Stanford

Roseanna N. Zia

Associate Professor of Chemical Engineering

Curriculum Vitae available Online

Bio

BIO

Roseanna N. Zia is an Associate Professor of Chemical Engineering at Stanford University and, by courtesy, Mechanical Engineering. She received her Ph.D. from the California Institute of Technology in Mechanical Engineering in 2011 with Professor John F. Brady, for development of theory in colloidal hydrodynamics and microrheology. Zia subsequently conducted post-doctoral study of colloidal gels at Princeton University, in collaboration with Professor William B. Russel. Zia began her faculty career at Cornell in January 2013, then subsequently moved her research group to Stanford University in 2017.

Dr. Zia's research includes developing micro-continuum theory for structure-property relationships of flowing suspensions, elucidating the mechanistic origins of the colloidal glass transition, and microscopic modeling of reversibly bonded colloidal gels, which resulted in discovery that gel aging is actually ongoing but very slow phase separation and the finding that mechanical yield of colloidal gels is actually a non-equilibrium phase transition, triggered by changes in osmotic pressure. Her research group aims to unlock the fundamental connections between colloidal-scale physics and life-essential processes in biological cells using theoretical colloid physics, biological modeling, and high-fidelity computational models. Her group's ultimate vision is to create a generalized platform for uncovering disease mechanisms and pathways for physics-based therapeutics.

Dr. Zia's work has been recognized by several awards, including the PECASE Award, the ONR Director of Research Early Career Award, the Office of Naval Research (ONR) Young Investigator award, the NSF CAREER Award, the NSF BRIGE Award, the Publication Award from the Society of Rheology, and the Engineering Sonny Yau ('72) Teaching Award. Most recently she was named an Otterson Faculty Fellow at Stanford.

Dr. Zia serves as an Associate Editor for the Journal of Rheology, and on the Advisory Board of the AIChE Journal.

ACADEMIC APPOINTMENTS

- Associate Professor, Chemical Engineering
- Member, Bio-X
- Member, Wu Tsai Neurosciences Institute

HONORS AND AWARDS

- Corrsin Lecturer, Johns Hopkins University (2020 - 2021)
- Croft Lecturer, University of Missouri (2021)
- Otterson Faculty Fellow, Stanford University (2021)
- PECASE Award, National Science Foundation (2019)

- PECASE Award, Department of Defense (2019)
- Director of Research Early Career Award, Office of Naval Research (2017)
- Terman Faculty Fellow, Stanford University (2017)
- Frontiers of Engineering, National Academy of Engineering (2015)
- Sonny Yau ('72) Teaching Award, Cornell University College of Engineering (2015)
- White House Workshop on the National Strategic Computing Initiative, Initiative held by Executive Order of President Barack Obama (2015)
- Best Paper Award 01J Session, AIChE (2014)
- Frontiers in Engineering Education, National Academy of Engineering (2014)
- Young Investigator Award, Office of Naval Research (2014)
- BRIGE Award, National Science Foundation (2013)
- CAREER Award, National Science Foundation (2013)
- Morgan Faculty Fellow, Cornell University (2013)
- Publication of the Year, Journal of Rheology (2013)
- Best Poster, Princeton University Symposium (2012)
- Everhart Lecturer, California Institute of Technology (2011)
- Graduate Dean's Award, California Institute of Technology (2011)
- PEO Scholar Award, PEO (2010)
- Best Overall Poster Award, California Institute of Technology Poster Symposium (2009)
- Best Poster Award, Society of Rheology - International Congress on Rheology (2008)

BOARDS, ADVISORY COMMITTEES, PROFESSIONAL ORGANIZATIONS

- Associate Editor, Journal of Rheology (2016 - present)
- Editorial Board Member, AIChE Journal (2020 - present)
- Editorial Board Member, Physics of Fluids (2016 - 2019)
- Guest Editor, PLOS One (2017 - present)
- Meeting Programming Chair, Fluid Mechanics, AIChE (2021 - 2021)
- Chair, Media & Science Relations Committee, American Physical Society Division of Fluid Dynamics (2019 - present)
- Vice Chair, Media and Science Relations Committee, APS DFD (2018 - 2019)
- Fluids Programming Committee, AIChE (2015 - present)
- Program Comittee, American Physical Society DFD (2015 - 2018)
- Liaison, AIP Publishing Partnerships Committee for Soc. Rheology (2016 - present)
- Chair, Electronic Publishing Committee (2013 - 2014)

PROFESSIONAL EDUCATION

- PhD, California Institute of Technology , Mechanical Engineering (2011)

LINKS

- Zia Research Group: https://ziagroup.stanford.edu

Research & Scholarship

CURRENT RESEARCH AND SCHOLARLY INTERESTS

Colloidal gels, glasses, and suspensions form over 95% of biological fluids, most pharmaceutical fluids, and are ubiquitous across personal-care, agricultural, and industrial-coating materials. Despite the pervasiveness of these fluid-suspended, microscopically small particles (colloids), many of their behaviors have defied explanation – such as the sudden collapse of colloidal gels, vitrification that thwarts crystallization, and their physical role in biological cell function. In addition to these opportunities, the frontier of cellular biology resides at the colloidal scale, requiring a merger between physics and biology, which have evolved almost orthogonally since the 19th century. My lab focuses on unifying mesoscale physics and chemistry with cellular-level biology through novel theoretical modeling and large-scale computational simulations. Our work includes four areas: 1) constructing a micro-continuum theory of complex fluids to predict heterogenous flows of arbitrary composition; 2) mechanistically explaining non-equilibrium phase transitions in colloidal systems; 3) modeling confined and large-scale hydrodynamically-interacting colloidal suspensions; and 4) modeling the physics of living cells. I chose these areas specifically to support my group's ultimate vision: accurate, physics-based modeling of whole-cell function where physical laws predict biological behavior.

Core Competencies: My lab's expertise is in uncovering the physics of far-from-equilibrium behaviors of soft matter and explaining how they emerge from microscopic forces. We have developed three core competencies:

• Micro-continuum theory using energy and momentum methods. Theoretical modeling of colloids using microhydrodynamics is routine, but application to dense or heterogeneous suspensions is an immense challenge. Our energy methods are a powerful tool to encode complex boundary conditions yet preserve structural detail.

• Physics-based computational modeling. Computational modeling of suspensions is robust for small or unconfined systems, but current methods obtain large system size by sacrificing on the geometry or transport processes they represent. Our novel physics-based and deep-learning algorithms address these limitations.

• Physics-based modeling of biological cell functions. Biochemical models of life cannot explain many growth- or condition-dependent changes in biological cell function. We merge colloidal-scale modeling with biological process chemistry to reveal entirely new physics-based mechanisms of life-essential cell processes.

Teaching

COURSES

2021-22

- Energy and Mass Transport: CHEMENG 120B (Spr)
- Microhydrodynamics: CHEMENG 310, ME 451D (Win)
- Special Topics in Suspension Dynamics: CHEMENG 523 (Aut, Win, Spr, Sum)

2020-21

- Colloquium: CHEMENG 699 (Aut, Win, Spr)
- Energy and Mass Transport: CHEMENG 120B (Spr)
- Graduate Practical Training: CHEMENG 299 (Sum)
- Microhydrodynamics: CHEMENG 310 (Win)
- Special Topics in Suspension Dynamics: CHEMENG 523 (Aut, Win, Spr, Sum)
- Suspension Mechanics: CHEMENG 442 (Sum)

2019-20

- Colloquium: CHEMENG 699 (Aut, Win, Spr)
- Energy and Mass Transport: CHEMENG 120B (Spr)
- Graduate Practical Training: CHEMENG 299 (Sum)

- Microhydrodynamics: CHEMENG 310, ME 451D (Win)
- Special Topics in Suspension Dynamics: CHEMENG 523 (Aut, Win, Spr, Sum)

2018-19

- Colloquium: CHEMENG 699 (Aut, Win, Spr)
- Energy and Mass Transport: CHEMENG 120B (Spr)
- Microhydrodynamics: CHEMENG 310, ME 451D (Win)
- Special Topics in Suspension Dynamics: CHEMENG 523 (Aut, Win, Spr, Sum)
- Suspension Mechanics: CHEMENG 442 (Spr)

STANFORD ADVISEES

Doctoral Dissertation Reader (AC)

Chunzi Liu, Akshay Maheshwari

Postdoctoral Faculty Sponsor

Jae Hwan Jeong

Doctoral Dissertation Advisor (AC)

Aaron Brown, Jen Hofmann, Alp Sunol

Doctoral Dissertation Co-Advisor (AC)

Goldie Roth, Theo Yang

Postdoctoral Research Mentor

Jae Hwan Jeong

GRADUATE AND FELLOWSHIP PROGRAM AFFILIATIONS

- Biophysics (Phd Program)

Publications

PUBLICATIONS

- **Modeling the colloidal physics of translation elongation in E. coli**
  Maheshwari, A., Gonzalez-Gonzalez, E., Sunol, A. M., Endy, D., Zia, R. N.
  CELL PRESS.2022: 122
- **Colloidal hydrodynamics of the bacterial nucleoid and its impact on diffusion and spatial organization in the cytoplasm**
  Sunol, A. M., Zia, R. N.
  CELL PRESS.2022: 121
- **A colloidal polymer model for the condensnation of intrinsically disordered proteins**
  Yang, T., Jarosz, D., Zia, R. N.
  CELL PRESS.2022: 199A
- **Size-selective characterization of porous media via tortuous network analysis** *JOURNAL OF RHEOLOGY*
  Ryu, B. K., Zia, R. N.
  2022; 66 (1): 219-233
- **The confined Generalized Stokes-Einstein relation and its consequence on intracellular two-point microrheology.** *Journal of colloid and interface science*
  Aponte-Rivera, C., Zia, R. N.
  1800; 609: 423-433

- **Toward a flow-dependent phase-stability criterion: Osmotic pressure in sticky flowing suspensions.** *The Journal of chemical physics*
  Huang, D. E., Zia, R. N.
  2021; 155 (13): 134113
- **Parallel accelerated Stokesian dynamics with Brownian motion** *JOURNAL OF COMPUTATIONAL PHYSICS*
  Ouaknin, G. Y., Su, Y., Zia, R. N.
  2021; 442
- **Impact of polydispersity and confinement on diffusion in hydrodynamically interacting colloidal suspensions** *JOURNAL OF FLUID MECHANICS*
  Gonzalez, E., Aponte-Rivera, C., Zia, R. N.
  2021; 925
- **Phase mechanics of colloidal gels: osmotic pressure drives non-equilibrium phase separation.** *Soft matter*
  Johnson, L. C., Zia, R. N.
  2021
- **Faxen formulas for particles of arbitrary shape and material composition** *JOURNAL OF FLUID MECHANICS*
  Dolata, B. E., Zia, R. N.
  2021; 910
- **Vitrification is a spontaneous non-equilibrium transition driven by osmotic pressure.** *Journal of physics. Condensed matter : an Institute of Physics journal*
  Wang, J. G., Zia, R. N.
  2021
- **"Dense diffusion" in colloidal glasses: short-ranged long-time self-diffusion as a mechanistic model for relaxation dynamics.** *Soft matter*
  Wang, J. G., Li, Q., Peng, X., McKenna, G. B., Zia, R. N.
  2020
- **Heterogeneous dispersions as microcontinuum fluids** *JOURNAL OF FLUID MECHANICS*
  Dolata, B. E., Zia, R. N.
  2020; 888
- **Stress decomposition in LAOS of dense colloidal suspensions** *JOURNAL OF RHEOLOGY*
  Ong, E. X., Ramaswamy, M., Niu, R., Lin, N. C., Shetty, A., Zia, R. N., McKinley, G. H., Cohen, I.
  2020; 64 (2): 343–51
- **Transient nonlinear microrheology in hydrodynamically interacting colloidal dispersions: flow cessation** *JOURNAL OF FLUID MECHANICS*
  Mohanty, R. P., Zia, R. N.
  2020; 884
- **Stress decomposition in LAOS of dense colloidal suspensions** *Journal of Rheology*
  Ong, E. Y., Ramaswamy, M., Niu, R., Lin, N. Y., Shetty, A., Zia, R. N., McKinley, G. H., Cohen, I.
  2020; 64 (2): 343-351
- **Colloidal hydrodynamics of biological cells: A frontier spanning two fields** *PHYSICAL REVIEW FLUIDS*
  Maheshwari, A. J., Sunol, A. M., Gonzalez, E., Endy, D., Zia, R. N.
  2019; 4 (11)
- **Modeling the Brownian hydrodynamics of intracellular motion**
  Zia, R., Maheshwari, A., Endy, D., Gonzalez, E., Sunol, A.
  AMER CHEMICAL SOC.2019
- **Sticky, active microrheology: Part 1. Linear-response.** *Journal of colloid and interface science*
  Huang, D. E., Zia, R. N.
  2019; 554: 580–91
- **Influence of structure on the linear response rheology of colloidal gels** *JOURNAL OF RHEOLOGY*
  Johnson, L. C., Zia, R. N., Moghimi, E., Petekidis, G.
  2019; 63 (4): 583–608

- **Toward a nonequilibrium Stokes-Einstein relation via active microrheology of hydrodynamically interacting colloidal dispersions** *JOURNAL OF COLLOID AND INTERFACE SCIENCE*
  Chu, H. W., Zia, R. N.
  2019; 539: 388–99
- **Sticky-probe active microrheology: Part 2. The influence of attractions on non-Newtonian flow.** *Journal of colloid and interface science*
  Huang, D. E., Zia, R. N.
  2019; 562: 293–306
- **Toward a nonequilibrium Stokes-Einstein relation via active microrheology of hydrodynamically interacting colloidal dispersions.** *Journal of colloid and interface science*
  Chu, H. C., Zia, R. N.
  2018; 539: 388–99
- **Exploring the validity of time-concentration superposition in glassy colloids: Experiments and simulations** *PHYSICAL REVIEW E*
  Peng, X., Wang, J., Li, Q., Chen, D., Zia, R. N., McKenna, G. B.
  2018; 98 (6)
- **The Impact of Hydrodynamics on Viscosity Evolution in Colloidal Dispersions: Transient, Nonlinear Microrheology** *AICHE JOURNAL*
  Mohanty, R. P., Zia, R. N.
  2018; 64 (8): 3198–3214
- **Physical biology of the cancer cell glycocalyx.** *Nature physics*
  Chin-Hun Kuo, J., Gandhi, J. G., Zia, R. N., Paszek, M. J.
  2018; 14 (7): 658-669
- **Physical biology of the cancer cell glycocalyx** *NATURE PHYSICS*
  Kuo, J., Gandhi, J. G., Zia, R. N., Paszek, M. J.
  2018; 14 (7): 658–69
- **Yield of reversible colloidal gels during flow start-up: release from kinetic arrest.** *Soft matter*
  Johnson, L. C., Landrum, B. J., Zia, R. N.
  2018
- **Gravitational collapse of colloidal gels: non-equilibrium phase separation driven by osmotic pressure** *SOFT MATTER*
  Padmanabhan, P., Zia, R.
  2018; 14 (17): 3265–87
- **Equilibrium structure and diffusion in concentrated hydrodynamically interacting suspensions confined by a spherical cavity** *JOURNAL OF FLUID MECHANICS*
  Aponte-Rivera, C., Su, Y., Zia, R. N.
  2018; 836: 413–50
- **Y Non-equilibrium pair interactions in colloidaldispersions** *JOURNAL OF FLUID MECHANICS*
  Dolata, B. E., Zia, R. N.
  2018; 836: 694–739
- **Active and Passive Microrheology: Theory and Simulation** *ANNUAL REVIEW OF FLUID MECHANICS, VOL 50*
  Zia, R. N., Davis, S. H., Moin, P.
  2018; 50: 371–405
- **The non-Newtonian rheology of hydrodynamically interacting colloids via active, nonlinear microrheology** *JOURNAL OF RHEOLOGY*
  Chu, H. W., Zia, R. N.
  2017; 61 (3): 551–74
- **Pair mobility functions for rigid spheres in concentrated colloidal dispersions: Stresslet and straining motion couplings** *JOURNAL OF CHEMICAL PHYSICS*
  Su, Y., Swan, J. W., Zia, R. N.
  2017; 146 (12): 124903

- **Delayed yield in colloidal gels: Creep, flow, and re-entrant solid regimes** *JOURNAL OF RHEOLOGY*
  Landrum, B. J., Russel, W. B., Zia, R. N.
  2016; 60 (4): 783–807
- **Active microrheology of hydrodynamically interacting colloids: Normal stresses and entropic energy density** *JOURNAL OF RHEOLOGY*
  Chu, H. W., Zia, R. N.
  2016; 60 (4): 755–81
- **Simulation of hydrodynamically interacting particles confined by a spherical cavity** *PHYSICAL REVIEW FLUIDS*
  Aponte-Rivera, C., Zia, R. N.
  2016; 1 (2)
- **Force-induced diffusion in suspensions of hydrodynamically interacting colloids** *JOURNAL OF FLUID MECHANICS*
  Hoh, N. J., Zia, R. N.
  2016; 795: 739–83
- **Pair mobility functions for rigid spheres in concentrated colloidal dispersions: Force, torque, translation, and rotation** *JOURNAL OF CHEMICAL PHYSICS*
  Zia, R. N., Swan, J. W., Su, Y.
  2015; 143 (22): 224901
- **Hydrodynamic diffusion in active microrheology of non-colloidal suspensions: the role of interparticle forces** *JOURNAL OF FLUID MECHANICS*
  Hoh, N. J., Zia, R. N.
  2015; 785: 189–218
- **A micro-mechanical study of coarsening and rheology of colloidal gels: Cage building, cage hopping, and Smoluchowski's ratchet** *JOURNAL OF RHEOLOGY*
  Zia, R. N., Landrum, B. J., Russel, W. B.
  2014; 58 (5): 1121–57
- **Large amplitude oscillatory microrheology** *JOURNAL OF RHEOLOGY*
  Swan, J. W., Zia, R. N., Brady, J. F.
  2014; 58 (1): 1–41
- **Far-from-equilibrium sheared colloidal liquids: Disentangling relaxation, advection, and shear-induced diffusion** *PHYSICAL REVIEW E*
  Lin, N. C., Goyal, S., Cheng, X., Zia, R. N., Escobedo, F. A., Cohen, I.
  2013; 88 (6): 062309
- **Active microrheology: Fixed-velocity versus fixed-force** *PHYSICS OF FLUIDS*
  Swan, J. W., Zia, R. N.
  2013; 25 (8)
- **Stress development, relaxation, and memory in colloidal dispersions: Transient nonlinear microrheology** *JOURNAL OF RHEOLOGY*
  Zia, R. N., Brady, J. F.
  2013; 57 (2): 457–92
- **Microviscosity, microdiffusivity, and normal stresses in colloidal dispersions** *JOURNAL OF RHEOLOGY*
  Zia, R. N., Brady, J. F.
  2012; 56 (5): 1175–1208
- **Modeling hydrodynamic self-propulsion with Stokesian Dynamics. Or teaching Stokesian Dynamics to swim** *PHYSICS OF FLUIDS*
  Swan, J. W., Brady, J. F., Moore, R. S.
  2011; 23 (7)
- **Single-particle motion in colloids: force-induced diffusion** *JOURNAL OF FLUID MECHANICS*
  Zia, R. N., Brady, J. F.
  2010; 658: 188–210