Changhao Li

Postdoctoral Scholar
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Research Interests

- Soft matter physics, solid mechanics, non-equilibrium thermodynamics
- Morphogenesis, self-patterning, phase separation and chaos in active matter
- Nonlinear, history-dependent mechanics and rheology of living biological materials
- Physics-informed machine learning, multiscale modeling methods, parallel and high-performance computing

Education

The Pennsylvania State University — State College, PA, USA
- *Ph.D. in Engineering Mechanics* — *Aug 2018 - Aug 2024*
  Dissertation: Agent-based modeling of biological active matter — *Advisor: Dr. Sulin Zhang*

Beihang University — Beijing, China
- *Bachelor of Engineering in Engineering Mechanics* — *Aug 2014 - Jul 2018*
  Thesis: Elasticity of fibrous composites with different microstructures — *Advisor: Dr. Yuli Chen*

The University of Tokyo — Tokyo, Japan
- *Exchange Undergraduate Student* — *Sep 2017 - May 2018*
  Project: Thermoelectric transport modeling of carbon nanotube junctions — *Advisor: Dr. Junichiro Shiomi*

Honors and Awards

- Trainee Pilot Awards of Center for Engineering Mechanobiology (CEMB) — *2024*
- Dale and Jeanne Mosier Fund for Excellence — *2023*
- Penn State College of Engineering Travel Award — *2023*
- C. Norwood Wherry Memorial Graduate Fellowship in Engineering — *2021*
- Professor and Mrs. Ralph U. Blasingame Memorial Graduate Fellowship in Engineering — *2021*
- Harry G. Miller Fellowship in Engineering — *2020*
- H. Marcus Dean's Chair in Engineering Scholarship — *2019*
- Penn State University Graduate Fellowship — *2018*
- Outstanding Graduates of Beihang University — *2018*

Publications

- Li, C., Feng, L., Park, Y.J., Yang, J., Li, J., & Zhang, S. (2024). Machine learning traction force maps for contractile cell monolayers. ***Extreme Mechanics Letters***, p.102150.
  DOI: https://doi.org/10.1016/j.eml.2024.102150

- Li, C., Nijjer, J., Feng, L., Zhang, Q., Yan, J., & Zhang, S. (2024). Agent-based modeling of stress anisotropy driven nematic ordering in growing biofilms. ***Soft Matter***, 20(16), 3401-3410..
  Highlighted by the editor of *Soft Matter* as the front cover article.
  DOI: https://doi.org/10.1039/D3SM01535A

- Nijjer, J., Li, C. (co-first author), Kothari, M., ..., Cohen, T., Zhang, S., & Yan, J. (2023). Biofilms as self-shaping growing nematics. ***Nature Physics***, 19(12), pp.1936-1944.
  Hightlighted by Penn State News, Yale News and *Nature Physics* at the same issue.
  DOI: https://doi.org/10.1038/s41567-023-02221-1

- Li, W., Li, C. (co-first author), Zhang, G., ..., & Wang, Q. (2021). Molecular ferroelectric-based flexible sensors exhibiting supersensitivity and multimodal capability for detection. ***Advanced Materials***, 33(44), p.2104107.
  DOI: https://doi.org/10.1002/adma.202104107

- Nijjer, J., Li, C., Zhang, Q., Lu, H., Zhang, S., & Yan, J. (2021). Mechanical forces drive a reorientation cascade leading to biofilm self-patterning. ***Nature communications***, 12(1), p.6632.
  Highlighted by the editor of *Nature Communications*.
  DOI: https://doi.org/10.1038/s41467-021-26869-6

- Feng, L., Zhao, T., Xu, H., Shi, X., Li, C., Hsia, K.J., & Zhang, S. (2023). Physical forces guide curvature sensing and cell migration mode bifurcating. ***PNAS nexus***, 2(8), p.pgad237.
  DOI: https://doi.org/10.1093/pnasnexus/pgad237

- Yao, B., Hong, W., Chen, T., Han, Z., Xu, X., Hu, R., Hao, J., Li, C., ..., & Wang, Q. (2020). Highly stretchable polymer composite with strain-enhanced electromagnetic interference shielding effectiveness. ***Advanced Materials***, 32(14), p.1907499.
  DOI: https://doi.org/10.1002/adma.201907499

In Preparation/Under Review:

- Ataie, Z. Li, C. (co-first author), Risbud, A., Kheirabadi, S., Zhang, S., & Sheikhi. A. (2024), Cellular snowballing: cell migration drives self-assembly of cell-hydrogel biohybrid spheroids. ***Science Advances*, in review.**
- Li, C., Ataie, Z., Sheikhi. A., & Zhang, S. (2024), Agent-based modeling for assembling dynamics of cellular organoids. **In preparation**.

Presentations

- Li, C., Zhang, S., (2024). Mechanically guided self-patterning of confined three-dimensional growing biofilms. ***UMass Summer School Workshop 2024*. Poster**.
- Li, C., Zhang, S., (2024). An agent-based modeling platform for large-scale parallel simulations of biological active matter. ***ESM Today Workshop 2024*. Oral presentation**.
- Li, C., Zhang, S., Yan, J., & Nijjer, J. (2023). Mechanically guided self-patterning of growing biofilms. ***SES 2023 Annual Meeting*. Oral presentation**.
- Zhang, S., Li, C., Feng, L., Park, Y., Yang, J., Li, J. (2023). Keynote: Machine learning traction force maps of cell monolayers: toward a digital traction force microcopy. ***SES 2023 Annual Meeting*. Keynote presentation**.
- Li, C., Zhang, S., (2023). Machine learning traction force maps of cell monolayer. ***ESM Today Workshop 2023*. Poster**.
- Nijjer, J., Henzel, T., Li, C., Zhang, S., Cohen, T. and Yan, J., (2022). Growth of bacterial biofilms at interfaces. ***2022 APS March Meeting*. Oral presentation**.
- Li, C., Zhang, S., (2022). Mechanical stresses pattern cell ordering in bacterial biofilms. ***2022 LiMC2 Workshop*. Poster**.
- Zhang, S., Li, C., (2022). A deep-learning based painter to predict cell traction force maps. ***USNC/TAM 2022*. Oral presentation**.
- Li, C., Nijjer, J., Yan, J. and Zhang, S. (2021). Agent-based modeling for biofilm growth under mechanical confinement. ***2021 APS March Meeting*. Poster**.
- Nijjer, J., Li, C., Zhang, S. and Yan, J., (2021). Self-organization of bacteria in confined interstitial biofilms. ***2021 APS March Meeting*. Oral presentation**.
- Li, C., Zhang, S., (2021). Agent-based modeling of *V.cholerae* bacteria biofilms. ***ESM Today Workshop 2021*. Poster**.

Skill Highlights

- Agent-based modeling and discrete element modeling for biological active matter
- Nonlinear, time-dependent, multi-physics mean-field modeling for active matter and electrochemical systems
- Machine learning and deep learning for biomedical image data and time series
- Rich experience on interdisciplinary collaboration and solid training on scientific writing/visualization

Tools: Finite Element Analysis (ABAQUS, COMSOL, FEniCSx), Programming (C++, Python, Fortran, Matlab, Mathematica), Machine Learning (PyTorch, Keras), Molecular Dynamics (LAMMPS, GROMACS, Material Studio), Phase-field Modeling, High-performance Computing (CUDA, Eigen).

Research Experience

- **The Pennsylvania State University** Advisor: Dr. Daniel J. Cosgrove
  Postdoctoral Scholar in Department of Biology *Aug 2024 - Present*
  - **Coarse-grained molecular dynamics (CGMD) model of plant cell wall creep**: Quantified microscopic stress-dependent creep law by the transition state theory, and integrated the creep law to the CGMD model to extend the simulation timescale from 10^{-6} s to 10^{3} s. Implemented the time integration algorithm in the open-source MD software LAMMPS. The model captures the stress-mediated kinetics of plant cell wall creep, and also reveals the microstructure rearrangement and stress redistribution during creep.

  - **Computer-vision-based tool to calculate root hair length from images**: Developed an algorithm to automatically detect root hair geometry and calculate root hair length from microscope images. Integrated the algorithm into an high-throughput workflow, reducing the time for measuring a single image from 10 mins to 0.1 s without loss of precision.

- **The Pennsylvania State University** Advisor: Dr. Sulin Zhang
  Graduate Reserach Assistant in Department of Engineering Science and Mechanics *Aug 2018 - Aug 2024*
  - **Agent-based model (ABM) of bacteria biofilms**: Developed an agent-based model for complex growth dynamics of *Vibrio Cholerae* biofilms under mechanical confinements. Parameterized cell-substrate, cell-gel, and cell-cell interfacial interactions with experimental collaborators, then implemented the ABM into LAMMPS. The model reproduces morphological bifurcation under confinements of different stiffnesses, and stress-mediated cell patterning similar to nematic ordering of liquid crystals.
  - **Machine learning traction force maps for epithelial cells**: Trained a generative adversarial network (GAN) on experimentally measured and computationally simulated traction force maps of HCT-8 cells. Developed a high-throughput simulation workflow to generate a large database of cellular traction force maps. The GAN successfully captures size-dependent, curvature-dependent, and contractility-dependent traction force distributions.
  - **Multiscale finite element model (FEM) of flexible ferroelectric sensors**: Parameterized a nonlinear mechanical and piezoelectric constitutive law of a porous ferroelectric sensor, by microstructural FEM of the representative volume. Inserted the constitutive law into the device-level FEM, revealing the mechanism of high piezoelectric sensitivity. Derived a scaling law for the relation between sensitivity and porosity.
  - **Agent-based model of cell-microgel self-assembly**: Developed an agent-based model for cellular migration-driven assembly of bioactive spheroids. The model recapitulates a three-stage kinetics of the self-assembly process, and reveals the biophysical mechanisms of 2D-3D transition of the cell-microgel aggregation. The ABM has been implemented in LAMMPS and provides a versatile platform for the simulations of active colloids.

- **The University of Tokyo** Advisor: Dr. Junichiro Shiomi
  Undergraduate Research Intern in Department of Mechanical Engineering *Sep 2017 - May 2018*
  - **Thermoelectric transport processes of intersected carbon nanotubes (CNTs)**: Applied Green's function method to simulate the electronic transport properties of two intersected CNTs with different angles. Used non-equilibrium molecular dynamics (NEMD) simulations to study thermal transport properties. Designed automatic simulation workflows for parametric sweeps of Green's function method and NEMD simulations, and built a database for material informatics studies.

Industry Experience

- **Dassault Systèmes - SIMULIA** Pleasonton, CA
  Industry Process Expert Intern *May 2023 - Sep 2023*
  - **C++ multiphysics solver for reactive flow in porous media**: Built a finite difference method solver for Darcy-Nernst-Planck-Poisson system. Tested numerical efficiency and stability of various iterative methods.
  - **Deep-learning-based microstructure generator**: Trained a generative adversarial networks to transform 2D experimental images of battery electrode into 3D digital microstructures, for electrochemical reactive flow simulations.
  - **High-fedelity fuel cell simulations**: Applied FEniCSx to build a FEM-based application for simulating multiphysics processes in proton exchange membrane fuel cells, including mass/charge transfer and nonlinear electrochemical kinetics.

Other Experience

- **Journal Reviewer:** Extreme Mechanics Letters, International Journal of Solids and Structures, STAR Protocols, ASME Open Journal of Engineering
- **Proposal Writing**: NSF Award 2035051, 2024 CEMB Trainee Pliot Award
- **Teaching**: Teaching assistant for Statics (EMCH 210) and Dynamics (EMCH 212) for 6 semesters
- **Student Judge**: ESM Today Workshop 2019, 2022, 2023
- **Membership**: American Physical Society, Center for Lignocelluose Structure and Formation