MEG/PHY, Class of 2011), "Multiplexed Biosensor via Spreading Sessile Drops," AY 2010-2011. CIT Honors Research. Jointly advised with S. Garoff.
30. Mathew Swisher (MEG, Class of 2012), "Tipstreaming drops as nanoparticles reactors," Summer 2009, AY 2009-2010, "Double Emulsions to Study Protein Denaturation at Oil-Water Interfaces," AY 2010-2011. CIT Honors Research: "Stability of Armored Emulsion Drops in a Microscale Shear Flow," AY 2011-2012. Jointly advised with L. Walker.
29. Benjamin Ellison (PHY, Class of 2011), "Temperature Controller for Microfluidic Shear Cell," Summer 2010.
28. Douglas Vogus (CHE, Bucknell University, Class of 2012), "Adsorption of Alkylated DNA to the Air/Water Interface," Summer 2010. Jointly advised with J. Schneider.
27. Justin Yi (MEG, Class of 2010), "Planar chip platform for molecular assay," AY 2009-2010. CIT Honors Research.
26. Charbel Eid (MEG, Class of 2010), "Stripping a surface for an ELISA chip," AY 2009-2010. CIT Honors Research.
25. Katharina Schrank (CHE, Aachen exchange student), "Microfluidic Droplet Separator," Spring 2009. Jointly advised with L. Walker.
24. Eric Blood (MEG, Class of 2010), "Understanding the Effectiveness of a Blended-Wing Body Design," AY 2008-2009. (Independent reading supervisor).
23. Lauren Walch (MEG, Class of 2010), "Design of a Closed Chamber to Control Evaporation and Condensation for the Formation of Highly Uniform Microcavity Arrays," AY 2008-2009. Supported by a SURG Fellowship for Spring 2009.
22. Nicholas Lamp (MEG, Class of 2010), "Measuring Sorption Kinetics of Nonionic Surfactants at Oil-Water Interfaces," Summer 2008.

21. Nicholas Grossos (CHE & EPP, Class of 2010), "Synthesis of Gold particles in a microfluidic network: Determining tunability of particle size and monodispersity," Summer 2008. Supported by the CMU MRSEC REU Program. Jointly advised with L. Walker.
20. Shaun Swanson (MEG, Class of 2010), "Understanding the Formation of Ordered Micro Cavities in PDMS Films and Possible Applications," Summer 2008. Supported by a Summer Undergraduate Research Fellowship from the Undergraduate Research Office. AY 2009-2010, Dept Honors Research, "Novel applications for highly uniform micropore arrays."
19. Sarah Pace (Macromolecular Science, Class of 2009, Case Western University), "Measuring Sorption Dynamics of Nonionic Surfactants," Summer 2007.
18. Ramya Ramesh (MEG, Class of 2009), "Creating Integrated Polymerase Chain Reaction Devices Using Droplet-Based Microfluidic Technology," Summer 2007 and Spring 2008. Supported by a Summer Undergraduate Research Fellowship from the Undergraduate Research Office.
17. Timothy Cheung (MEG, Class of 2008), "Two-phase Flow in Model Porous Networks," Summer 2007.
16. Justin Feig (MEG, Class of 2007), "A Lab-on-a-Chip Device for Controlling the Cellular Environment," CIT Honors Project, Spring 2007. Jointly advised with Y. Rabin.
15. Christine Appleby (MEG, Class of 2008), "Coalescence of Driven Sessile Droplets on Surfaces," Summer 2006 and AY 2006-2007.
14. Joel Bergstein (MEG, Class of 2008), "Coalescence at Microfluidic Junctions," Summer 2006.
13. Andrew Lerner (MEG, Class of 2006), "Laboratory Modules for Microfluidics and Interfacial Fluid Mechanics," Spring 2006.
12. Christina Nguyen (MEG, Class of 2006), "Influence of Serpentine Microfluidic Geometry on Mixing in Droplets," CIT Honors Project, AY 2005-2006.
11. Raphael Rogman (MEG, Class of 2007), "Production of Tin Microdroplets Using Gas CoFlow in a Micromachined Flow Focusing Device," Summer 2005. Supported by a Summer Undergraduate Research Fellowship from the Undergraduate Research Office. Jointly advised with O.B. Ozdoganlar.
10. **Required parameters are missing or incorrect.** (MEG, Class of 2006), "A Comprehensive Model for Droplet Breakup at a T Junction," Summer 2005 and AY 2005-2006.

9. Erick Johnson (MEG, Class of 2006), “Flexible Valves for Inline Control of Droplet Size,” Summer 2005, and CIT Honors Project, AY 2005-2006.
8. Nicholas End (MEG, Class of 2006), “Flexible Valves for Microfluidic Devices,” Spring 2005, and CIT Honors Project, AY 2005-2006.
7. Benjamin Mullican (MEG, Class of 2006), “Characterization of Gel Inks,” Spring 2005.
6. Crystal Yeldell (MEG, Class of 2005), “Laboratory Modules for Microfluidics and Interfacial Fluid Mechanics,” Spring 2005.
5. Joshua Taylor (MEG, Class of 2006), “Image Analysis of Two-Phase Flows in Microfluidic Devices,” AY 2004-2005.
4. Juan Kopp (MEG, Class of 2005), “Data and Image Acquisition User Interfaces,” AY 2004-2005.
3. Aaron Vanderbeek (MEG, Class of 2006), “First Generation Microfluidic Chemical Assays Using Drop-based Technology,” Summer 2004. Supported by a Summer Undergraduate Research Fellowship from the Undergraduate Research Office.
2. Zhexian Liang (MEG, Class of 2004), “Flexible Valves for Microfluidic Devices,” AY 2003-2004.
1. Lynn Daniels (PHY, Class of 2004), “Contact-Line Deposition of Particles,” AY 2003-2004.

Master’s Students

22. Martin Burton (CHE), “Dynamics of Microbial Communities,” Masters Project, Dec. 2018.
21. Zixian Cui (CHE), “Thin Film Development in Confined Bubbles with Adsorbing Particles,” Masters Project, Dec. 2017.
20. Boyuan Liu (CHE), “Phase Separation of Polymer-Polymer-Surfactant Mixtures Using Microfluidic Droplet Arrays,” Masters Project, Dec. 2016. Software Engineer, PSG Solutions.
19. Gourav Shet (MEG), “Analysis of Crystallization Kinetics In Microscale Droplet Arrays,” Masters Research Project, expected May 2017. Mechanical Design Engineer, KLA Tencor.
18. Lisa D’Costa (CHE), “Adsorption dynamics and mechanics of silica-CTAB complexes at air-water interface,” Masters Project, Dec. 2015. Co-advised with Lynn Walker.

17. Jialiu Zhang (CHE), "In-line Spectroscopy of Phase Separating Polymers in Microfluidic Droplets," Masters CPS Project, Dec. 2014.
16. Prashansa Desai (CHE), "Dynamics of Glycine Crystallization in a Dehydrating Microfluidic Droplet," Masters CPS Project, Dec. 2014. Co-advised with Lynn Walker. Architectural Beauty.
15. Zefang Jiang (CHE), "The Hydraulic Resistance of a Microfluidic Trap via Computational Fluid Dynamics," Masters Project, December 2013. Engineering Consultant, INVISTA.
14. Nisha Holla (CHE), "Characterization of Transport Processes in a Microtensiometer Device," Masters Project, December 2013. Co-advised with L. Walker. Co-founder, Biomoneta.
13. Nichole Asermeley (CHE), "Particle Tracking to Determine the Effective Diffusivity in Suspension Droplets Trapped in a Microfluidic Device," Masters Project, August 2013. Co-advised with L. Walker.
12. Yang Guo (CHE), "Analysis of Surface Interactions of Rhamnolipid in a Microtensiometer," Masters Project, Dec 2012. Co-advised with L. Walker. Ph.D. student, Colorado School of Mines.
11. Ruta Kulkarni (MEG), MS-C course project Fall 2011. "Modular Droplet Microfluidic Devices." Senior Consultant, Avencore.
10. Chaitanya Kavuri (MEG), "Multi-Assay Biosensor in a Single Drop," Project Masters, December 2012. Co-advised with S. Garoff.
9. Samuel Oberdick (PHY, PhD Research Rotation), "Lubrication Analysis of Mixing in Droplets Coalescing on a Surface," Spring 2011. Co-advised with S. Garoff.
8. Samuel Powers (MEG), "Double Emulsions to Study Protein Denaturation at Oil-Water Interfaces," MS-C Course Project AY 2010-2011, May 2011. Research Engineer, Sandia National Laboratories.
7. Pilgyu Kang (MEG), "Driven Spreading and Coalescence of Sessile Droplets," Project Masters, June 2009. Assistant Professor, George Washington University.
6. Maria Poon (MEG), "Droplet Coalescence and Splitting at Microfluidic T-Junctions," MS-C course project Spring 2007.
5. Nadia Noharrudin (MEG), "Droplet Breakup Dynamics at Microfluidic T-Junctions," MS-C course project Summer-Fall 2006. R&D Engineer at Glumetrics, Inc.
4. Fabian Brugger (MEG), "Two-Phase Flow in Model Porous Media for CO₂ Sequestration," MS-C course project AY 2005-2006 and Summer 2006. Engineering Manager, Omnicell.

3. Hans Mayer (MEG), “Microscale Tipstreaming and Surfactant Dynamics at Highly Curved Interfaces,” Project Masters, December 2005.
2. Jeffrey Smouse (MEG), “Monte Carlo Simulations of Liquid Crystalline Microstructures,” MS-C course project Fall 2004. Technical Services Manager, Siemens Industry USA.
1. Aaron Greiner (CHE), “Microfluidic Synthesis of Elastic Droplets”, Project Masters, August 2004. Earned a Ph.D. in 2009 from Michigan State University, Chemical Engineering. Process R&D Engineer at Dow Corning.

Ph.D. Students

17. Dylan Lewis (CHE), “Aqueous Two Phase Extraction to Purify and Characterize Protein Polymer Conjugates,” September 2018 to present. Jointly advised with Alan Russell.
16. Yanxin Li (CHE), “Partitioning of Nanoscale Particles in Polymer-Surfactant Phase Separating Mixtures,” September 2016 to present.
15. Scott Pedu (CHE), “Crystallization Kinetics in Microscale Batch Reactors,” September 2016 to present.
14. Charles Sharkey (CHE), “Synthesis and Dynamics of Elastic Capsules with Controlled Interfacial Elasticity,” September 2015 to present.
13. Thomas Brubaker (MEG), “A microfluidic lab on a chip device for real-time measurement of the freezing temperature spectrum and phase transitions of picoliter droplets,” September 2015 to present. Jointly advised with R. Sullivan.
12. Blake Bleier (CHE), “Microfluidic Screening of Colloidal Stability of Non Aqueous Suspensions,” September 2013 to May 3, 2018. Jointly advised with L. Walker.
11. Stephanie Kirby (CHE), “Controlled Generation and Characterization of Multi-Component Fluid-Fluid Interfaces,” April 18, 2017. Jointly advised with L. Walker. Staff Engineer, Moderna.
10. Christopher Nelson (MEG), “Probing The Phase Behavior Of Complex Fluids Using Microliter Droplet Reactors,” April 28, 2016. Formulation Engineer, Dow Chemical Corporation.
9. Todd Moyle (CHE), “Microscale Tipstreaming of Submicron Droplets,” April 24, 2015. Jointly advised with L. Walker. Research Engineer, Air Products.
8. Ying Zhang (PHY), “Coalescence and Mixing of Sessile Drops on Surfaces,” October 7, 2015. Jointly advised with S. Garoff. Staff Engineer, Toyota.

7. Sharon Vuong (CHE), “A Microfluidic Platform for the Control and Analysis of Phase Transitions in Concentrating Droplets,” June 30, 2014. *National Science Foundation Graduate Research Fellowship*. Senior Engineer, Dow Chemical.
6. Anthony Kotula (CHE), “Dilatational Rheology and Controlled Generation of Microscale Complex Fluid Interfaces,” April 21, 2014. Research Scientist, Polymers Division, NIST.
5. Nicolas Alvarez (CHE), “An Experimental and Theoretical Study of Surfactant Dynamics at Microscale Interfaces,” April 14, 2011. Jointly advised with L. Walker. *National Science Foundation Graduate Research Fellowship*. Assistant Professor, Drexel University.
4. Sourav Chatterjee (MEG), “Statics and Dynamics of Microscale Defects in Liquid Crystals,” July 18, 2011. Data Scientist, Facebook.
3. Wingki Lee (CHE), “Controlling Tipstreaming in Flow Focusing Devices,” April 26, 2010. Jointly advised with L. Walker. Senior Chemical Engineer, Schlumberger Research, Houston, TX.
2. Gordon Christopher (MEG), “Droplet Breakup and Coalescence Dynamics in Microfluidic Devices,” August 1, 2008. Associate Professor, Texas Tech University, Mechanical Engineering.
1. Shahab Shojaei-Zadeh (MEG), “Confinement and Flow of Microscopic Defects in Layered Liquids,” December 10, 2007.

Postdoctoral Researchers and Visitors

5. Corine Jackman, Ph.D. Chemical Engineering. Presidential Postdoctoral Fellowship. November 2019 to October 2021, Project: “Microfluidic Approaches to Bacterial Interactions in the Lung Microbiome.”
4. Artem Bezrukov, Ph.D. Chemistry. Visiting Scholar to Carnegie Mellon Chemical Engineering, January to April 2019, Project: “Polymer-surfactant interactions in microfluidic channels.” Regular position: Associate Professor of Physical Chemistry, Kazan Technological University, Russia.
3. Christopher Wirth, Ph.D. Chemical Engineering, “Interfacial behavior of coatings,” June 2012 to June 2013, Collaborative project with PPG. Assistant Professor of Chemical and Biomedical Engineering, Cleveland State University.
2. Jorge Jimenez, Ph.D. Mechanical Engineering, “Lab-on-a-Chip for Controlling the Cellular Environment,” September 2007 to September 2008, co-advised with Y. Rabin. Currently Research Engineer in Health Care R&D Group, Praxair, Buffalo, NY.

1. Paul Tortora, Ph.D. Mechanical Engineering, “CT Imaging of Two-Phase Flows for Carbon Sequestration,” January 2006 to July 2008. Project Engineer, Bloomy.

Thesis Committee Students

44. Brian Josey (PHY), “Association of Neurotransmitters with Lipid Bilayer Membranes,” 2019 (Chair: M. Losche).
43. Jason Kabarowski (CHE), “Particle Motion in Unsteady Stokes Flow,” 2019 (Chair: A. Khair).
42. Daniel Beilharz (Ecole Polytechnique Paris-Saclay, France), “Patchy Pillars in Contact with Liquids,” External Examiner, 2018 (Supervisor: Prof. David Quéré).
41. Junchi Ma (CHE), “Interfacial Rheology of Ashphaltenes,” 2018 (Chair: Walker)
40. Andrew Fox (CHE), “Inertial Forces on Anisotropic Particles,” 2018 (Chair: Khair)
39. Bhavya Balu (CHE), “Modeling Concentrated Electrolyte Systems,” 2018 (Chair: Khair)
38. Raj Sengupta (CHE), “Surfactant Adsorption at Fluid-Fluid Interfaces Under the Influence of an Electric Field,” 2017-2019 (Chair: Khair)
37. Prathamesh Desai (MEG), “Tribosurface Interactions involving Particulate Media with Calibrated Properties: Experiments, Modeling and Machine Learning,” 2017 (Chair: Higgs)
36. Samuel Oberdick (PHY), “Patterned Magnetic Structures via Directed Assembly of Nanoparticles and E-beam Lithography,” 2016 (Chair: Majetich).
35. Randy Gamble (CHE), “Characterization of Micelle ELFSE Buffers for Rapid Kilobase DNA Separations,” 2015-2018 (Chair: Schneider).
34. Toni Bechtel (CHE), “Framework to Predict and Decompose the Stress of Complex Fluids in Transient, Large Amplitude Flows,” 2015-2018 (Chair: Khair).
33. Nicholas Chisholm (CHE), “Quantification of Locomotion Across Reynolds Numbers,” 2014 (Chair: Khair).
32. Alexander Hallenbeck (CHE), “Microfluidic Approach to Solvent Characterization for CO₂ Capture Applications,” 2013-16 (Chair: Kitchin).
31. Melissa Day (CHE), “Atmospheric Organic Aerosol and Climate Change,” 2014 (Chair: Pandis).

30. Ramankur Sharma (CHE), “Surfactant-Assisted Spreading on Entangled Aqueous Polymer Solutions with Applications to Pulmonary Drug Delivery,” 2014 (Chairs: Przybycien, Tilton, Garoff).
29. Michael Burkholder (MEG), “Nonlinear analysis and control of the two-phase flow dynamics in polymer electrolyte fuel cells,” 2013-2015 (Chair: Litster).
28. Javier Lanaue (CHE), “Electrohydrodynamics of Complex Interfaces,” 2013 (Chairs: Khair and Walker).
27. Rasmus Hansen (Department of Chemical and Biochemical Engineering, Technical University of Denmark), “Modeling of Transport in Surface Based Bio-Sensors,” External Examiner, 2012 (Supervisors: Prof. Ole Hassager, Prof. Henrik Bruus, and Dr. Thomas Callisen).
26. Joseph Prata (Chemistry), “Chemical Functionalization and Technological Applications of Hyaluronic Acid,” 2012 (Chair: Washburn).
25. Jeongho Kim (BME), “Shape Optimization of Blood Contacting Devices And Multi-Component Blood Flow Using the Mixture Theory,” 2010-2012 (Chair: Antaki).
24. Matthew Reichert (CHE), “Competitive Adsorption Of Dispersant And Biosurfactant At The Oil-Water Interface As It Applies To Oil Spill Remediation,” 2010 - 2013 (Chair: Walker).
23. Angela Holmen (CHE), “Improving Efficiency of Micelle-End Labeled Free Solution Electrophoresis by Decreasing Micelle Lifetimes and Micelle Fractional Polydispersity,” 2010 - 2013 (Chair: Schneider).
22. Marissa Miracolo (MEG), “Secondary Organic Aerosol Formation from Emissions from Combustion Sources,” 2009-2011 (Chairs: Robinson and Donahue).
21. Christopher Wirth (CHE), “The Role of Electrochemistry in 2-D Assembly of Colloidal Particles on a Planar Electrode,” 2009-2012 (Chairs: Sides and Prieve).
20. Beautia Dew (BME), “Marangoni spreading as a drug delivery mechanism for treatment of cystic fibrosis,” 2008 (Chairs: Przybycien, Garoff and Tilton).
19. Sheetal Pai (CHE), “Poly(ethylene glycol)-Modified Proteins: Implications for Poly(lactide-co-glycolide)-Based Microsphere Delivery,” 2008-2011 (Chairs: Przybycien and Tilton).
18. Brandon Kuczynski (MEG), “Probing Biological Systems using a Microfluidic Chemical Signal Generator,” 2008 (Chairs: Leduc and Messner).
17. Joeska Husny (Division of Chemical Engineering, The University of Queensland, Australia), “Dynamics of Drop Formation in Microfluidic Devices,” External Examiner, 2008 (Supervisor: Prof. Justin Cooper-White).

16. Hee Joon Lee (MEG), “Thermal-Fluids Design of Evaporative Micro-channel Systems,” 2008 (Chair: Yao).
15. Eugene Cheung (MEG), “Biologically Inspired Fibrillar Adhesion and Friction on Biological Tissues,” 2008 (Chair: Sitti).
14. John Thomas (MEG), “Enhanced Water Flow through Carbon Nanotubes,” 2008 to 2010 (Chair: McGaughey).
13. Yuli Wei (PHY), “Effect of Elasticity on Dynamic Contact Angle,” 2007 to 2009 (Chairs: Garoff and Walker).
12. Rui Zhao (BME), “Experimental Observation and Theoretical Investigation of Microscopic Blood Flow Dynamics,” 2006 to 2008 (Chair: Antaki).
11. Adam Bowles (CHE), “AFM Measurements of Disjoining Pressure of Fluorinated Poly-ethers on Surfaces,” 2006 to 2009 (Chairs: Schneider & White).
10. Elon Terrell (MEG), “Granular Flow Simulations with Applications to Slurry Flow and Chemical Mechanical Polishing,” 2007 (Chair: Higgs).
9. Bahareh Bekham (MEG), “Bacterial Flagella-based Propulsion of Micrometer Scale Hybrid Swimming Robots,” 2008 (Chair: Sitti).
8. Jean-Marie Le Corre (MEG), “Mechanistic Modeling of Critical Heat Flux in Multi-dimensional Subcooled Flow Boiling,” 2007 (Chairs: Amon & Yao).
7. Amrinder Nain (MEG), “Proximal Probe-based Nanorobotic Fabrication, Modeling and Characterization of Three Dimensional Polymer Micro/Nanofibers,” 2004-2007 (Chairs: Amon & Sitti).
6. Shu Nie (PHY), “Buckling of Si and Ge Surfaces,” 2004-2007 (Chair: Feenstra).
5. Ioanna Pagani (BME), “Probing and Modeling The Erythrocyte Cytoskeleton,” 2006 (Chairs: Ghattas & Leduc).
4. Dimiter Draganov (PHY), “Transition Region and Precursing Films of Polymer Melts,” 2006 (Chairs: Garoff & Suter).
3. Yi Wang (MEG), “Modeling and Simulations of Lab-on-a-Chip Systems,” 2005 (Chair: Lin).
2. Gita Seevaratnam (CHE), “Wetting of Model Non-Newtonian Fluids,” 2005 (Chairs: Walker & Garoff).
1. Keith Humfeld (PHY), “Interface shapes and thin film structures of complete, partial, and pseudo partial wetting systems,” 2004 (Chair: Garoff).

Educational Contributions

- Industry-Academia Workshop on “Transport and Mechanics at Fluid-Fluid Interfaces,” held at Carnegie Mellon University, November 2, 2012, with Lynn Walker. Attendees from five companies (Lubrizol, PPG, P&G, Kodak, and Chevron).
- Lecturer on Microfluidics, 13th European School on Rheology, Laboratory for Applied Rheology and Polymer Processing, Leuven, Belgium, September 5 – 9, 2011.
- Tutorial Lecture on “An Introduction to interfaces and multiphase flows in microfluidics” at the Institute for Mathematics and Its Applications Workshop on Microfluidics: Electrokinetic and Interfacial Phenomena, University of Minnesota, December 5-11, 2009.
- Awarded a Struminger Junior Faculty Fellowship in the Department of Mechanical Engineering to develop “An Integrated Computation and Experiment Based Design Project for Fluid Mechanics”, \$10,000, AY 2009-2010. Developed and implemented a CFD-based project in which students simulate flow past submerged bodies (cylinders, airfoils) and examine aspects of the results. Incorporated interactive elements to the project by having each team simulate a different set of conditions and compiling the results to include in lectures on external flows and boundary layers. The project has evolved into a case study project that allows students to explore contemporary topics in fluid mechanics including social, economic, ethical, and environmental issues.
- Co-developed and co-taught a one-day short course entitled “Microfluidics for Rheologists” at the Society of Rheology Annual Meeting, Salt Lake City, October 6, 2007. With T. Squires, P. Doyle, and V. Breedveld.
- Developed and implemented new course, “Microfluidics”(S06, S07). Elective course for upper level undergraduates and graduate students in engineering and science; cross-listed in Mechanical Engineering, Chemical Engineering, and Biomedical Engineering. Course materials focus on fundamentals of flow and transport in microscale devices, designing functional microfluidic chips, and applications in biotechnology. Students participate in four major projects examining the use of computations, microfluidics experimentation, current literature, and interdisciplinary teamwork to design a functional device. Course has been assigned permanent course numbers 24-615 (MEG), 06-623 (CHE), 42-643 (BME).
- Developed and implemented new course, “Interfacial Fluid Mechanics”(F03, S05). Focus on classic interfacial flow problems, recent literature, and applications. Includes semester-long research project with oral presentation and written report.
- Wrote a laboratory manual for Thermal Fluids Experimentation and Design (2008). S.L. Anna, J.L. Jimenez-Rios and Y. Rabin, “Laminar Visualization Table,” Lab tutorial for 24-321, 2007
- Created laboratory modules for undergraduate fluid mechanics. Modules include: microfluidic flow visualization, microfluidic dilution T-chip, surface characterization, and elongational viscosity measurement. Piloted by undergraduate research assistants.

- Member, Undergraduate Education Committee, Dept. of Mechanical Engineering. Reviewed pre-requisites for core undergraduate courses (Spring 2007) and recommended ways to streamline the required pre-requisites.

Publications

Archival Papers Critically Reviewed Before Publication

47. S. Barman, M.L. Davidson, L.M. Walker, S.L. Anna, J.A. Zasadzinski, "Inflammation Product Effects on Dilatational Mechanics Trigger the Laplace Instability," submitted to *Science Advances*, January 30, 2020.
46. T. Brubaker, M. Polen, P. Cheng, V. Ekambaram, J. Somers, S.L. Anna, and R.C. Sullivan, "Development and Characterization of a "Store and Create" Microfluidic Device to Determine the Heterogeneous Freezing Properties of Ice Nucleating Particles," *Aerosol Science and Technology*, (2019) DOI: 10.1080/02786826.2019.1679349.
45. B.J. Bleier, S.L. Anna and L.M. Walker, "Microfluidic droplet-based tool to determine phase behavior of a fluid system with high composition resolution," *Journal of Physical Chemistry B*, DOI: 10.1021/acs.jpcc.8b01013, Published on web March 16, 2018.
44. S.M. Kirby, S.L. Anna, and L.M. Walker, "Effect of surfactant tail length and ionic strength on the interfacial properties of nanoparticle-surfactant complexes," *Soft Matter*, **14** (2018) 112-123.
43. X. Zhang, S.M. Kirby, Y. Chen, S.L. Anna, L.M. Walker, and F.R. Hung, and P.S. Russo, "Formation and Elasticity of Membranes of the Class II Hydrophobin Cerato-ulmin at Oil-Water Interfaces," *Colloids and Surfaces B*, **164** (2018) 98-106.
42. B.J. Bleier, B.A. Yezer, S.L. Anna and L.M. Walker, "Droplet-Based Characterization of Surfactant Efficacy in Colloidal Stabilization of Carbon Black in Nonpolar Solvents," *Journal of Colloid and Interface Science*, **493** (2017) 265-274.
41. S.M. Kirby, X. Zhang, P.S. Russo, S.L. Anna, and L.M. Walker, "Formation of a Rigid Hydrophobin Film and Disruption by an Anionic Surfactant at an Air/Water Interface," *Langmuir*, **32** (2016) 5542-5551.
40. A.P. Kotula and S.L. Anna, "Insoluble Layer Deposition and Dilatational Rheology at a Microscale Spherical Cap Interface," *Soft Matter*, **12** (2016) 7038-7055.
39. M. Manga, T. Hunter, O. Cayre, D. York, M. Reichert, S.L. Anna, L.M. Walker, R. Williams, and S. Biggs, "Measurements of sub-micron particle adsorption and particle film elasticity at oil-water interfaces," *Langmuir*, **32** (2016) 4125-4133.
38. S.L. Anna, "Droplets and Bubbles in Microfluidic Devices," *Annual Review of Fluid Mechanics*, **48** (2016) 285-309.

37. Y. Zhang, D. Chatain, S.L. Anna, and S. Garoff, "Stability of a compound sessile drop at the axisymmetric configuration," *Journal of Colloid and Interface Science*, **462** (2016) 88-99.
36. A.P. Hallenbeck, A. Egbebi, K.P. Resnik, D. Hopkinson, S.L. Anna, and J.R. Kitchin, "Comparative microfluidic screening of amino acid salt solutions for post-combustion CO₂ capture," *International Journal of Greenhouse Gas Control*, **43** (2015) 189-197.
35. S.M. Kirby, S.L. Anna, and L.M. Walker, "Sequential adsorption of an irreversibly adsorbed nonionic surfactant and an anionic surfactant at an oil/aqueous interface," *Langmuir*, **31** (2015) 4063-71.
34. A.P. Kotula and S.L. Anna, "Regular perturbation analysis of small amplitude oscillatory dilatation of an interface in a capillary pressure tensiometer," *Journal of Rheology*, **59** (2015) 85-117.
33. Y. Zhang, S.D. Oberdick, E.R. Swanson, S.L. Anna, and S. Garoff, "Gravity driven current during the coalescence of two sessile drops," *Physics of Fluids*, **27** (2015) 022101.
32. M.D. Reichert, N.J. Alvarez, C.F. Brooks, A.M. Grillet, L.A. Mondy, S.L. Anna, and L.M. Walker "The importance of experimental design on measurement of dynamic interfacial tension and interfacial rheology in diffusion-limited surfactant systems," *Colloids and Surfaces A*, **467** (2015) 135-142.
31. K.V. Rodriguez Granado, S.L. Anna, L.R. Rojas-Solorzano, and S. Verma, "Numerical simulation of droplet formation in a microchannel device," *The International Journal of Multiphysics*, **7** (2016) 271 – 286.
30. T.M. Moyle, L.M. Walker, and S.L. Anna, "Controlling thread formation during tipstreaming through an active feedback control loop," *Lab on a Chip*, **13** (2013) 4534 – 41.
29. T.M. Moyle, L.M. Walker, and S.L. Anna, "Predicting conditions for microscale surfactant mediated tipstreaming," *Physics of Fluids*, **24** (2012) 082110.
28. A.P. Kotula and S.L. Anna, "Probing timescales for probing particle adsorption using slug bubbles in rectangular microchannels," for the Themed Issue on *Soft Matter Principles of Microfluidics* edited by edited by Professor Lydéric Bocquet, Professor Todd Squires, and Professor Annie Colin, *Soft Matter*, **8** (2012) 10759 – 10772.
27. N.J. Alvarez, L.M. Walker, S.L. Anna, "A Criterion to Assess the Impact of Confined Volumes on Surfactant Transport to Liquid-Fluid Interfaces," *Soft Matter*, **8** (2012) 8917 – 8925.
26. S. Chatterjee and S.L. Anna, "Interaction of Toroidal Focal Conic Defects with Shear Flow," *Soft Matter*, **8** (2012) 6698 – 6705.
25. N.J. Alvarez, S.L. Anna, T. Saigal, R.D. Tilton, L.M. Walker, "Interfacial Dynamics and Rheology of Polymer-Grafted Nanoparticles at Air-Water and Xylene-Water interfaces," *Langmuir*, **28** (2012) 8052 – 8063.

24. S.M. Vuong and S.L. Anna, "Tuning Bubbly Structures in Microchannels," *Biomicrofluidics, Special Issue on Multiphase Microfluidics*, Guest Ed. Saif Khan, **6** (2012) 022004. Re-published in *Virtual Journal of Nanoscale Science and Technology*, **25** (17) Apr 23, 2012, and *Virtual Journal of Biological Physics Research*, April 15, 2012.
23. N.J. Alvarez, D.R. Vogus, L.M. Walker, and S.L. Anna, "Using bulk convection to approach kinetic-limited surfactant dynamics," *Journal of Colloid and Interface Science*, **372** (2012) 183-191.
22. S. Chatterjee and S.L. Anna, "Formation and Ordering of Topological Defect Arrays Produced by Dilatational Strain and Shear Flow in Smectic-A Liquid Crystals," *Physical Review E*, **85** (2012) 011701.
21. N.J. Alvarez, W. Lee, L.M. Walker, and S.L. Anna, "The Effect of Alkane Tail Length of CiE8 Surfactants on Transport to the Silicone Oil-Water Interface," *Journal of Colloid and Interface Science*, **355** (2011) 231-236.
20. W. Lee, L.M. Walker, and S.L. Anna, "Competition between Viscoelasticity and Surfactant Dynamics in Flow Focusing Microfluidics," *Macromolecular Materials and Engineering, Special Issue on Rheology, Mixing, and Flow of Polymeric Materials*, **296** (2011) 203-213.
19. M. Ferer, S.L. Anna, P. Tortora, J. R. Kadambi, M. Oliver, G.S. Bromhal, and D. H. Smith, "Two-Phase Flow in Porous Media: Predicting Its Dependence on Capillary Number and Viscosity Ratio," *Transport in Porous Media* **86** (2011) 243-259.
18. N.J. Alvarez, L.M. Walker, and S.L. Anna, "A Microtensiometer to Probe the Effect of Radius of Curvature on Surfactant Transport to a Spherical Interface," *Langmuir*, **26** (2010) 13310-13319.
17. N.J. Alvarez, L.M. Walker, and S.L. Anna, "Diffusion-limited adsorption to a spherical geometry: The impact of curvature and competitive time scales," *Physical Review E*, **82** (2010) 011604. Re-published in *Virtual Journal of Nanoscale Science and Technology*, **22** (5) Aug 2, 2010.
16. G.F. Christopher and S.L. Anna, "Passive breakup of viscoelastic droplets and filament self-thinning at a microfluidic T-junction," *Journal of Rheology* **53** (2009) 663-683.
15. N.J. Alvarez, L.M. Walker, and S.L. Anna, "A non-gradient based algorithm for the determination of surface tension from a pendant drop: Application to low Bond number drop shapes," *Journal of Colloid and Interface Science* **333** (2009) 557-562.
14. W. Lee, L.M. Walker and S.L. Anna, "Role of geometry and fluid properties in droplet and thread formation processes in planar flow focusing," *Physics of Fluids* **21** (2009) 032103.
13. S. Shojaei-Zadeh, Shaun R. Swanson and S.L. Anna, "Highly uniform micro-cavity arrays in flexible elastomer film," *Soft Matter* **5** (2009) 743-746. Selected as a "top five article in Soft Matter in 2009" by the chair of the editorial board, May 28, 2009.
12. G.F. Christopher, J. Bergstein, N.B. End, C. Nguyen, and S.L. Anna, "Coalescence and Splitting of Droplets at Microfluidic Junctions," *Lab on a Chip* **9** (2009) 1102-1109.

11. G.F. Christopher, N.N. Noharuddin, J.A. Taylor and S.L. Anna, "Experimental observations of the squeezing-to-dripping transition in microfluidic T-junctions," *Physical Review E*, **78** (2008) 036317. Re-published in Virtual Journal of Nanoscale Science and Technology, **18** (13) Sep 29, 2008.
10. S.L. Anna and G.H. McKinley, "Effect of a controlled pre-deformation history on extensional viscosity of dilute polymer solutions," *Rheologica Acta*, **47** (2008), 841-859.
9. G.F. Christopher and S.L. Anna, "Microfluidic methods for generating continuous droplet streams," *Journal of Physics D – Applied Physics*, **40** (2007) R319-R336.
8. S.L. Anna and H.C. Mayer, "Microscale Tipstreaming in a Microfluidic Flow Focusing Device," *Physics of Fluids*, **18** (2006) 121512.
7. S. Shojaei-Zadeh and S.L. Anna, "Role of Surface Anchoring and Geometric Confinement on Focal Conic Textures in Smectic-A Liquid Crystals," *Langmuir* **22** (2006) 9986-93.
6. D.R. Link, S.L. Anna, H.A. Stone, and D.A. Weitz, "Geometrically-Mediated Breakup of Drops in Microfluidic Devices," *Physical Review Letters*, **92** (2004) 054503. Re-published in Virtual Journal of Nanoscale Science and Technology, **9** (7) Feb. 23, 2004.
5. S.L. Anna, N. Bontoux, and H.A. Stone, "Formation of dispersions using 'flow-focusing' in microchannels," *Applied Physics Letters*, **82** (2003) 364-366.
4. S.L. Anna, G.H. McKinley, "Elasto-Capillary Thinning and Breakup of Model Elastic Liquids," *Journal of Rheology*, **45** (2001) 115-138.
3. S.L. Anna, G.H. McKinley, D.A. Nguyen, T. Sridhar, S.J. Muller, J. Huang, and D.F. James, "An Inter-laboratory Comparison of Measurements from Filament-Stretching Rheometers Using Common Test Fluids," *Journal of Rheology*, **45** (2001) 83-114.
2. S.L. Anna, C. Rogers, and G.H. McKinley, "On Controlling the Kinematics of a Filament Stretching Rheometer Using a Real-Time Active Control Mechanism," *Journal of Non-Newtonian Fluid Mechanics*, **87** (1999) 307-335.
1. J.R. Mackey, K.K. Das, S.L. Anna, and G.H. McKinley, "A Compact Dual-Crystal Modulated Birefringence Measurement System for Microgravity Applications," *Measurement Science and Technology*, **10** (1999) 946-955.

Papers in Symposium or Conference Proceedings Fully Reviewed Prior to Publication

7. L.R. Rojas-Solórzano, S.L. Anna, C.H. Amon, B. Bradeddine, "Numerical simulation of a rollerball microfluidic device," *Proceedings of the 7th International Conference on Nanochannels, Microchannels and Minichannels*, ICNMM2009, June 22 – 24, 2009, Pohang, South Korea.
6. M. Ferer, S.L. Anna, P. Tortora, J.R. Kadambi, M. Oliver, G.S. Bromhal, D.H. Smith, "Crossover from fractal fingering to compact invasion for drainage: modeling and

experiment,” *Energy Procedia*, 9th International Conference on Greenhouse Gas technology, Washington, D.C. November 2008.

5. S.L. Anna, H.C. Mayer, W. Lee, G.F. Christopher, A.J. Greiner, L.M. Walker, “Additive-Assisted Continuous Microfluidic Formation of Uniform Micron-Scale Droplets,” *Proceedings of the AES-ATEMA 2007 International Conference on Advances and Trends in Engineering Materials and their Applications*, August 6-10, 2007, Montreal, Canada. *Invited Plenary Lecture*.
4. H.C. Mayer and S.L. Anna, “A Microfluidic Tensiometer,” *Proceedings of the IMECE2004*, 2004 ASME International Mechanical Engineering Congress, November 13-19, 2005, Anaheim, CA, IMECE2004-62096.
3. G.F. Christopher, N. Noharuddin and S.L. Anna, “Droplet Breakup in Shear and Elongation Dominated Flows in Microfluidic Devices,” *Proceedings of the IMECE2005*, 2005 ASME International Mechanical Engineering Congress, November 5-11, 2004, Orlando, FL, IMECE2005-80625.
2. S.L. Anna, N. Bontoux, and H.A. Stone, “Synthesis of Dispersions Using ‘Flow-Focusing’ in a Microfluidic Device,” presented at the *Materials Research Society Fall Meeting*, Boston, MA, December 2002.
1. M.R. Krejsa, P.H. Mariucci, S.L. Anna, T.J. Carabine, R.A. Dill, J.J. Tria, “Analytical Characterization of Curing Chemistry in a Polyester/Aziridine/Epoxy/Blocked Isocyanate System,” *Proceedings of the 29th Annual International Waterborne, High-Solids and Powder Coatings Symposium*, New Orleans, LA, February 2002, pp. 247-260.

Other Papers in Symposium or Conference Proceedings

4. W. Lee, L.M. Walker and S.L. Anna, “Impact of Viscosity Ratio on the Dynamics of Droplet Breakup in a Microfluidic Flow Focusing Device,” *The XVth International Congress on Rheology*, Monterey, CA, USA, August 2008.
3. S.L. Anna and G.H. McKinley, “The Evolution of Tensile Stresses in Uniaxial Elongational Flows of Dilute Polymer Solutions Subjected to a Known Preshear History,” *XIIIth International Congress on Rheology*, Cambridge, UK, August 2000.
2. G.H. McKinley, S.L. Anna, A. Tripathi, and M. Yao, “Extensional Rheometry of Polymeric Fluids and the Uniaxial Elongation of Viscoelastic Filaments,” Plenary paper (presented by McKinley), *15th Annual Meeting of the International Polymer Processing Society*, Netherlands, June 1999.
1. G.H. McKinley, S.H. Spiegelberg, S.L. Anna, and M. Yao, “Extensional Rheometry of Polymer Solutions and the Uniaxial Elongation of Viscoelastic Filaments,” presented at

the 4th Microgravity Fluid Physics & Transport Phenomena Conference, Cleveland, OH, August 1998.

Sections or Chapters in Edited Monographs or Similar Volumes

3. M.R. Booty, M. Siegel, and S.L. Anna, “Hybrid Numerical Method for Interfacial Flow with Soluble Surfactant and Its Application to an Experiment in Microfluidic Tip Streaming,” Chapter 15 in *Computational Methods for Complex Liquid-Fluid Interfaces*, Eds. M.T. Rahni, M. Karbaschi, and R. Miller, CRC Press, ISBN: 978-1-4987-2208-7 (2016) pp. 309-330.
2. S.L. Anna, “Non-Newtonian Fluids in Microfluidics,” in *Encyclopedia of Micro- and Nanofluidics*, Ed. D. Li, Springer-Verlag, ISBN: 978-0-387-49000-7 (June 2008).
1. S.L. Anna, S.H. Spiegelberg, and G.H. McKinley, “Elastic Instability in Elongating Fluid Filaments,” in *A Gallery of Fluid Motion*, Eds. M. Samimy, K.S. Breuer, L.G. Leal, and P.H. Steen, Cambridge University Press (2003) p. 62.

Other Writings (Technical Reports and Testimony)

6. S.L. Anna, J.L. Jimenez-Rios and Y. Rabin, “Laminar Visualization Table,” Lab tutorial for 24-321, 2007.
5. M.R. Krejsa, P.H. Mariucci, S.L. Anna, T.J. Carabine, R.A. Dill, J.J. Tria, “Analytical Characterization of Curing Chemistry in a Polyester/Aziridine/Epoxy/Blocked Isocyanate System,” Solutia Technical Report, October 2001.
4. A.M. Striegel, S.L. Anna, M.R. Krejsa, J.B. Hurlbut, D. Alward, R. Wilson, B. Kochanowski, “Competitive Window Film for Acoustic Damping,” Solutia Technical Report, September 2001.
3. S.L. Anna and J.B. Hurlbut, “General Guidelines for Modifying the Glass Transition Behavior of Polymer Systems,” Technical Document, Solutia, Inc., December 2000.
2. S.L. Anna, “Filament Stretching of Model Elastic Liquids,” Doctoral Thesis, Harvard University, 2000.
1. S.L. Anna, S.H. Spiegelberg, and G.H. McKinley, “Elastic Instability in Elongating Fluid Filaments,” Contribution to Gallery of Fluid Motion, *Physics of Fluids*, **9** (9) 1997. Re-published in *A Gallery of Fluid Motion*, Eds. M. Samimy, K.S. Breuer, L.G. Leal, and P.H. Steen, Cambridge University Press (2003) p. 62.

Discussion or Reviews of Work

1. You Tube Video; “Behind the Researcher: Microfluidics & Fortissimo”, <https://www.youtube.com/watch?v=4DMile52u4g>, February 14, 2019
2. You Tube Video; “Multi-Phase Materials: Interface Materials in Applications”, <https://www.youtube.com/watch?v=kNqiOp6d5gM>, August 27, 2015
3. Reviews of Link *et al.*, *Phys. Rev. Lett.* **92** (2004) no. 054503:
 - a) “Breaking Up Isn’t Hard To Do,” David Lindley, *Physical Review Focus*, **13**, Jan. 30 2004.
 - b) “Channel Shapes Split Microdrops,” *MIT’s Technology Review*, Technology Research News, March 17 2004
(http://www.technologyreview.com/articles/rnb_031004.asp?trk=nl).

Patents

3. C.A. Orme, S. Baker, Y. Yu, S.L. Anna and C. Sharkey, “Ultra-Low Density Solids Formed From Colloidosomes,” Provisional Patent Application Filed October 26, 2017. Docket No. IL-13251. Converted to Non-Provisional Application October 25, 2018.
2. S.L. Anna and S. Garoff, “Apparatus and Process for Producing Patterned, Micron and Nanometer Size Reaction and Mixing Zones for Fluids Deposited on Smooth, Rough and Porous Surfaces and Applications of That Process,” Full Patent Application Filed February 15, 2011. Docket No. 279430.108_PCT.
1. H.A. Stone, S.L. Anna, N. Bontoux, D.R. Link, D.A. Weitz, I. Gitlin, P. Garstecki, W. DiLuzio, G.M. Whitesides, and E. Kumacheva, “Method and Apparatus for Fluid Dispersion,” U.S. Patent Application 60/392,195 & 60/424,042 and Intl. Patent Application PCT/US03/20542, June 3, 2003.

Grants and Contracts Awarded

Principal Investigator

21. Nanocrystal dynamics on a bubble – correlating interfacial rheology with coherent x-ray scattering, NSLS-II General User Proposal, Beam time on Beamline 11-ID, Brookhaven National Laboratory, May 2018 – August 2018.

20. Porous Nanocrystal Composites Assembled from Colloidosomes, Department of Energy – Lawrence Livermore National Laboratory, January 2017 – September 2018, \$120,000.
19. Synthesis and Dynamics of Elastic Capsules with Controlled Interfacial Elasticity, National Science Foundation, May 2015 – April 2019, \$364,613.
18. Control of Mixing Driven by Coalescence of Sessile Drops, National Science Foundation, PI: Anna, co-I: Garoff, September 2013 – August 2016, \$350,000.
17. Unrestricted Gift, Evonik Corporation, July 2013, \$7,500.
16. Unrestricted Gift, PPG, July 2012, \$10,535.
15. Characterization of Dispersant Adsorption Timescales Using a Microscale Tensiometer, part of The Consortium for the Molecular Engineering of Dispersant Systems with Tulane University (V. John, PI), “The Science and Technology of Dispersants as Relevant to Deep-Sea Oil Releases,” Gulf of Mexico Research Initiative, CMU PI: Anna, CMU co-PI: Walker, October 2011 – September 2014, \$333,000.
14. Microscale Flows to Engineer Fluid Interfaces Containing Macromolecular and Colloidal Species, National Science Foundation, PI: Anna, co-I: Walker, September 2010 – August 2013, \$310,000.
13. An Integrated Computation and Experiment Based Design Project for Fluid Mechanics, Struminger Junior Faculty Fellowship, September 2009 – August 2010, \$10,000.
12. Augmenting Microfluidic Detection Capabilities Beyond Imaging, Dean’s Infrastructure Investment, June 2010, \$150,000.
11. Controlling Microscale Tipstreaming for Sustained Formation of Nanoscale Droplet Reactors, National Science Foundation, PI: Anna, co-I: Walker, October 2007 – September 2010, \$246,000.
10. A Lab-on-a-Chip Device for Controlling the Cellular Environment, Pennsylvania Infrastructure Technology Alliance, PI: Anna, co-I: Rabin & Campbell, December 2006 – August 2008, \$55,200.
9. NER: Microfluidic-Enabled Synthesis of Nanoparticles and Hierarchical Nanoclusters, PI: Anna, co-I: L. Walker, National Science Foundation, May 2006 – June 2008, \$116,000.
8. Microfluidic Technology for Synthesis of Metal Nanoparticles, PI: Anna, co-I: Walker, Pennsylvania Infrastructure Technology Alliance, October 2005 – May 2007, \$77,573.
7. CT Imaging of CO₂ Sequestration in Brine Saturated Sandstone, PI: Anna, co-I: Ferer (WVU), DOE National Energy Technology Laboratory Collaborative Initiative, September 2005 – October 2009, \$353,171.

6. CAREER: Fluid Dynamics of Microscopic Defects in Layered Liquids, National Science Foundation, May 2006 – April 2011, \$409,000.
5. Microfluidic Synthesis of Structured Particles for Drug Delivery, ICES-Dowd Graduate Fellowship for Gordon Christopher, September 2005 – August 2006, \$65,700.
4. SGER: Microfluidics as a Platform to Study Confinement of Complex Fluid Microstructures at Intermediate Length Scales, National Science Foundation, May 2005 – April 2006, \$50,000.
3. Novel Microflow Processing of 3D Ordered Nanostructures, Pennsylvania Infrastructure Technology Alliance, June 2004 – May 2005, \$40,525.
2. Motion and Internal Flow of Elastic Droplets in Confined Geometries, American Chemical Society Petroleum Research Fund Type G Starter Grant, September 2004 – August 2006, \$35,000.
1. A Microfluidic Tensiometer, Berkman Faculty Development Fund, March 2004, \$5,034.

Co-Principal Investigator

9. Ice nucleation properties of well characterized single particle-droplet pairs assessed using a microfluidic platform, National Science Foundation, PI: R. Sullivan, co-I: Anna, September 2018 – August 2020, \$250,000.
8. Fundamentals of Emulsion Stability, PI: Walker, co-I: Anna; joint with Todd Squires, UC-Santa Barbara, Dow Chemical Company UPI Project, March 2017 – August 2020, \$600,000 CMU portion.
7. A microfluidic lab on a chip device for real-time measurement of the freezing temperature spectrum and phase transitions of picoliter droplets, Collaborative Student Seed Grant from Department of Mechanical Engineering, PI: R. Sullivan, co-I: Anna, August 2015 – July 2016, Two years of student support.
6. Connecting Interfacial Properties to Emulsion Stability for Complex Particle-Laden Interfaces, National Science Foundation, PI: Walker, co-I: Anna, August 2014 – July 2017, \$349,999.
5. Organic Suspension Stability (PI: Walker, co-Is: Anna, Schneider, Prieve, Sides, Khair), Dow Chemical Company, November 2011 – October 2016, \$1,297,155.
4. IDR: Carbon Nanotube Aerogel Networks for Next-Generation Thermal Management (PI: McGaughey, co-Is: Anna, Islam, Pipe), National Science Foundation, September 2009 – August 2012, \$965,874.

3. Identifying And Facilitating Ventricular Recovery On Mechanical Support (PI: Kameneva, Antaki; co-Is: Finol, Miller, Anna), National Institutes of Health (subcontract from Univ. of Pittsburgh), July 2007 – June 2012, \$936,841.
2. MRI: Acquisition of a Laser Scanning Multi-Photon Confocal Microscope to Investigate Structure and Dynamics of Soft Materials of Biological and Synthetic Origin (12 investigators, PI: Islam; co-Is: Anna, Kovacevic, Leduc and Matyjaszewski; Faculty Associates: Kowalewski, Ettensohn, Schneider, Dahl, Peteanu, Bockstaller, Garoff), National Science Foundation, June 2006 – May 2009, \$518,260.
1. Feasibility of a Novel Technique for Fabrication of Micro/Nano-Scale Spheres and for Multi-Scale Layered Manufacturing from Metals and Polymers, Pennsylvania Infrastructure Technology Alliance, PI: Ozdoganlar, co-I: Weiss & Anna, December 2006 – August 2008, \$55,200.

Faculty Associate

2. MRI: Acquisition of an Environmental Scanning Electron Microscope for Visualization, Characterization and Manipulation of Nanoscale Systems (PIs: Ozdoganlar and Beuth), National Science Foundation, June 2007 – May 2010, \$498,325.
1. MRI: Acquisition of SAXS for Nanostructural Characterization of Self-Assembled Materials (9 investigators, PI: Walker; co-Is: Bockstaller, Kowalewski, and Schneider; Faculty Associates: Anna, Matyjaszewski, McCullough, Suter, and Washburn), National Science Foundation, June 2005 – May 2008, \$430,350.

Professional Activities

Seminars

Invited Seminars at Universities

56. “Enabling synthesis and analysis of new materials using picoliter and nanoliter droplets,” Department of Chemistry, Colorado School of Mines January 24, 2020
55. “Confined flows of bubbles with particle laden interfaces,” Chemical and Biological Engineering, Cornell University February 4, 2019
54. “Confined flows of bubbles with particle laden interfaces,” Mechanics: Modeling, Experimentation, Computation Seminar, Massachusetts Institute of Technology, Department of Mechanical Engineering April 3, 2018

53. "Confined flows of bubbles with particle laden interfaces," Stanley Corrsin Memorial Lecture, Johns Hopkins University, Department of Chemical & Biomolecular Engineering March 15, 2018
52. "Phase change and partitioning in nanoliter droplets," Illinois Institute of Technology, Department of Chemical & Biological Engineering October 17, 2017
51. "Phase change and partitioning in nanoliter droplets," Colorado School of Mines, Department of Chemical & Biological Engineering February 10, 2017
50. "Droplet microfluidics with particle laden interfaces," Georgetown University, Physics Colloquium February 9, 2016
49. "Droplet microfluidics with particle laden interfaces," Stanford University, Fluid Mechanics Seminar December 1, 2015
48. "Controlling particle laden interfaces with droplet microfluidics," University of Illinois at Urbana-Champaign, Fluid Mechanics Seminar September 25, 2015
47. "Connecting particle loading at interfaces with interfacial rheology and capsule stability," Penn State University, Department of Chemical Engineering February 12, 2015
46. "Connecting particle loading at interfaces with interfacial rheology and capsule stability," Oregon State University, School of Chemical, Biological, and Environmental Engineering February 2, 2015
45. "Connecting particle loading at interfaces with interfacial rheology and capsule stability," University of California – Santa Barbara, Department of Chemical Engineering October 30, 2014
44. "Connecting particle loading at interfaces with interfacial rheology and capsule stability," University of Colorado – Boulder, Department of Chemical and Biological Engineering October 28, 2014
43. "Connecting particle loading at interfaces with interfacial rheology and capsule stability," Virginia Tech, Engineering Science and Mechanics October 22, 2014
42. "Using Mass Transport to Control Microscale Emulsion Formation," University of Wisconsin-Madison, Bob Bird 90th Birthday Symposium, Department of Chemical and Biological Engineering January 30 – 31, 2014
41. "Connecting the Mechanics of Complex Fluid Interfaces to Emulsion Formation and Stability," University of Minnesota, College of Science and Engineering, Distinguished Women Scientists and Engineers Speakers Program December 11 – 12, 2013
40. "Probing Dilational Interfacial Stresses of Complex Fluid Interfaces at Microscale Spherical Bubbles," Stanford University, Special Seminar, Visit to Shaqfeh and Fuller Groups in Chemical Engineering June 3, 2013
39. "Interfacial Dynamics and Mechanics at the Microscale," University of Oklahoma, School of Chemical, Biological & Materials Engineering April 25, 2013
38. "Interfacial Dynamics and Mechanics at the Microscale," Mississippi State University, David C. Swalm School of Chemical Engineering April 16, 2013

37. “Interfacial Dynamics and Mechanics at the Microscale,” Texas Tech University,
Department of Mechanical Engineering March 18, 2013
36. “Interfacial Dynamics and Mechanics at the Microscale,” University of Maryland,
Fluid Dynamics Reviews Seminar Series December 7, 2012
35. “Interfacial Transport and Mechanics at the Microscale,” Technical University of
Denmark, Department of Chemical and Biochemical Engineering April 12, 2012
34. “Interfacial Transport and Mechanics at the Microscale,” Carnegie Mellon University,
Department of Mechanical Engineering March 2, 2012
33. “Designing Continuous Tipstreaming of Submicron Droplets,” University of
Pennsylvania, Department of Chemical and Biomolecular
Engineering November 9, 2011
32. “Competing Timescales for Surfactant Transport and Flow at Microscale Fluid-Fluid
Interfaces,” Michigan Technological University, Department of Chemical
Engineering December 3, 2010
31. “Competing Timescales for Surfactant Transport and Flow at Microscale Fluid-Fluid
Interfaces,” New Jersey Institute of Technology, Department of Mathematical
Sciences October 1, 2010
30. “Competing Timescales for Surfactant Transport and Flow at Microscale Fluid-Fluid
Interfaces,” Rensselaer Polytechnic Institute, Department of Chemical & Biological
Engineering September 15, 2010
29. “Surfactant Laden Interfaces in Microfluidic Devices,” Georgia Tech, Department of
Chemical Engineering January 13, 2010
28. “Surfactant Laden Interfaces in Microfluidic Devices,” University of Texas - Austin,
Department of Chemical Engineering September 22, 2009
27. “Surfactant Laden Interfaces in Microfluidic Devices,” Pennsylvania State University,
Polymer Physics Seminar Series September 29, 2009
26. “Surfactant Laden Interfaces in Microfluidic Devices,” The Benjamin Levich Institute
for Physico-Chemical Hydrodynamics November 3, 2009
25. “Surfactant Laden Interfaces in Microfluidic Devices,” Lehigh University, Department
of Chemical Engineering December 2, 2009
24. “Droplets and Defects: Microscale Flows of Microstructured Materials,” Tulane
University, Chemical and Biomolecular Engineering Department April 3, 2009
23. “Droplets and Defects: Microscale Flows of Microstructured Materials,” University of
Wisconsin – Madison, Rheology Research Center Lecture September 26, 2008
22. “Droplets and Defects: Microscale Flows of Microstructured Materials,” Brown
University, Division of Engineering April 29, 2008
21. “Droplets and Defects: Microscale Flows of Microstructured Materials,” Carnegie
Mellon University, Department of Mechanical Engineering April 25, 2008

20. "Surfactant-Mediated Tipstreaming in Microfluidic Devices," Cornell University, Fluid Dynamics Seminar Series March 11, 2008
19. "Microfluidic Tipstreaming for the Formation of Nanoscale Droplet Reactors," University of Vermont, Department of Mechanical Engineering September 19, 2007
18. "Picoliter Droplet Reactors via Microscale Tipstreaming," University of Chicago, Department of Physics, Computations in Science Seminar February 7, 2007
17. "Picoliter Droplet Reactors via Microscale Tipstreaming," Massachusetts Institute of Technology, Program in Polymer Science and Technology December 13, 2006
16. "Picoliter Droplet Reactors via Microscale Tipstreaming," Brown University, Division of Engineering, Fluid Dynamics Seminar November 28, 2006
15. "Two-Phase Flows in Microfluidic Devices: Mass Transport to Highly Curved Fluid Interfaces," University of Pittsburgh, Mechanical Engineering January 21, 2005
14. "Toward Lab In a Drop: Exploiting Two-Phase Flows and Highly Curved Interfaces for Microfluidic Technology," University of Connecticut, Department of Chemical Engineering October 26, 2005
13. "Toward Lab In a Drop: Exploiting Two-Phase Flows and Highly Curved Interfaces for Microfluidic Technology," Carnegie Mellon University, Department of Chemical Engineering October 12, 2005
12. "Designing Emulsions One Drop At A Time," Carnegie Mellon University, Department of Physics October 27, 2003
11. "Designing Emulsions One Drop At A Time," University of Wisconsin – Madison, Departments of Mechanical Engineering and Chemical Engineering March 4, 2003
10. "Designing Emulsions One Drop At A Time," Stanford University, Department of Chemical Engineering February 20, 2003
9. "Designing Emulsions One Drop At A Time," University of California, Santa Barbara, Departments of Mechanical and Chemical Engineering February 18, 2003
8. "Designing Emulsions One Drop At A Time," Johns Hopkins University, Department of Chemical Engineering February 6, 2003
7. "Designing Emulsions One Drop At A Time," California Institute of Technology, Division of Engineering and Applied Sciences January 30, 2003
6. "Designing Emulsions One Drop At A Time," University of Delaware, Department of Chemical Engineering January 27, 2003
5. "Designing Emulsions One Drop At A Time," Northwestern University, Departments of Mechanical Engineering and Chemical Engineering January 23, 2003
4. "Designing Emulsions One Drop At A Time," Carnegie Mellon University, Department of Mechanical Engineering January 16, 2003
3. "Designing Emulsions One Drop At A Time," University of Rochester, Department of Chemical Engineering January 9, 2003

2. “Designing Emulsions One Drop At A Time,” Colorado State University, Department of Chemical Engineering December 20, 2002
1. “Filament Stretching of Model Elastic Liquids,” University of Rhode Island, Chemical Engineering March 28, 2000

Invited Seminars at Companies

10. “Evolution of a particle coating on a confined fluid interface,” Dow Chemical Corporation, Midland, MI June 10, 2019
9. “A Microtensiometer Platform to Quantify Mechanics and Dynamics of Complex Fluid Interfaces,” Bristol-Myers Squibb, New Brunswick, NJ March 9, 2016
8. “Droplet Based Microfluidic devices for Quantification of Phase Change,” Dow Chemical Corporation, Collegeville, PA March 12, 2015
7. “Controlling Complex Fluid-Fluid Interfaces: Beyond the Isotherm,” Dow Chemical Corporation, Midland, MI April 14, 2014
6. “Interfacial Dynamics and Mechanics at the Microscale,” Lubrizol Corporation, Wycliffe, OH February 13, 2014
5. “A Microtensiometer to Separate and Analyze Dynamics and Mechanics of Complex Fluid Interfaces,” Evonik Meets Science North America, Evonik Industries AG, Atlantic City, NJ September 18 – 19, 2013
4. “Interfacial Dynamics and Mechanics at the Microscale,” PPG Industries, Inc. Insight Group, Allison Park, Coatings Innovation Center August 20, 2012
3. “Surfactant Laden Interfaces in Microfluidic Devices,” National Institutes of Standards and Technology, Polymers Division February 19, 2010
2. “Filament Stretching of Model Elastic Liquids,” Unilever Corporate Research, Colworth, UK June 2002
1. “Filament Stretching of Model Elastic Liquids,” Solutia, Inc., Springfield, Massachusetts March 30, 2000

Invited Talks at Conferences

25. “Evolution of a particle coating on a confined fluid interface,” Invited Speaker, 2019 *Physics and Chemistry of Microfluidics Gordon Conference*, Hong Kong June 2019
24. “Formation and disruption of a particle coating on a confined bubble,” Invited Talk, *Novel Complex Flows (Invited Session)*, Area 1J *Fluid Mechanics, AIChE Annual Meeting*, Pittsburgh November 2018
23. “Phase Separation and Partitioning in Polymer-Surfactant Mixtures in Nanoliter Droplets,” Invited Keynote, *ACS Colloid and Surface Science Symposium*, The City College of New York July 2017

22. “Dilatational Modulus Beyond Gibbs,” Invited Talk, Plenary Session, Fluid Interfaces, Area 01J Fluid Mechanics, AIChE Annual Meeting, Salt Lake City November 9, 2015
21. “Generation of Stable Non-Spherical Capsules with Controlled Interfacial Coverage of Surface-Active Particles,” Invited Talk, Polymer Processing and Rheology Division, AIChE Annual Meeting, Atlanta, GA November 16 – 20, 2014
20. “Generation of Monodisperse Non-Spherical Capsules Controlled by Particle Loading at the Interface,” Invited Talk, Mid-Atlantic Soft Matter Workshop, Johns Hopkins University, Baltimore, MD August 4, 2014
19. “Characterizing the Dilatational Interfacial Rheology of Insoluble Layers in a Microscale Tensiometer,” Invited Talk, Workshop on Interfacial Rheology, IPRIME Annual Meeting, University of Minnesota, Minneapolis, MN May 26 – 28, 2014
18. “Microfluidic Droplet Dehydration for Concentrating Processes in Biomolecules,” Invited Talk, American Physical Society March Meeting, Focus Session: Microfluidics and Nanofluidics III - Pattern Formation and Droplets, Denver, CO March 3 – 7, 2014
17. “Microfluidic Droplet Dehydration for Separation and Purification of Biomolecules,” Invited Plenary, American Electrophoresis Society Annual Meeting, San Francisco, CA November 3 – 8, 2013
16. “Probing Dilational Interfacial Stresses of Complex Interfaces Using a Microscale Spherical Bubble,” Invited Talk, Complex Fluids & Flows in Industry & Nature II, Pacific Institute for the Mathematical Sciences, Vancouver, BC July 24-26, 2013
15. “Interpreting Interfacial Dilatational Rheology of an Oscillating Microscale Bubble,” Invited Talk, American Chemical Society Spring Meeting, Symposium on “Emulsions, Bubbles and Foams: Fundamentals and Applications,” New Orleans, April 7 – 11, 2013
14. “Tipstreaming and other methods of producing fine fluid threads,” Invited Talk, American Physical Society – Division of Fluid Dynamics Annual Meeting, San Diego, California November 20-22, 2012
13. “Measurement of interfacial elasticity using an oscillating microscale spherical cap,” Keynote Speaker, Symposium on “Interfacial Rheology, Microrheology and Microfluidics,” The XVIth International Congress on Rheology, Lisbon, Portugal August 5-9, 2012
12. “Engineering Microscale Interfaces Using Convection and Curvature,” Keynote Speaker, TechConnect World, Santa Clara, CA June 18-21, 2012
11. “Interfacial Transport and Mechanics at the Microscale,” Keynote Address, North Dakota Symposium on Fluid Dynamics and Interfacial Phenomena April 25, 2012
10. “Interfacial Transport at the Microscale,” Featured HML Alumni Speaker at the 10th Anniversary Celebration of the Hatsopoulos Microfluids Laboratory, Massachusetts Institute of Technology, Department of Mechanical Engineering April 4, 2012
9. “Interfacial Transport at the Microscale,” Senior Guest Speaker at the 8th Zsigmondy Colloquium of the German Colloid Society March 5-7, 2012

8. S.L. Anna, W. Lee, N.J. Alvarez, and L.M. Walker, “Scaling arguments for tipstreaming of submicron drops,” presented at the *Institute for Mathematics and its Applications Workshop: Microfluidics: Electrokinetic and Interfacial Phenomena*, Minneapolis, MN December 2009
7. “Microscale Flows of Microstructured Materials,” Invited Speaker, 2009 *Physics and Chemistry of Microfluidics Gordon Conference*, Lucca, Italy June 28 – July 3, 2009
6. “The Dynamics of Tipstreaming in Microfluidic Flow Focusing Devices,” Invited Session Speaker, *Frontiers in Applied and Computational Mathematics 2008 Conference*, New Jersey Institute of Technology May 19-21, 2008
5. “Additive-Assisted Continuous Microfluidic Formation of Uniform Micron-Scale Droplets,” Invited Plenary Lecture, AES-ATEMA 2007 International Conference on Advances and Trends in Engineering Materials and their Applications, Montreal, Canada August 6, 2007
4. “Thread Formation and Tipstreaming in a Microfluidic Flow Focusing Device,” Invited Contribution, 15th U.S. National Congress of Theoretical and Applied Mechanics, Mini-Symposium on Jet, Drop, and Bubble Breakup in Small-Scale Flows, Boulder, CO June 2006
3. “Thread Formation and Tipstreaming in a Microfluidic Flow Focusing Device,” Invited contribution, Workshop on Interfacial Dynamics in Complex Fluids, Banff International Research Station, Banff, Canada May 2006
2. “Surfactant and Polymer Effects on Microscale Drop Formation,” Invited Plenary Speaker, 2005 *Annual Meeting of the Korean Society of Rheology*, Seoul National University, Korea November 4, 2005
1. “Cusps and Threads: Observations of Microscale Tipstreaming,” Invited Contribution, *IUTAM Symposium on Interactions for Dispersed Systems in Newtonian and Viscoelastic Fluids*, Guanajuato, Mexico March 26-30, 2006

Contributed Talks at Conferences

159. S. Anna, Z. Cui, and C. Sharkey, “Coating and crumpling of particle-coated bubbles in confined geometries,” presented at the *American Physical Society Division of Fluid Dynamics Annual Meeting*, Seattle, Washington, November 2019.
158. C. Sharkey, Z. Cui, and S.L. Anna, “Coating and crumpling of armored gas-filled capsules,” presented at the *American Institute of Chemical Engineers Annual Meeting*, Orlando, Florida, November 2019.
157. D. Lewis, S.L. Anna, and A. Russell “Characterization of protein-polymer conjugates using aqueous two-phase systems,” presented at the *American Institute of Chemical Engineers Annual Meeting*, Orlando, Florida, November 2019.
156. Y. Li and S.L. Anna, “Using droplet based millifluidic platform to separate biomolecules in aqueous two-phase systems,” presented at the *American Institute of Chemical Engineers Annual Meeting*, Orlando, Florida, November 2019.

155. S. Pedu and S.L. Anna, "Measuring the rate of co-crystal nucleation utilizing continuous microfluidic droplet generation," presented at the *American Institute of Chemical Engineers Annual Meeting*, Orlando, Florida, November 2019.
154. S.L. Anna, "Formation, Development and Disruption of a Particle Coating on a Confined Bubble" *Focus Session: Hydrodynamics of Particles and Macromolecules at Fluid Interfaces, American Physical Society Division of Fluid Dynamics Annual Meeting*, Atlanta, Georgia, November 2018.
153. C.S. Sharkey and S.L. Anna, "Development of interfacial mechanical strength for armored gas filled capsules," poster presented at the *American Institute of Chemical Engineers Annual Meeting*, Pittsburgh, PA, November 2018.
152. S.M. Kirby, S.L. Anna, and L.M. Walker, "Dynamics of Adsorption of Rhamnolipid Biosurfactants at Air/water and Oil/water Interfaces," presented at the *American Institute of Chemical Engineers Annual Meeting*, Pittsburgh, PA, November 2018.
151. T. Brubaker, M. Polen, L. Jahn, P. Cheng, V. Ekambaram, S.L. Anna, and C.R. Sullivan, "The Development and Characterization of a 'Store and Create' Microfluidic Device to Study Ice Nucleation Particles," presented at the *ASME Micro & Nano Forum, IMECE 2018*, Pittsburgh, PA, November 2018.
150. T. Brubaker, M. Polen, L. Jahn, P. Cheng, V. Ekambaram, S.L. Anna, and C.R. Sullivan, "The Development and Characterization of a 'Store and Create' Microfluidic Device to Study Ice Nucleation Particles," presented at the *International Aerosol Conference*, St. Louis, MO, September 2018.
149. C.S. Sharkey and S.L. Anna, "Development Of Local Interfacial Strains And Stresses In The Formation Of Asymmetric Particle-Stabilized Capsules," presented at the *American Physical Society Division of Fluid Dynamics Annual Meeting*, Denver, CO, November 2017.
148. C.W. Nelson and S.L. Anna, "Microliter-scale Phase Separating Polymer Droplets to Estimate Partition Coefficients of Single Walled Carbon Nanotubes," presented at the *Society of Rheology 88th Annual Meeting*, Tampa, FL, February 2017.
147. S.M. Kirby, S.L. Anna and L.M. Walker, "Dynamics and Mechanics of Nanoparticle-Surfactant Complex Coated Fluid-Fluid Interfaces," presented at the *Society of Rheology 88th Annual Meeting*, Tampa, FL, February 2017.
146. C.S. Sharkey and S.L. Anna, "Interfacial Stability and Bubble Formation with Amphiphile – Metal Oxide Particle Complexes," presented at the *Society of Rheology 88th Annual Meeting*, Tampa, FL, February 2017.
145. C.S. Sharkey, A.P. Kotula and S.L. Anna, "The Role of Colloidal Interactions on the Formation of Particle Stabilized Capsules," presented at the *American Physical Society Division of Fluid Dynamics Annual Meeting*, Portland, OR, November 2016.

144. C.S. Sharkey, S.M. Kirby, A.P. Kotula, L.M. Walker and S.L. Anna, "Controlling Interfacial Composition, Coverage, and Mechanics for Stable Capsule Formation," presented at the *American Institute of Chemical Engineers Annual Meeting*, San Francisco, CA, November 2016.
143. C.W. Nelson and S.L. Anna, "Measuring Partition Coefficients of Single Wall Carbon Nanotubes in Aqueous Two-Phase Microliter Droplets," presented at the *American Institute of Chemical Engineers Annual Meeting*, San Francisco, CA, November 2016.
142. A. Hallenbeck, A. Egbebi, K.P. Resnick, D. Hopkinson, S.L. Anna and J.R. Kitchin, "Comparative Microfluidic Screening of Amino Acid Salt Solutions for Post-Combustion CO₂ Capture," presented at the *American Institute of Chemical Engineers Annual Meeting*, Salt Lake City, UT, November 2015.
141. B.J. Bleier, S.L. Anna and L.M. Walker, "Transition from Steric to Electrostatically Stabilized Carbon Black Suspensions in Nonpolar Solvents," presented at the *American Institute of Chemical Engineers Annual Meeting*, Salt Lake City, UT, November 2015.
140. C.W. Nelson, S.M. Vuong, S.L. Anna, and L.M. Walker, "Microfluidic Platforms for Characterization of Flocculation and Gelation in Colloidal Suspensions," poster presented at the *American Institute of Chemical Engineers Annual Meeting*, Salt Lake City, UT, November 2015.
139. C.W. Nelson and S.L. Anna, "Transport Across Spontaneously Generated Interfaces with Ultralow Tension," poster presented at the *American Institute of Chemical Engineers Annual Meeting*, Salt Lake City, UT, November 2015.
138. A.P. Kotula and S.L. Anna, "Disentangling the mechanisms underlying the dilatational modulus of irreversibly adsorbed layers," presented at the *Society of Rheology Annual Meeting*, Baltimore, MD, October 2015.
137. S.M. Kirby, S.L. Anna, and L.M. Walker, "Impact of composition on the interfacial mechanics of multicomponent fluid-fluid interfaces," presented at the *Society of Rheology Annual Meeting*, Baltimore, MD, October 2015.
136. L.M. Walker, S.M. Vuong and S.L. Anna, "Characterization of phase behavior and gelation of colloidal suspensions in microscale drops," presented at the *89th ACS Colloid and Surface Science Symposium*, Pittsburgh, PA, June 2015.
135. L. D'Costa, A.P. Kotula, S.L. Anna and L.M. Walker, "Interfacial dynamics and mechanics of nanoparticles of varying colloidal properties," poster presented at the *89th ACS Colloid and Surface Science Symposium*, Pittsburgh, PA, June 2015.
134. C.W. Nelson and S.L. Anna, "A high throughput droplet-based platform for measuring partition coefficients in aqueous two phase systems by absorption spectroscopy," presented at the *89th ACS Colloid and Surface Science Symposium*, Pittsburgh, PA, June 2015.

133. A.P. Kotula, S.M. Kirby, T. Moyle, L.M. Walker and S.L. Anna, "Dilatational modulus of irreversibly adsorbed layers at complex fluid interfaces," presented at the *89th ACS Colloid and Surface Science Symposium*, Pittsburgh, PA, June 2015.
132. C. Gupta, S.M. Kirby, S.L. Anna, and N. Washburn, "Anomalous interfacial dynamics of polymer-grafted lignin surfactants probed with microtensiometry," presented at the *89th ACS Colloid and Surface Science Symposium*, Pittsburgh, PA, June 2015.
131. B. Bleier, S.L. Anna and L.M. Walker, "Determining critical dispersant concentration of colloidal suspensions in nonpolar media via droplet based microfluidics," presented at the *89th ACS Colloid and Surface Science Symposium*, Pittsburgh, PA, June 2015.
130. S.M. Kirby, X. Zhang, P. Russo, L.M. Walker and S.L. Anna "Interfacial tension dynamics and interfacial mechanics of the hydrophobin cerato-ulmin," presented at the *89th ACS Colloid and Surface Science Symposium*, Pittsburgh, PA, June 2015.
129. C.W. Nelson and S.L. Anna, "Dehydration driven wetting transitions of aqueous two phase droplets in a microfluidic device," presented at the *89th ACS Colloid and Surface Science Symposium*, Pittsburgh, PA, June 2015.
128. Y. Zhang, D. Chatain, S.L. Anna, and S. Garoff, "Stability analysis of compound sessile drops at non-zero bond number," presented at the *89th ACS Colloid and Surface Science Symposium*, Pittsburgh, PA, June 2015.
127. X. Zhang, S.M. Kirby, S.L. Anna, L.M. Walker and P. Russo, "Self-assembly and absorption behavior of *Cerato-ulmin* hydrophobin proteins at air-water and oil-water interfaces," presented at the *89th ACS Colloid and Surface Science Symposium*, Pittsburgh, PA, June 2015.
126. S.M. Vuong, B.J. Bleier, S.L. Anna, and L.M. Walker, "Probing Colloidal Aggregation through Concentrating Processes in Microscale Droplet Reactors," presented at the *American Institute of Chemical Engineers Annual Meeting*, Atlanta, GA, November 2014. Identified as "Best Presentation" of the *Colloidal Hydrodynamics Session in Area 01J Fluid Mechanics*.
125. S.M. Vuong, B.J. Bleier, S.L. Anna, and L.M. Walker, "Probing colloidal flocculation during solvent removal in microscale droplet reactors," presented at the *Society of Rheology Annual Meeting*, Philadelphia, PA, October 2014.
124. A. Kotula and S.L. Anna, "Generation of stable non-spherical capsules with controlled interfacial coverage of surface-active particles," presented at the *Society of Rheology Annual Meeting*, Philadelphia, PA, October 2014.
123. B.J. Bleier, S.M. Vuong, S.L. Anna, and L.M. Walker, "Probing Colloidal Flocculation During Solvent Removal in Microscale Droplet Reactors," poster presented at the *ACS Colloid and Surface Science Symposium*, Philadelphia, PA, June 2014.

122. T.M. Moyle, L.M. Walker, and S.L. Anna, "Size measurements of sub-micron droplets generated via tipstreaming and the effect of altering operating conditions," presented at the *ACS Colloid and Surface Science Symposium*, Philadelphia, PA, June 2014.
121. A.P. Kotula and S. L. Anna, "Generation of monodisperse particle-stabilized bubbles with similar nonspherical shape controlled by particle loading at the interface," presented at the *ACS Colloid and Surface Science Symposium*, Philadelphia, PA, June 2014.
120. A.P. Kotula and S. L. Anna, "Dilatational properties of insoluble monolayers examined by oscillating microbubble," presented at the *ACS Colloid and Surface Science Symposium*, Philadelphia, PA, June 2014.
119. C.W. Nelson and S. L. Anna, "Phase separation and de-wetting of aqueous two phase systems in a microfluidic droplet array," presented at the *ACS Colloid and Surface Science Symposium*, Philadelphia, PA, June 2014.
118. S.M. Kirby, S. L. Anna, and L.M. Walker, "Sequential adsorption behavior of a model dispersant-biosurfactant system at an oil/aqueous interface," presented at the *ACS Colloid and Surface Science Symposium*, Philadelphia, PA, June 2014.
117. Y. Zhang, S. L. Anna, D. Chatain and S. Garoff, "Competition of interfacial and gravitational energies in determining the configuration of a compound sessile drop," presented at the *ACS Colloid and Surface Science Symposium*, Philadelphia, PA, June 2014.
116. S.M. Vuong, S.L. Anna, L.M. Walker, "Microfluidic platform for characterization of phase behavior and gelation in colloidal suspensions," presented at the *17th U.S. National Congress on Theoretical & Applied Mechanics*, East Lansing, MI, June 2014.
115. A.P. Kotula, C.W. Nelson, and S.L. Anna, "Controlled generation of monodisperse particle-stabilized droplets with arbitrary interfacial coverage," presented at the *17th U.S. National Congress on Theoretical & Applied Mechanics*, East Lansing, MI, June 2014.
114. S.M. Kirby, S.L. Anna, and L.M. Walker, "Sequential adsorption studies of Tween 80 and Aerosol-OT at an oil/aqueous interface," presented at the *Gulf of Mexico Oil Spill & Ecosystem Science Conference*, Mobile, AL, January 2014.
113. L.M. Walker, M.D. Reichert, S.L. Anna, "Complex surfactant layers at fluid-fluid interfaces and the impact on droplet coalescence," presented at the *Gulf of Mexico Oil Spill & Ecosystem Science Conference*, Mobile, AL, January 2014.
112. T.M. Moyle, L.M. Walker, and S.L. Anna, "Tipstreaming from the rear of surfactant laden droplets traveling through a microchannel," presented at the *APS-DFD Annual Meeting*, Pittsburgh, PA, November 2013.

111. C.W. Nelson and S.L. Anna, “Dehydration induced phase transitions in a microfluidic droplet array for the separation of biomolecules,” presented at the *APS-DFD Annual Meeting*, Pittsburgh, PA, November 2013.
110. S.M. Vuong, L.M. Walker and S.L. Anna, “Controlled Gelation of Particle Suspensions Using Controlled Solvent Removal in Picoliter Droplets,” presented at the *APS-DFD Annual Meeting*, Pittsburgh, PA, November 2013.
109. A.P. Kotula, C.W. Nelson and S.L. Anna, “Controlled generation of monodisperse particle-stabilized droplets with arbitrary interfacial coverage,” presented at the *APS-DFD Annual Meeting*, Pittsburgh, PA, November 2013.
108. Y. Zhang, S.D. Oberdick, S. Garoff and S.L. Anna, “Gravity driven current during sessile drop coalescence on a surface,” presented at the *APS-DFD Meeting*, Pittsburgh, PA, November 2013.
107. A.P. Kotula and S.L. Anna, “Probing Dilatational Interfacial Stresses of Complex Interfaces Using a Microscale Spherical Bubble,” presented at the *AIChE Annual Meeting*, San Francisco, CA, November 2013.
106. A.P. Kotula, C.W. Nelson and S.L. Anna, “Controlled generation of monodisperse particle-stabilized droplets with arbitrary interfacial coverage,” presented at the *AIChE Annual Meeting*, San Francisco, CA, November 2013.
105. A.P. Kotula and S.L. Anna, “Probing Dilatational Interfacial Stresses of Complex Interfaces Using a Microscale Spherical Bubble,” presented at the *Society of Rheology Annual Meeting*, Montreal, Quebec, Canada, October 2013.
104. A.P. Kotula and S.L. Anna, “Linear stability of oscillating pinned bubbles in interfacial rheological measurements,” presented at the *Society of Rheology Annual Meeting*, Pasadena, CA, February 2013.
103. M.D. Reichert, S.L. Anna, and L.M. Walker, “Relating Interfacial Mechanics and Coalescence Behavior of Irreversibly Adsorbed Tween-80 Layers at Oil/Water Interfaces,” presented at the *Gulf of Mexico Oil Spill & Ecosystem Science Conference*, New Orleans, LA, January 21 – 23, 2013.
102. M.D. Reichert, N.J. Alvarez, L.M. Walker and S.L. Anna, “Microscale interfaces as a tool for characterizing complex interfacial systems,” presented at the *Gulf of Mexico Oil Spill & Ecosystem Science Conference*, New Orleans, LA, January 21 – 23, 2013.
101. A.P. Kotula and S.L. Anna, “Interfacial Rheology of an Oscillating Spherical Cap,” presented at the *AIChE Annual Meeting*, Pittsburgh, PA, October 2012.
100. M.D. Reichert, S.L. Anna, and L.M. Walker, “Surfactant Transport, Interfacial Rheology, and Film Drainage of a Model Oil-Dispersant-Aqueous System,” presented at the *AIChE Annual Meeting*, Pittsburgh, PA, October 2012.

99. A.P. Kotula and S.L. Anna, "The Dynamics and Break-up of Confined Bubbles Translating in Surface-Active Colloidal Dispersions," presented at the *AIChE Annual Meeting*, Pittsburgh, PA, October 2012.
98. T.M. Moyle, L.M. Walker, and S.L. Anna, "Modeling, Predicting, and Controlling Microscale Tipstreaming," presented at the *AIChE Annual Meeting*, Pittsburgh, PA, October 2012.
97. N. Asermely, S.L. Anna, and L.M. Walker, "Microscale Transport with Application to Sensing Stability in Non-Aqueous Suspensions," presented at the *AIChE Annual Meeting*, Pittsburgh, PA, October 2012.
96. Y. Zhang, S. Oberdick, S. Garoff, and S.L. Anna, "Mixing in Sessile Drops Merging On a Surface," presented at the *AIChE Annual Meeting*, Pittsburgh, PA, October 2012.
95. A.P. Kotula and S.L. Anna, "Dynamics of adsorption of particles to fluid-fluid interfaces in a microchannel," to be presented at the *86th ACS Colloid and Surface Science Symposium*, Johns Hopkins University, Baltimore, MD, June 2012. Selected for the Langmuir Student Awards Topical Session.
94. T.M. Moyle, L.M. Walker, and S.L. Anna, "A Predictive Model to Estimate Operating Conditions for Microscale Tipstreaming," to be presented at the *86th ACS Colloid and Surface Science Symposium*, Johns Hopkins University, Baltimore, MD, June 2012.
93. A.P. Kotula, M.D. Reichert, L.M. Walker, and S.L. Anna, "Measurement of Interfacial Elasticity Using a Microscale Tensiometer," to be presented at the *86th ACS Colloid and Surface Science Symposium*, Johns Hopkins University, Baltimore, MD, June 2012.
92. A.P. Kotula and S.L. Anna, "Dynamic adsorption of micro- and nanoparticles to fluid-fluid interfaces in a microchannel," presented at the *243rd ACS National Meeting*, San Diego, CA, March 2012.
91. L.M. Walker, M.D. Reichert and S.L. Anna, "Quantification of the interfacial dynamics of a model oil-brine-dispersant system for improved surfactant design," presented at the *243rd ACS National Meeting*, San Diego, CA, March 2012.
90. Y. Zhang, S. Oberdick, S. Garoff, and S.L. Anna, "Mixing in Sessile Drops Merging on a Surface," presented at the *APS Division of Fluid Dynamics Annual Meeting*, Baltimore, MD, November 2011.
89. N.J. Alvarez, D.R. Vogus, L.M. Walker, and S.L. Anna, "Using Bulk Convection to Approach Kinetic-Limited Surfactant Dynamics," presented at the *APS Division of Fluid Dynamics Annual Meeting*, Baltimore, MD, November 2011.

88. N.J. Alvarez, M.D. Reichert, L.M. Walker, and S.L. Anna, "The Effect of Curvature and Finite Bulk Solution Volume On Surfactant Dynamics," presented at the *AIChE Annual Meeting*, Minneapolis, MN, October 2011.
87. N.J. Alvarez, D.R. Vogus, L.M. Walker, and S.L. Anna, "Using Bulk Convection to Approach Kinetic-Limited Surfactant Dynamics," presented at the *AIChE Annual Meeting*, Minneapolis, MN, October 2011.
86. S.M. Vuong and S.L. Anna, "Tuning Bubbly Structures in Microchannels," presented at the *Society of Rheology Annual Meeting*, Cleveland, OH, October 2011.
85. A.P. Kotula, S.M. Vuong, M.D. Reichert, L.M. Walker, S.L. Anna, "A comparison of the quiescent stability and structural rearrangement of particle-stabilized and surfactant-stabilized 2D foams," poster presented at the *Society of Rheology Annual Meeting*, Cleveland, OH, October 2011.
84. N.J. Alvarez, T. Saigal, R.D. Tilton, S.L. Anna, L.M. Walker, "Transport and interfacial rheology of polymer-grafted nanoparticles at air-water and oil-water interfaces," presented at the *Society of Rheology Annual Meeting*, Cleveland, OH, October 2011.
83. M.D. Reichert, N.J. Alvarez, S.L. Anna, L.M. Walker, "Quantification of the interfacial rheology of a model oil-brine-dispersant system at microscale interfaces," presented at the *Society of Rheology Annual Meeting*, Cleveland, OH, October 2011.
82. S. Chatterjee and S.L. Anna, "The interaction of topological defects with shear flows in thermotropic smectic liquid crystals," presented at the *Society of Rheology Annual Meeting*, Cleveland, OH, October 2011.
81. S.M. Vuong and S.L. Anna, "Tuning Bubbly Structures in Microchannels," presented as a poster at the *2011 Gordon Research Conference on Physics and Chemistry of Microfluidics*, Waterville Valley, NH, June 2011.
80. N.J. Alvarez, T. Moyle, W. Lee, L.M. Walker, S.L. Anna, "Kinetic limited transport of soluble surfactants in microscale tipstreaming," presented at the *85th ACS Colloid and Surface Science Symposium*, Montreal, Canada, June 2011.
79. N.J. Alvarez, D. Vogus, L.M. Walker, S.L. Anna, "Kinetic-limited transport of surfactant at the air-water interface," presented at the *85th ACS Colloid and Surface Science Symposium*, Montreal, Canada, June 2011.
78. N.J. Alvarez, T. Saigal, R.D. Tilton, S.L. Anna, L.M. Walker "Dynamic interfacial tension and interfacial rheology of polymer grafted nanoparticles at the air-water and xylene-water interface," presented at the *85th ACS Colloid and Surface Science Symposium*, Montreal, Canada, June 2011.

77. A.P. Kotula, Y. Oh, K.H. Kim, M.F. Islam, S.L. Anna, "Determining Permeability Using Droplet Imbibition in Fiber Networks," presented at the *85th ACS Colloid and Surface Science Symposium*, Montreal, Canada, June 2011.
76. R.D. Tilton, K. Matyjaszewski, S.L. Anna, L.M. Walker, P.C. Contact, A. Dédinaite, E. Thormann, G. Dunér, N.J. Alvarez, T. Saigal, "Interfacial properties and applications of polymer-grafted nanoparticles", presented at the *ACS Fall National Meeting*, Denver, CO, August 2011.
75. N.J. Alvarez, R.D. Tilton, S.L. Anna, L.M. Walker "Interfacial rheology and dynamic behavior of polymer grafted nanoparticles at the air-water interface," presented at the *241st ACS National Meeting*, Anaheim, CA, March 2011.
74. N.J. Alvarez, W. Lee, L.M. Walker, S.L. Anna, "Surfactant adsorption timescales in microfluidic droplet formation," presented at the *241st ACS National Meeting*, Anaheim, CA, March 2011.
73. S.L. Anna, N.J. Alvarez, W. Lee, and L.M. Walker, "The onset of microscale tipstreaming with soluble nonionic surfactants," presented at the *APS Division of Fluid Dynamics Annual Meeting*, Long Beach, CA, November 2010.
72. N.J. Alvarez, D. Vogus, L.M. Walker, and S.L. Anna, "Using Convective Flow to Reach the Kinetic Limit of Surfactant Transport to a Stationary Microbubble," presented at the *APS Division of Fluid Dynamics Annual Meeting*, Long Beach, CA, November 2010.
71. N.J. Alvarez, S.L. Anna, and L.M. Walker, "The Role of Diffusion in Dynamic Interfacial Tension Data: The Transition From Diffusion-Limited to Kinetic-Limited Dynamics," presented at the *AIChE Annual Meeting*, Salt Lake City, UT, November 2010.
70. N.J. Alvarez, S.L. Anna, and L.M. Walker, "Low Concentration Dynamic Surface Tension Measurements of Macromolecular Systems," presented at the *AIChE Annual Meeting*, Salt Lake City, UT, November 2010.
69. N.J. Alvarez, D. Vogus, S.L. Anna, and L.M. Walker, "Effect of Low-Reynolds Number Flow On Surfactant Transport to a Stationary Spherical Cap: Experiments and Theory," Fluid Mechanics Poster Session, presented at the *AIChE Annual Meeting*, Salt Lake City, UT, November 2010.
68. S.L. Anna, N.J. Alvarez, W. Lee, and L.M. Walker, "The Role of Surfactant Mass Transport in the Formation of Microscale Droplets," presented at the *AIChE Annual Meeting*, Salt Lake City, UT, November 2010.
67. W. Lee, L.M. Walker, and S.L. Anna, "Cooperative effects of surfactant and viscoelasticity in microscale thread formation," presented at the *Society of Rheology Annual Meeting*, Santa Fe, NM, October 2010.

66. S. Chatterjee and S.L. Anna, "Shear Induced Ordering of Defect Textures arising from the Undulation Instability of Layered Fluids," presented at the *Society of Rheology Annual Meeting*, Santa Fe, NM, October 2010.
65. S.L. Anna, W. Lee, N.J. Alvarez, and L.M. Walker, "Role of surfactant mass transport in the formation of microscale droplets," presented at the *84th Annual ACS Colloid and Surface Science Symposium*, Akron, OH, June 2010.
64. N.J. Alvarez, L.M. Walker, and S.L. Anna, "The Diffusion-Limited Transport Timescale: Effect of Curvature and Finite Bulk Solution Volume," presented at the *84th Annual ACS Colloid and Surface Science Symposium*, Akron, OH, June 2010.
63. N.J. Alvarez, W. Lee, L.M. Walker, and S.L. Anna, "A Comparison of Nonionic Surfactant Dynamics at the Oil-Water and the Air-Water Interface," presented at the *84th Annual ACS Colloid and Surface Science Symposium*, Akron, OH, June 2010.
62. S.L. Anna, W. Lee, N.J. Alvarez, and L.M. Walker, "The Impact of Surfactant Sorption Kinetics on Microscale Tipstreaming," presented at the Banff international Research Station (BIRS) workshop "Small scale hydrodynamics: theory and application in microfluidics and thin films" Banff, Canada, February 7 – 12, 2010.
61. N.J. Alvarez, S.L. Anna, and L.M. Walker, "Microtensiometer to directly probe kinetic adsorption constants," presented at the *AIChE Annual Meeting*, Nashville, TN, November 2009.
60. W. Lee, N.J. Alvarez, S.L. Anna, and L.M. Walker, "Adsorption Kinetics of Alkyl Polyethylene Oxide Surfactants at the Water-Oil Interface," presented at the *AIChE Annual Meeting*, Nashville, TN, November 2009.
59. G.F. Christopher and S.L. Anna, "Passive breakup of viscoelastic droplets and filament self-thinning at a microfluidic T-junction," presented at the *AIChE Annual Meeting*, Nashville, TN, November 2009.
58. S. Chatterjee and S.L. Anna, "Microscale shear flow of focal conic defects in layered liquids," presented at the *AIChE Annual Meeting*, Nashville, TN, November 2009.
57. W. Lee, K. Schrank, L.M. Walker, and S.L. Anna, "Separation and Stabilization of Deformable Drops in Microfluidics," presented at the *APS Division of Fluid Dynamics Annual Meeting*, Minneapolis, MN, November 2009.
56. S.L. Anna, P. Kang, S. Shojaei-Zadeh, and C. Appleby, "Forced Spreading and Coalescence of Viscous Drops," presented at the *APS Division of Fluid Dynamics Annual Meeting*, Minneapolis, MN, November 2009.
55. W. Lee, L.M. Walker, and S.L. Anna, "Control of Filament Formation in Flow Focusing," presented at the *Society of Rheology Annual Meeting*, Madison, WI, October 2009.

54. G.F. Christopher and S.L. Anna, "Passive breakup of viscoelastic droplets and filament self-thinning at a microfluidic T-junction," presented at the *Society of Rheology Annual Meeting*, Madison, WI, October 2009.
53. S. Chatterjee and S.L. Anna, "Microscale shear flow of focal conic defects in layered liquids," presented at the *Society of Rheology Annual Meeting*, Madison, WI, October 2009.
52. S.L. Anna and S. Chatterjee, "Microscale shear flow of focal conic defects in layered liquids," presented at the *Institute for Mathematics and its Applications Workshop: Flowing Complex Fluids: Fluid Mechanics – Interaction of Microstructure and Flow*, Minneapolis, MN, October 2009.
51. Y. Wei, P. Kang, S.L. Anna, S. Garoff, E. Ramé, and L. M. Walker, "Wetting by Non-Newtonian Fluids," presented at the *IACIS International Conference and ACS Colloid & Surface Science Symposium*, New York City, NY, June 2009.
50. N.J. Alvarez, S.L. Anna, and L.M. Walker, "Kinetically Controlled Adsorption to Freshly Formed Interfaces," presented at the *IACIS International Conference and ACS Colloid & Surface Science Symposium*, New York City, NY, June 2009.
49. W. Lee, L.M. Walker, and S.L. Anna, "Impact of Surfactant Sorption Kinetics on Microscale Tipstreaming," presented at the *IACIS International Conference and ACS Colloid & Surface Science Symposium*, New York City, NY, June 2009.
48. N.J. Alvarez, S.L. Anna, and L.M. Walker, "Kinetically Controlled Adsorption to Freshly Formed Interfaces," presented at the *APS March Meeting*, Pittsburgh, PA, March 2009.
47. S. Chatterjee and S.L. Anna, "Behavior of Focal Conic Defects in Shear Flow," presented at the *APS March Meeting*, Pittsburgh, PA, March 2009.
46. W. Lee, L.M. Walker, and S.L. Anna, "Impact of Surfactant Sorption Kinetics on Microscale Tipstreaming," presented at the *APS March Meeting*, Pittsburgh, PA, March 2009.
45. P. Kang, S. Shojaei-Zadeh, C. Appleby, and S.L. Anna, "Scaling Law for Driven Spreading and Coalescence of Droplets on a Surface," presented at the *APS March Meeting*, Pittsburgh, PA, March 2009.
44. M. Ferer, Shelley L. Anna, Paul Tortora, J. R. Kadambi, M. Oliver, Grant S. Bromhal, and Duane H. Smith, "Crossover from fractal advance to compact advance: predictions, modeling and experiment," *"Challenges of Porous Media" Inaugural Meeting of Interpore*, Kaiserslautern, Germany, March 11-14, 2009.
43. W. Lee, L.M. Walker, and S.L. Anna, "Impact of Surfactant Sorption Kinetics on Microscale Tipstreaming," *Conference on Advances in Microfluidics and Nanofluidics*, Hong Kong, January 5, 2009.

42. S.L. Anna, L.M. Walker, and W. Lee, "The Role of Surfactant Dynamics on Tipstreaming in Planar Flow Focusing," presented at the *61st Annual Meeting of the APS Division of Fluid Dynamics*, San Antonio, TX, November 2008.
41. W. Lee, S.L. Anna, and L.M. Walker, "The Dynamics of Tipstreaming in Microfluidic Flow Focusing Devices," presented at the *AIChE Annual Meeting*, Philadelphia, PA, November 2008.
40. P. Tortora, S.L. Anna, M. Ferer, G. Bromhal, and D. Smith, "The effect of viscosity ratio on immiscible viscous fingering in model porous networks," presented at *The XVII International Conference on Computational Methods in Water Resources*, Session on Pore Scale Reactive Transport Modeling and Upscaling To the Continuum Scale, San Francisco, CA, July 2008.
39. W. Lee, S.L. Anna, and L.M. Walker, "Impact of Surfactant Desorption Kinetics on Microscale Tipstreaming," presented at the *82nd Annual ACS Colloid and Surface Science Symposium*, Raleigh, NC, June 2008.
38. N. Alvarez, S.L. Anna, and L.M. Walker, "The Effect of Residence Time on the Synthesis of Gold Particles in a Microfluidic Network," presented at the *82nd Annual ACS Colloid and Surface Science Symposium*, Raleigh, NC, June 2008.
37. S. Shojaei-Zadeh and S.L. Anna, "A Constant Volume Process for Forming Highly Ordered Microporous PDMS Films," presented at the *82nd Annual ACS Colloid and Surface Science Symposium*, Raleigh, NC, June 2008.
36. S.L. Anna, W. Lee and L. Walker, "Dynamics of Microscale Tipstreaming", presented at the *60th Annual Meeting of the APS Division of Fluid Dynamics*, Salt Lake City, UT, November 2007.
35. S. Shojaei-Zadeh and S.L. Anna, "A Microfluidic Network for Investigating the Flow of Layered Liquids in Confinement," presented at the *60th Annual Meeting of the APS Division of Fluid Dynamics*, Salt Lake City, UT, November 2007.
34. P. Tortora, S.L. Anna, M. Ferer, G. Bromhal, and D. Smith, "Experimental observation of fluid invasion in model porous networks", presented at the *AIChE Annual Meeting*, Salt Lake City, UT, November 2007.
33. S.L. Anna, W. Lee and L. Walker, "Role of Desorption Kinetics in Surfactant-Mediated Microscale Tipstreaming", presented at the *AIChE Annual Meeting*, Salt Lake City, UT, November 2007.
32. G.F. Christopher and S.L. Anna, "Dynamics of Microfluidic Droplet Breakup of Viscoelastic Polymer Solutions", presented at the *Society of Rheology Annual Meeting*, Salt Lake City, UT, October 2007.

31. S.L. Anna, W. Lee and L. Walker, "Role of Desorption Kinetics in Surfactant-Mediated Microscale Tipstreaming", presented at the *Society of Rheology Annual Meeting*, Salt Lake City, UT, October 2007.
30. W. Lee, S.L. Anna, and L.M. Walker, "Extending the Threads in Surfactant-Mediated Microscale Tipstreaming," presented at the *81st Annual ACS Colloid and Surface Science Symposium*, Newark, DE, June 2007.
29. S. Shojaei-Zadeh, C. Appleby, and S.L. Anna, "Driven Coalescence of Sessile Drops on PDMS Surfaces," presented at the *59th Annual Meeting of the APS Division of Fluid Dynamics*, Tampa, FL, November 2006.
28. G.F. Christopher, J. Bergstein, N.B. End, and S.L. Anna, "Coalescence of Droplets in Microfluidic Channels," presented at the *59th Annual Meeting of the APS Division of Fluid Dynamics*, Tampa, FL, November 2006.
27. N. Noharuddin, G.F. Christopher, and S.L. Anna, "On the Effects of Channel Geometry and Long Scale Time Dependence on Microfluidic Drop Breakup," presented at the *59th Annual Meeting of the APS Division of Fluid Dynamics*, Tampa, FL, November 2006.
26. S. Shojaei-Zadeh and S.L. Anna, "Effect of focal conic defects in flow of smectic-A liquid crystals in a microchannel," presented at the *78th Annual Meeting of the Society of Rheology*, Portland, ME, October 2006.
25. G.F. Christopher and S.L. Anna, "Physical properties of shear gel particles created using microfluidic channels," presented at the *78th Annual Meeting of the Society of Rheology*, Portland, ME, October 2006.
24. G.F. Christopher, N. Noharuddin, N.B. End, E.L. Johnson, and S.L. Anna, "Control Of Droplet Breakup And Coalescence At Microfluidic Junctions," presented at the *15th U.S. National Congress of Theoretical and Applied Mechanics*, Mini-Symposium on Jet, Drop, and Bubble Breakup in Small-Scale Flows, Boulder, CO, June 2006.
23. S. Shojaei-Zadeh and S.L. Anna, "In-situ Generation of Focal Conic Defects in Flow of Smectic-A Liquid Crystals in Microchannels," presented at the *American Physical Society March Meeting*, Baltimore, MD, March 2006.
22. H.C. Mayer and S.L. Anna, "Observations of Tipstreaming in a Flow Focusing Microfluidic Device," presented at the *American Physical Society Division of Fluid Dynamics 58th Annual Meeting*, Chicago, IL, November 2005.
21. G.F. Christopher, N. Noharuddin, and S.L. Anna, "Time dependence of 'local' capillary number during droplet breakup in a microfluidic T junction," presented at the *American Physical Society Division of Fluid Dynamics 58th Annual Meeting*, Chicago, IL, November 2005.

20. H.C. Mayer and S.L. Anna, "Observations of Tipstreaming in a Flow Focusing Microfluidic Device," presented at the *American Institute of Chemical Engineers Annual Meeting*, Cincinnati, OH, November 2005.
19. G.F. Christopher and S.L. Anna, "Formation of Microspheres Using a Heat Sensitive Gel in a Microfluidic Device," presented at the *77th Annual Society of Rheology Annual Meeting*, Vancouver, BC, October 16-20, 2005.
18. H. Mayer and S.L. Anna, "Experimental observations of dynamic surface tension at highly curved microfluidic interfaces," presented at the *79th ACS Colloid and Surface Science Symposium*, Clarkson University, June 2005.
17. S. Shojaei-zadeh and S.L. Anna, "A Novel Method for Controlling the Size and Spatial Order of Defect Domains in a Smectic A Liquid Crystal," presented at the *79th ACS Colloid and Surface Science Symposium*, Clarkson University, June 2005.
16. S.L. Anna, A.J. Greiner, J.A. Taylor, and G.F. Christopher, "Synthesis of Droplets via Shear-Dominated Flows in Microfluidic Devices," presented at the *79th ACS Colloid and Surface Science Symposium*, Clarkson University, June 2005.
15. S.L. Anna and H. Mayer, "A Microfluidic Tensiometer," presented at the *APS March Meeting*, Los Angeles, CA, March 2005.
14. A.J. Greiner, J.A. Taylor, G.F. Christopher, and S.L. Anna, "Synthesis of Newtonian and Polymeric Droplets via Shear-Dominated Flows in Microfluidic Devices," presented at the *76th Annual Meeting of the Society of Rheology*, Lubbock, TX, February 2005.
13. A.J. Greiner and S.L. Anna, "Tailor Making Polymer Droplets in Microfluidic Devices," *American Institute of Chemical Engineers Annual Meeting*, Austin, TX, November 2004.
12. S.L. Anna, D.R. Link, H.A. Stone, and D.A. Weitz, "Geometrically Mediated Breakup of Drops in Microfluidic Devices," presented at the *American Physical Society Division of Fluid Dynamics 56th Annual Meeting*, Meadowlands, NJ, November 2003.
11. S.L. Anna, D.R. Link, H.A. Stone, and D.A. Weitz, "Geometrically Mediated Breakup of Drops in Microfluidic Devices," presented at the *Society of Rheology Annual Meeting*, Pittsburgh, PA, October 2003.
10. S.L. Anna, N. Bontoux, and H.A. Stone, "Formation of Dispersions Using 'Flow-Focusing' in Microchannels," presented at the *American Physical Society Division of Fluid Dynamics 55th Annual Meeting*, Dallas, TX, November 2002.
9. S.L. Anna and H.A. Stone, "Microstructural Control of Dispersions Using Microfluidic Devices," *American Institute of Chemical Engineers Annual Meeting*, Indianapolis, IN, November 2002.

8. S.L. Anna, N. Bontoux, and H.A. Stone, "Formation of Dispersions Using 'Flow-Focusing' in Microchannels," poster presented at the *Microfluidics in the 21st Century Workshop*, Institute for Pure and Applied Mathematics, University of California Los Angeles, Los Angeles, CA, November 2002.
7. S.L. Anna, N. Bontoux, and H.A. Stone, "Formation of Dispersions Using 'Flow-Focusing' in Microchannels," poster at the *Gordon Research Conference on Complex Fluids*, Oxford, UK, June 2002.
6. S.L. Anna and G.H. McKinley, "Quantifying the Stretching and Breakup of Dilute Polymer Solutions in Two Different Filament Stretching Experiments," *American Institute of Chemical Engineers Annual Meeting*, Dallas, TX, November 1999.
5. S.L. Anna, M. Yao, and G.H. McKinley, "The Effect of a Known Pre-shear History on the Transient Stress Growth in Uniaxial Elongational Flows of Dilute Polymer Solutions," presented at *Society of Rheology Annual Meeting*, Madison, WI, October 1999.
4. S.L. Anna, G.H. McKinley, D.A. Nguyen, T. Sridhar, S.J. Muller, J. Huang, and D.F. James, "An Inter-laboratory Comparison of Measurements from Filament-Stretching Rheometers Using Common Test Fluids," presented at *Society of Rheology Annual Meeting*, Madison, WI, October 1999.
3. S.L. Anna, M. Yao, and G.H. McKinley, "Necking and Breakup of Viscoelastic Fluid Filaments in Filament Stretching Devices During Stretching and Subsequent Stress Relaxation," presented at *Society of Rheology Annual Meeting*, Monterey, CA, October 1998.
2. S.L. Anna, C. Rogers, and G.H. McKinley, "Transient Extensional Rheometry of Viscoelastic Fluids Using a Real-Time Active Control Mechanism in a Filament Stretching Rheometer," presented at *Mechanics of Nonlinear Materials Conference*, Banff, Canada, May 1998.
1. S.L. Anna, S.H. Spiegelberg, and G.H. McKinley, "Transient Extensional Rheology of Polystyrene and Polyacrylamide Boger Fluids and the Effects of Salt Concentration on the Extensibility of PAA Macromolecules," presented at *Society of Rheology Annual Meeting*, Galveston, TX, February 1997. Received a Student Travel Grant from the Society of Rheology.

Government Committees, Civic Appointments, Board Memberships

1. Society Representative for Society of Rheology, U.S. National Committee on Theoretical and Applied Mechanics January 1, 2018 to present

2. Member, Panel on Review of the Physical Measurement Laboratory at the National Institute of Standards and Technology, appointed by the National Research Council, held at NIST, Gaithersburg, MD, September 29 – October 1, 2015.
3. Invited Participant, Workshop “Complex Fluids and Complex Flows” at the Institute for Mathematics and Its Applications (IMA), University of Minnesota, Minneapolis, MN, October 12 – 16, 2009 (“Flowing Complex Fluids: Fluid Mechanics-Interaction of Microstructure and Flow”) **and** December 5 – 12, 2009 (“Microfluidics: Electrokinetic and Interfacial Phenomena”).
4. Selected to attend the National Academies of Engineering 2008 U.S. Frontiers of Engineering Symposium, Sandia National Laboratories, Albuquerque, NM, September 18-20, 2008.
5. *National Science Foundation Workshop for Frontiers in Transport Phenomena Research & Education: Energy Systems, Biological Systems, Security, Information Technology & Nanotechnology*, University of Connecticut, Storrs, CT, May 17-18, 2007.

Membership and Activities in Honorary Fraternities, Professional Societies

1. *Chair-Elect*, American Physical Society Division of Fluid Dynamics, 2019 – 2020. Will serve as Chair and Past Chair in subsequent years.
2. *Vice Chair*, American Physical Society Division of Fluid Dynamics, 2018 – 2019.
3. *Chair, Diversity in Nominations Committee*, American Physical Society Division of Fluid Dynamics, 2017 – 2018.
4. *Vice Chair, Diversity in Nominations Committee*, American Physical Society Division of Fluid Dynamics, 2016 – 2017.
5. *Member, Metzner Award Committee*, Society of Rheology, 2017 – 2019.
6. *Fluid Dynamics Prize Selection Committee*, American Physical Society, 2015.
7. *Chair, Fluid Mechanics Programming Committee*, Area 01J Fundamentals in Fluid Mechanics, American Institute of Chemical Engineers, Elected Term: 2012 – 2014.
8. *Member at Large*, Executive Committee, Society of Rheology, 2011-2013. As Member-at-Large, participated in selection of *Journal of Rheology* publication award for 2012 – 2014.
9. *Member at Large*, Executive Committee, American Physical Society Division of Fluid Dynamics, 2014-2017.

10. *Chair, Andreas Acrivos Dissertation Award Selection Committee*, APS Division of Fluid Dynamics, 2012.
11. *Vice Chair, Fluid Mechanics Programming Committee*, Area 01J Fundamentals in Fluid Mechanics, American Institute of Chemical Engineers, Elected Term: 2010 – 2012.
12. *Vice Chair, Acrivos Dissertation Award Selection Committee*, APS Division of Fluid Dynamics, 2011.
13. *Chair, Membership Committee*, Society of Rheology, committee member 2005-2008, chair 2008-2011. Proposed and implemented PhD student member graduation gift.
14. *Fluid Mechanics Programming Committee Member*, Area 01J Fundamentals in Fluid Mechanics, American Institute of Chemical Engineers, Elected Term: 2006 – 2016.
15. *Member*, American Association for the Advancement of Science, since 2018.
16. *Member*, American Chemical Society, since 2011.
17. *Member*, American Society of Mechanical Engineers, 2004 – 2016.
18. *Member*, American Physical Society, since 2001.
19. *Member*, American Institute of Chemical Engineers, since 1999.
20. *Member*, Society of Rheology, since 1995.

Editorial Roles on Publications, Major Activities in Professional Meetings

1. Editorial Board, *Physical Review Fluids*, August 2018 to July 31, 2021.
2. Associate Editor, *Physical Review Fluids*, February 2016 to July 2018.
3. Associate Editor, *Physics of Fluids*, August 2014 to February 2016.
4. Chair, *Gordon Research Conference on Physics & Chemistry of Microfluidics*, June 2015. With J. Posner.
5. Vice Chair, *Gordon Research Conference on Physics & Chemistry of Microfluidics*, July 2013. With J. Posner.
6. Technical Program Organizer, Society of Rheology Annual Meeting, Pasadena, CA, February 10 – 14, 2013. With Carlos Rinaldi.
7. Discussion Leader, *Gordon Research Conference on Physics & Chemistry of Microfluidics*, Waterville Valley, NH, June 26 – July 1, 2011.

8. Meeting Program Coordinator, Area 01J Fundamentals in Fluid Mechanics, American Institute of Chemical Engineers, for the *AIChE Annual Meeting*, Salt Lake City, UT, November 2010. As part of this position, I obtained \$2000 sponsorship from Proctor & Gamble for a student/postdoctoral poster competition.
9. Reviewer: Physics of Fluids, Physical Review Letters, Physical Review E, Journal of Non-Newtonian Fluid Mechanics, Langmuir, Journal of Rheology, Colloids and Surfaces A, Industrial Chemical and Engineering Research, Nanotechnology, Technical Papers for IMECE Congress, IEEE Transactions on CAD, Journal of Physics D, National Science Foundation, American Chemical Society Petroleum Research Fund, Research Grants Council of Hong Kong, Wiley, Cambridge University Press, A*Star Biomedical Research Council – Singapore, Swiss National Science Foundation, Israel Science Foundation, International Journal of Multiphase Flow, Journal of Fluid Mechanics, Lab on a Chip, Soft Matter, Proceedings of the National Academy of Science.
10. Short Course Co-Instructor, “Microfluidics and Microrheology,” with T. Squires, P. Doyle, and V. Breedveld, 79th Annual Meeting of the Society of Rheology, Salt Lake City, UT, October 6, 2007.
11. Session chair, “Microfluidics,” at the 86th *ACS Colloids and Surface Symposium*, Baltimore, MD, June 2012.
12. Symposium organizer, “Electrokinetics & Microfluidics Symposium,” 13th IACIS International Conference on Surface and Colloid Science (ICSCS) and 83rd ACS Colloid & Surface Science Symposium, Columbia University, New York, NY, June 14-19, 2009.
13. Session chair, “Drops,” at the APS Division of Fluid Dynamics Meeting, Long Beach, CA, November 2010.
14. Session chair, “Current Fluid Mechanics,” at the APS March Meeting, Pittsburgh, PA, March 2009.
15. Session chair, “Droplet Generation and Behavior,” in the *Microfluidics Symposium, The XVth International Congress on Rheology*, Monterey, CA, USA, August 2008.
16. Session chair, “Microfluidics and Small Scale Flows,” AIChE Annual Meeting, Salt Lake City, UT, November 2007.
17. Session chair, “Microfluidics and Small Scale Flows,” AIChE Annual Meeting, San Francisco, CA, November 2006.
18. Session chair, “Blends, Emulsions, and Multiphase Flows,” 78th Annual Meeting of the Society of Rheology, Portland, ME, October 2006.

19. Session chair, "Measurement Techniques in Microfluidics," IMECE Congress, Orlando, FL, November 2005.
20. Session chair, "Rheology at the Microscopic Scale," Society of Rheology Annual Meeting, Lubbock, TX, February 2005.
21. Session chair, "Multiphase Flows in Microfluidic Devices," ASME International Mechanical Engineering Congress, Anaheim, CA, November 2004.
22. Session chair, "Interfacial Flows" and "Interfacial Flows of Complex Fluids," American Institute of Chemical Engineers Annual Meeting, Austin, TX, November 2004.
23. Session chair, "Extensional Flows and Extensional Rheometry," 72nd Annual Meeting, Society of Rheology, Hilton Head, SC, February 2001.

Awards, Prizes, Honors

- | | |
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| 1. Fellow, American Physical Society | 2014 |
| 2. Honorable Mention, Emerging Female Scientist, Carnegie Science Awards | 2012 |
| 3. Russell V. Trader Career Faculty Fellowship, Department of Mechanical Engineering, Carnegie Mellon University | 2011-2013 |
| 4. George Tallman Ladd Research Award, Carnegie Mellon University | 2006 |
| 5. National Science Foundation CAREER Award | 2005-2011 |
| 6. Achievement Award, Solutia, Inc., Springfield, Massachusetts | January 2001 |
| 7. Fannie and John Hertz Foundation Graduate Fellowship
The Fannie and John Hertz Foundation, 2456 Research Drive, Livermore CA 94550 | 1995 to 2000 |
| 8. Richard E. Cutkosky Alumni Award, Dept. of Physics, CMU | 1995 |
| 9. Phi Beta Kappa | 1995 |
| 10. Andrew Carnegie Society Presidential Scholar | 1994 to 1995 |

Service on CMU Committees

1. Member (Ex Officio, on behalf of the Dean), Committee to Review the Policy on Teaching Track Faculty Spring 2020
2. Member (Ex Officio, on behalf of the Dean), Committee to Review the Policy on Special Faculty Spring 2019 – Summer 2020

3. Member, EPP Department Head Search Committee AY 2019-2020
4. Review Committee Member, Tepper School of Business Reappointment, Promotion,
and Tenure Process Spring 2019
5. Search Committee Member, Vice President for Marketing and Communications 2019
6. Research Ecosystem Committee, College of Engineering 2018 – 2019
7. CIT Faculty Chair, College of Engineering 2018 – 2019
8. CIT Diversity Committee, College of Engineering 2018 – present
9. Lead, Strategic planning for Diversity, Inclusion, and Equality for the Department of
Chemical Engineering Spring 2018
10. Co-Chair (with Raj Rajkumar, ECE), Committee to Evaluate the Dean of the College
of Engineering 2017 – 2018
11. CIT Faculty Chair Elect, College of Engineering 2017 – 2018
12. Chair, Faculty Search Committee, Chemical Engineering 2017 – 2018
13. Selection Committee for the 2018 Honorary Degree Recipients 2017 – 2018
14. University Reappointment, Promotion and Tenure Committee 2016 – 2018
15. CIT Awards and Recognition Committee for Faculty, Mech Eng Rep 2016 – 2017
16. Search Committee for Department Head of Physics 2016 – 2017
17. Co-Chair, Awards Committee, Mechanical Engineering 2016 – 2017
18. Chair, Graduate Education Committee, Mechanical Engineering 2013 – 2016
19. Member, Faculty Search Committee, Chemical Engineering 2015 – 2017
20. Graduate Recruiting Committee, Chemical Engineering AY 2012 – 2014
21. Departmental Seminar Organizer, Chemical Engineering Fall 2012
22. Search Committee for Dean of Libraries AY 2012 - 2013
23. Berkman Faculty Development Committee, CIT Representative AY 2010 - 2012
24. Senate University Libraries Advisory Committee, CIT Representative AY 2010 - 2012
25. Academic Advising Award Selection Committee 2008, 2010, 2012

26. Undergraduate Research Advisor, Chemical Engineering 2010 – 2015
27. CPS Seminar Organizer, Chemical Engineering Fall 2010
28. Pi Tau Sigma Faculty Advisor, Department of Mechanical Engineering 2008 – 2011
29. Institute Fellow, NETL – Institute for Advanced Energy Solutions 2008 – 2010
30. Faculty Affiliate, Center for Complex Fluids Engineering 2003 – present
31. Chemical Engineering Qualifier Committee, Member 2009, 2012, 2016-17
32. Mechanical Engineering Graduate Education Committee, Member 2007 – 2017
Participated in developing a new “Research Methods Based” Qualifier Format
33. Advisor, Bennett Student Research Symposium, Department of Mechanical Engineering 2007 – 2009
34. CMU Undergraduate Research Office Committee, Member 2007 – 2014
35. Mechanical Engineering Undergraduate Education Committee, Member 2003 – 2007
36. Mechanical Engineering Qualifier Committee, Member, Fluid Mechanics, Chair of committee 2005-2008 2003 – 2017
37. Untenured Women Faculty in CIT, Monthly Meetings, Participant 2003 – 2012

Outreach Activities

1. NSBE General Body Meeting; Panelist, “How to Get Into Undergraduate Research”, February 27, 2019
2. Guest webinar speaker, Distinguished Conversation Series, Nazarbayev University School of Engineering, Astana, Khazakistan. Spoke with students from Young Researcher Association, Undergraduate IET Campus, and IMECE Chapter about graduate school, career and life trajectories in academia. Faculty Contact: Luis Rojas-Solorzano September 7, 2018
3. Attendee, NSBE URM Engineering Student Success Symposium for Deans and Diversity Administrators, Salt Lake City, UT June 22 – 24, 2018
4. Mentor, Joyce Chen (SCS Class of 2019), Panhellenic Mentorship for Enrichment (MentE) Program 2017 – 2018
5. Panelist, Workshop for Junior Faculty, AIChE Womens Initiatives Committee, *AIChE Annual Meeting*, Salt Lake City, November 8, 2015

6. Faculty Mentor, Lizmarie Comencia-Ortiz (MEG Class of 2012), NASA MUST Mentorship Program AY 2011-2012
7. Participated in PreHealth Committee meetings for 3 engineering students applying to medical school 2009, 2011, 2012
8. Panelist, Parent Program, “Wow! That’s Engineering!” Event (Society of Women Engineers) September 18, 2010
9. Guest speaker, YWCA TechGYRLS, Pittsburgh, PA May 10, 2010
10. Mentor to PhD Students, “Preparing a Startup Package”, CMU Graduate Programs Office, Pittsburgh, PA June 25, 2009
11. Guest speaker, YWCA TechGYRLS, Pittsburgh, PA October 25, 2008
12. Alumni Relations Volunteer Forum June 9, 2007
13. National Energy Technology Focus Group, Panelist June 13, 2007
14. Visit to Westinghouse High School. Guest lecturer in high school physics courses, demonstration of engineering concepts via inkjet printing applications. March 9, 2006
15. Society of Women Engineers High School Day. Presentation of interactive material educating high school women about mechanical engineering. 2003-2008
16. Westinghouse High School Visit to Mechanical Engineering. Laboratory tour educating underrepresented high school students about mechanical engineering and microfluidics. March 17, 2005
17. Judge, CIT Honors Research Poster Competition, *Meeting of the Minds Undergraduate Research Symposium* AY 2005 – 2006 and AY 2007 – 2008
18. Doctoral Thesis Committee Member, 10 MEG students, 6 CHE students, 4 BME students, and 4 PHY students
19. Society of Women Engineers and Women In Science, guest speaker at several meetings 2003 – 2004

Fellowships Awarded to Undergraduate Projects Advised

1. First Generation Microfluidic Chemical Assays Using Drop-Based Technology, Summer Undergraduate Research Fellowship, Aaron Vanderbeek (MEG, Class of 2006), Summer 2004, \$3000.
2. Producing Metal Micro- and Nano-Spheres In A Controlled Fashion, Summer Undergraduate Research Fellowship, Raphael Rogman (MEG, Class of 2007), Summer 2005, \$3500.

3. Creating Integrated Polymerase Chain Reaction Devices Using Droplet-Based Microfluidic Technology, Summer Undergraduate Research Fellowship, Ramya Ramesh (MEG, Class of 2009), Summer 2007, \$3000.
4. Understanding the Formation of Ordered Micro Cavities in PDMS Films and Possible Applications, Summer Undergraduate Research Fellowship, Shaun Swanson (MEG, Class of 2010), Summer 2008, \$3500.
5. Design of a Closed Chamber to Control Evaporation and Condensation for the Formation of Highly Uniform Microcavity Arrays, SURG Fellowship, Lauren Walch (MEG, Class of 2010), Spring 2009, \$500.
6. Encapsulating Living Organisms in Microfluidic Drops, SURF Fellowship, Sarah McCormick (CHE, Class of 2013), Summer 2012, \$3500.
7. Kinetics of Co-Crystallization of Caffeine as a Model Pharmaceutical Compound, SURF Fellowship, Matthew Carroll (PHY, Class of 2018), Summer 2016, \$3500.
8. Measuring the Magnetic Susceptibility of Magnetic Capsules, SURG Grant, Jacob Rushkoff (CHE, Class of 2020), Spring 2019, \$500.
9. Encapsulation of Bacteria in Sub-Nanoliter Droplets for High Throughput Single-Cell mRNA Sequencing, SURG Grant, Augustine Duffy (CHE, Class of 2021), Spring 2020, \$500.

Formal Professional Development Workshops and Programs

1. Summer Leadership Development Workshop, Carnegie Mellon University, Pittsburgh June 2018
2. Executive Leadership in Academic Technology and Engineering (ELATE) Program, Drexel University May 2018 – March 2019

Institutional Action Project: Development of leadership and professional development modules for mid-career and senior faculty

3. Mental Health First Aid USA, Carnegie Mellon University, December 15, 2017
4. COACHing Strong Women in the Art of Strategic Persuasion Workshop, American Institute of Chemical Engineers Women's Initiative Committee, November 8, 2009
5. Ask for it: How Women Can Use Negotiation Workshop, Professor Linda Babcock, Carnegie Mellon University, October 22, 2008