Yifan Rao, Ph.D.

Distinguished Postdoctoral Fellow, Andlinger Center for Energy and the Environment, Princeton University
41 Olden Street, Engineering Quadrangle E312, Princeton, NJ 08544
Email: yifan.rao@princeton.edu | Google Scholar

RESEARCH INTERESTS

Mechanics-guided design of adaptive and intelligent matter through geometry, materials, and multiphysics interactions, combining experiments, analytical modeling, and computational methods.

- **Origami-inspired robots and metamaterials:** Kinematics, nonlinear mechanics, and dynamics of reconfigurable and multistable origami systems under coupled physical interactions for programmable deformation, actuation, state control, and robotic functions.
- **Mechanics of thin films and slender structures:** Deformation, instability, and interfacial mechanics of thin and slender structures under coupled elastic, interfacial, and geometric effects, with applications to flexible and wearable devices.
- **Mechanics of 2D materials:** Coupled adhesion, interfacial shear, and deformation of atomically thin materials for precision metrology, strain engineering, and control of strain-dependent properties.

ACADEMIC APPOINTMENTS

Distinguished Postdoctoral Fellow, Princeton University July 2024 – Present
Andlinger Center for Energy and the Environment; Advisors: Prof. Glaucio H. Paulino and Prof. Minjie Chen

Graduate Research Assistant, The University of Texas at Austin August 2018 – May 2024
Department of Aerospace Engineering and Engineering Mechanics; Advisor: Prof. Nanshu Lu

Graduate Research Assistant, Tongji University September 2015 – June 2018
School of Aerospace Engineering and Applied Mechanics; Advisor: Prof. Zheng Zhong

EDUCATION

Ph.D., Engineering Mechanics, The University of Texas at Austin May 2024
Dissertation: "Thin Film Bulging and Poking with Adhesive Contact." Advisor: Prof. Nanshu Lu. GPA: 4.0/4.0

M.Eng., Engineering Mechanics, Tongji University, Shanghai, China June 2018
Thesis: "Modeling and Analysis of Soft Matter Considering Mass Transport, Heat Conduction, and Chemical Reaction." Advisor: Prof. Zheng Zhong

B.Eng., Engineering Mechanics, Tongji University, Shanghai, China July 2015

HONORS AND AWARDS

2026	Early Career Presenter Fellowship, American Academy of Mechanics, USNC/TAM26
2025	Rising Stars in Mechanical Engineering (workshop hosted by MIT)
2025, 2023	Future Faculty Award, Society of Engineering Science (SES) Annual Technical Meeting
2023	Travel Award, Materials Research Society (MRS) Early Career Professionals Subcommittee, 2023 MRS Fall Meeting
2023	Travel Award, Gordon Research Conference (GRC) on Science of Adhesion
2023, 2022	Eugene A. Ripperger Scholarship Fund in Engineering Mechanics, UT Austin
2023, 2022	Professional Development Award, UT Austin
2022	Travel Award, SES Annual Technical Meeting
2022	Travel Award, Research University Alliance (RUA) Annual Conference
2021, 2018	Warren A. and Alice L. Meyer Endowed Scholarship in Engineering, UT Austin
2020, 2019	Eric Baker Becker III Memorial Graduate Scholarship, UT Austin

FELLOWSHIPS AND RESEARCH SUPPORT

Distinguished Postdoctoral Fellowship, Andlinger Center, Princeton University 2024 – 2026
Project: "Optimal Energy Embedding for Multifunctional Origami-Engineered Robots." Competitive, independently proposed postdoctoral fellowship.

PUBLICATIONS

14 refereed journal articles (12 published, 2 in press), 1 manuscript under revision, 1 *Nature* News & Views, and 1 refereed conference paper. First or co-first author on 6 refereed journal articles.

Yifan Rao = *this author;* † = *co-first author;* * = *corresponding author.*

Refereed Journal Articles

[J14] **Yifan Rao**†, Konstantinos Manos†, Tuo Zhao, Minjie Chen*, Glaucio H. Paulino*. Origami state machine with time-varying magnetic fields. *Proceedings of the National Academy of Sciences*, 123, e2615316123, 2026. DOI: https://doi.org/10.1073/pnas.2615316123

[J13] Konstantinos Manos†, **Yifan Rao**†, Tuo Zhao†, Minjie Chen*, Glaucio H. Paulino*. Multimodal robotic matter enabled by unified magnetic control primitives. *Science Advances*, in press, 2026.

[J12] Shixi Zang, **Yifan Rao**, Damiano Pasini, Glaucio H. Paulino*. Origami with a twist. *Applied Mechanics Reviews*, in press, 2026.

[J11] **Yifan Rao**, Nanshu Lu*. Effects of adhesive and frictional contacts on the nanoindentation of two-dimensional material drumheads. *Journal of the Mechanics and Physics of Solids*, 192, 105828, 2024. DOI: https://doi.org/10.1016/j.jmps.2024.105828

[J10] Hongbian Li, Philip Tan, **Yifan Rao**, Sarnab Bhattacharya, Zheliang Wang, Sangjun Kim, Susmita Gangopadhyay, Hongyang Shi, Matija Jankovic, Heeyong Huh, Zhengjie Li, Pukar Maharjan, Jonathan Wells, Hyoyoung Jeong, Yaoyao Jia, Nanshu Lu*. E-tattoos: toward functional but imperceptible interfacing with human skin (invited review). *Chemical Reviews*, 124(6), 3220–3283, 2024. DOI: https://doi.org/10.1021/acs.chemrev.3c00626

[J9] Zheliang Wang, Hao Sheng, Xinyi Lin, **Yifan Rao**, Jia Liu, Nanshu Lu*. A shear-lag model for laminated beams with extreme modulus mismatch between layers (editor-invited article). *Mechanics of Materials*, 188, 104844, 2024. DOI: https://doi.org/10.1016/j.mechmat.2023.104844

[J8] Hongbian Li, Hyonyoung Shin, Minsu Zhang, Andrew Yu, Heeyong Huh, Gubeum Kwon, Nicholas Riveira, Sangjun Kim, Susmita Gangopadahyay, Jessie Peng, Zhengjie Li, **Yifan Rao**, Luis Sentis, José del R. Millán, Nanshu Lu*. Hair-compatible sponge electrodes integrated on VR headset for electroencephalography. *Soft Science*, 3, 22, 2023. DOI: https://doi.org/10.20517/ss.2023.11

[J7] **Yifan Rao**, Eunbin Kim, Zhaohe Dai, Jinlong He, Ying Li, Nanshu Lu*. Size-dependent shape characteristics of 2D crystal blisters. *Journal of the Mechanics and Physics of Solids*, 175, 105286, 2023. DOI: https://doi.org/10.1016/j.jmps.2023.105286

[J6] Siyi Liu†, Jinlong He†, **Yifan Rao**, Zhaohe Dai, Huilin Ye, John C. Tanir, Ying Li*, Nanshu Lu*. Conformability of flexible sheets on spherical surfaces. *Science Advances*, 9(16), eadf2709, 2023. DOI: https://doi.org/10.1126/sciadv.adf2709

[J5] Hongwoo Jang, Kaan Sel, Eunbin Kim, Sangjun Kim, Xiangxing Yang, Seungmin Kang, Kyoung-Ho Ha, Rebecca Wang, **Yifan Rao**, Roozbeh Jafari, Nanshu Lu*. Graphene e-tattoos for unobstructive ambulatory electrodermal activity sensing on the palm enabled by heterogeneous serpentine ribbons. *Nature Communications*, 13, 6604, 2022. DOI: https://doi.org/10.1038/s41467-022-34406-2

[J4] Siyi Liu, **Yifan Rao**, Hongwoo Jang, Philip Tan, Nanshu Lu*. Strategies for body-conformable electronics. *Matter*, 5(4), 1104–1136, 2022. DOI: https://doi.org/10.1016/j.matt.2022.02.006

[J3] Zhaohe Dai, **Yifan Rao**, Nanshu Lu*. Two-dimensional crystals on adhesive substrates subjected to uniform transverse pressure. *International Journal of Solids and Structures*, 257, 111829, 2022. DOI: https://doi.org/10.1016/j.ijsolstr.2022.111829

[J2] **Yifan Rao**†, Shutao Qiao†, Zhaohe Dai, Nanshu Lu*. Elastic wetting: substrate-supported droplets confined by soft elastic membranes. *Journal of the Mechanics and Physics of Solids*, 151, 104399, 2021. DOI: https://doi.org/10.1016/j.jmps.2021.104399

[J1] **Yifan Rao**, Zheng Zhong*. Modeling and analysis of bending behavior of polymeric bilayers caused by chemical reaction. *Chinese Quarterly of Mechanics*, 39(3), 475–485, 2018.

Manuscripts Under Revision

[M1] Yasuhiro Miyazawa†, **Yifan Rao**†, Kevin T. Liu, Dahun Lee, Seokgyu Yang, Jinkyu Yang*, Glaucio H. Paulino*. Origami dynamics. *Advanced Science*, under revision.

Invited Commentary

[N1] **Yifan Rao**, Nanshu Lu. The electronic patch that's impervious to sweat (News & Views). *Nature*, 628, 39–40, 2024. DOI: https://doi.org/10.1038/d41586-024-00789-z

Refereed Conference Papers

[C1] Konstantinos Manos, **Yifan Rao**, Tuo Zhao, Kevin Liu, Daniel Zhou, Glaucio H. Paulino, Minjie Chen*. Wireless actuation of magnetic robots with a modular 60 mT 3-D Helmholtz coil system. *Proceedings of the 2025 IEEE Applied Power Electronics Conference and Exposition (APEC)*, 1274–1278, 2025. DOI: https://doi.org/10.1109/APEC48143.2025.10977109

RESEARCH EXPERIENCE

Optimal energy embedding for modular, origami-inspired soft robots Princeton, 2024 – Present
Advisors: Prof. Glaucio H. Paulino and Prof. Minjie Chen

- Developed reduced-order Lagrangian models for the kinematics, mechanics, and snap-through dynamics of multistable Kresling origami assemblies under magnetic actuation.
- Realized magnetic origami state machines with sensing-free universal reset and programmable transitions to any target state using rotating and pulsed fields (PNAS 2026).
- Established unified magnetic control primitives in a programmable 3-D Helmholtz coil system for multimodal locomotion, hierarchical assembly, and shape morphing of modular robotic matter (Science Advances 2026).

Centrifugation-enabled micro-dome arrays for soft capacitive pressure sensors UT Austin, 2023 – 2024
Advisor: Prof. Nanshu Lu

- Leveraged centrifugation for rapid and versatile manufacturing of micro-dome arrays.
- Established process–microstructure–property relations for micro-dome-integrated soft capacitive pressure sensors through electromechanical simulations and experiments.

AFM-enabled drumhead nanoindentation of 2D materials UT Austin, 2022 – 2023
Advisor: Prof. Nanshu Lu

- Formulated boundary value problems revealing the effects of tip–membrane adhesion and friction, finite tip size, and membrane–substrate sliding on force–deflection curves.
- Proposed an approximate formula, more accurate than Schwerin-type solutions, to simultaneously extract in-plane stiffness and membrane–substrate interfacial shear strength (JMPS 2024).

Experiments, modeling, and simulations of 2D crystal nanoblisters UT Austin, 2020 – 2022
Advisor: Prof. Nanshu Lu

- Combined experiments, continuum theory, and coarse-grained molecular dynamics to identify three size-dependent regimes of 2D crystal blister shapes (JMPS 2023).
- Extracted 2D crystal–substrate adhesion from blister shape characteristics, and analyzed pseudomagnetic fields in strain-engineered graphene bubbles (IJSS 2022).

Mechanics of membrane-confined droplets on rigid and compliant substrates UT Austin, 2018 – 2020
Advisor: Prof. Nanshu Lu

- Developed a theoretical framework for "elastic wetting," governed by the interplay between liquid surface tension and membrane elastic tension (JMPS 2021).
- Performed finite element simulations in Abaqus to quantify the effect of substrate compliance, and proposed an in-situ method to extract interfacial tensions.

Multiphysics modeling of hydrogels under finite deformation Tongji University, 2015 – 2018
Advisor: Prof. Zheng Zhong

- Developed a theoretical framework coupling mass transport, heat conduction, and chemical reaction in hydrogels undergoing large deformation.
- Performed COMSOL simulations of the coupled behavior, including reaction-induced bending of polymeric bilayers.

PRESENTATIONS

Invited Talks and Seminars

[I5] Society of Engineering Science (SES) Annual Technical Meeting Oct 2026
"Origami state machine with time-varying magnetic fields," West Lafayette, IN

[I4] SMatCH Seminar, Princeton University Dec 2025
"Programmable actuation and control of super-modular magneto-origami soft robots," Princeton, NJ

[I3] New Light: Rising Stars in Energy and the Environment, Princeton University Jul 2025
"Optimal energy embedding for modular, origami-inspired soft robots," Princeton, NJ

[I2] Gordon Research Seminar (GRS) on Science of Adhesion Jul 2023
"Theoretical extraction of adhesion of 2D materials from spontaneously formed bubbles or nanoindentation on drumheads," South Hadley, MA

[I1] Department of Civil and Environmental Engineering, University of Houston (host: Prof. Roberto Ballarini) Apr 2023
"AFM-based mechanical characterization of nanomembranes," Houston, TX

Contributed Oral Presentations

[O7] U.S. National Congress on Theoretical and Applied Mechanics (USNC/TAM26) Jun 2026
"Programmable actuation and control of super-modular magneto-origami soft robots," Pasadena, CA

[O6] SES Annual Technical Meeting Oct 2025
"Programmable actuation and control of super-modular magneto-origami soft robots," Atlanta, GA

[O5] MRS Fall Meeting Nov 2023
"Advancing nanoindentation analysis for characterizing the mechanical, elastic, and interfacial properties of two-dimensional materials," Boston, MA

[O4] SES Annual Technical Meeting Oct 2023
"Elasto-centrifugal blistering for creating soft hairy surfaces," Minneapolis, MN

[O3] SES Annual Technical Meeting Oct 2022
"Transition from Griffith to vdW interface governed 2D crystal nanoblisters," College Station, TX

[O2] U.S. National Congress on Theoretical and Applied Mechanics (USNC/TAM22) Jun 2022
"Mechanics and application of elastic wetting: substrate-supported droplets confined by soft elastic membranes," Austin, TX

[O1] SES Annual Technical Meeting (virtual) Sep 2020
"Elastic wetting: droplets confined by ultrathin elastic membranes," Online

Poster Presentations

[P11] Princeton Catalysis Symposium Oct 2026
"Origami state machine with time-varying magnetic fields," Princeton, NJ

[P10] SES Annual Technical Meeting, Future Faculty Symposium Oct 2025
"Nonlinear and multiphysics mechanics from thin films to folding structures," Atlanta, GA

[P9] Princeton Materials Institute Symposium Apr 2025
"Electro-magneto-mechanical systems: manufacturing, analysis and simulation," Princeton, NJ

[P8] Air Force Research Laboratory (AFRL) Regional Mid-Atlantic Network Jul 2024
"Electro-magneto-mechanical systems: manufacturing, analysis and simulation," Princeton, NJ

[P7] AmeriMech Symposium: Fracture of Soft Materials May 2024
"Growth and failure in elasto-centrifugal blistering," Austin, TX

[P6] MRS Fall Meeting, Meet the New Faculty Candidate Poster Session Nov 2023
"Characterization, design, and manufacture of nanomembranes for enhanced multi-physics performance," Boston, MA

[P5] SES Annual Technical Meeting, Future Faculty Symposium Oct 2023
"Characterization, design, and manufacture of nanomembranes for enhanced multi-physics performance," Minneapolis, MN

[P4] Gordon Research Conference (GRC) on Science of Adhesion Jul 2023
"Theoretical extraction of adhesion of 2D materials from spontaneously formed bubbles or nanoindentation on drumheads," South Hadley, MA

[P3] Research University Alliance (RUA) Annual Conference Sep 2022
"Transition from Griffith to vdW interface governed 2D crystal nanoblisters," Pasadena, CA

[P2] U.S. National Congress on Theoretical and Applied Mechanics (USNC/TAM22) Jun 2022
"Mechanics and application of elastic wetting: substrate-supported droplets confined by soft elastic membranes," Austin, TX

[P1] SES Annual Technical Meeting (virtual) Sep 2020
"Elastic wetting: droplets confined by ultrathin elastic membranes," Online

TEACHING EXPERIENCE

Teaching Assistant, CEE 545 Origami Engineering (Instructor: Prof. Glaucio H. Paulino) Princeton, Fall 2026
Guest Lecturer, CEE 545 Origami Engineering (Instructor: Prof. Glaucio H. Paulino) Princeton, Fall 2025
Guest Lecturer, EM 397 Thin Film Mechanics (Instructor: Prof. Nanshu Lu) UT Austin, Spring 2023
Teaching Assistant, EM 319 Mechanics of Solids UT Austin, Spring 2020 – Fall 2022
Teaching Assistant, EM 306 Statics UT Austin, Fall 2018 – Fall 2019

MENTORING

Remy Garcia-Kakebeen, Undergraduate, Princeton University Spring 2026 – Present
Department of Operations Research and Financial Engineering
Independent research project: "Stochastic Bistability: A Markov Decision Process Framework for Kresling Actuation Systems"

PROFESSIONAL SERVICE AND LEADERSHIP

Scientific Leadership

- Session Chair, Session 407 "Mechanics-guided design of soft robotics," USNC/TAM26, Pasadena, CA, 2026
- Co-Chair, Gordon Research Seminar on Science of Adhesion, 2025

Peer Review

- **Journals:** *Proceedings of the National Academy of Sciences; Nano Letters; Journal of the Mechanics and Physics of Solids; Extreme Mechanics Letters; International Journal of Non-Linear Mechanics; IEEE Transactions on Instrumentation and Measurement; Frontiers in Mechanical Engineering*
- **Conferences:** ASME International Mechanical Engineering Congress & Exposition (IMECE 2026); Summer Biomechanics, Bioengineering, and Biotransport Conference (SB3C 2023)

Outreach

- Co-organizer, Exhibition Booth for the 35th Anniversary of the Council on Science and Technology (CST), Princeton University, 2025
- Co-organizer, Origami Engineering Workshop, Princeton University, 2024
- Co-organizer, Explore UT Science and Engineering Outreach, UT Austin, 2019

RESEARCH TECHNIQUES

- **Theoretical mechanics:** nonlinear mechanics of membranes, plates, and slender structures; contact, adhesion, and interfacial sliding; elastocapillarity; variational and reduced-order Lagrangian modeling of multistable and origami structures.
- **Computational modeling:** finite element analysis (Abaqus, ANSYS), multiphysics simulation (COMSOL); scientific computing in Python, MATLAB, Fortran, Mathematica, and Maple.
- **Magnetic actuation and robotic prototyping:** operation and control of a programmable 3-D Helmholtz coil system for wireless magnetic actuation; fabrication of origami robots and modules using laser cutting and 3D printing; CAD design and 3D modeling using AutoCAD and SolidWorks.
- **Experimental mechanics and fabrication:** Instron mechanical testing, dynamic mechanical analysis (DMA), atomic force microscopy (AFM), scanning electron microscopy (SEM), optical microscopy; spin coating and centrifugation-based fabrication of soft micro-dome sensors.