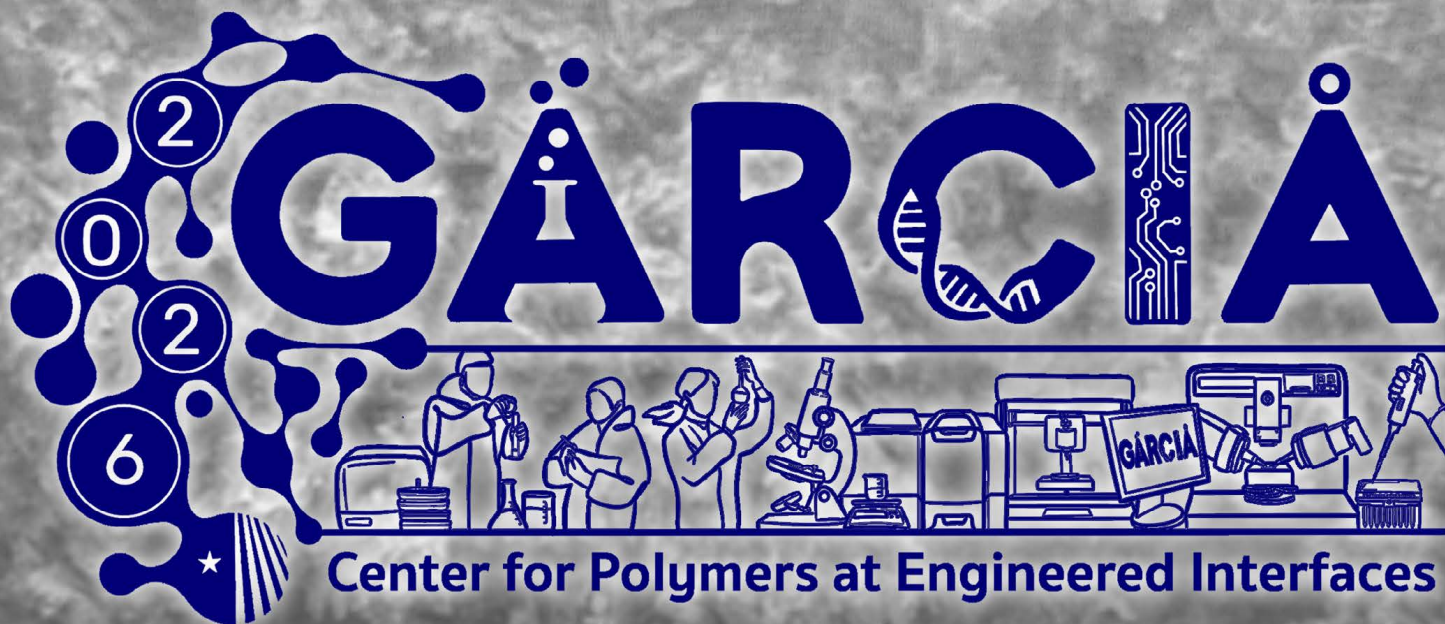
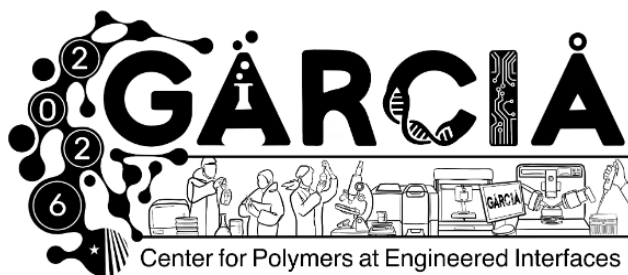




Center for Polymers at Engineered Interfaces



**Research Scholars Program
Summer 2026**



The Garcia Center for Polymers at Engineered Interfaces was founded in 1996 and is named after the late Queens College professor, Narciso Garcia, who was a pioneer in the integration of education and research. The Center focuses on the broad application of materials research to engineering, medicine, and energy, and recently, AI, machine learning, and computational modeling. The Center also supports innovation through entrepreneurship and has multiple collaborations with industry and national laboratories. In the research program, high school students work together with undergraduates, PhD, post PhD and faculty who collaborate in addressing challenges at the cutting edge of modern science. The students are encouraged to publish in refereed scientific journals, present their results at national conferences, and develop patents to protect their intellectual property. Our goal is to convey to the students the excitement we enjoy daily in research and provide for them a supportive network within the scientific community. Research is a lifelong experience and we hope to remain as a resource to our students long after "graduation".

This sentiment was best expressed this year by Angel Zhang who designed the logo voted by the students to represent the Garcia program for 2026.

She wrote, "The logo was designed to highlight the unity of the Garcia community. The molecular network symbolizes the connections formed among students, mentors, and professors throughout the summer. Like the repeating units of a polymer, each participant contributes uniquely to strengthen the community as a whole. In the word Garcia itself, elements such as the Erlenmeyer flask, DNA molecule, circuit board represent the diverse fields of chemistry, biology, engineering, and computation explored in the program, while the angstrom (Å) indicates the nanoscale at which much of materials research is conducted at. The illustration below depicts researchers working together at a shared lab bench, emphasizing the collaboration and teamwork that define the Garcia experience and scientific research in general".

Sincerely,
Miriam Rafailovich

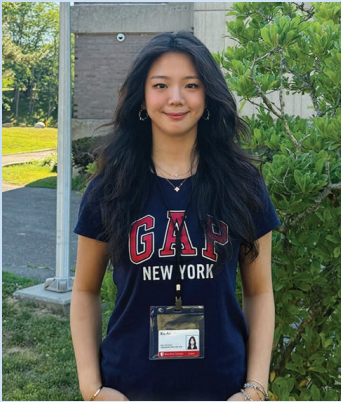
Jon Sokolov

Miriam H. Rafailovich

Jonat Sokolov



High School Students



Ria An



Braylon Ashby



Heidi Bao



Aarush Batra



Eric Chen



Audrey Chin



Lydia Choi



Melody Dai



Sounak Debnath



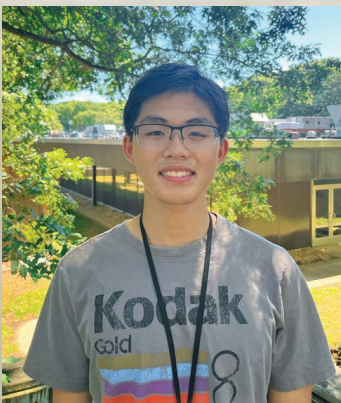
Aarav Desai



Albert Eksarevskiy



Gavin Finkel



Alexander Fu



Mira Goldhaber



Janet Guan



Kevin Han

High School Students



Aidan He



Ashley He



Lucas Hofflich



Charles Huang



Henry Huang



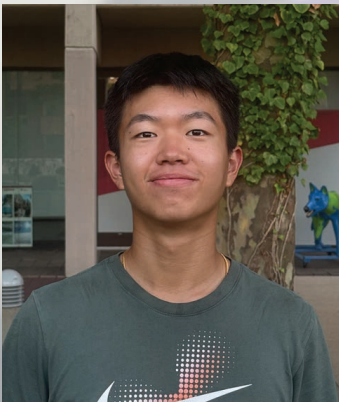
Theo Jeon



Arthur Jiang



William Jiang



Leroy Jing



Ian Kim



Advik Kishore



Annabelle Klein



Marie Kouzmine



Alfred Lee



Konstin Lee



Larry Lee

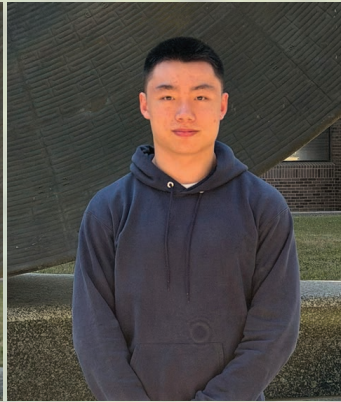
High School Students



Vera Lew



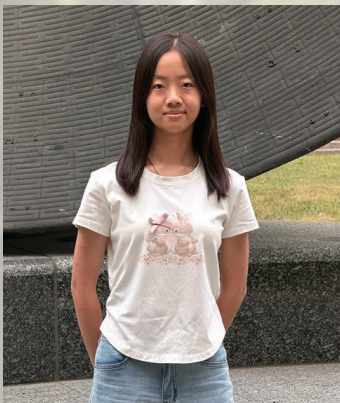
Alan Li



Andrew Li



Jiaqi Li



Megan Li



Jason Lian



Bella Lin



Jayden Lin



Nicole Lin



Roy Lin



Kevin Liu



Sharon Liu



Muling Lu



Ariana Lye



Taylor Maguire



Jack Merlo

High School Students



William Neice



William Ni



Lily Oh



Solenji Onwueme



Joel Pae



Sean Park



Bhavya Patel



Anish Peri



Ashwath Ram



Justin Ren



Sofia Rosa



Steve Samuel



Isaac Sedighi



Emily Segall



Chuansu Shang



Sean She

High School Students



Yusuf Sheikh



Caleb Son



Jenny Song



Jacob Stern



Brian Sun



Fred Sun



Jonathan Symonds



Audrey Tan



Niki Tavakoli



Cindy Tint



Lelin Tsai



Taly Turchin



Ameya Vathanan



Alessandro Verona



Sahil Vora



Alina Wang

High School Students



Andrew Wang



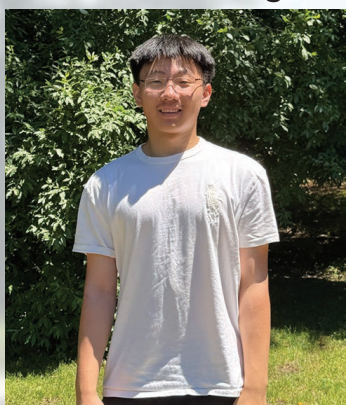
Camilie Wang



Lucas Wang



Terrence Wang



William Wang



Max Weiner



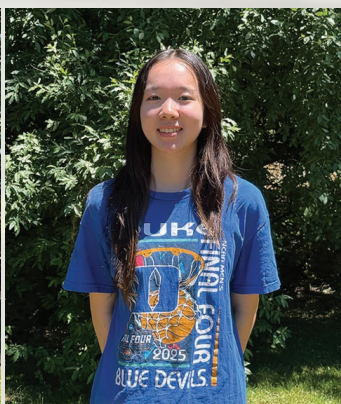
Azzy Xiang



Eric Xie



Brian Xiong



Kaylee Xu



Brian Yang



Phil Yao



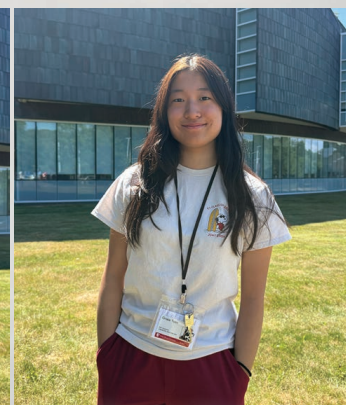
Vicky Ye



Alexander Yoon



Lucy Yu



Grace Yuan

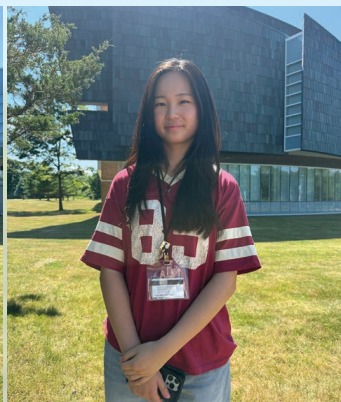
High School Students



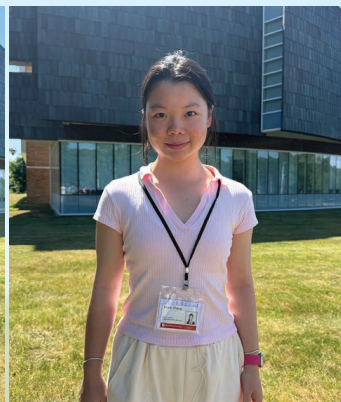
Eric Zang



Grace Zeng



Amber Zhang



Angel Zhang



Leo Zhang



Luke Zhang



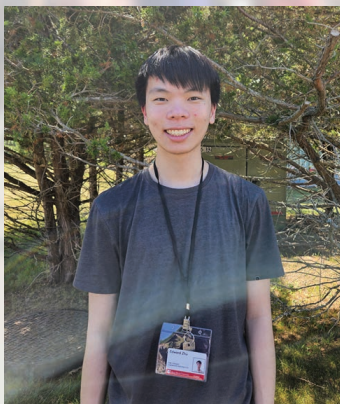
Tracy Zhang



Hanchen Zhou



Lenny Zhou



Edward Zhu



Virginia Zhu



Research Experience for Undergraduates (REU)



Syringa Abshire-Cohen



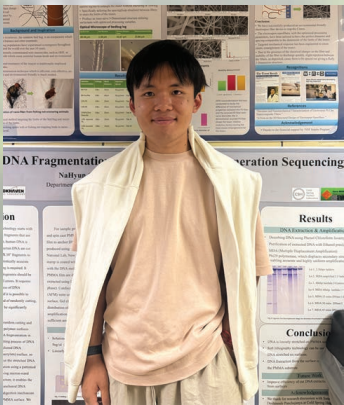
Kenneth Chang



Bandari Chen



Jian Chen



Dylan Deng



Jashmin Gill



Hannah Goykadosh



Leonard Johnson



Sophia Kang



Ethan Lee



Tiffany Li



Daniel Lim



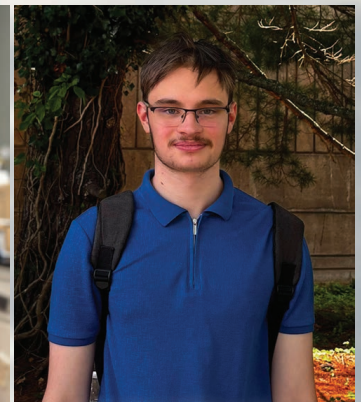
Hunter Maguire



Sergio Rosa



Adithya Santhosh



Andrei Scurtu

Research Experience for Undergraduates (REU)



Cyrus Sedgh



Samuel Sylvia



Patricia Tomas



Issac Varghese



Julianna Vrabec



Justin Wightman



Dennis Xu



Sophie Xu



Said Yashaev



Wendy Yu



Phoebe Zheng



Grads and Post Docs



Fernando
Aguilar Perez



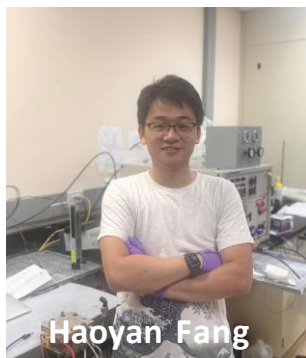
Allen Bethancourt



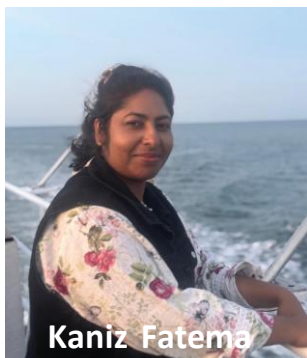
Muyun Cui



Sangita Das



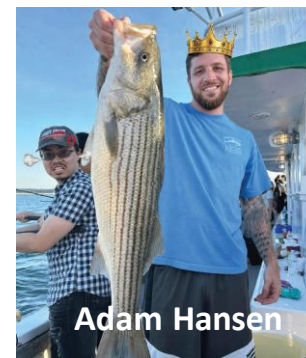
Haoyan Fang



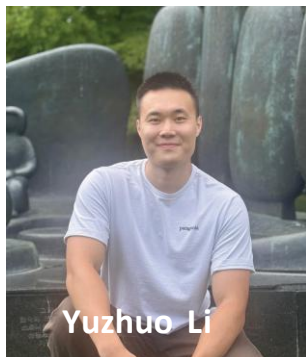
Kaniz Fatema



Shi Fu



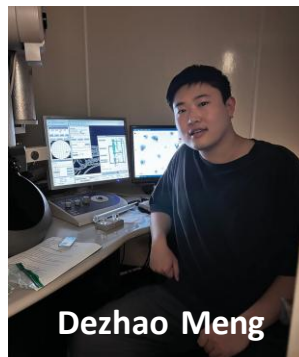
Adam Hansen



Yuzhuo Li



Huiting Luo



Dezhao Meng



Md Farabi Rahman



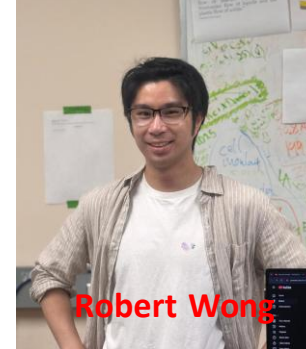
Akash Ranjan Pati



Aaron Sloutski



Nabila Jaman
Trinti



Robert Wong



Hugh Rosshirt



Sayani Bhunia



Kevin Kayang



Shoumik Saha



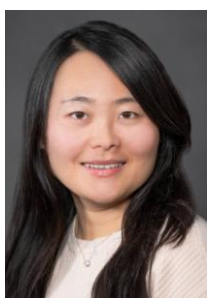
Amol Pophali



Nilanjan
Chakraborty



Dilip
Gersappe



Simou
Sun



Michael
Cuiffo

Staff



Ann Tucker



Bichen Wu



Jay Gao



Marcia Simon



Jon Sokolov



Stephen
Walker



Sayantani
Sikder



John
Jerome



Georgios
Romanos



Tai-De Li



Nicholas
Marcella



Chandramouli
Sadasivan



Jessica
Hofflich



Rachel
Brownlee



Taejin Kim



Miriam
Rafailovich



Rebecca Isseroff



Nidhi Rajput



Gurtej Singh



Yufen Deng



Chao Chen



Speakers

Interested in Project Bite?
Email: sophia@stonybrook.edu



Artificial Intelligence
Information Theory
Science
Institute of Technology
Research: Science of informational systems involving human information theory, artificial intelligence

EXCUSE
ANIMAL ABUSE
MEDICAL TORTURE
INNOCENT

Mountains (1.0)

#SNACK SUPER
SONOMIX

SAIORI FLY
GRAND HARBOUR
TRADE EVERYWHERE

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Class 12: 30g	1794.11
Class 13: 30g	1794.11
Class 14: 30g	1794.11
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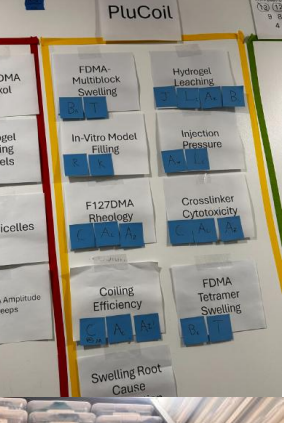
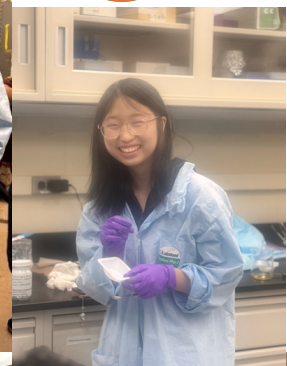
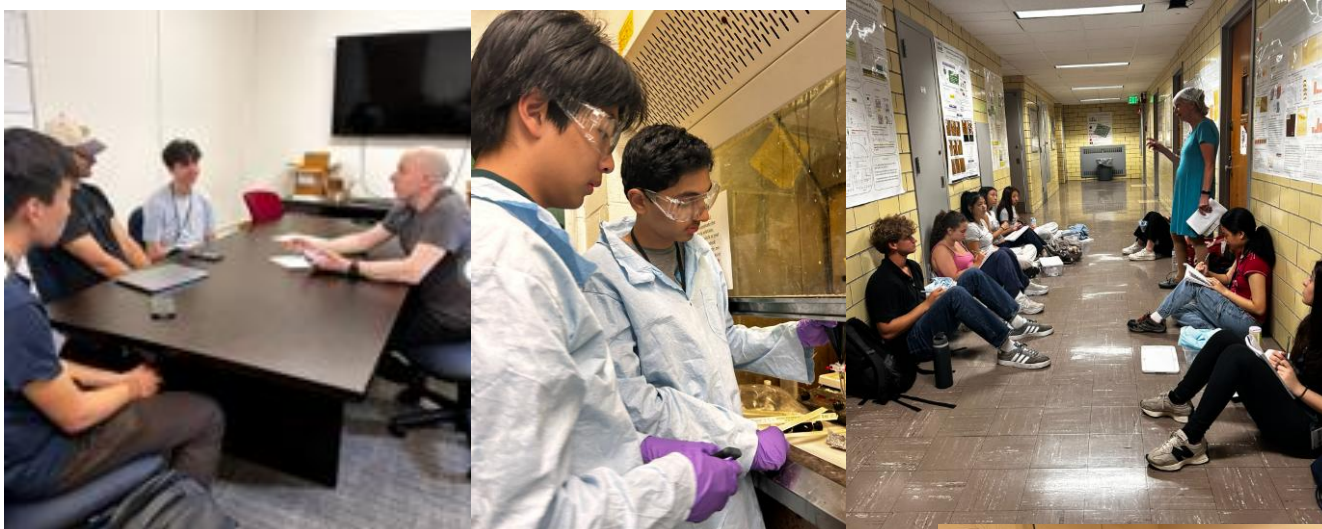
Spin Casting!



In The Lab!



In The Lab



Student Presentations!



Fishing!





Getting Outside!

Ropes Course!

Softball!





ESCAPE ROOM



Canoeing!



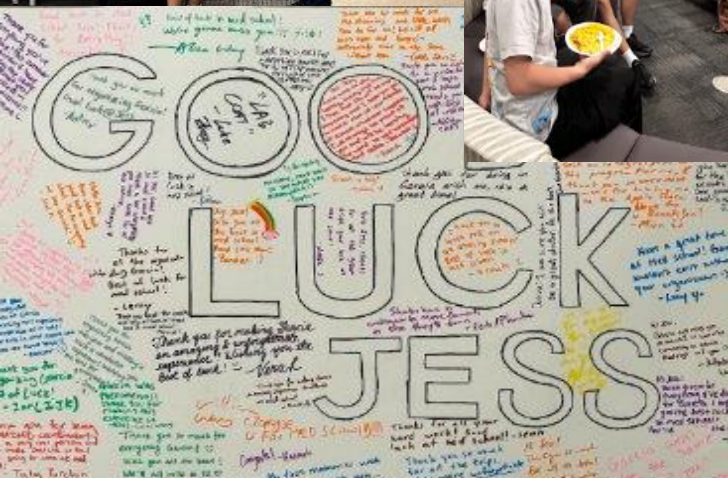


GARCIA
GRAND
ADVENTURES





BEST WISHES JESS





Summer Scholar Schedule of Weekly Activities

Each day starts with a mandatory group meeting at 10:15 AM!

Daily Schedule: Week of 6/24

	Wednesday – 6/24	Thursday – 6/25	Friday – 6/26
	10:15 – 10:30: Program Introductions 10:30 – 10:40: Peter Diplock Welcome to Stony Brook 10:40 – 11:40: Maria Giovanna Triveri Cardiomyopathies & Pulmonary Hypertension 11:40 – 4:00: Campus Tour 4:00 – 4:30: Scott Gershowitz Fire Safety Training	10:15 – 10:30: Organizational Meeting 10:30 – 11:30: Walter Julias, EH&S Hazardous Waste Training 11:30 – 12:15: Janet Oseni, EH&S Radiation Safety Training 12:15 – 1:15: Lunch 1:15 – 2:00: Nilanjan Chakraborty Teaching Robots to Manipulate 2:00 – 2:45: Lav Varshney Ethics in AI and Engineering 2:45 – 3:30: Chao Chen Topology-Driven Biomedical Imaging 3:30 – 4:30: Aaron Sloutski Introduction to Polymer Science	10:15 – 10:30: Organizational Meeting 10:30 – 11:30: Chris Kuhlow, EH&S Biological Hazards & Bloodborne Pathogens Training 11:30 – 12:30: Ying Liu, EH&S Chemical Hazards Training 12:30 – 1:00: Pizza Working Lunch 1:00 – 1:45: Dilip Gersappe Multi-Scale Modeling of Materials 1:45 – 2:30: Clara Tran Introduction to SBU Libraries & Use of AI in Research 2:45 – 3:30: Jack Nicholson Computer Vision

Summer Scholar Schedule of Weekly Activities

Each day starts with a mandatory group meeting at 10:15 AM!

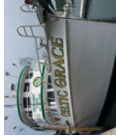
Daily Schedule: Week of 6/29

Monday – 6/29	Tuesday – 6/30	Wednesday – 7/1	Thursday – 7/2	Friday – 7/3
10:15 – 10:20: Organizational Meeting 10:20 – 11:00: Madeleine Augustine Working at Boeing 11:00 – 3:45: Facilities Tour 3:45 – 4:30: Devinder Mahajan Renewable Energy with Hydrogen	10:15 – 10:20: Organizational Meeting 10:20 – 10:30: Group Picture 10:30 – 11:25: Safety Exam 11:25 – 12:15: Stephen Walker Microbiology 12:15 – 1:00: Marcia Simon Engineering Skin 1:00 – 1:45: Lunch 1:45 – 2:30: Steve Schwarz Introduction to Spin Casting 2:30 – 4:30: Journal Club	10:15 – 10:20: Organizational Meeting 10:20 – 11:00: Dino Ravnic Research in Plastic Surgery 11:00 – 11:45: Rebecca Isseroff The Amazing Graphene & Keeping a Lab Notebook 11:45 – 4:30: Spin Casting Experiment Part 1	10:15 – 10:30: Organizational Meeting 10:30 – 4:30: Spin Casting Experiment Part 2	10:15 – 10:50: Organizational Meeting & Statistics Lecture 10:50 – 11:35: Simou Sun Biocolloids & Biointerfaces 11:35 – 12:10: Pizza Working Lunch 12:10 – 12:45: Giorgios Kementzidis Fibrinogen Simulations 12:45 – 1:30: Shanshan Yao Smart Materials for Bio- Integration 1:30 – 2:30: Gurtej Singh Skin Grafts for Wound Healing Applications

Summer Scholar Schedule of Weekly Activities

Each day starts with a mandatory group meeting at 10:15 AM!

Daily Schedule: Week of 7/6

Monday – 7/6	Tuesday – 7/7	Wednesday – 7/8	Thursday – 7/9	Friday – 7/10
10:15 – 10:30: Organizational Meeting 10:30 – 11:15: Miriam Rafailovich Biopolymers 11:15 – 12:15: Jonathan Sokolov DNA 12:15 – 1:00: Lunch 1:00 – 2:00: Chandramouli Sadasivan Treating Brain Aneurysms 2:00 – 4:30: Project Talks: Akash Ranjan Pati – Flame Retardants Shi Fu – Skin Grafts Haoyan Fang – Fuel Cells Adam Hansen – Biomechanics & Protein Structures Robert Wong – Aneurysms Kaniz Fatema – Soil Enhancement	10:15 – 10:30: Organizational Meeting 10:30 – 11:00: Md Farabi Rahman – Fuel Cells 11:00 – 11:45: Tai De Li – XPS, AFM, & TOF-SIMS 11:45 – 12:30: Chang Yon Nam Atomic Layer Deposition 12:30 – 1:15: Lunch 1:15 – 2:00: David Sprouster Nuclear Materials 2:00 – 2:45: Nav Nidhi Rajput Materials Informatics Infrastructure for Electrochemical Systems 2:45 – 4:30: Battle of the Groups – Spin Casting Presentations Part I 5:30 – 9:30: Fishing Trip! 	10:15 – 11:30: Organizational Meeting & Battle of the Groups Part II 11:30 – 12:30: Ying Liu, EH&S: SOP Writing 12:30 – 1:15: Lunch 1:15 – 1:50: Adam Singer – Working in Emergency Medicine 1:50 – 3:40: Project Talks: Aaron Sloutski – Biopolymers Shoumik Saha – Molecular Simulations Leela Sotsky – Hydrogen Storage Sangita Das – Polymer Nanocomposites Dezhao Meng– Rhizobial EPS & Metal Ion Interaction Muyun Cui – Cells 3:40 – 4:30: Project Fair!	10:15 – 10:30: Organizational Meeting 10:30 – 1:00: Project Fair (cont.) 1:00: Lab Work! (According to your group's schedule)	10:15 – 10:30: Organizational Meeting 10:30 – 11:00: DISC and the Robot 11:00 – 11:15: 1st Research Update – Nuclear Materials 11:15: Pizza Grab & Go Lunch & Lab Work! (According to your group's schedule)

Summer Scholar Schedule of Weekly Activities

Each day starts with a mandatory group meeting at 10:15 AM!

Daily Schedule: Week of 7/13

Monday – 7/13	Tuesday – 7/14	Wednesday – 7/15	Thursday – 7/16	Friday – 7/17
10:15 – 10:30: Organizational Meeting 10:30: Lab Work! (According to your group's schedule)	10:15 – 10:30: Organizational Meeting 10:30 – 11:30: Amy Marschilok Battery Storage 11:30: Lab Work! (According to your group's schedule)	10:15 – 10:30: Organizational Meeting 10:30: Lab Work! (According to your group's schedule)	10:15 – 10:30: Organizational Meeting 10:30: Lab Work! (According to your group's schedule)	10:15 – 10:30: Organizational Meeting 10:30 – 11:30: Jack Fuhrer, Renaissance School of Medicine Applying to Medical School 10:30 – 11:30: Research Updates: Flame Retardant Groups 11:30 – 12:00: Working Pizza Lunch 12:00 – 12:30: Michelle Hutchins, UPenn Applying to VIPER 12:30: Lab Work! (According to your group's schedule)

Summer Scholar Schedule of Weekly Activities

Each day starts with a mandatory group meeting at 10:15 AM!

Daily Schedule: Week of 7/20

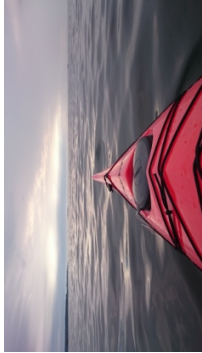
Sunday – 7/19:	Monday – 7/20	Tuesday – 7/21	Wednesday – 7/22	Thursday – 7/23	Friday – 7/24
	10:15 – 10:30: Organizational Meeting 10:30 – 11:30: Taejin Kim Heterogeneous Catalysis Research 10:30: Lab Work! (According to your group's schedule)	10:15 – 11:00: Organizational Meeting & AFM Lecture 11:00: Lab Work! (According to your group's schedule) 6:00: Annual Garcia Softball Game! 	10:15 – 10:30: Organizational Meeting 10:30: Lab Work! (According to your group's schedule)	10:15 – 10:30: Organizational Meeting 10:30 – 11:15: Student Research Updates 11:15: Working Pizza Lunch & Lab Work! (According to your group's schedule) 	10:15 – 10:30: Organizational Meeting 10:30 – 11:15: Student Research Updates 11:15: Working Pizza Lunch & Lab Work! (According to your group's schedule)

**Trip to
Brookhaven
National
Lab's
NSLS-II
Summer
Sunday!**

Summer Scholar Schedule of Weekly Activities

Each day starts with a mandatory group meeting at 10:15 AM!

Daily Schedule: Week of 7/27

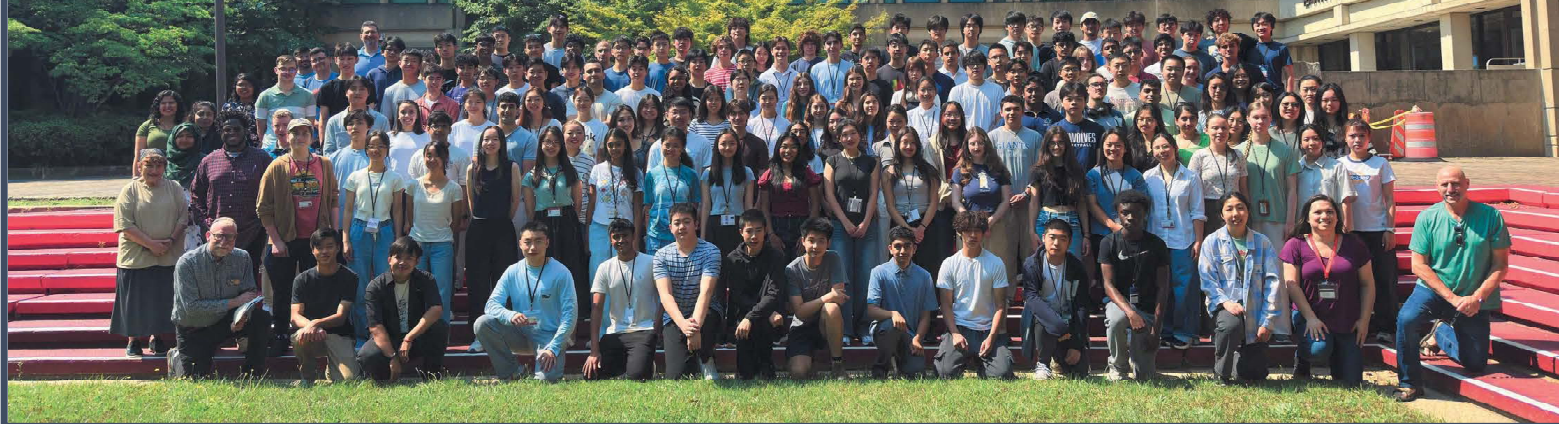
Monday – 7/27	Tuesday – 7/28	Wednesday – 7/29	Thursday – 7/30	Friday – 7/31
 Annual Garcia Canoe Trip! Nissequogue River	10:15 – 10:30: Organizational Meeting 10:30 – 12:00: Student Research Updates 12:00: Lab Work! (According to your group's schedule) 5:45: Liquid Nitrogen Ice Cream & Student Research Updates	10:15 – 10:30: Organizational Meeting 10:30 – 11:30: Student Research Updates 10:30: Lab Work! (According to your group's schedule) 7:00: Garcia 2026 Orchestra Concert Dinner!	10:15 – 10:30: Organizational Meeting 10:30 – 12:00: Student Research Updates 12:00: Lab Work! (According to your group's schedule) 6:00: Ropes Course at Adventure Park! 	10:15 – 10:30: Organizational Meeting & Dr. Giorgios Romanos 10:30 – 11:30: Student Research Updates 11:30 – 12:00: Working Pizza Lunch 12:00: Lab Work! (According to your group's schedule)

Summer Scholar Schedule of Weekly Activities

Each day starts with a mandatory group meeting at 10:15 AM!

Daily Schedule: Week of 8/3

Sunday – 8/2:		Monday – 8/3	Tuesday – 8/4	Wednesday – 8/5	Thursday – 8/6	Friday – 8/7
Trip to Llama Farm! 		10:15 – 10:30: Organizational Meeting 10:30 – 11:30: Student Research Updates 11:30: Lab Work! (According to your group's schedule)	10:15 – 10:30: Organizational Meeting 10:30 – 11:30: Student Research Updates 11:30: Lab Work! (According to your group's schedule)	10:15 – 10:30: Organizational Meeting & Dr. Rachel Brownlee, DLAR 10:30 – 11:30: Student Research Updates 11:30: Lab Work! (According to your group's schedule)	10:15 – 10:30: Organizational Meeting 10:30 – 11:30: Student Research Updates 11:30: Lab Work! (According to your group's schedule)	



Please join us for the

García 2026 End-of-Summer Research Symposium

Friday, August 7th, 2026

10:15AM – 1:30PM

SAC Ballroom A

Stony Brook University

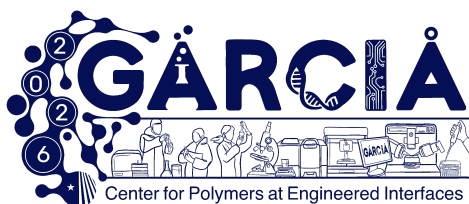
**Research Presentations:
Garcia Program Students**

Welcome – Steve Vaccarelli

Musical Arrangement – Garcia 2026's Sokolov Quartet

Gala Luncheon – Wing Wan of West Hempstead

Parking in Lots 12, 19, 20, or Admin Garage



End-of-Summer Research Symposium

Friday, August 7th 2026 - SAC Ballroom A

10:15 AM	<i>Musical Arrangement: Jon Sokolov Ensemble</i> <i>Conducted by Prof. John Jerome</i>
	Welcome: Mr. Steven Vaccarelli – Brown Bros Harriman
10:30 AM	Session 1: Flame Retardants and Nanocomposites Chairs: Jashmin Gill, Phoebe Zheng, Adithya Santhosh – Stony Brook University
1.1	Durable Phosphorus-Nitrogen Flame Retardant for Cotton Fabric: A Gas- and Condensed-Phase Synergistic Approach Sounak Debnath – Huron High School, Ann Arbor, Michigan Chuansu Shang – Shenzhen Middle School, Shenzhen, Guangdong, China
1.2	Investigation of Freezing Behavior Within Star Polymer Networks Larry Lee – Texas Academy of Math and Science, Denton, Texas Leo Zhang – The Harker School, San Jose, California
1.3	Optimizing Melt-Mixing Sequences and 3D Printing Parameters for Conductive and Flexible Graphene-Enhanced Biodegradable PLA/PBAT Nanocomposites Melody Dai – Basis Independent Silicon Valley, San Jose, California Gavin Finkel – HAFTR High School, Cedarhurst, New York Alexander Fu – Union County Magnet High School, Scotch Plains, New Jersey Janet Guan – Mission San Jose High School, Fremont, California Charles Huang – North Hollywood High School, North Hollywood, California Eric Xie – Geffen Academy at UCLA, Los Angeles, California Tracy Zhang – Harrow International School Hong Kong, New Territories, Hong Kong SAR
1.4	Electrochemical Fabrication and Characterization of Chitosan–Metal Nanocomposite Coatings on Stainless Steel for Sensor and Neuromorphic Applications Yusuf Sheikh – Newfield High School, Selden, New York
1.5	Characterizing the Thermal and Heating Properties of Biodegradable Conductive Polymer Composite Blends Caleb Son – Mount Hebron High School, Ellicott City, Maryland
1.6	Nanoconfinement, Polymer Chemistry, and Nanoclay Effects on Supercritical CO ₂ -Induced Relaxation in PS, PMMA, and PS/PMMA Thin Films Alexander Yoon – Maria Carrillo High School, Santa Rosa, California

1.7	Performance Evaluation of a Sustainable Phosphorus-Based Vegetation Flame Retardant For Wildfire Mitigation Aarush Batra – Edison Academy Magnet School, Edison, New Jersey Aarav Desai – Chino High School, Chino, California Marie Kouzmine – The Bear Creek School, Redmond, Washington Roy Lin – Munster High School, Munster, Indiana
10:50 AM	Session 2: AI-Enabled Science Chairs: Bandari Chen & Jian Chen – Stony Brook University; Andrei Scurtu – Transilvania University of Brasov, Romania; Wendy Yu – Duke University
2.1	AI-Assisted Cervical Vertebral Maturation Classification Using CBCT Images
2.2	Automated Characterization of Maxillary Sinus Pathology using Cone-Beam Computed Tomography Sahil Vora – Staples High School, Westport, Connecticut Jenny Song – Shanghai High School International Division, Shanghai, China
2.3	Developing Open-Source Automated Workflows for Quantum Chemistry Calculations in MISPR Using ORCA Leroy Jing – William Fremd High School, Palatine, Illinois William Wang – Lakeside School, Seattle, Washington
2.4	Topology-Assisted AI Models for Prediction on Breast Cancer Contrast-Enhanced Spectral Mammography (CESM) Images Eric Chen – The Pingry School, Basking Ridge, New Jersey
2.5	Digital Image Speckle Correlation (DISC)-Based Analysis of Facial Muscle Movements for Detecting and Monitoring Neurological Disorders
2.6	Digital Image Speckle Correlation (DISC)-Based Analysis of Soft Tissue Deformation for Robotic-Assisted Needle Procedures Annabelle Klein – Yeshiva University High School for Girls, Hollis, New York Alfred Lee – Baldwin High School, Baldwin, New York
2.7	Evaluation of Belief-Guided Multi-Stage Simulated Annealing Konstin Lee – The Stony Brook School, Stony Brook, New York
2.8	Robot Motion Planning via Egocentric Object Screw Trajectory Recording Using Project Aria Glasses Mira Goldhaber – The Berkeley Carroll School, Brooklyn, New York
2.9	Mapping 3D SpaceMouse Asynchronous Inputs for Teleoperation of Franka Emika Panda Arm and Imitation Learning Benchmark Tests in Physics Simulator Albert Eksarevskiy – Lakeside School, Seattle, Washington Alan Li – Peddie School, Hightstown, New Jersey
11:10 AM	Session 3: Protein Structures Chairs: Sergio Rosa – Lehigh University; Tiffany Li – University of Michigan; Sophia Kang – Stony Brook University

3.1	Domain-Resolved Computational Modeling of Fibrinogen Interactions with Collagen and Albumin Isaac Sedighi – Syosset High School, Syosset, New York Brian Sun – Niskayuna High School, Niskayuna, New York Grace Yuan – Thomas Jefferson High School for Science and Technology, Alexandria, Virginia
3.2	Post-Treatment Washing Enables Lower-Pressure Supercritical CO₂ Decellularization of Murine Dermal Tissue to Promote Extracellular Matrix Preservation Theo Jeon – Bergen County Technical High School at Teterboro, Teterboro, New Jersey William Neice – Lake Oswego High School, Lake Oswego, Oregon Ashley He – Tomball Memorial High School, Tomball, Texas Yiting Bao – No.2 High School of East China Normal University, Shanghai, China Lucas Wang – Sewickley Academy, Sewickley, Pennsylvania Grace Yuan – Thomas Jefferson High School for Science and Technology, Alexandria, Virginia
3.3	Localized Release of Tagmented DNA Suspended on PMMA and SU-8 Gratings via Proteinase Droplets Edward Zhu – Montgomery Blair High School, Silver Spring, Maryland Jack Merlo – South Side High School, Baldwin, New York
3.4	Investigating Molecular Mechanisms of Collagen-Fibrinogen Interactions and Thrombin-Independent Fibrillar Structure Formation Ria An – The Loomis Chaffee School, Windsor, Connecticut Arthur Jiang – Old Scona Academic, Edmonton, Alberta, Canada Lily Oh – Saint Mark's School of Southborough, Southborough, Massachusetts Lenny Zhou – The Culver Academies, Culver, Indiana
3.5	Investigating the Mechanism of Surface-Induced Thrombin-Free Fibrinogen Assembly Through All-Atom Molecular Dynamics Simulations William Jiang – The Harker School, San Jose, California Jason Lian – Niskayuna High School, Niskayuna, New York Ashwath Ram – Edison Academy Magnet School, Edison, New Jersey
3.6	Investigating Interactions Between Fibrinogen and Weight-Percent Varied DOPC-Cholesterol Supported Lipid Bilayers Ariana Lye – Syosset High School, Syosset, New York
3.7	The Impact of Partially Reduced Graphene Oxide on Enzymatic Activity in Fibrin Clot Lysis and Formation for Coagulopathies and Hemorrhage
3.8	
	Characterizing the Surface Binding Mechanisms of Fibrinogen and Partially Reduced Graphene Oxide for Thrombogenic Clotting Virginia Zhu – Del Norte High School, San Diego, California Niki Tavakoli – Phillips Academy Andover, Andover, Massachusetts Muling Lu – Williamsville East High School, East Amherst, New York Azzy Xiang – Dublin Jerome High School, Dublin, Ohio Sophia Rosa – South Side High School, Rockville Centre, New York
11:30 AM	Session 4: Energy Materials Chairs: Kenneth Chang – Vanderbilt University; Daniel Lim – Cornell University

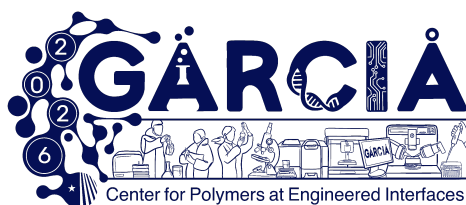
4.1	Synthesis and Catalytic Evaluation of Reduced Graphene Oxide and Nickel-Decorated Reduced Graphene Oxide for Carbon Monoxide Oxidation Brian Yang – Torrey Pines High School, San Diego, California Eric Zang – William P. Clements High School, Sugar Land, Texas
4.2	Investigating Synthesis and Structure of Alumina-supported Cobalt Oxide Catalysts for Oxidation of Carbon Monoxide Kevin Han – Palos Verdes Peninsula High School, Rolling Hills Estates, California
4.3	Engineering Cu-Based Bimetallic Nanoparticle-Nafion Interfaces for Enhanced Performance and CO Tolerance of PEM Fuel Cells Joel Pae – Korea International School, Seongnam-si, Gyeonggi-do, South Korea Anish Peri – Eden Prairie High School, Eden Prairie, Minnesota Ameya Vathanan – Ardrey Kell High School, Charlotte, North Carolina Phil Yao – Newport High School, Bellevue, Washington
4.4	Investigation of Synergy Effect on Alkaline Exchange Membrane Fuel Cell by using ALD Coated TiO₂ and Gold Nanoparticles Aidan He – Manhasset Secondary School, Manhasset, New York Brian Xiong – Roslyn High School, Roslyn Heights, New York
11:45 AM	Session 5: Biomechanics Chairs: Ethan Lee – Stony Brook University; Dennis Xu – Carnegie Mellon University
5.1	Lecithin Retinol Acyltransferase Alters Cytoskeletal Structure and Young's Modulus in Squamous Cell Carcinoma Cells Bhavya Patel – Biotechnology High School, Freehold, New Jersey Sean She – Shanghai Starriver Bilingual School, Shanghai, China Max Weiner – Salanter Akiba Riverdale High School, Bronx, New York
5.2	Investigating the Effects of TiO₂ Nanoparticles on Angiogenesis in HUVEC-EGFP Cultures Lucas Hofflich – Tuckahoe High School, Eastchester, New York Jiaqi Li – Columbus Academy, Gahanna, Ohio Taylor Maguire – Garden City High School, Garden City, New York William Ni – The Pennington School, Pennington, New Jersey Sean Park – Chattahoochee High School, Johns Creek, Georgia Jacob Stern – Davis Renov Stahler Yeshiva High School for Boys, Woodmere, New York
11:50 AM	Session X JESTI – Journal of Ethics in Scientific and Technological Innovations Chairs: Marie Kouzmine & Ria An
X.1	Kiruna, 2021: A Case Study into Moral Hazard and a Test for Moral Hazard Objections to Research Sean Park – Chattahoochee High School, Johns Creek, Georgia Luke Zhang – Southfield Christian School, Southfield, Michigan
X.2	The Ethics of Preserving Identity During Awake Craniotomy Angel Zhang – Carlucci American International School of Lisbon, Sintra, Lisbon, Portugal

X.3	<i>The Space Race's Second Lap! An Ethical Analysis of the Modern Space Revitalization</i> Gavin Finkel – HAFTR High School, Cedarhurst, New York
11:55 AM	Session 6: Materials Engineering Chairs: Sam Sylvia – Stony Brook University; Dylan Deng – Washington University in St. Louis
6.1	Grain Boundary Characterization of Carbide Ceramics for Nuclear Fusion First-Wall Applications Henry Huang – Mountain View High School, Mountain View, California Jonathan Symonds – Salanter Akiba Riverdale High School, Bronx, New York Alessandro Verona – American School of Milan, Milan, Italy
6.2	Effects of Substrate Microsteps on SiC Growth Xuanming Liu – Syosset High School, Syosset, New York Fred Sun – BASIS Independent Silicon Valley, San Jose, California Taly Turchin – Eastlake High School, Sammamish, Washington
12:00 PM	Session 7: Nanotoxicology Chairs: Patricia Tomas – University of Connecticut; Julianna Vrabec – Purdue University
7.1	Topology-based Analysis of TiO ₂ Effects on Endothelial Cell Network Formation Vera Lew – Davis Senior High School, Davis, California
7.2	Evaluating Titanium Particles Released During Dental Implant Placement Vicky Ye – Ward Melville High School, East Setauket, New York Lucy Yu – Wellesley High School, Wellesley, Massachusetts
7.3	Substrate-Mediated Mitigation of TiO ₂ Nanoparticle Effects on Osteoblast Mineralization Lucas Hofflich – Tuckahoe High School, Eastchester, New York Jiaqi Li – Columbus Academy, Gahanna, Ohio Taylor Maguire – Garden City High School, Garden City, New York William Ni – The Pennington School, Pennington, New Jersey Sean Park – Chattahoochee High School, Johns Creek, Georgia Jacob Stern – Davis Renov Stahler Yeshiva High School for Boys, Woodmere, New York
12:10 PM	Session 8: Hydrogels for Industrial Applications Chairs: Sophie Xu, Cyrus Sedgh, Issac Varghese – Stony Brook University; Hunter Maguire – Columbia University
8.1	Determination of Ion Interactive Properties of Ethanol Precipitable Material from <i>Rhizobium tropici</i> Andrew Li – Deerfield Academy, Deerfield, Massachusetts Justin Ren – Shanghai Starriver Bilingual School, Shanghai, China

8.2	Investigating the pH Buffer Properties of Rhizobial Exopolysaccharides Andrew Li – Deerfield Academy, Deerfield, Massachusetts Sharon (Yu-Shan) Liu – Morrison Academy Kaohsiung, Kaohsiung, Taiwan (Republic of China) Justin Ren – Shanghai Starriver Bilingual School, Shanghai, China Caleb Son – Mount Hebron High School, Ellicott City, Maryland Kaylee Xu – Flour Bluff High School, Corpus Christi, Texas Alexander Yoon – Maria Carrillo High School, Santa Rosa, California
8.3 8.4	Sustainable Metal Nanoparticle Synthesis via Rhizobial Exopolysaccharides Controlled High-Efficiency Removal of Heavy Metals via Rhizobial Exopolysaccharides for Sustainable Water Treatment Sharon (Yu-Shan) Liu – Morrison Academy Kaohsiung, Kaohsiung, Taiwan (Republic of China) Caleb Son – Mount Hebron High School, Ellicott City, Maryland Kaylee Xu – Flour Bluff High School, Corpus Christi, Texas Alexander Yoon – Maria Carrillo High School, Santa Rosa, California
8.5	Engineering a Stable Emulsion Formulation for a Fragrance & Mineral-Based Insect Repellent Audrey Tan – James Madison High School, Vienna, Virginia Luke Zhang – Southfield Christian School, Southfield, Michigan
12:22 PM	Session 9: Biomedical Hydrogels Chairs: Syringa Abshire-Cohen – Stony Brook University; Leonard Johnson – Stony Brook University; Hannah Goykadosh – Binghamton University; Justin Wightman – Stevens Institute of Technology
9.1	Engineering Poly(vinyl alcohol)-Based Vascular Graft and Aneurysm Model Systems Ian Jake Kim – West High School, Salt Lake City, Utah Megan Li – Zhengzhou Middle School, Zhengzhou, Henan, China Nicole Lin – Basis Independent Fremont (Upper School), Fremont, California Grace Zeng – International School, Bellevue, Washington
9.2	Fundamental Characterization Studies of Injectable Pluronic-Based Polymer Coils for Embolization of Brain Aneurysms Audrey Chin – Palos Verdes Peninsula High School, Rolling Hills Estates, California Advik Kishore – Flower Mound High School, Flower Mound, Texas Bella Lin – Island Trees High School, Levittown, New York Lelin Tsai – Greenwich High School, Greenwich, Connecticut Camilie Wang – Keystone Academy, Beijing, China Amber Zhang – The Bishop's School, San Diego, California
9.3	Integrated Mechanical Characterization and Optimization of PluCoil Hydrogels for Endovascular Treatment of Intracranial Aneurysms Braylon Ashby – Baldwin High School, Baldwin, New York Audrey Chin – Palos Verdes Peninsula High School, Rolling Hills Estates, California Yeeun (Lydia) Choi – Korea International School, Seongnam-Si, Gyeonggi-do, South Korea Advik Kishore – Flower Mound High School, Flower Mound, Texas Bella Lin – Island Trees High School, Levittown, New York Camilie Wang – Keystone Academy, Beijing, China

	Amber Zhang – The Bishop's School, San Diego, California Hanchen Zhou – Shanghai World Foreign Language Academy, Shanghai, China
9.4	Injectable Crosslinking Calcium Hydroxide Salicylic Acid (CASA) Hydrogel for Antibacterial Delivery in Endodontic Therapy
9.5	In-Situ Crosslinking Calcium Hydroxide Salicylic Acid (CASA) Drug Delivery System for Rapid Wound Disinfection in Austere Environments Solenyi Onwueme – Atholton High School, Columbia, Maryland Emily Segall – Yeshiva University High School for Girls, Hollis, New York Cindy Tint – Bellaire High School, Houston, Texas
9.6	Chlorine Concentration in Commercial Hypochlorous Acid Compound Correlates to Efficacy as a Bacterial Sporicide Solenyi Onwueme – Atholton High School, Columbia, Maryland Emily Segall – Yeshiva University High School for Girls, Hollis, New York Cindy Tint – Bellaire High School, Houston, Texas Vicky Ye – Ward Melville High School, East Setauket, New York Lucy Yu – Wellesley High School, Wellesley, Massachusetts
9.7	Optimization of F127DMA Hydrogel Crosslinking and Bioprinting Parameters for Aneurysm Model Fabrication
9.8	Optimization of Polyvinyl Alcohol (PVA) Dip-coated Vessels for Aneurysm Model Fabrication Steve Samuel – Solon High School, Solon, Ohio Alina Wang – Basis Bilingual School Chengdu, Chengdu, Sichuan, China Terrence Wang – Stony Brook School, Stony Brook, New York
9.9	Biodegradable Hydrogel Agents for Endovascular Embolization of Brain Aneurysms Jayden Lin – Bridgeland High School, Cypress, Texas Angel Zhang – Carlucci American International School of Lisbon, Sintra, Lisbon, Portugal
9.10	Engineering a Glycation-Resistant Scaffold to Promote Cell Migration and Differentiation in Diabetic Wound Healing Theo Jeon – Bergen County Technical High School at Teterboro, Teterboro, New Jersey William Neice – Lake Oswego High School, Lake Oswego, Oregon Ashley He – Tomball Memorial High School, Tomball, Texas Yiting Bao – No.2 High School of East China Normal University, Shanghai, China Grace Yuan – Thomas Jefferson High School for Science and Technology, Alexandria, Virginia Lucas Wang – Sewickley Academy, Sewickley, Pennsylvania
12:50 PM	Gala Luncheon by Wing Wan of West Hempstead

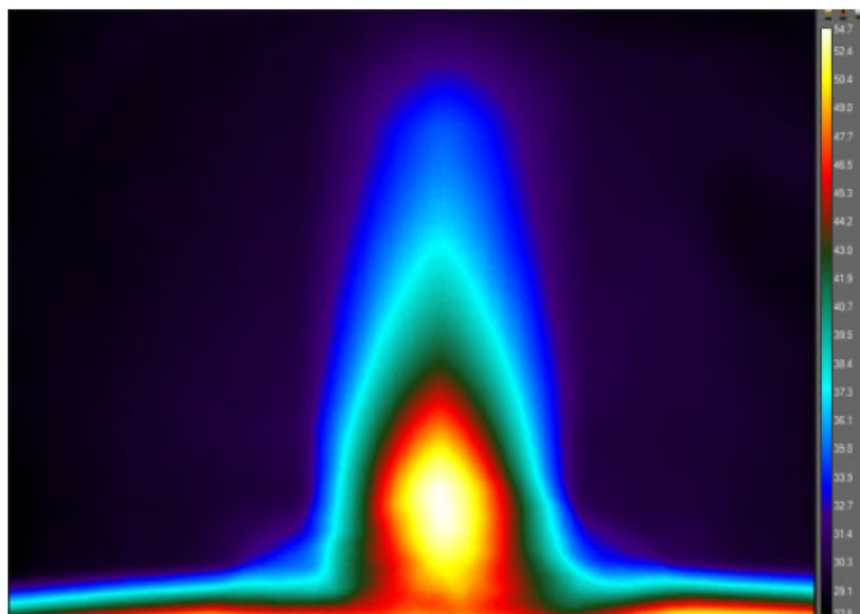
Support by the Morin Charitable Trust is gratefully acknowledged.



Session I: Flame Retardants and Nanocomposites

Mentors:

**Akash Ranjan Pati,
Sangita Das,
Shoumik Saha**



Durable Phosphorus-Nitrogen Flame Retardant for Cotton Fabric: A Gas- and Condensed-Phase Synergistic Approach

Sounak Debnath¹, Chuansu Shang², Jashmin Gill³, Akash Ranjan Pati³, Miriam Rafailovich³

¹Huron High School, MI 48105, ²Shenzhen Middle School, China Shenzhen 518024, ³Department of Materials Sciences & Chemical Engineering, Stony Brook University, NY 11790

Cotton has historically been one of the most widely used textiles due to its comfort, breathability, and biodegradability. However, its high flammability, characterized by a limiting oxygen index of approximately 18%, constitutes a serious fire hazard.¹ To address this, several classes of flame retardant (FR) materials have been developed, including boron-, halogen-, and phosphorus-based compounds. These FRs operate via either condensed-phase mechanism, in which they form a protective carbon char barrier, or gas-phase mechanism, wherein fire-propagating free radicals are scavenged and terminated. Nevertheless, many existing studies exhibit notable limitations: some employ potentially toxic chemicals and higher loadings of FR while others yield excessively long char lengths.² This study examines the synergistic interaction between two non-toxic flame retardants, ammonium polyphosphate (APP) and resorcinol bis(diphenyl phosphate) (RDP), with the aim of leveraging both mechanisms concurrently.

The FR treatment procedure employed a two-step process to effectively bind chemically the FR to the cotton: pretreatment and FR application. The pretreatment consisted of dipping raw cotton in 1 wt% NaOH at 70 °C followed by 1.5 M citric acid (CA) treatment for 1 hour. In the FR application step, the cotton was submerged in FR formulation. A polymeric surfactant, Pluronic F-127, was used to evenly disperse the hydrophobic RDP in the FR. In addition, dicyandiamide (DICY) was introduced as a catalyst for CA to facilitate the cross-linking reaction between the pretreated cotton and the FR solution. Previously optimized FR formulation concentrations (10% APP / 5% RDP / 1% F-127 / 5% DICY) were used for this study. After drying and curing, the FR-treated cotton samples were washed with 0.15 wt% sodium dodecyl sulfate solution to evaluate the durability of the FR over several laundering cycles (LCs).

Chemical bonding between the FR and cotton was verified by Fourier-transform infrared spectroscopy (FTIR), and is evidenced by the presence of P-O-C and P=O peaks at 1000-1200 cm⁻¹ and 1250 cm⁻¹, respectively (Fig. 1a).³ Furthermore, the flame retardant-treated cotton samples displayed a mean weight increase of 17.13 ± 5 %, signifying the successful bonding of the flame retardant onto the fabric matrix. Flame retardancy was assessed by vertical burn tests conducted on both raw and FR-treated cotton fabrics in accordance with ASTM D6413. The FR-treated cotton exhibited an initial average char length of 1.42 inches, which increased to 3.31 inches after 8 LCs, suggesting the FR was chemically bonded to the cotton (Fig. 1b). In contrast, raw cotton burnt to completion without char residue, demonstrating the effectiveness and durability of the FR treatment. Furthermore, thermogravimetric analysis (TGA) was performed to evaluate the thermal degradation of the FR-treated samples, revealing a significantly higher residual char yield (~21 %) compared to raw cotton (~1 %) due to the delayed degradation of cellulose (Fig. 1c). Scanning electron microscopy (SEM) confirms the uniform coating of the cotton fibers by the FR (Fig. 1d). Finally, energy-dispersive X-ray spectroscopy (EDS) analysis of the burnt FR-treated cotton and burnt laundered 8X samples reveal the presence of phosphorus, thus corroborating the condensed-phase mechanism of the FR.

Future work aims to extend washing durability to 30 LCs, investigate the gas-phase mechanism underlying the rapid self-extinguishing behavior, and assess the cytotoxicity of the FR-treated cotton.

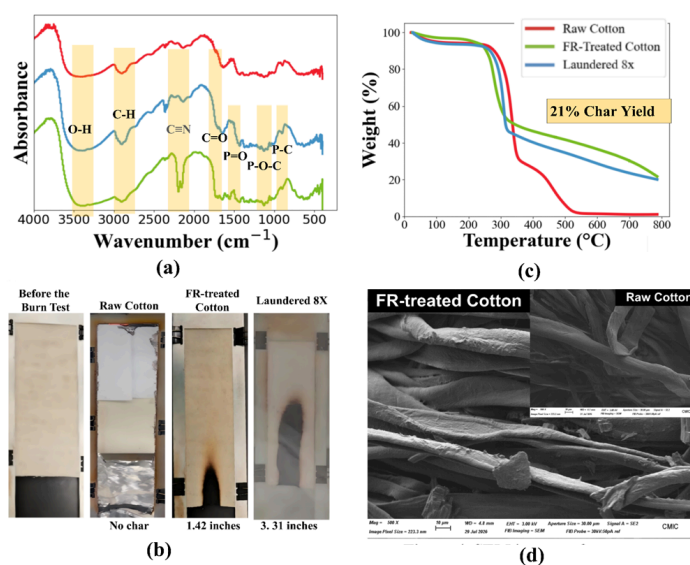


Figure 1: (a) FTIR, (b) burn test images, and (c) TGA of raw, FR-treated, and laundered cotton (d) SEM images of raw and FR-treated cotton

¹Ling, Chao, et al. "A Review on the State of Flame-Retardant Cotton Fabric: Mechanisms and Applications." *Industrial Crops and Products*, vol. 194, 2023, art. 116264.

²Jiang, Yong-Man, et al. "Preparation and Flame Retardant Properties of Cotton Fabrics Treated with Resorcinol Bis(Diphenyl Phosphate)." *Cellulose*, vol. 28, 2021, pp. 4455–4467

³Ni, Qingting, et al. "Synergistic Flame Retardant Effect of Phosphorus-Nitrogen System for the Preparation of High-Performance Flame-Retardant Cotton Fabrics." *Surfaces and Interfaces*, vol. 69, July 2025, p. 106833.

⁴Wei, Jieyu, et al. "Preparing Durable Flame Retardant and Formaldehyde Free Cotton Fabrics with Crosslinked Flame Retardant System." *Polymer Degradation and Stability*, vol. 239, Sept. 2025, p. 111382.

Investigation of Freezing Behavior Within Star Polymer Networks

Larry Lee¹, Leo Zhang², Shoumik Saha³, Dilip Gersappe³, Miriam Rafailovich³

¹Texas Academy Of Mathematics and Science, Denton, Texas 76201, ²The Harker School, San Jose, California 95129, ³Stony Brook University, Stony Brook, NY 11794

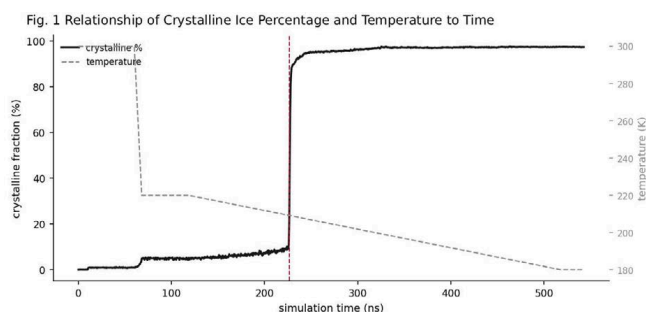
The formation and growth of ice crystals at low temperature poses a challenge to multiple fields including biomedical engineering and infrastructure stability. The first antifreeze materials were developed through antifreeze proteins, though such materials remain difficult to manufacture and scale. Poly(vinyl alcohol) (PVA) is currently the most studied synthetic antifreeze polymer, displaying significant Ice Recrystallization Inhibition (IRI) activity.¹

Previous studies conclude that the IRI Mechanism of PVA depends on its hydrodynamic volume, rather than the previously proposed hydroxyl group functionality. The potentials of manufacturing of increasingly complex star polymers remains significant, for designs such as end-functionalized group are proposed to have the potential to increase IRI activity of shorter arms.² At this moment, 4-arm star PVA molecules with end-functionalized groups have been successfully manufactured, though their IRI activity has not been studied yet.³ This study utilizes MD methods to understand the performance of star polymers with a magnitude of arms that has not been studied before, in order to aid future research in more sophisticated star-PVA molecules.

Simulations are performed in LAMMPS. A single star polymer with 3 arms of length 10 monomers is placed at the center of a periodic box and solvated by generating water on a BCC lattice, deleting any overlapping water molecule. The core is held fixed throughout. The system is first equilibrated using the NVT ensemble at 300K using only Lennard-Jones potentials. After, a previously developed united-atom model is adapted to model each star arm as a Methyl Group. Bonded interactions are represented by a harmonic potential.⁴ Water is modeled with the monoatomic mW potential. NPT is then used to maintain 1 atm of pressure while cooling to 220 K and subsequently to 180 K. The radius of gyration is calculated to match experimental data.

Figure 1 demonstrates a significant increase in crystalline ice at 209K, well below the freezing temperature of water in the mW model. The significant increase in crystalline ice suggests a rather weak IRI activity, though more simulations are needed to establish a control group and also understand the difference between this study and the previous study.

Several computations are pending to finish in a few days. We expect to see a noticeable increase in IRI activity for star PVA with longer arms, though potentially new mechanisms can be revealed for star PVAs with more arms.



[1] Zhang, X., Tian, Y., Yang, H., Jiang, X., Li, Y., Huang, X., Yang, J., & Zhang, L. (n.d.). Development and Applications of Antifreeze Materials: From Nature to Design. *Advanced Materials*, n/a(n/a), e73293. <https://doi.org/https://doi.org/10.1002/adma.73293>

[2] Congdon, T. R., Notman, R., & Gibson, M. I. (2017). Synthesis of star-branched poly(vinyl alcohol) and ice recrystallization inhibition activity. *European Polymer Journal*, 88, 320–327. <https://doi.org/10.1016/j.eurpolymj.2017.01.039>

[3] Murakami G, Kubo T, Satoh K. Precision Synthesis of End-Functionalized Star Poly(vinyl alcohol)s by RAFT Polymerization and Post-polymerization Modification. *Precis Chem.* 2023 Jun 13;1(4):256-263. doi: 10.1021/prechem.3c00051. PMID: 40881838; PMCID: PMC12382265.

[4] Kenji Mochizuki, Yuqing Qiu, Valeria Molinero; Promotion of Homogeneous Ice Nucleation by Soluble Molecules. *Journal American Chemical Society* 29 November 2017; 139 (47): 17003–17006. <https://doi.org/10.1021/jacs.7b09549>

Optimizing Melt-Mixing Sequences and 3D Printing Parameters for Conductive and Flexible Graphene-Enhanced Biodegradable PLA/PBAT Nanocomposites

Melody Dai ¹, Gavin Finkel ², Alexander Fu ³, Janet Guan ⁴, Charles Huang ⁵, Eric Xie ⁶, Tracy Zhang ⁷, Sangita Das ⁸, Miriam Rafailovich ⁸

¹ BASIS Independent Silicon Valley, San Jose, CA, ² HAFTR High School, Cedarhurst, NY, ³ Union County Magnet High School, Scotch Plains, NJ, ⁴ Mission San Jose High School, Fremont, CA, ⁵ North Hollywood High School, North Hollywood, CA, ⁶ Geffen Academy at UCLA, Los Angeles, CA, ⁷ Harrow International School Hong Kong, Hong Kong, New Territories, HK, ⁸ Stony Brook University, Stony Brook, NY

The shift towards sustainable devices has inspired interest in biodegradable polymer composites. When blended with graphene, they are environmentally-friendly alternatives to conventional conductors.^{1,2} Their piezoresistive and flexible properties also have significant applications in wearable electronics.² However, current characterization of those properties is limited. This study addresses the existing gap by optimizing the conductive properties of a biodegradable two-phase polylactic acid (PLA) / polybutylene adipate-co-terephthalate (PBAT) nanocomposite with conductive graphene nanoplatelet (GNP H-5) filler.

The conductive properties of graphene-enhanced PBAT / PLA nanocomposites were optimized by studying melt-mixing sequences and 3D printing processes. Three sequences were tested: blending (I) PBAT, PLA, and GNP simultaneously (singlebatch), (II) PBAT and GNP first (PBAT masterbatch), and (III) PLA and GNP first (PLA masterbatch). In all batches, PBAT and PLA were blended in a 3:1 ratio with a 5–20% range of GNP concentrations. Both molded and printed samples were created.

Four-point probe testing yielded maximum conductivities of 0.817 S/m (singlebatch) and 0.33 S/m (PBAT masterbatch), indicating PBAT masterbatch samples were less conductive than singlebatch samples (Fig. 1). This discrepancy was attributed to GNP localization in the graphene-affinitive PBAT phase,³ which disrupts the GNP network by reducing platelet size. The PLA masterbatch showed similar trends with lower overall conductivity. Additionally, printed samples were less conductive than molded samples across all three batches; agglomeration of PBAT on the outer layer of filament likely increased GNP separation. SEM data supported this conclusion by depicting a smooth surface in printed samples, characteristic of the PBAT phase.

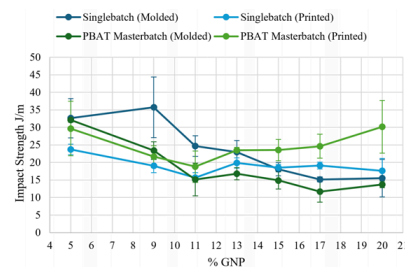


Figure 2. Impact strength for molded/3D printed and singlebatch/ PBAT masterbatch samples of 5%-20% GNP.

These findings reveal promising ways to improve the conductivity of biodegradable nanocomposites without compromising mechanical strength, supporting the broader integration of sustainable materials into modern electronics. Future work will focus on the effect of 3D printing parameters such as printing speed and nozzle temperature on conductive properties. The conductivity of the filament itself will also be investigated to analyze how graphene-PBAT interactions during extrusion contribute to post-printing conductivity changes.

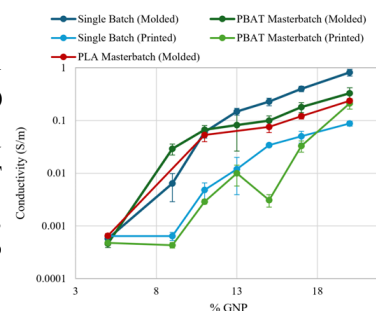


Figure 1. Average conductivity plotted against GNP concentration for single batch and PBAT masterbatch samples (both molded and 3D printed).

Impact tests demonstrated no significant decrease in impact strength with larger GNP concentrations (Fig. 2), implying minimal change in brittleness due to interdiffusion of PBAT between graphene layers. Meanwhile, tensile tests showed increasing Young's modulus and decreasing percent elongation with increasing GNP concentration, indicating greater stiffness with the presence of graphene. However, the 20% GNP samples maintained percent elongations of roughly 6% (Fig. 3), which is sufficiently high for 3D printing.

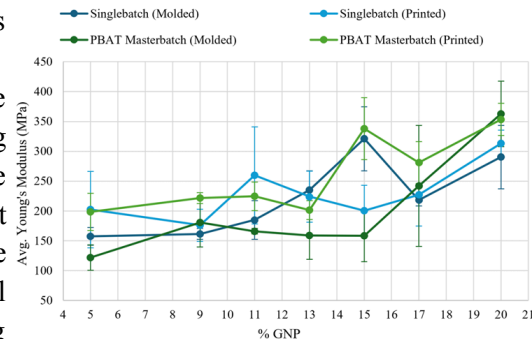


Figure 3. Average Young's Modulus plotted against % GNP for single batch molded, single batch printed, PBAT masterbatch molded, and PBAT masterbatch printed samples.

¹Okpuwhara, Rita O. and Oboirien, Bilainu O, Nano Trends, vol. 12, no. 12, Dec. 2025, 100166, ISSN 2666-9781

²Zhan, Chuanxing, et al., Journal of Materials Chemistry C, vol. 5, no. 7, Feb. 2017, pp.1569-1585, ISSN 2050-7526

³Lin, Y.-C., et al., ACS Applied Materials & Interfaces, vol. 16, no. 47, Nov. 2024, pp. 65245–65254, ISSN 1944-8252

Electrochemical Fabrication and Characterization of Chitosan–Metal Nanocomposite Coatings on Stainless Steel for Sensor and Neuromorphic Applications

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Chitosan–metal nanocomposite coatings are multipurpose interfaces, integrating biocompatibility and tunable film chemistry of chitosan with the metallic nanoparticles. These chitosan-metal nanocomposites are found to be conductive and reactive yet protected by the chitosan in both wet and solid electrochemical testing.

This work presents an adjustable electrodeposition strategy for fabricating silver (Ag), gold (Au), palladium (Pd), and copper (Cu) nanoparticle coatings on electrodeposited chitosan films formed on 304 stainless steel substrates. The long-term goal of developing sensing platforms and neuromorphic computing elements whose function depends on tunable, and memristive charge-transport behavior.

304 stainless steel substrates were ultrasonically cleaned before chitosan electrodeposition (one or two layers, -3.0 V, 60 or 120 s). Ag, Pd, and Cu were electrodeposited for 60 or 120 s, while Au deposition was investigated across potentials from -1.0 V to +0.5 V. Coatings were analyzed by FTIR, XRF, optical microscopy, and cyclic voltammetry in either 0.01 M NaOH solution or a dry cell setup.

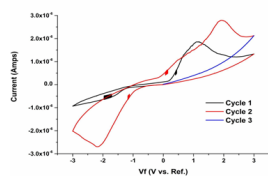


Figure 2: Electrochemical Characterization; Cyclic Voltammetry of Au -0.7v

Ag incorporation increases with both the number of chitosan layers and the Ag deposition time. Au incorporation is potential-dependent across the -1.0 to +0.5 V range, with the highest enrichment observed at -0.7 V among the conditions tested to date. Pd incorporation is an order of magnitude lower than Ag or Cu and decreases as the thickness increases, suggesting the chitosan layer may limit Pd clustering. Cu incorporation is comparatively insensitive to chitosan layer number or deposition time. Optical microscopy reveals structural variations across deposition conditions, featuring distinct spots that resemble either clustered nanoparticles or separate solid growths.

Cyclic voltammetry indicates that the electrochemical response of these composites is sensitive to thermal and atmospheric conditions. Ongoing work to determine whether charge transport is dominated by a metallic nanoparticle network, thermally activated hopping between nanoparticles or atomic clusters, or ionic conduction through the chitosan matrix itself continues.

Early results demonstrate memristive-like switching, including a hysteresis loop, suggesting charge transport in these composites may be tunable through fabrication conditions rather than fixed. Further characterization (Raman, SEM, UV-Vis, XPS) will probe nanoparticle morphology and chemical/optical interactions with the chitosan matrix, laying the foundation for evaluating memristive electronic properties relevant to future bio-sensing and neuromorphic applications.

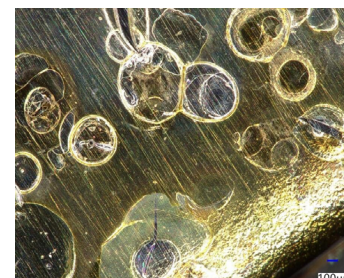


Figure 1: Optical Microscopy: Coating morphology of Au; 100x Magnification, 100μm, -0.7v

- 1) M. Cui¹, P. K. Jha, G.P. Halada, “Novel Synthesis Route for Palladium Nanoparticles”, Patent # 9,932,685, awarded: April 3, 2018.
- 2) M. Cui¹, G. P. Halada “Electrochemically Formed Chitosan-Nanoparticle Composites for Memristor and Sensor Applications.” Technology ID: 050-9643.
- 3) Suginta, W., Khunkaewla, P., & Schulte, A. (2013). Electrochemical Biosensor Applications of Polysaccharides Chitin and Chitosan. *Chemical Reviews*, 113(7), 5458–5479. <https://doi.org/10.1021/cr300325r>
- 4) Hosseini, N. R., & Lee, J.-S. (2015). Biocompatible and Flexible Chitosan-Based Resistive Switching Memory with Magnesium Electrodes. *Advanced Functional Materials*, 25(35), 5586–5592. <https://doi.org/10.1002/adfm.201502592>

Characterizing the Thermal and Heating Properties of Biodegradable Conductive Polymer Composite Blends

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There is a growing need for biodegradable materials in electronics due to the rise of electronic waste in the 21st century. Thus, materials with tunable and high-performance heating properties are valued for their uses in disposable heating components and self-regulating current protection mechanisms. Past studies have shown that graphene nanoplatelets dispersed in a biodegradable polymer matrix can yield effective joule-heating and positive temperature coefficient properties¹ while also showing the potential for binary phase segregation in composite systems to yield improved conductive properties².

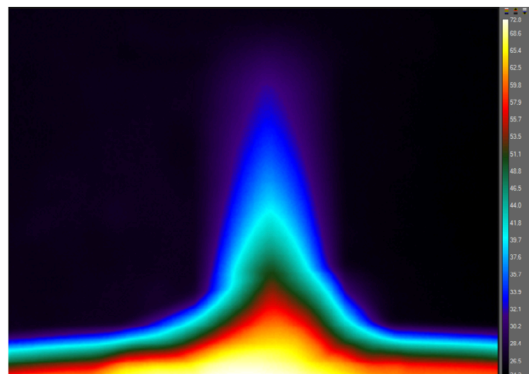


Figure 1: Thermal Image of Molded 9% wt GNP Sample

Polybutylene adipate terephthalate (PBAT) and Polylactic acid (PLA) were melt-mixed in a 3:1 ratio and blended at 5%, 9%, 13%, 15%, and 20% wt concentrations of graphene nanoplatelets (GNPs) in a C.W. Brabender, while both molded and 3D-printed samples were tested. Thermal images of samples were taken utilizing a FLIR A300 infrared temperature sensor camera. An aluminum foil stand was placed atop a temperature-controlled hot plate to load and hold samples steadily during heating and temperature readings.

Work of adhesion calculations yielded from contact angle data showed that GNPs were strongly attracted to the PBAT phase the PBAT/PLA composite system, indicating a binary phase segregated mechanism, with a 12 mN/m jump from PLA/GNP work of

adhesion to PBAT/GNP. Infrared images of molded and printed samples being heated from a hot plate showed even distribution and conductivity of heat throughout the sample, while higher GNP concentrations were proven to raise thermal conductivity across all samples. Additionally, infrared recordings of the composite as electricity was passed through samples confirmed joule heating properties by capturing a rise in temperature of nearly 20 degrees celsius for 20% wt samples, with readings being taken as 60 V and 250 mA of power were passed through the sample. Finally, heating and cooling recordings showed that heating to steady state required about 5 minutes of current, while cooling to room temperature took about 8-9 minutes.

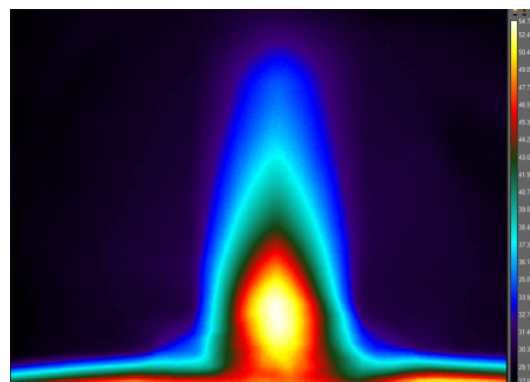


Figure 2: Thermal Image of Molded 20% wt GNP Sample

Potential applications of this strategy and material include localized heaters in medical implants, shape memory polymers in soft robotics and smart materials, and eco-friendly consumer electronics. Future work includes SEM/TEM imaging of samples to confirm binary phase segregation of GNPs, pre and post-annealing testing of thermal and electrical conductivity, positive temperature coefficient characterization, extending joule heating characterization beyond 20% wt GNP concentration, and optimizing printing and extruding settings for higher-performing 3D-printed composites.

¹Lichang Lu, Hongxu Guo, Yushen Wang, Kate Xinyi Liu, Ignacio Martin-Fabiani, Ton Peijs, Emiliano Bilotti, Han Zhang, Yi Liu, Dual enhancement of Joule heating and positive temperature coefficient behaviour in biodegradable nanocomposites via hybrid carbon nanofiller networks, Composites Part A: Applied Science and Manufacturing, Volume 199, 2025, 109167, ISSN 1359-835X.

²Yu-Chung Lin, Yiwei Fang, Xiaoyang Liu, Aniket Raut, Yifan Yin, David Sprouster, Esther Tsai, Steve Nitodas, Yuval Shmueli, Jonathan Sokolov, Miriam Rafailovich; Utilizing Binary Phase Segregation and Extrusion to Enhance the Electronic Properties of Graphene Nanocomposites. ACS Appl. Mater. Interfaces 27 November 2024; 16 (47): 65245–65254.

Nanoconfinement, Polymer Chemistry, and Nanoclay Effects on Supercritical CO₂-Induced Relaxation in PS, PMMA, and PS/PMMA Thin Films

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Spin-coated glassy polymer thin films are frequently trapped in nonequilibrium states containing residual solvent, free volume, and residual stresses. At nanoscale thicknesses, relaxation may also depend on the increased relative influence of surface-polymer and polymer-substrate interfaces.¹ These effects are especially complex in immiscible polymer blends, where thermal annealing can induce phase separation, vertical segregation, and surface roughening. This study investigates how polymer chemistry, film thickness, phase-separated morphology, and RDP-modified clay loading affect thermal and post-scCO₂ relaxation in polystyrene (PS), poly(methyl methacrylate) (PMMA), and 50/50 wt/wt PS/PMMA thin films.

Films were prepared from 123,000 g/mol polymers by spin coating onto piranha-cleaned silicon oxide substrates. Separate solution concentrations were calibrated to produce approximately matched 45 nm, 90 nm, and 135 nm films. RDP-clay was incorporated into the PS/PMMA blend at 0, 1, and 3 wt% relative to total polymer mass. Film thicknesses were measured by ellipsometry before and after thermal annealing, and the surface morphology of the blend films was characterized by atomic force microscopy (AFM). Film relaxation was quantified as the percentage decrease in film thickness relative to the as-coated film.

Annealing reduced the measured thickness of all three polymer systems, the extent of which decreased with increasing film thickness. PS showed the smallest thermal relaxation, while PMMA and the PS/PMMA blend showed greater changes. Adding RDP-clay reduced the thermal relaxation of the PS/PMMA blend relative to the unfilled control, though no clear difference was observed between the 1 and 3 wt% clay conditions. AFM revealed finer droplet-matrix morphologies with smaller, less coarse dispersed domains in clay-containing films (Figure 1), consistent with the clay's suppression of domain coarsening.² Domain-area analysis revealed a significant

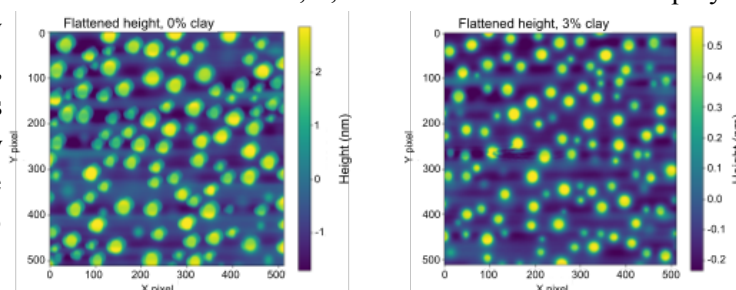


Figure 1. Effect of RDP-clay on the surface morphology of annealed PS/PMMA blend films. Flattened AFM height images of 135nm blend films containing 0 wt% RDP-clay (left) and 3 wt% RDP-clay (right). Scan size was 10,000nm.

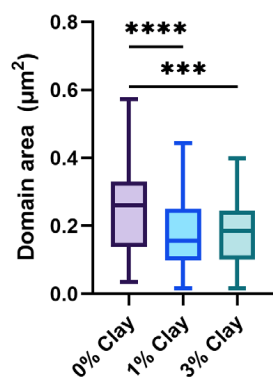


Figure 2. Box-and-whisker plots of the effect of clay concentration on droplet-domain area in 135nm Blend films. ***p<0.001, ****p<0.0001

reduction from the clay-free blend to after clay incorporation, with significant differences between 0% and both clay-containing conditions (Figure 2).

Subsequent scCO₂ treatment produced no significant change in film thickness under the conditions tested, suggesting that any scCO₂-induced swelling or post-depressurization densification was limited by the already-equilibrated polymer domains post-annealing, and not detectable by ellipsometry. However, scCO₂ may still alter phase-separation shape, size, roughness, or organization. Further AFM characterization will therefore be used to determine how scCO₂ exposure modifies the surface morphology of the PS/PMMA blends and the effects of RDP-clay on these changes. Together, these results provide further insight into how film thickness, blend morphology, nanoclay loading, and CO₂ exposure influence nonequilibrium behavior in polymer thin films.

¹ Keddie, J. L., R. A. L. Jones, and R. A. Cory. "Size-Dependent Depression of the Glass Transition Temperature in Polymer Films." *Europhysics Letters (EPL)* 27, no. 1 (1994): 59–64. <https://doi.org/10.1209/0295-5075/27/1/011>.

² Ha, Mai, Ayman Atallah, and Ramanan Krishnamoorti. "Effect of Organically Modified Layered Silicates on the Morphology of Symmetrical Blends of Polystyrene and Poly(Methyl Methacrylate)." *Polymer* 52, no. 25 (2011): 5890–96. <https://doi.org/10.1016/j.polymer.2011.10.016>.

Performance Evaluation of a Sustainable Phosphorus-Based Vegetation Flame Retardant For Wildfire Mitigation

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With nearly 78,000 wildfires scorching over 5 million acres in 2025¹, the threat to US landscapes has grown to critical levels. To combat this rising danger, phosphorus-based flame retardants (FRs) for foliage have grown in popularity, working through both condensed-phase inhibition, which forms a protective char layer, and gas-phase inhibition, which neutralizes high-energy free radicals that fuel combustion. The industry-standard FR, Phos-Chek, however, acts only in the former phase.² In this study, we develop an FR formulation comprising ammonium polyphosphate (APP), which acts in the condensed phase,³ RDP, which acts in both phases,⁴ and Pluronic F-127, a polymeric surfactant to finely disperse the hydrophobic RDP in solution. Through various trials, the optimal solution formula was found to be 7.5% APP, 5% RDP, and 2% Pluronic F-127 by weight.

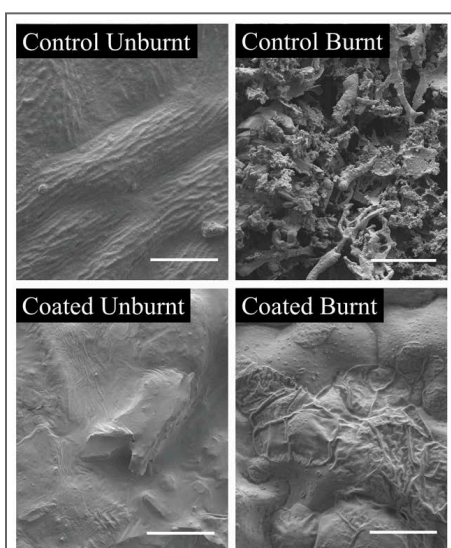


Figure 1. SEM images of samples (scale bar is 20 μm)

For the FR application, dry sugar maple (*Acer saccharum*) leaves were sprayed five times per side with a hand spray bottle, and dry East Asian cherry (*Prunus serrulata*) branches were sprayed with an Attich power sprayer, then air-dried. Fourier transform infrared spectroscopy and energy-dispersive X-ray spectroscopy confirmed the successful deposition of the FR coating. Mean leaf surface roughness

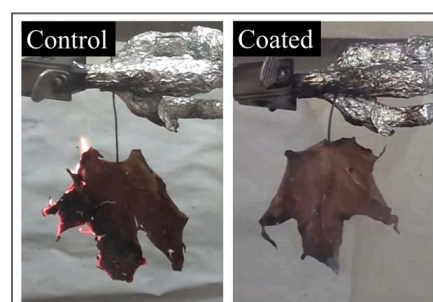


Figure 2. Sugar maple leaves 2 seconds after blowtorch removed (control burn time- ~3 sec, ember time- >120 sec; coated burn and ember time- <1 sec)

decreased from 58.1 ± 19.5 nm to 6.43 ± 2.46 nm after coating application, as measured by atomic force microscopy, indicating spreading of the FR coating. This was further confirmed by the scanning electron microscope (SEM) images (Fig. 1). In burn tests, leaves and branches were ignited for six seconds with a propane torch. The control leaves burned for ~3 s after the torch was removed and had embers for >120 s, whereas the coated leaves burned and had embers for <1 s (Fig. 2). Similarly, control branch leaves disintegrated into ash as compared to significantly thicker char in the case of FR treated leaves. Thermogravimetric analysis showed a high char yield of 26.9 % by weight for FR coated leaves (Fig. 3a), and Raman spectroscopy corroborated the formation of protective char in the coated burnt leaf, indicated by more graphitization with a lower I_D/I_G ratio of 0.50 compared to 0.61 (Fig. 3b). SEM of the coated char revealed an intumescent structure with excellent preservation of leaf morphology (Fig. 1). Finally, phytotoxicity is currently being evaluated with cucumber plants (*Cucumis sativus*) through chlorophyll, plant height, and soil pH analyses, with preliminary results indicating FR treated plants are healthier than controls.

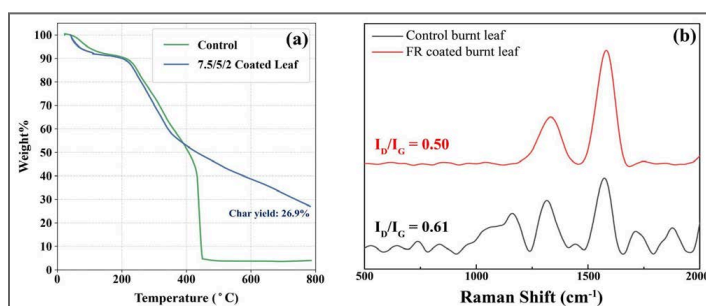


Figure 3. (a) TGA results (b) Raman curves of burnt leaves

These findings indicate that the FR formulation has promising applications to wildfire prevention. Additional testing, such as gas-phase inhibition analysis and prolonged phytotoxicity evaluation, will be conducted in the future to deepen our understanding of flame extinguishment and its effects.

¹M.W. Jones, et al. (2026). Wildfires in 2025. *Nature Reviews Earth & Environment*, 7, 334-336.

²Phos-CHEK 259-FX. Perimeter Solutions. (2026). <https://www.perimeter-solutions.com/product/phos-chek-259-fx-2/>.

³T. Chu, et al. (2024). The application of ammonium polyphosphate in unsaturated polyester resins: A mini review. *Polymer Degradation and Stability*, 225, 110796.

⁴X. Zeng, et al. (2026). Synergistic effects of resorcinol bis (diphenyl phosphate) (RDP) on the flame retardancy, foaming behavior, and thermal stability of poly (2,6-dimethyl-1,4-phenylene oxide) / polyamide (PPO/PA) composites. *Polymer Testing*, 156, 109129.

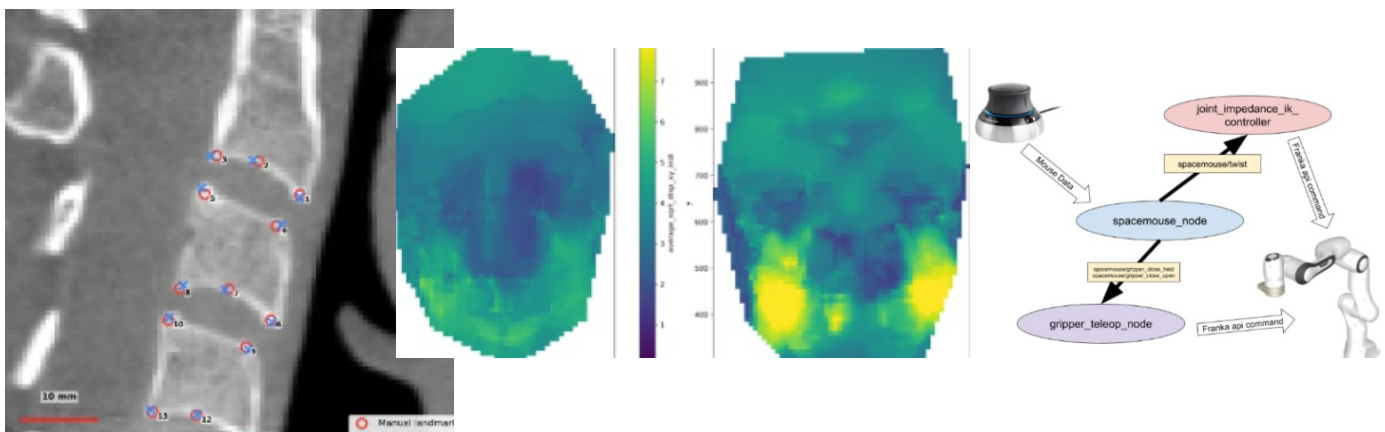
Session 2: AI Enabled Science

Mentors:

Fernando Aguilar Perez

Nabila Jaman Tripti

John Nicholson



AI-Assisted Cervical Vertebral Maturation Classification Using CBCT Images

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Orthodontic patients are typically adolescents, so assessing growth status and potential is critical for predicting craniofacial changes and guiding treatment decisions. Several radiographic methods exist to estimate patient growth potential, but due to concerns of radiation exposure, the Cervical Vertebral Maturation (CVM) method was introduced, estimating growth stage by evaluating morphological changes of the C2–C4 cervical vertebrae on radiographic scans [1]. However, manual CVM assessment, including identifying vertebral landmarks and interpreting vertebral shape, is labor-intensive and subject to observer variability. Using existing cone-beam computed tomography (CBCT) images already acquired for orthodontic diagnosis could provide skeletal-maturity information without requiring an additional radiograph and its associated radiation exposure. Therefore, there is an opportunity to utilize three-dimensional imaging and artificial intelligence (AI) to provide more objective, reproducible, and automated skeletal maturity assessment. In this study, we developed a two-stage deep-learning pipeline [2] for automated cervical vertebra localization and anatomical landmark detection from CBCT scans to support CVM classification.

First, 62 CBCT scans were manually annotated in 3D Slicer to create C2–C4 segmentation masks and identify 13 anatomical landmarks across the three vertebrae. The scans were then divided into training, validation, and held-out test cases in a 70-15-15 split. We then developed a two-stage deep-learning pipeline in PyTorch, in which a 3D U-Net first localized the C2–C4 region and selected a clear sagittal view. A separate landmark-detection model then predicted the locations of the anatomical points. Performance was evaluated by measuring the distance between the predicted landmarks and the corresponding manual annotations.

Across nine validation cases, the 3D localization model achieved a mean Dice score of 0.765; because its purpose was coarse localization rather than precise boundary delineation, the key finding was that its predicted C2–C4 regions contained all 117 landmarks. Using the full pipeline, 48.7%, 68.4%, and 81.2% of landmarks were within 2, 3, and 4 mm of the manual annotations, respectively. These results support the feasibility of automated landmark detection for future CVM analysis. The predicted landmarks can be used to calculate vertebral shape measurements, such as height-to-width ratios and inferior border concavity, which will serve as inputs for automated CVM stage classification. As shown in Fig. 1, the AI-predicted landmarks are closely aligned with the manual annotations in a representative validation scan.

Overall, our results demonstrate that the proposed two-stage pipeline can localize the C2–C4 region and detect anatomical landmarks from CBCT scans, providing reliable geometric measurements for later classification. The proposed workflow provides an efficient and reliable approach for automated vertebral localization and landmark detection, establishing a foundation for future AI-assisted CVM assessment. Future work will extend the system by incorporating a classification model that can automatically determine the corresponding CVM stage according to extracted anatomical measurements.

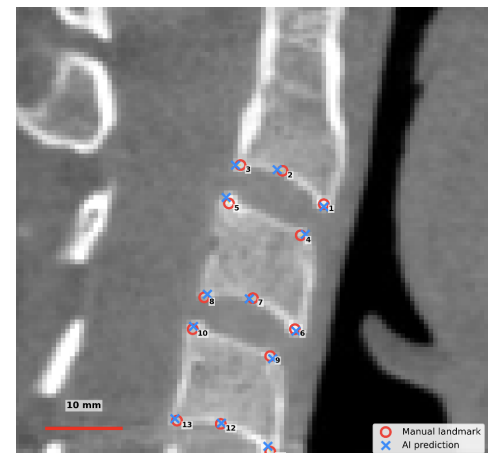


Fig. 1 Manual landmarks (red circles) and AI predictions (blue X marks) on C2–C4.

[1] McNamara JA Jr, Franchi L. The cervical vertebral maturation method: A user's guide. *Angle Orthod*. 2018;88(2):133-143. doi:10.2319/111517-787.1

[2] Çiçek, Ö., Abdulkadir, A., Lienkamp, S.S., Brox, T., Ronneberger, O. (2016). 3D U-Net: Learning Dense Volumetric Segmentation from Sparse Annotation. In: Ourselin, S., Joskowicz, L., Sabuncu, M., Unal, G., Wells, W. (eds) *Medical Image Computing and Computer-Assisted Intervention – MICCAI 2016*. MICCAI 2016. Lecture Notes in Computer Science(), vol 9901. Springer, Cham. https://doi.org/10.1007/978-3-319-46723-8_49

Automated Characterization of Maxillary Sinus Pathology using Cone-Beam Computed Tomography

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Chronic sinusitis is a condition affecting millions of patients worldwide. It's often associated with mucosal thickening (MT), mucous retention cyst (MRC), and sinus obstruction [1]. Accurately identifying these abnormalities is important for chronic sinusitis diagnosis and surgical planning. Currently, doctors annotate on cone-beam computed tomography (CBCT) imaging, which provides visualization of maxillary sinus, to support clinical diagnosis. However, manual segmentation is time-consuming and subject to observer variability. This study aims to develop a 3D U-Net deep learning model for automated sinuses segmentation in CBCT scans.

Firstly, we manually annotated raw CBCT scans using the 3D Slicer to create “ground-truth” segmentation masks. In a healthy maxillary sinus, the cavity is primarily air-filled, so CBCT segmentation only consists of air and background regions. However, pathological changes alter this appearance [1]. MT, an inflammatory swelling of the sinus lining commonly associated with sinus infection or chronic inflammation, introduces an additional swelling tissue region that is identified as “MT.” MRC is benign, fluid-filled ball-like sacs that might also appear within the sinus and are classified as “MRC.” Consequently, CBCT images may contain different combinations of air, MT, MRC, and background regions depending on the patient's condition. Therefore, accurate maxillary sinus segmentation from CBCT is important for quantitative assessment.

Then, we implemented a 3D U-Net model [2] in PyTorch and trained on split, normalized CBCT volumes. Performance was evaluated using the Dice coefficient, Intersection over Union (IoU), precision, and recall. Optimization techniques, including testing and reselecting probability threshold on validation dataset and largest-connected-component cleanup, were applied to reduce false-positive segmentations. The healthy-sinus model achieved high segmentation accuracy, with Dice and IoU scores exceeding 0.95 and 0.91, on the held-out test set after optimization. As in Fig. 1, our model's predicted masks closely follow the anatomical boundaries of the healthy sinus in ground-truth segmentations across different slices, discarding disconnected air pockets. Evaluation of the MT model is ongoing.

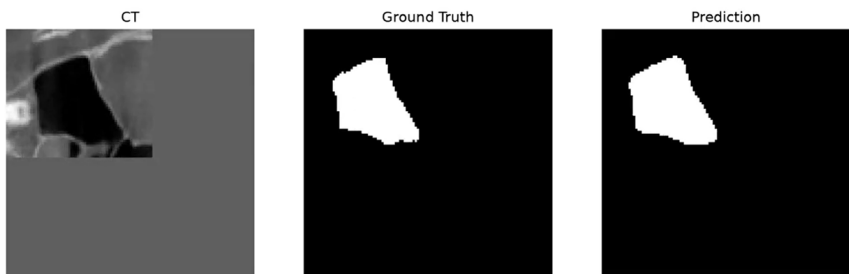


Fig. 1 Visualization of segmentation results comparing the original CBCT slice, ground-truth mask, and model prediction

Overall, our results demonstrate that a 3D U-Net can accurately segment both healthy and MT-infected maxillary sinuses from CBCT scans. The proposed workflow and further optimizations provide an efficient and reliable approach for automated sinus segmentation and establish a foundation for future AI-assisted diagnosis of maxillary sinus infections. Future work will extend the system to include a unified multi-class segmentation model and a separate classifier capable of distinguishing among healthy sinuses, mucosal thickening, mucous retention cysts, and other sinus conditions.

[1] Bozdemir E, Gormez O, Yıldırım D, Aydoğmuş Erik A. Paranasal sinus pathoses on cone beam computed tomography. *J Istanbul Univ Fac Dent*. 2016 Jan 12;50(1):27-34. doi: 10.17096/jiufd.47796. PMID: 28955552; PMCID: PMC5573450.
[2] Çiçek, Ö., Abdulkadir, A., Lienkamp, S.S., Brox, T., Ronneberger, O. (2016). 3D U-Net: Learning Dense Volumetric Segmentation from Sparse Annotation. In: Ourselin, S., Joskowicz, L., Sabuncu, M., Unal, G., Wells, W. (eds) *Medical Image Computing and Computer-Assisted Intervention – MICCAI 2016*. MICCAI 2016. Lecture Notes in Computer Science(), vol 9901. Springer, Cham. https://doi.org/10.1007/978-3-319-46723-8_49

Developing Open-Source Automated Workflows for Quantum Chemistry Calculations in MISPR Using ORCA

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Understanding the relationship between molecular and bulk properties in electrolyte solutions is key in developing next-generation batteries for efficient energy storage. However, the complexity of electrolyte solutions makes their properties difficult to predict using computational methods such as density functional theory (DFT) and molecular dynamics (MD). Large industry and national laboratory efforts¹ have built extensive DFT datasets for single molecules. Yet, the development of open-source computational tools to characterize the properties of full electrolyte solutions remains a challenge.

MISPR² (Materials Informatics for Structure-Property Relationships) is an open-source workflow automation tool for DFT and MD simulations of electrolyte properties. By combining these two methods, MISPR effectively characterizes bulk electrolyte properties using MD simulations with molecular properties derived from DFT calculations. This work addresses current challenges by extending MISPR to use ORCA, a DFT calculation tool that was chosen because of its speed and open-source availability.

We benchmark ORCA against Gaussian, a DFT tool which is already implemented into MISPR, across a set of representative electrolyte solvents (DME, FEME, DOL, DEGDM, and water), lithium-ion binding complexes, and solvent-electrolyte clusters. To evaluate respective performance, we compared calculated energies and computational cost.

For both engines, we used the B3LYP functional and the 6-31(G)/d basis set. For solvent molecules, we performed ESP, BDE, and binding energy calculations. Finally, we performed geometry optimization and frequency analysis on a set of solvent-electrolyte clusters. Similar calculations were performed with consistent computational resources and settings. The final single-point energies calculated by ORCA and Gaussian are nearly identical, with the largest difference being 4.53 kcal/mol (solvents), and 22.34 kcal/mol (clusters). ORCA performs faster for larger systems, but Gaussian was faster for the simpler solvents. This may be due to ORCA's RIJCOSX approximation, which reduces cost for larger systems but is comparatively slow in small molecules.

In the future, we plan on utilizing the resulting dataset to develop machine learning interatomic potential (MLIP) models to predict bulk electrolyte properties, like viscosity and ionic conductivity. MLIPs reproduce potential energy surfaces near DFT accuracy with a fraction of the computational cost, allowing for MD simulations of electrolyte systems at length and time scales that current ab-initio methods cannot. This would allow for bulk transport properties to be predicted directly from molecular chemistry, rather than approximated or measured empirically.

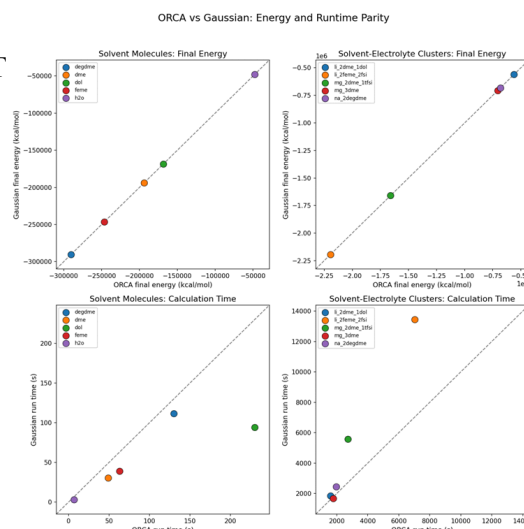


Figure 1. Parity comparison of ORCA and Gaussian final single-point energies (top row) and calculation time (bottom row) for individual solvent molecules (left column) and solvent-electrolyte clusters (right column). Each point represents one system; the dashed line indicates $y = x$ (perfect agreement).

¹ Gharakhanyan, V., Barroso-Luque, L., Yang, Y. *et al.* Open Molecular Crystals 2025 (OMC25) dataset and models. *Sci Data* **13**, 354 (2026). <https://doi.org/10.1038/s41597-026-06628-2>.

² Atwi, R., Bliss, M., Makeev, M. *et al.* MISPR: an open-source package for high-throughput multiscale molecular simulations. *Sci Rep* **12**, 15760 (2022). <https://doi.org/10.1038/s41598-022-20009-w>.

Topology-Assisted AI Models for Breast Diagnostic Classification in Contrast-Enhanced Spectral Mammography

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Mammography is the primary and most effective tool used for the early detection of breast cancer, allowing clinicians to identify abnormalities before they become clinically palpable.¹ Contrast-enhanced (CESM) builds on this by injecting an iodinated contrast agent and acquiring paired low- and high-energy exposures, which are then recombined to isolate regions of contrast uptake tied to tumor neovasculature, information standard mammography cannot capture.¹ However, characterizing the underlying breast tissue captured in these images remains difficult as standard deep learning and radiometrics models struggle to capture the topological detail of connected components and loops.

On a 2D image, persistent homology tracks how connected components (H0) and loops (H1) merge, form, and disappear as a threshold is swept across the image's intensity values, recording each feature's birth and death

threshold as a point on a persistence diagram. Features that persist across a wide range of thresholds, meaning their birth and death values are far apart, are considered more topologically significant, while short-lived features are typically treated as noise.² Instead of creating persistent diagrams on image intensity values, we propose a novel approach of calculating these topological features on the gradients of class activation maps³ (GradCAM) of a fine-tuned

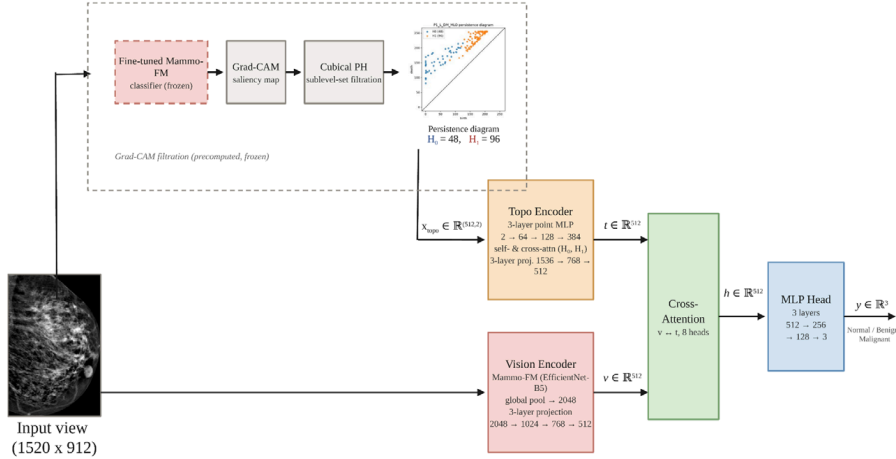


Fig 1: Deep learning pipeline with Topological Inputs

Mammo-FM⁴ image encoder before adding them to our deep learning pipeline (Figure 1).

First, we fine-tune the image encoder of Mammo-FM on both the digital mammography (DM) and contrast-enhanced spectral mammography (CESM) views of each image of the breast. We create persistent diagrams on the GradCAM output of our fine-tuned image encoder, before passing it to a topological encoder that is before passing it to a permutation invariant topological encoder that applies self-attention within each homology dimension and cross-attention between H0 and H1, then pools the result, following Meng et al.'s (2026) hierarchical topology encoder design⁵. We then combine the outputs of our topological branch with the embeddings achieved by the image encoder using self-attention before using an MLP for prediction.

To measure the results of our model, we use the Categorized Digital Database for Low Energy and Subtracted Contrast Enhanced Spectral Mammography (CDD-CESM) dataset, which provides 2,006 high-resolution images (average 2355x1315 pixels) from 326 female patients with diagnoses of “normal,” “benign,” or “malignant.”¹ Future work will include direct comparison of performance with and without topological features.

[1] Khaled, R., Helal, M., Alfarghaly, O., Mokhtar, O., Elkorany, A., El Kassas, H., & Fahmy, A. (2022). Categorized contrast enhanced mammography dataset for diagnostic and artificial intelligence research. *Scientific Data*, 9, 122.

<https://doi.org/10.1038/s41597-022-01238-0>

[2] Edelsbrunner, H., & Harer, J. (2010). *Computational topology: An introduction*. American Mathematical Society.

[3] Selvaraju, R. R., Cogswell, M., Das, A., Vedantam, R., Parikh, D., & Batra, D. (2017). Grad-CAM: Visual explanations from deep networks via gradient-based localization. In *Proceedings of the IEEE International Conference on Computer Vision* (pp. 618-626). <https://doi.org/10.1109/ICCV2017.74>

[4] Ghosh, S., et al. (2025). Mammo-FM: Breast-specific foundational model for integrated mammographic diagnosis, prognosis, and reporting. arXiv: <https://doi.org/10.48550/arXiv.2512.00198>

[5] Meng, G., Gu, P., Liang, P., Lalor, J. P., Chambers, E. W., & Chen, D. Z. (2026). TopoCL: Topological contrastive learning for medical imaging. arXiv: <https://doi.org/10.48550/arXiv.2603.14647>

Digital Image Speckle Correlation (DISC)-Based Analysis of Facial Muscle Movements for Detecting and Monitoring Neurological Disorders

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Digital Image Speckle Correlation (DISC), is an optical technique designed to detect surface deformation across a series of images. DISC can be used in clinical evaluations to assess facial muscle function as it can analyze underlying micro-muscle movements that are often invisible to the human eye. In a medical setting, DISC can help detect and monitor disorders that restrict muscle movement, increase reaction time, or lead to facial asymmetry such as Bell's Palsy and Parkinson's¹. We hypothesized that using DISC we can illustrate the difference between the facial movements of a patient with Parkinson's and members of a control group.

The study design comprised two main parts: data acquisition from both subjects with Parkinson's and a control group and video analysis using DISC. For the data acquisition, subjects placed their head inside of a head rest positioned approximately 20 inches away from a device consisting of a camera, computer screen, and ring light. Subjects were instructed to remain still and follow the directions displayed on the screen. Next, the screen cycled through a series of commands encouraging the subjects to make a specific facial expression (smile/frown) or return to a resting state. This process was recorded on the camera for later analysis. The completed recordings were cropped to isolate regions of interest and then dissected into frames. Subsequently, they were run through DISC, which analyzed the displacement of subjects' skin pores between consecutive frames¹. The data produced by DISC was then plotted to show subjects' reaction time. Finally, a heatmap exhibiting the concentration of movements over the entire duration of a specific command type was generated. This heatmap featured a blue-yellow scale where yellow zones are areas presenting the highest amount of motion over time.

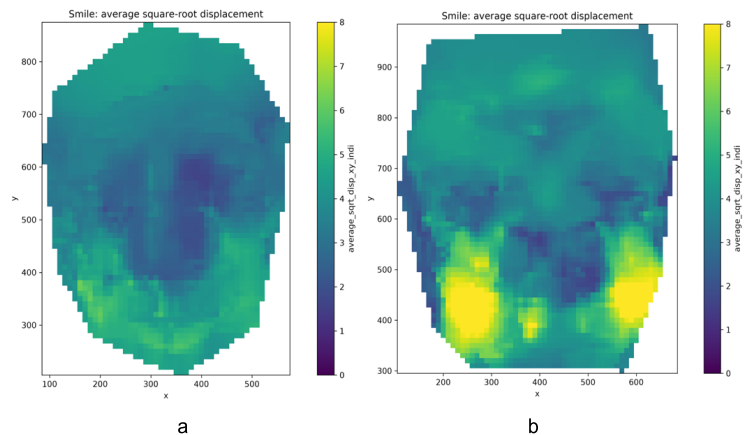


Figure 1: A side by side visual of (a) a person with Parkinson's and (b) a control subject responding to the same instruction to smile

We found that the movements of a person with Parkinson's (Fig. 1a) were much more dispersed compared to the concentrated reactions of a control subject (Fig. 2a) when they were both instructed to smile. This demonstrates that DISC can accurately track patients' muscle movement and the resulting data can be displayed in a meaningful way for human analysis.

In the future, we want to analyze more expansive data to help establish a baseline for normal facial muscle movement and, using that, develop an artificially intelligent program that can identify whether or not a patient has Parkinson's.

[1] Fu, S., Polak, P., Fiore, S., Passman, J. N., Davis, R., Manu, L. M., & Rafailovich, M. (2025). Digital image speckle correlation (DISC): Facial muscle tracking for neurological and psychiatric disorders. *Diagnostics*, 15(13), Article 1574.

<https://doi.org/10.3390/diagnostics15131574>

Digital Image Speckle Correlation (DISC)-Based Analysis of Soft Tissue Deformation for Robotic-Assisted Needle Procedures

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The use of robotic technology in surgical procedures allows for surgeons to perform precise and minimally invasive surgery using manually controlled robotic arms. With the growing capabilities of artificial intelligence, the vision of robots performing autonomous medical procedures is more attainable than ever. However, for needle-based procedures, current robotic technologies cannot reliably detect when a needle punctures a patient's skin and the robot should reduce force. This severely restricts the safety of autonomous needle-based procedures as a robot is unable to recognize needle insertion depth, potentially harming the patient. To help resolve this issue, we opted to use digital image speckle correlation (DISC). Originally developed to analyze the stress response of materials, DISC is an optical technique that detects surface deformation across a series of images¹. We hypothesized that by analyzing the deformation pattern around the puncture site in recordings of a robotic arm puncturing skin with a needle, the program could identify the moment the needle penetrates the skin.

The study design consisted of two main parts: data acquisition from robotic arm puncture trials and video analysis utilizing DISC. For the data acquisition portion, a 48 megapixel camera was used to record videos of the DOBOT Magician Robot, which was equipped with a 3D printed attachment holding a needle, puncturing pig skin. Pig skin was used as it's considered principally similar to human skin and is commonly used for research purposes². During the recording process, interference due to environmental noise was limited by lowering ambient light, utilizing a ring light, restricting motion around the testing station, and positioning the experiment away from air vents. After the recordings were obtained, they were trimmed to only include the sections of interest and then dissected into frames. Next, the frames were run through the DISC program, which analyzed the displacement of the skin pores between consecutive frames¹. A heatmap overlay is then applied to visualize the displacement identified by DISC via a cool-warm color spectrum, where warmer colors denote regions of greater activity.

The results from the DISC were then extracted to generate plots demonstrating the relationship between sum xy-displacement (surface deformation) and z-displacement (needle depth). This resulted in a polynomial graph (Fig. 1) whose peak represented the point the needle punctured the skin. By taking the derivative of the xy-displacement and plotting it against the z-displacement, distinct peaks became apparent. We hypothesize that each of these peaks represents a breaking point through an individual layer of skin, causing a sudden increase in motion on the surface.

Our findings demonstrate that DISC is a viable solution for allowing robots to autonomously detect when a needle pierces through skin as it can quantitatively identify the moment the skin is punctured. With these capabilities, robotic arms can perform subcutaneous, intradermal, and intramuscular injections. In future studies, we want to explore the effects of skin defects or lesions on force propagation over the surface, collect a wider and more diverse dataset for artificial intelligence analysis, and determine methods for reducing the noises of the needle movement.

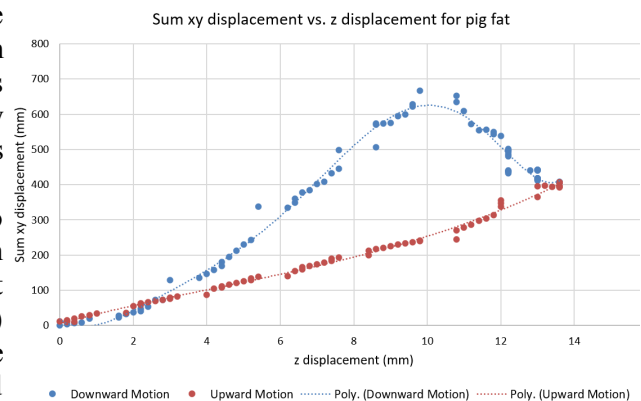


Figure 1: The relationship between needle depth and surface deformation

[1] Fu, S., Polak, P., Fiore, S., Passman, J. N., Davis, R., Manu, L. M., & Rafailovich, M. (2025). Digital image speckle correlation (DISC): Facial muscle tracking for neurological and psychiatric disorders. *Diagnostics*, 15(13), Article 1574. <https://doi.org/10.3390/diagnostics15131574>

[2] Fu, S., Bonn, R., Luo, H., et al. (2026). Optimizing timing of autologous skin cell suspension after enzymatic debridement of porcine burns: Evaluation with digital image speckle correlation (DISC). *JID Innovations*, 6(5), Article 100481. <https://doi.org/10.1016/j.xjidi.2026.100481>

Evaluation of Belief-Guided Multi-Stage Simulated Annealing

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Simulated annealing escapes local minima by accepting occasional worsening moves,^{1,2} but discards nearly everything it learns, keeping only the best point found. This study evaluates whether an allocation that retains the rest of that record improves on restarting at the incumbent best point. The framework stores an evaluation count and best observed value per region, ranks regions by quality discounted by how much evidence backs it, and starts each episode in the highest ranking region. It never modifies the Metropolis rule, cooling schedule, proposal, or objective, so every policy runs an identical inner search and differs only in where episodes start.

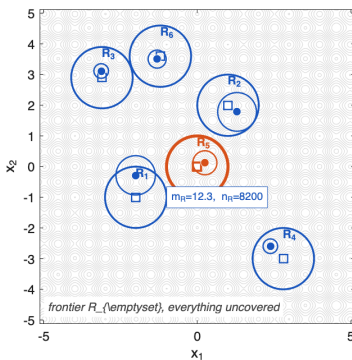


Figure 1: The region map in two dimensions, showing each region's fixed anchor, best point, best value and evaluation with the selected

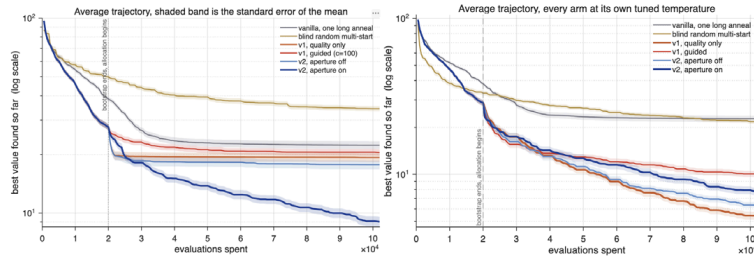


Figure 2: Same six variants on 10D rotated Rastrigin, at one shared temperature on the left and at their own tuned temperatures on the right.

A fixed budget was spent as episodes of 2000 evaluations, with every fifth episode restarting uniformly at random regardless of policy. Six policies ran on rotated Rastrigin, Ackley and Schwefel in ten dimensions across ten budgets from 10,000 to 100,000 evaluations, each tuned on its own temperature grid and raced on disjoint held-out seeds.

Two landscapes were additionally built to favor the mechanism, a double funnel from the 38 atom Lennard-Jones cluster³ and a 500 basin landscape with no global funnel.

Evidence weighting was null to negative in all thirty benchmark and budget cells, winning 38 to 54 runs of 100 on Rastrigin, 2 to 16 on Ackley, and 21 to 49 on Schwefel. On the 500 basin landscape uniform restarting beat incumbent restarting in all twelve cells at 72 to 114 wins of 150, confirming the landscape defeated the incumbent heuristic, yet

evidence weighting still never beat uniform restarting. The architecture itself did beat a single long annealing run on Rastrigin and Schwefel, though it reversed on Ackley beyond 20,000 evaluations. Maximising the score is identical to minimising the best observed value plus a logarithmic penalty on the evaluation count, so the incumbent cancels, only one parameter is identifiable, and the method is incumbent restarting under an evidence

penalty. That same penalty is what raises the rank of the region chosen, so the mechanism's one provable property and its empirical cost are the same term. Notably, the map from policy to final value is flat, since a correctly parameterised rule tied incumbent restarting while disagreeing about where to restart at 92.6 percent of decisions. The only mechanism that carried an effect was displacing the restart, which requires no memory and is the principle behind basin hopping and iterated local search^{3,4}. Future work would test landscapes requiring a productive search longer than a single episode, the one structural weakness of memoryless restarting.

¹Metropolis, N., Rosenbluth, A. W., Rosenbluth, M. N., Teller, A. H., & Teller, E. (1953).

²Kirkpatrick, S., Gelatt, C. D., & Vecchi, M. P. (1983). Optimization by Simulated Annealing. *Science*, 220(4598), 671-680. <https://doi.org/10.1126/science.220.4598.671>

³Wales, D. J., & Doye, J. P. K. (1997). Global Optimization by Basin-Hopping and the Lowest Energy Structures of Lennard-Jones Clusters Containing up to 110 Atoms. *The Journal of Physical Chemistry A*, 101(28), 5111-5116.

⁴Lourenco, H. R., Martin, O. C., & Stutzle, T. (2003). Iterated Local Search. In *Handbook of Metaheuristics* (pp. 320-353). Springer. https://doi.org/10.1007/0-306-48056-5_11

Robot Motion Planning via Egocentric Object Screw Trajectory Recording Using Project Aria Glasses

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As modern robotics grows more advanced, the motions that robots are expected to achieve have become more complex and object constrained. In recent years, researchers have begun programming these motions through kinesthetic demonstration, rather than through hard coded mathematical constraints.¹ Two well-known approaches for Programming by Demonstration (PbD) are: Dynamic Movement Primitives, which extrapolate motion plans from a single demonstration and Hidden Markov Models that require multiple demonstrations. However, motion constraints, which essentially characterize many manipulation tasks like pouring, scooping etc., cannot be represented explicitly by these methods. One way of doing PbD with explicit representation of motion constraints is the use of screws to represent motion. The use of constant screw segments to represent motion constraints [1] and screw linear interpolation based algorithms for generating motion [2] can transform an end effector constrained kinesthetic demonstration to create a new motion plan for complex tasks in only one demonstration.[1]

The meaningful differentiation between previous research in screw trajectory based motion planning for robotics and our research lies in our usage of video recorded demonstrations rather than physically human guided demonstrations. In order to record these demonstrations, we used a pair of Meta's Project Aria Generation 2 smart glasses [3], which capture specific egocentric (first perspective handtracking) information.

In order to capture a demonstration that could be recreated by a robotic arm, we focused on the specific motion of the object being manipulated, which in this case was a block being stacked, rather than the much more joint restricted hands. To obtain this object trajectory, we placed April Tags on our object, and used cv2 in order to obtain raw 4x4 matrices of the object pose (position and orientation) within the camera at each point in time.

Then, we created a Python pipeline which can transform the raw matrices into a usable world frame trajectory of the object. (Fig. 1) To do this, we had to first multiply our raw trajectory by a transformation matrix based on the camera's calibration, and we next had to multiply the new device frame trajectory by a transformation matrix based on the glasses trajectory at each moment in time.

Once we had access to the world frame matrix trajectory of our object, we could then plug that trajectory into C++ algorithms that extracted the constant screw segments representing the motion and transformed them into a joint space plan for a new task instance (i.e., placement of the objects) [1]. The new guiding poses and gripper conditions were then ready to be used for Pybullet based robotic arm simulations, and then subsequently to be tested out on the robot. In this testing, we found that our pipeline was able to successfully create a new joint trajectory for a new task instance despite our demonstration having been recorded, rather than kinesthetic on the robot. We confirmed this through the successful simulation and physical demonstration of block stacking on the Franka Pandas robotic arm. (Fig. 2)

Now that we have developed a simple pipeline for Project Aria recording based robot motion planning, our primary goal is to try out more complex motion demonstrations, and ensure that our pipeline remains usable. We are also committed to finding more accurate object tracking methodology.

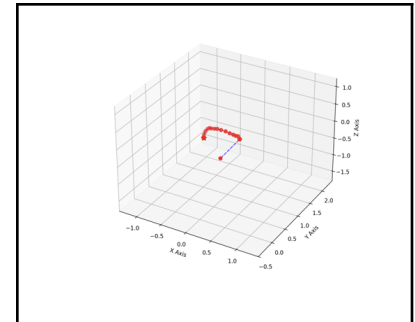


Figure 1: Mapped trajectory for object based on Project Aria recording (pre noise removal)

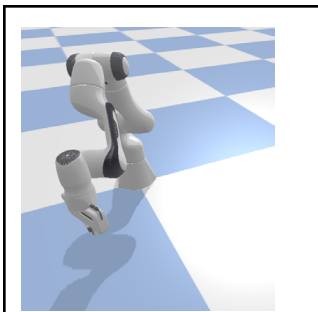


Figure 2: Result of simulation in Pybullet

[1] D. Mahalingam and N. Chakraborty, "Human-Guided Planning for Complex Manipulation Tasks Using the Screw Geometry of Motion," Arxiv, <https://arxiv.org/pdf/2209.05672>.

[2] A. Sarker, A. Sinha, and N. Chakraborty, "On screw linear interpolation for point-to-point path planning | IEEE conference publication | IEEE Xplore," IEEE Xplore, <https://ieeexplore.ieee.org/document/9341651/>

[3] https://github.com/facebookresearch/projectaria_tools

[4] <https://github.com/ssylvia/wolf-0/kinlib-aria>

Mapping 3D SpaceMouse Asynchronous Inputs for Teleoperation of Franka Emika Panda Arm and Imitation Learning Benchmark Tests in Physics Simulator

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For robotic arms to autonomously perform tasks, models are trained on data, including demonstrations. Reinforcement learning (RL) methods produce adequate results but require large amounts of training data and time. Imitation learning (IL) models can mimic tasks from less data but require expert demonstrations for best results, which necessitates skilled operators and robust demonstration methods.¹ Different IL algorithms also vary in learning rate, computational complexity, and performance for different task types.

Current data for IL is provided to robots via kinesthetic demonstrations.² However, this method falls short in harsh environments for humans or for incompatible robots. One alternative is teleoperation, which has been implemented on other robot models. One project implements a 6 degree-of-freedom (DOF) mouse for versions of the Franka Emika compatible with ROS2.³ We adapt this methodology using a 3D Connexion SpaceMouse (SM) Compact with a Franka Emika Panda arm on ROS1. We then extend our teleoperation methodology to novel IL applications, testing in the MuJoCo physics simulator. Prior work has benchmarked some RL algorithms on robotic arms in MuJoCo.⁴ However, the models have been trained on procedurally-generated demonstrations and with limited algorithm variety. We explore IL algorithms training on human-provided SM teleoperation data.

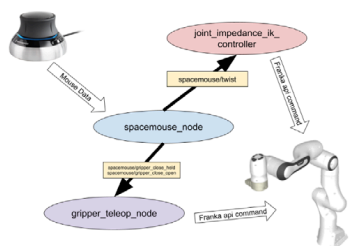


Fig 1: Communication pipeline for teleoperation from SM to ROS nodes to Franka Panda Emika.

Our physical teleoperation system consists of three nodes using the ROS1 Noetic framework (Fig 1). One node polls 6-DOF inputs and button states from the SM and publishes them to ROS topics. Two controller nodes subscribe to these topics. One uses the Franka_ROS library to send commands to the robot and shift the end-effector position, and one uses the Franka_gripper library to control the gripper state. For accurate motion, singularity avoidance, and collision detection, we use the built-in ROS MoveIt inverse kinematics (IK) solver, which employs the Dampened Least Squares (DLS) algorithm. We successfully compile the nodes to perform simple tasks, such as block-stacking and pick-and-place. The source code is available on GitHub.^[5] Future work involves adapting the existing controls to other robotic arms by reusing the SM package with a modified Franka_ROS controller.

Our IL testing in MuJoCo implements a SM input class, reading raw data using PySpaceMouse (along with a keyboard input alternative using Pynput) with a common interface that transforms operator data into velocity vectors and collects them in a pickle file. The operator data is specified to be for either a pick-and-place or push task. We then parse operator data in Behavioral Cloning (BC) and Adversarial Inverse Reinforcement Learning (AIRL) IL scripts. We plot success and learning metrics over training epochs or timesteps for each algorithm to benchmark their performance. We also supervise a visual evaluation of the model performing each task. The source code is available on GitHub.^[6] We find that AIRL successfully learns from teleoperation demonstrations, with mean block-to-goal distance in pick-and-place tasks generally decreasing as the model refines its approach from time steps 30000 to 100000 (Fig 2). We also find AIRL to be more successful than BC, with BC remaining at a 0% success rate across 60 epochs and having no clear improvement in block-to-goal distance as it trains. This is expected given the nature of the BC algorithm and the task. Now that we have a proof-of-concept for benchmarking IL algorithms with teleoperation, we aim to test more algorithms (including Generative Adversarial Imitation Learning [GAIL] and a screw model of motion), optimize our training implementation, and apply IL to more complex tasks. Ultimately, we seek to use physical arm teleoperation data from our first project to train models for the arm with the best-performing IL algorithms from our tests.

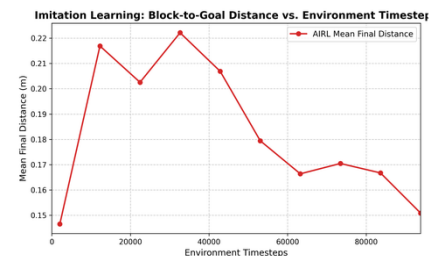


Fig 2: Change in block-to-goal distance for AIRL-trained model learning pick-and-place task over time. Note the beginning spike in distance is expected given the nature of AIRL, exploring from a BC baseline before improving.

[1] Santana, P. (2026). *An Introduction to Deep Reinforcement and Imitation Learning*. arXiv. <https://doi.org/10.48550/arXiv.2512.08052>.

[2] Mahalingam, D. and Chakraborty, N. (2022). *Human-Guided Planning for Complex Manipulation Tasks Using the Screw Geometry of Motion*. arXiv. <https://doi.org/10.48550/arXiv.2209.05672>.

[3] Aydin, Ö. and Gassner, A. (2025). *Teleoperation of Franka FR3 with Spacemouse*. GitHub. https://github.com/frankarobotics/franka_spacemouse.

[4] Xu, Z. et al. (2024). *Open-Source Reinforcement Learning Environments Implemented in MuJoCo with Franka Manipulator*. arXiv. <https://doi.org/10.48550/arXiv.2312.13788>.

[5] https://github.com/alberteks/spacemouse_panda_controller

[6] <https://github.com/dmdeng1150/Spacemouse-Teleop-Imitation-Learning>

Session 3:

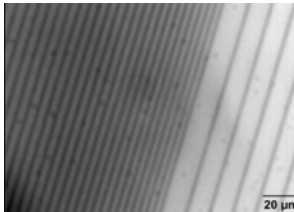
Protein Structures

Mentors:

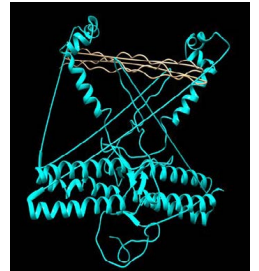
Adam Hansen

Bernard Essuman

Nabila Jaman Tripti



Shi Fu



Huiting Luo

Christian Saby

Giorgios Kementzidis

Sayani Bhunia

Domain-Resolved Computational Modeling of Fibrinogen Interactions with Collagen and Albumin

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Blood clotting is essential for limiting blood loss after vascular injury, but excessive or abnormally organized clot formation can obstruct circulation and contribute to serious cardiovascular complications, such as strokes and heart attacks. Fibrinogen is central to this process because thrombin converts it into fibrin, which polymerizes to form the structural framework of a clot. However, fibrin assembly is complicated by interactions with surrounding molecules, such as collagen and albumin, which can reshape the developing fibrin network. Following endothelial injury, exposed subendothelial collagen provides a strongly thrombogenic surface. Collagen has also been shown to interact directly with fibrinogen and fibrin, thereby allowing fibrin to become physically integrated into the collagen fiber network [1]. Albumin is particularly relevant as well because, as the most abundant plasma protein, it is present at high concentrations during fibrin polymerization. Native human albumin has been shown to alter the lateral assembly of fibrin polymers and promote the formation of finer fibrils [2]. Together, these findings motivate our molecular-level investigation of the domain-specific interactions between collagen, albumin, and fibrinogen as a concrete step toward a more comprehensive understanding of mechanisms that govern fibrin assembly and clot formation.

Structures of collagen, albumin, and the three fibrinogen domains were obtained from the RCSB Protein Data Bank [3]. Based on prior experimental results, albumin was docked in Cluspro with the fibrinogen α C domain, while collagen was docked with the α C, D, and E domains [4]. Five representative poses per pair were then selected based on interface-residue similarity and RMSD centrality, producing 20 models for further refinement with HADDOCK [5]. Predicted fibrinogen binding regions were compared with literature-reported functional sites, after which three albumin- α C poses and one collagen pose per fibrinogen domain were selected based on the lowest HADDOCK score (Fig. 1). These six systems were cleaned, solvated, ionized, and energy-minimized before production molecular dynamics simulations in GROMACS [7].

The next step will be to analyze the production MD results for structural stability, intermolecular contact persistence, and energetic measurements to identify the most stable predicted complexes under the simulated conditions. We also plan to run a molecular dynamics simulation of fibrinogen on a collagen sheet and a coarse-grained simulation with full-length fibrinogen to see whether and how our predicted molecular-level interactions persist at the mesoscale.

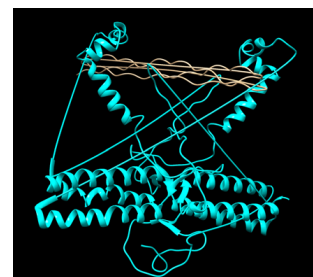


Fig 1. Selected docking pose of collagen (yellow) on the fibrinogen E domain (cyan), visualized in Chimera [6].

[1] Reyhani V, Seddigh P, Guss B, Gustafsson R, Rask L, Rubin K. "Fibrin binds to collagen and provides a bridge for α V β 3 integrin-dependent contraction of collagen gels." *Biochemical Journal*. 2014;462:113–123. doi: 10.1042/BJ20140201.

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[3] Burley SK, Bhikadiya C, Bi C, et al. "RCSB Protein Data Bank: powerful new tools for exploring 3D structures of biological macromolecules for basic and applied research and education in fundamental biology, biomedicine, biotechnology, bioengineering and energy sciences." *Nucleic Acids Research*. 2021;49(D1):D437–D451. doi: 10.1093/nar/gkaa1038.

[4] Kozakov D, Hall DR, Xia B, Porter KA, Padhorna D, Yueh C, Beglov D, Vajda S. "The ClusPro web server for protein–protein docking." *Nature Protocols*. 2017;12:255–278. doi: 10.1038/nprot.2016.169.

[5] Honorato RV, Trellet ME, Jiménez-García B, et al. "The HADDOCK2.4 web server for integrative modeling of biomolecular complexes." *Nature Protocols*. 2024;19:3219–3241. doi: 10.1038/s41596-024-01011-0.

[6] Pettersen, Eric F., et al. "UCSF Chimera—A Visualization System for Exploratory Research and Analysis." *Journal of Computational Chemistry*, vol. 25, no. 13, 2004, pp. 1605–12. Wiley Online Library, <https://doi.org/10.1002/jcc.20084>.

[7] Páll S, Zhmurov A, Bauer P, Abraham M, Lundborg M, Gray A, Hess B, Lindahl E. "Heterogeneous parallelization and acceleration of molecular dynamics simulations in GROMACS." *Journal of Chemical Physics*. 2020;153:134110. doi: 10.1063/5.0018516.

Post-Treatment Washing Enables Lower-Pressure Supercritical CO₂ Decellularization of Murine Dermal Tissue to Promote Extracellular Matrix Preservation

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Effective decellularization is essential for producing biologically compatible extracellular matrix (ECM) scaffolds for skin tissue engineering. Supercritical carbon dioxide (scCO₂) is a promising decellularization technique, removing cellular material without the harsh chemicals that damage the ECM.¹ However, higher scCO₂ pressures improve decellularization while compromising ECM structural stability, creating a tradeoff between DNA removal and tissue preservation. This study investigated whether post-treatment washing can reduce this dependence on processing pressure, enabling gentler scCO₂ conditions without compromising DNA removal.

Murine skin samples were decellularized using scCO₂ under varying pressures (242, 276, 311 bar), durations (1–2 hr), and cycle numbers (1–2), then washed with phosphate-buffered saline (PBS), 0.2% ethylenediaminetetraacetic acid (EDTA), or sodium chloride (NaCl) at varying concentrations (1%, 2%, 2.5%, 4%). Decellularization efficacy was assessed via DAPI fluorescence (residual nuclear material), and ECM preservation via differential scanning calorimetry (DSC), measuring collagen onset temperature (T_{onset}) and denaturation breadth (ΔT).

Higher pressure, duration, and cycle number all significantly improved DNA removal, but higher pressure also reduced T_{onset} and increased ΔT , indicating collagen destabilization. Among post-treatments, NaCl produced the greatest reduction in residual DAPI fluorescence at both pressures: 46.4% at 311 bar (Figure 1; $p = 0.035$) and 77.5% at 242 bar ($p < 0.0001$), outperforming PBS and EDTA. Increasing NaCl concentration further improved removal, with 4% producing the strongest effect. Critically, low-pressure scCO₂ with extended NaCl washing (24 h) produced residual DAPI fluorescence statistically equivalent to high-pressure scCO₂ at its maximum tolerable wash duration (12 h) (TOST, $p = 0.012$, $\Delta = \pm 5\%$), and equivalent to the SDS/Triton positive control (TOST, $p = 0.03$, $\Delta = \pm 5\%$), indicating that condition-optimized post-treatment protocols can match standard chemical decellularization regardless of initial processing pressure. Furthermore, NaCl treatment did not significantly affect T_{onset} or ΔT (Figure 2), indicating DNA removal was attained without further collagen destabilization.

Together, these results show that post-treatment NaCl washing decouples decellularization efficacy from processing pressure, allowing low-pressure scCO₂ to match both high-pressure and SDS-based decellularization while avoiding the collagen destabilization associated with harsher conditions. This offers a practical route to decellularized skin scaffolds with effective cellular removal and improved ECM preservation. Future analysis will evaluate the biological performance of these scaffolds in vivo by comparing scCO₂ pressures and post-treatment conditions in a murine model.

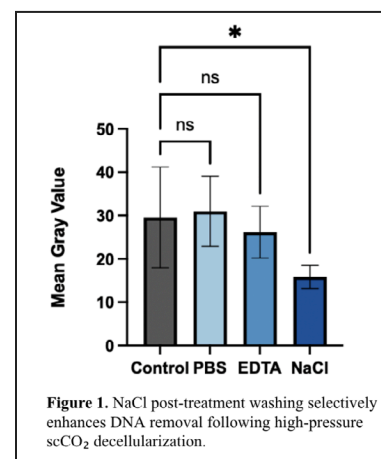


Figure 1. NaCl post-treatment washing selectively enhances DNA removal following high-pressure scCO₂ decellularization.

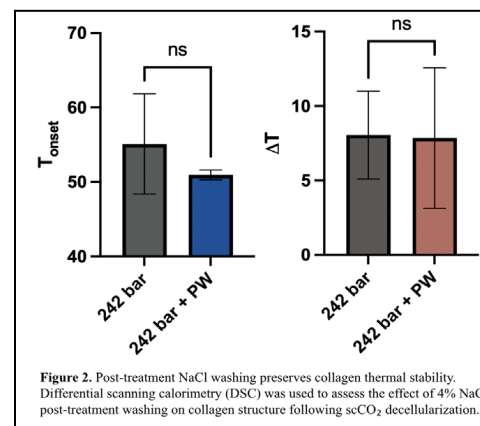


Figure 2. Post-treatment NaCl washing preserves collagen thermal stability. Differential scanning calorimetry (DSC) was used to assess the effect of 4% NaCl post-treatment washing on collagen structure following scCO₂ decellularization.

Localized Release of Tagmented DNA Suspended on PMMA and SU-8 Gratings via Proteinase Droplets

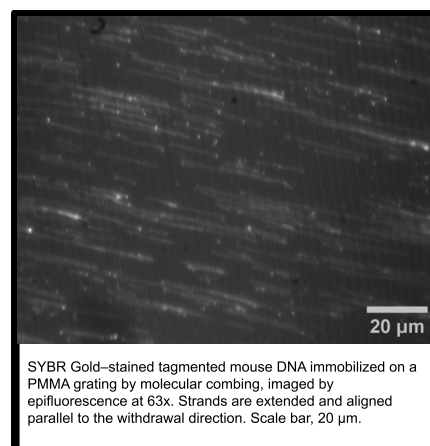
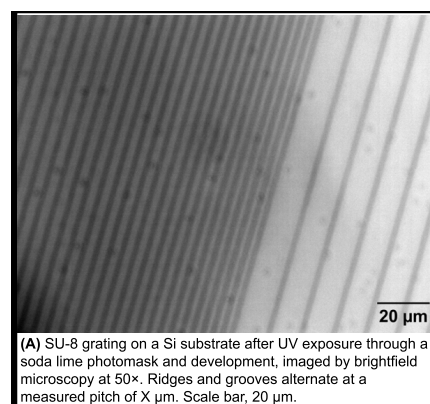
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Short-read sequencing has made human genome sequencing fast and inexpensive, but it reconstructs sequences by fragmenting DNA in solution and reassembling reads computationally. This fails in highly repetitive regions, where a short read cannot be uniquely placed. In fact, roughly 5–8% of the human genome, consisting of repetitive sequences in centromeres, telomeres, and segmental duplications, remained unresolved until the telomere-to-telomere effort of 2022, which required deep long-read coverage and substantial computational cost.¹ Though these repetitive sequences typically don't encode proteins, they are nonetheless extremely important in segregation, structure, and genome stability, necessitating a way to efficiently sequence them.

Our study presents progress towards a novel way to sequence even these repetitive DNA segments. Instead of breaking up the genome and computationally reassembling the sequences, we took an approach that preserved the sequencing order by linearizing the DNA for sequencing the small segments in order along the molecule. We first created PMMA and SU-8 photoresist gratings (repeat distance for PMMA was 3 μm , SU-8 varied from 6 μm to 40 μm) by spin-casting solutions onto Si chips and then softbaking them onto the Si chips in vacuum. After exposing them to UV light through a glass photomask and then developing the photoresist layers, we formed gratings into the photoresists. Exposure time and development time were varied to ensure deep enough gratings to provide steric clearance for application of transposases to cut and label the DNAs. The patterned samples were then dipped vertically into a solution of protein-bound tagmented mouse DNA and then taken out using a motorized system, immobilizing the DNA linearly across the grating patterns. A micropipette filled with 0.375% proteinase solution was used to apply a 1-2 μl drop to locally digest the transposases attached to the DNA. Both SU-8 and PMMA resist grating patterns of varying depths and spacings were prepared and studied for efficiency of DNA adsorption and linearization. After testing both photoresists with proteinase, we also found that the proteinase solution weakens the SyBr gold dye's intensity, and that heating to 37 degrees celsius interferes with DNA adherence to the surface and causes significant warping of the DNA strands. A lower temperature and longer digestion period was found to be helpful to reduce these effects. Finally, preliminary results show that the proteinase solution does release DNA from the transposomes.

In the future, verifying that this method does yield viable DNA strands to sequence using electrophoresis would provide convincing proof of concept. Then, measuring where the previous proteinase droplet has made contact with the grating and then adjusting the next droplet slightly upstream would lead to the sequencing of repetitive sequences within the genome without the need to reassemble order. This would greatly reduce the computational burden of assembly. Other possible next steps include figuring out a way to sequence the full strand of DNA, rather than just the portions suspended across gratings, and also reliably exposing only micron-scale portions of the DNA to the proteinase solution. Lastly, we could investigate whether it's the proteinase or the DNase buffer that weakens the SyBr gold dye.



¹Nurk, S. *et al.* The complete sequence of a human genome. *Science* **376**, 44–53 (2022). doi:10.1126/science.abj6987

Investigating the Molecular Mechanisms of Collagen-Fibrinogen Interactions and Thrombin-Independent Fibrillar Structure Formation

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Collagen and fibrinogen are essential fibrous proteins that coexist during wound healing, potentially influencing malignant fibrillogenesis during the healing process.¹ Thrombin-independent fibrin polymerization has previously been discovered on hydrophobic surfaces mediated by the N-terminal subdomain of the α C-domain and deposition of soluble fibrin,² while fibrin-collagen composite hydrogels display unique intertwined fibre structures, suggesting further protein interaction.³ However, whether collagen can similarly induce fibrillar assembly and the molecular basis of their interaction remain unknown.

In this study, we investigated whether collagen directly promotes fibrinogen adsorption and fibrillar assembly in the absence of thrombin and explored the underlying molecular interactions. Interaction of fibrinogen with a collagen surface was first tested by leaving silicon wafers in solutions of 5 μ g/mL and 50 μ g/mL of neutralized telocollagen for 18 h to deposit thin collagen films. 20 μ g/mL, 100 μ g/mL, and 4mg/mL solutions of fibrinogen were then left to deposit on the wafers for 1h and 18h and imaged with atomic force microscopy (AFM). Fluorescence staining was then conducted using anti-A α 17-19 and anti-B β 122-134 to identify fibrin-associated structures and untethering of α C domains, respectively. To investigate the underlying molecular mechanism, interactions between collagen and fibrinogen with truncated α C domains (des A α 414-610, des A α 505-610) were examined using confocal microscopy and thromboelastography to examine the role of the α C domain. In addition, 50 μ M P12 solution, a fibronectin-derived antithrombotic that binds to the N-terminal subdomain of the α C domain,⁴ was mixed with 3.96 mg/mL fibrinogen solution and deposited for 18h to examine inhibition of fibrillogenesis.

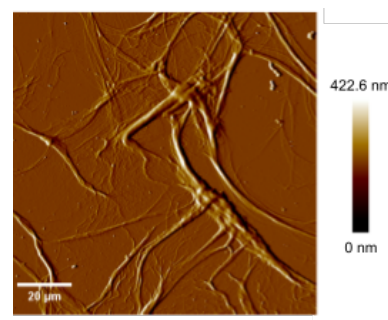


Fig. 1: Fibre Formation of 4mg/mL Fibrinogen on Collagen Thin Film after 18h

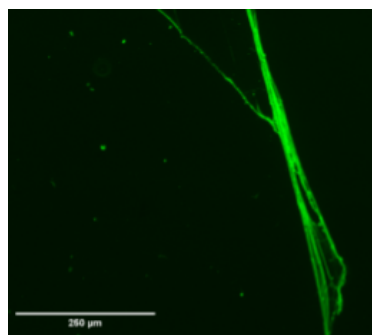


Fig. 2: Fluorescent Imaging of Polymerized Fibrin on Collagen Thin Film Stained with Anti-A α 17-19

Large fibrillar networks were observed to develop on the hydrophilic collagen surfaces with a contact angle of 26.55°, demonstrating that thrombin-independent fibrillar assembly is not restricted to hydrophobic surfaces (Fig. 1). Confocal imaging of anti-A α 17-19-stained samples revealed fluorescence along these structures, confirming the assemblies were composed of polymerized fibrin (Fig. 2). Furthermore, reduced fibrillar structures were observed following P12 treatment, suggesting that α C-mediated intermolecular interactions contribute to this process. Specifically, confocal results of fibrinogen with truncated α C domains revealed that fluorescence was preserved in des A α 505-610 fibrinogen but markedly reduced in des A α 414-610, implying that collagen binding is mediated by the A α 414-505 region.

These findings suggest that collagen actively facilitates fibrin formation independent of thrombin, challenging the conventional view of collagen as solely a structural support. Moreover, collagen, as a physiological extracellular matrix protein, recapitulates the surface-induced fibrillar assembly mechanism previously observed only on foreign hydrophobic materials. This previously unrecognized collagen-fibrinogen interaction provides new insights into extracellular matrix assembly and new design principles for wound-healing therapies, regenerative medicine, and safer blood-contacting biomedical devices.

¹ Kearney, Katherine J., et al. "The Role of Fibrin(ogen) in Wound Healing and Infection Control." *Seminars in Thrombosis and Hemostasis*, vol. 48, no. 2, 2022, pp. 174–187. <https://doi.org/10.1055/s-0041-1732467>.

² Hansen, Adam, et al. "Unraveling the Molecular Mechanism of In Situ Surface-Initiated Thrombogenesis." *Journal of Thrombosis and Haemostasis*, 2025, <https://doi.org/10.1016/j.jtha.2025.09.042>.

³ Luo, Huiting, et al. "Structural Analysis of a Collagen-Fibrin Scaffold Which Promotes Osteogenic Differentiation and Templated Biomineralization of Dental Pulp Stem Cells." *Dental Materials*, vol. 42, no. 6, 2026, pp. 1031–1042. Elsevier, <https://doi.org/10.1016/j.dental.2026.02.013>.

⁴ Hansen, Adam, et al. "Peptide-Mediated Inhibition of Surface-Initiated Thrombogenesis." *Journal of Thrombosis and Haemostasis*, 27 June 2026, <https://doi.org/10.1016/j.jtha.2026.06.029>.

Investigating the Mechanism of Surface-Induced Thrombin-Free Fibrinogen Assembly Through All-Atom Molecular Dynamics Simulations

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Fibrinogen is a blood protein that typically forms fibrin fibers after activation by thrombin, but it can also assemble into fibers on certain surfaces in the absence of thrombin. Previous experiments have shown that a surface can change fibrinogen's shape and affect its ability to attract additional molecules.¹ Understanding this process could help researchers design medical materials that are less likely to lead to unwanted clotting when they come into contact with blood. In this research, we used all-atom molecular dynamics simulations to examine how different parts of fibrinogen interact with material surfaces with different properties.

We simulated three different regions of fibrinogen on both pristine graphene and polyethylene (PE) for 2 ns at 303.15 K: A α 425–503 from the α C region due to its connection to fibrin polymerization and fiber growth², γ 400–411 (HHLGGAKQAGDV) as a comparison from the D region, and the E-region sequence A α 30–35 (DSDWPF) for a control. We ran a water-droplet simulation that produced a contact angle of 60° with the graphene surface, showing that this graphene model was relatively hydrophilic, while PE was a hydrophobic comparison (contact angle of 106°). We defined direct contact as at least one protein heavy atom from the entire protein within 3.5 Å of a surface atom.

Adsorption depended strongly on both the fibrinogen region and the surface. On graphene, both the γ and α C peptides adsorbed strongly, with final-500-ps contact occupancies of 100% and 98.0% and mean minimum distances of 3.29 Å and 3.61 Å, respectively (Figure 1). On hydrophobic PE, the γ peptide still adsorbed (84.3% contact and a mean minimum distance of 3.36 Å in the final 500 ps), whereas the α C fragment made no direct contact at any point and remained an average of 13.931 Å from the surface (Figure 2). The E-region control did not adsorb to either surface (3.5% occupancy on graphene, 0% on PE), which confirms that adsorption depends on the region of fibrinogen. This result suggests that hydrophobic surfaces may preferentially react with the D region of fibrinogen, leaving the α C region open for interaction with other fibrinogen molecules.

Longer trajectories and replicate simulations are required before determining whether hydrophobic surfaces consistently expose the α C region for intermolecular association. Confirmation of this mechanism could help explain how artificial surfaces initiate fibrinogen assembly and could guide the development of medical materials with lower risk of unwanted clotting.

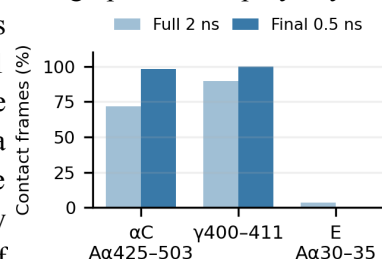


Figure 1. Graphene contact occupancy over the full 2 ns and final 0.5 ns.

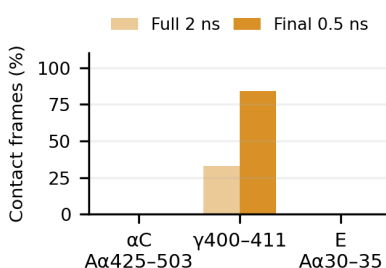


Figure 1. Polyethylene contact occupancy over the full 2 ns and final 0.5 ns.

¹Zhang, L. et al. "The influence of surface chemistry on adsorbed fibrinogen conformation, orientation, fiber formation and platelet adhesion." *Acta Biomaterialia* 54, 164–174 (2017). <https://doi.org/10.1016/j.actbio.2017.03.002>

²Tsurupa, G. et al. "Structure, Stability, and Interaction of the Fibrin(ogen) α C-Domains." *Biochemistry* 48, 12191–12201 (2009). <https://pmc.ncbi.nlm.nih.gov/articles/PMC2812052/>

Investigating Interactions Between Fibrinogen and Weight-Percent Varied DOPC-Cholesterol Supported Lipid Bilayers

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Approximately 900,000 cases of venous thromboembolisms (VTEs) occur each year in the US[1]. Despite VTEs being so common, there are still many aspects about their formation that are not entirely understood. Specifically, an ongoing field of research is the role of the lipid composition of both platelet and endothelial cells in pathological thrombogenesis. While many studies have looked at the effects of cholesterol content in membranes

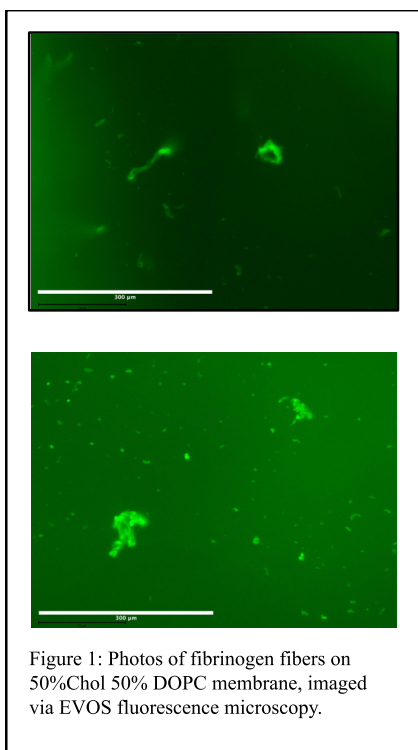


Figure 1: Photos of fibrinogen fibers on 50%Chol 50% DOPC membrane, imaged via EVOS fluorescence microscopy.

on the protein signalling that occurs during thrombogenesis, research is lacking on the effect that it has on the physical surface interactions between the membrane and fibrinogen proteins, one of the key agents in clotting [2]. Other studies have also emphasized the role of surface chemistry regarding fibrinogen adhesion, with some hydrophobic surfaces even prompting non-thrombin initiated fibrin formation [3]. This leads to the question of how cholesterol, which significantly changes the membrane packing and slightly alters its polarity, would impact the adhesion of fibrinogen. Further, it also leads to questioning the protein's attachment mechanism to the membrane.

Using supported lipid bilayers composed of Dioleolphosphatidylcholine (DOPC) and varied weight compositions of cholesterol (Chol), labeled with the dye Rhodamin B (RhoB). Protease-free human fibrinogen was applied to the bilayers at 4mg/mL and incubated overnight to promote adhesion. To view the fibrinogen, sheep antibody labeled with FITC was applied after the incubation period, then observed under two kinds of fluorescence microscopy. The entire surface was characterized via EVOS fluorescence microscopy to see the morphology of the fibers. A total internal reflectance fluorescence (TIRF) microscope was then used to observe the morphology of the bilayer in real time and take note of its fluidity. This was further quantitatively measured via a fluorescence recovery after photobleaching (FRAP) procedure that yields the 2D diffusion coefficient of the membrane.

An initial assessment via EVOS fluorescent microscopy confirmed large fiber formation in the presence of 50% Chol (Fig. 1) and also depicted instances of smaller fiber growth as well. Additionally, to further characterize the effects of the fibers on the membrane as well as the nature of protein adhesion, FRAPs were run before and after fibrinogen addition and incubation time. A significant decrease of the diffusion coefficients depending on fibrinogen presence suggested that the fibrinogen fibers decreased the membrane fluidity (Fig. 2). From that it may be possible to infer that, when in the absence of receptors, fibrinogen will adhere by embedding parts of itself into the membrane. This prompts further research to determine the conformation of the protein that is bound to the membrane and whether it matches previous literature detailing fibrinogen adhering to hydrophobic surfaces. It also begs further research into the exact effects of a gradient of cholesterol on fiber formation, quantitatively measured via area of coverage or fiber height.

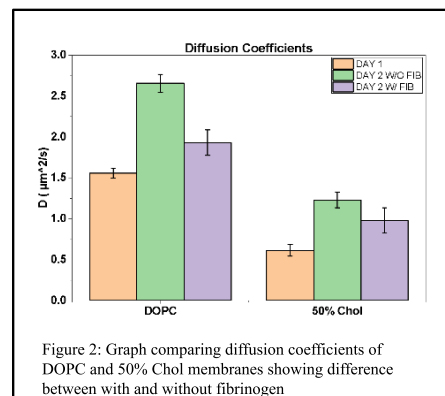


Figure 2: Graph comparing diffusion coefficients of DOPC and 50% Chol membranes showing difference between with and without fibrinogen

[1] Beckman, M. G., Hooper, W. C., Critchley, S. E., & Ortel, T. L. (2010). Venous thromboembolism: a public health concern. *American journal of preventive medicine*, 38(4 Suppl), S495–S501. <https://doi.org/10.1016/j.amepre.2009.12.017>

[2] Wang, N., & Tall, A. R. (2016). Cholesterol in platelet biogenesis and activation. *Blood*, 127(16), 1949–1953. <https://doi.org/10.1182/blood-2016-01-631259>

[3] Zhang, L., Casey, B., Galanakis, D. K., Marmorat, C., Skoog, S., Vorvolakos, K., Simon, M., & Rafailovich, M. H. (2017). The influence of surface chemistry on adsorbed fibrinogen conformation, orientation, fiber formation and platelet adhesion. *Acta biomaterialia*, 54, 164–174. <https://doi.org/10.1016/j.actbio.2017.03.002>

The Impact of Partially Reduced Graphene Oxide on Enzymatic Activity in Fibrin Clot Lysis and Formation for Coagulopathies and Hemorrhage

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Over 1.5 million deaths result from hemorrhage annually, with causes ranging from inherited impairments, including hemophilia and von Willebrand disease, to trauma-induced bleeding.¹ Current treatment methods, such as factor replacement therapy and blood transfusions, remain costly, and there is a high demand for increased treatment accessibility.²

The coagulation cascade's mechanism ends with thrombin cleaving the fibrinogen into fibrin, aggregating into a mesh along broken blood vessels. After vessel wall repair, the tPA cleaves plasminogen into plasmin to degrade the clot's fibrin mesh.³ In previous studies, an amphiphilic nanosheet of partially reduced graphene oxide (pRGO) enhanced the clotting process.⁴ It can be hypothesized that the addition of pRGO would also enhance lysis speed.

All tests were conducted using a thromboelastography machine (TEG), with each sample containing 360 μ L of solution including 5 μ L of tPA, 25 μ L of plasminogen, 1 u/mL of bovine thrombin, 2 mg/mL or 4mg/mL of fibrinogen, and Tris-buffered saline as the remaining amount. When tests with pRGO were run, 36 μ L of 18mM pRGO was added to the solution, and the buffer was adjusted accordingly.

Contrary to the hypothesis, it was found that pRGO significantly impeded clot lysis, demonstrated in **Figure 1**. For 4 mg/mL fibrinogen, the solution without pRGO showed LY60 (percent of clot lysed at 60 minutes) of 100%, while the solution with pRGO showed 42.5%, a 57.5% decrease, suggesting an inhibitory effect. The 2 mg/mL fibrinogen solutions maintained this trend, where the solution without pRGO reported LY60 of 100%, while the solution with pRGO reported 18.9%. In this case, the lysis completed at 60 minutes decreased by 81.1%.

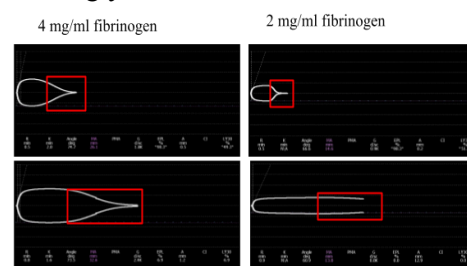


Figure 1: Comparison of TEG graphs with and without pRGO at two different fibrinogen concentrations

To examine underlying binding mechanisms, three premixtures were made, each consisting of buffer, pRGO, and either fibrinogen, tPA, or thrombin at the aforementioned concentrations. These premixtures sat for ten minutes before TEG testing. The non-premixed control at 2 mg/mL fibrinogen had an eventual LY60 of 11%. However, the tPA-pRGO premix had 0%, indicating that forcing pRGO to pre-bind with tPA prevented the normal lysis process. Furthermore, the fibrinogen-pRGO premix lysed the quickest, with LY60 of 41.7%. Thus, it is unlikely that the interaction between these two compounds inhibits lysis. Rather, pRGO likely causes abnormal activity in tPA that limits its lysing effect, and thus pRGO also likely does not cause fibrin to hide the sites plasmin accesses to cleave it. Clot formation was also found to be delayed in the thrombin-pRGO premix, with a clot initiation time of 2.2 minutes compared to 0.7 ± 0.265 minutes for the other three tests. This suggests that the interaction of pRGO and thrombin initially decreases thrombin's efficacy. However, the effect may be temporary, as the clotting process proceeded normally aside from the delay.

To build on these findings, future studies can fluorescently label key proteins, observing how each associates with pRGO using microscopy assays. Given the global burden of hemorrhage and capital-intensive treatments, pRGO's dual ability to strengthen clots while delaying their breakdown positions it as a promising and accessible biomaterial platform for future hemostatic therapies.

¹ Latif, R. K., Clifford, S. P., Baker, J. A., Lenhardt, R., Haq, M. Z., Huang, J., Farah, I., & Businger, J. R. (2023). Traumatic hemorrhage and chain of survival. *Scandinavian Journal of Trauma, Resuscitation and Emergency Medicine*, 31(1). <https://doi.org/10.1186/s13049-023-01088-8>.

² Thorat, T., Neumann, P. J., & Chambers, J. D. (2018). Hemophilia burden of disease: A systematic review of the cost-utility literature for hemophilia. *Journal of Managed Care & Specialty Pharmacy*, 24(7), 632-642. <https://doi.org/10.18553/jmcp.2018.24.7.632>.

³ Chaudhry, R., Killeen, R. B., & Babiker, H. M. (2025). *Physiology, Coagulation Pathways*. In StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing. Retrieved August 2, 2026 from <https://www.ncbi.nlm.nih.gov/books/NBK482253>.

⁴ Sun, D., Mayetani, J., Lim, S., Zhou, L., Isseroff, R., Hansen, A., & Rafailovich, M. (2025, December 3). *Effects of metallized partially reduced graphene oxide on enhancing thrombin activity in fibrinogen clot formation* [Symposium contribution]. 2025 Materials Research Society Fall Meeting & Exhibit, Boston, MA, United States.

Characterizing the Surface Binding Mechanism of Fibrinogen and Partially Reduced Graphene Oxide

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Roughly one in four deaths worldwide is caused by thrombosis.¹ Currently, the most common way to mitigate excessive clotting is through anticoagulant and thrombolytic drugs, but these techniques require costly monitoring and long-term care.² A deeper understanding of the coagulation cascade may aid the development of more effective thrombosis treatments.³

Partially reduced graphene oxide (pRGO), an amphiphilic nanosheet, enhances the clotting process with thrombin and fibrinogen; yet, polymerization of fibrin without thrombin has only been reported on hydrophobic surfaces due to surface-induced untethering of fibrinogen's α C domains, which exposes binding sites that promote self-assembly. Investigating the mechanisms of pRGO interactions with fibrinogen can offer both practical applications and new understandings, as the surface binding mechanism of pRGO is not fully understood.⁴

Atomic Force Microscopy (AFM) was utilized to image fibrin and fibrinogen activity in proximity to pRGO, as shown in **Figure 1**. A 450 μ L 4mg/mL fibrinogen and 50 μ L pRGO (18 mM) solution was dropped on a PS 15-coated Si wafer for imaging. Fibrin fibers clustered on top of pRGO sheets; neither was found on its own. pRGO thus has a strong affinity for fibrinogen. Furthermore, after dropping a 4mg/mL solution of fibrinogen onto a pRGO-coated surface, thick fibrin fibers formed without any visible pRGO sheets in proximity. This polymerization occurred despite the hydrophilic properties of the pRGO surface, where a water contact angle of $\sim 12^\circ$ was measured.

To further confirm the occurrence of surface binding between pRGO and fibrinogen during clotting, 25°C and 37°C thromboelastography (TEG) tests were run on 360 μ L solutions of 4 mg/mL fibrinogen (52.2 μ L), 18 mM pRGO (36 μ L, non-control only), 1 u/mL thrombin (3.6 μ L), and the remainder as Tris-buffered saline, reported in **Figure 2**. Regular clot formation at 25°C showcased a delayed clotting time of 10.2 minutes, while with pRGO, clotting time declined to 1.0 minute, similar to 1.8 minutes at 37°C. Lower temperatures had no significant effect on clotting time with pRGO, ruling out diffusion-based reactions where clotting would slow due to less molecular movement. Thus, there is likely a temperature-independent surface adsorption process occurring on the pRGO nanosheet, allowing particles to find each other easily.

Finally, immunofluorescence was used to elucidate the sites at which pRGO binds to fibrinogen. Antibodies targeting α C domains revealed them to be untethered, something necessary for fibrin layering and polymerization. This thus suggests a fibrin fiber formation mechanism similar to that of hydrophobic surfaces.

These results support a surface-mediated mechanism by which pRGO, even when hydrophilic, accelerates fibrin formation independently; future studies combining SEM imaging and mechanistic modeling with additional immunofluorescence can further define the molecular pathways underlying this behavior.

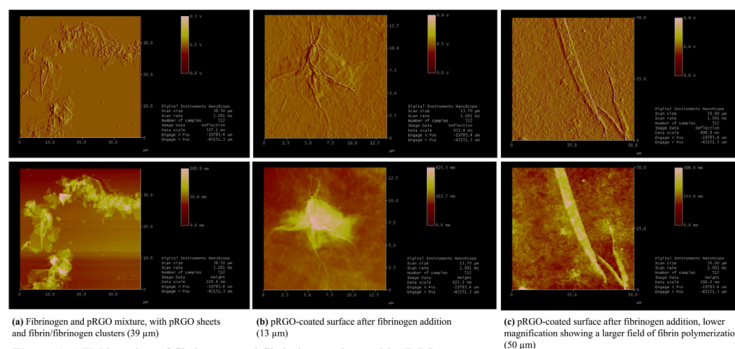


Figure 1. AFM imaging of fibrinogen and fibrin interactions with pRGO

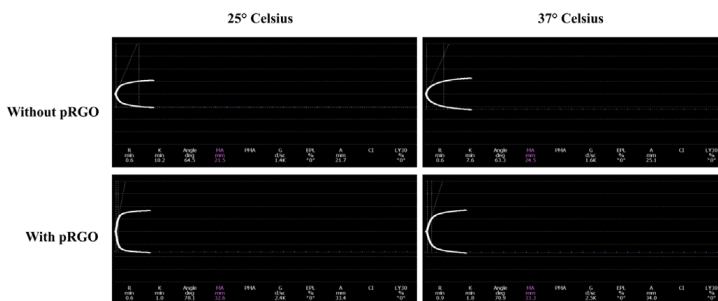


Figure 2. Comparison of TEG graphs with and without pRGO at 25° and 37° Celsius

¹ Wendelboe, A. M., & Raskob, G. E. (2016). Global burden of thrombosis. *Circulation Research*, 118(9), 1340-1347. <https://doi.org/10.1161/circresaha.115.306841>

² Morgovan, C., Frum, A., Stoicescu, L., Butuca, A., Dobrea, C. M., Arseniu, A. M., Chis, A. A., Muresan, M. L., Gligor, F. G., Ilie, I. R., & Ghibu, S. (2026). An overview of anticoagulant drugs pharmacology, therapeutic approaches, limitations and perspectives. *Pharmaceutics*, 18(2), 163. <https://doi.org/10.3390/pharmaceutics18020163>.

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Session 4: Energy Materials

Mentors:

Rebecca Isseroff

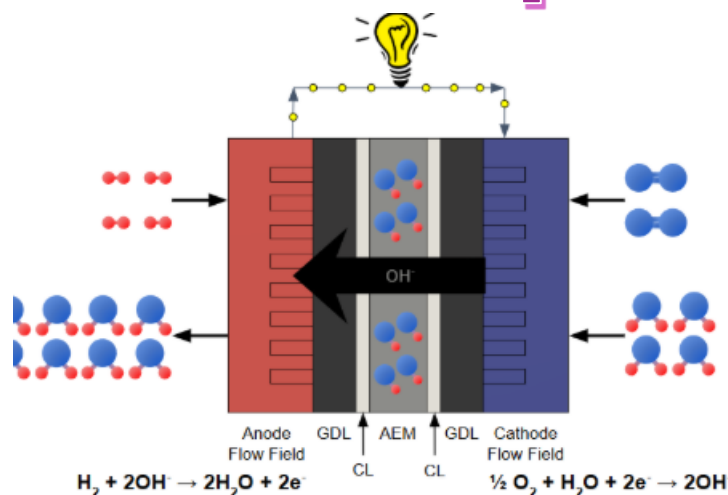
Haoyan Fang

Yuzhuo Li

Md Ashraful Islam

Niamul Hassan

Amol Pophali



Synthesis and Catalytic Evaluation of Reduced Graphene Oxide and Nickel-Decorated Reduced Graphene Oxide for Carbon Monoxide Oxidation

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Carbon monoxide (CO) is a toxic pollutant produced through incomplete combustion and remains an important target for heterogeneous oxidation into benign carbon dioxide. Graphene-based materials have emerged as promising catalysts for such oxidation due to their large surface area and tunable surface chemistry¹. Graphene oxide (GO) possesses abundant oxygen-containing functional groups that provide active adsorption sites, while reduced graphene oxide (rGO) has defect-rich surface chemistry that enhances molecular level catalysis². Previous studies have also suggested that the addition of metal nanoparticles can further promote CO oxidation. Herein we synthesize nickel nanoparticle-decorated rGO (Ni-rGO) to characterize the catalytic ability of Ni-rGO for carbon monoxide oxidation.

In this study, GO was synthesized using a modified Hummers' method and stored as a powder³. To produce rGO, the GO was dissolved in solution to 1 mg/mL concentration and subsequently reduced using 18 mM NaBH₄. Nickel-decorated rGO (Ni-rGO) was prepared by adsorbing 0.025 mM NiCl₂·6H₂O into the 1 mg/mL GO solution—producing approximately 0.15 wt% Ni—before reducing using 18 mM NaBH₄. The 0.025 mM nickel concentration was selected as it was the highest concentration that remained stable in solution without premature precipitation, promoting uniform nanoparticle deposition and minimizing aggregation. The GO, rGO, and Ni-rGO were then powdered and characterized using Raman spectroscopy and transmission electron microscopy (TEM).

Raman spectroscopy revealed distinct D and G bands in all three samples, confirming the preservation of the graphitic carbon framework throughout reduction and nickel incorporation (Fig. 2). Both bands shifted to lower wavenumbers following reduction, consistent with an increased carbon-to-oxygen ratio, while the I_D/I_G intensity ratio increased by approximately 23%, indicating the formation of smaller but more numerous sp² domains characteristic of defect-rich rGO⁴. No additional Raman-active nickel oxide phases were observed following nickel deposition, suggesting that the low metal loading introduced minimal structural disruption. TEM imaging confirmed successful deposition of dark nanoscale nickel particles on wrinkled graphene sheets (Fig. 1).

These results demonstrate successful synthesis of defect-rich rGO and Ni-rGO while preserving the underlying graphene framework and achieving uniform nickel nanoparticle deposition. Ongoing diffuse reflectance infrared Fourier transform spectroscopy (DRIFTS) measurements of CO adsorption and oxidation via GO, rGO, and Ni-rGO will establish correlations between catalyst structure and performance.

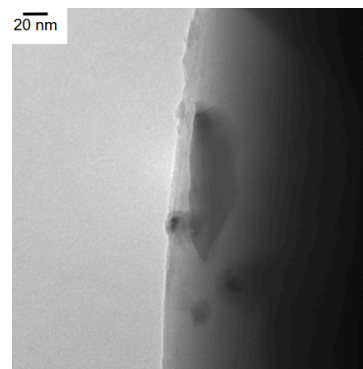


Figure 1: Transmission Electron Microscopy image of dark nickel nanoparticles embedded into reduced graphene oxide

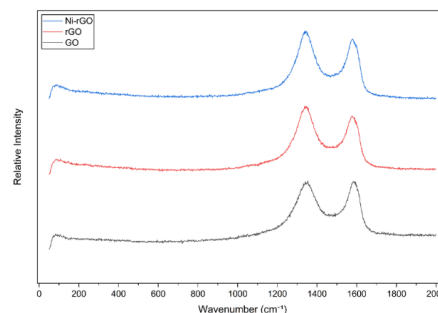


Figure 2: Raman spectra of graphene oxide, reduced graphene oxide, and nickel-decorated graphene oxide

- (1) Alam, M. W.; Allag, N.; Naveed-Ur-Rehman, M.; Islam Bhat, S. Graphene-Based Catalysts: Emerging Applications and Potential Impact. *Chem. Rec.* **2024**, *24* (11), e202400096. <https://doi.org/10.1002/tcr.202400096>.
- (2) Das, P.; Ibrahim, S.; Chakraborty, K.; Ghosh, S.; Pal, T. Stepwise Reduction of Graphene Oxide and Studies on Defect-Controlled Physical Properties. *Sci. Rep.* **2024**, *14* (1), 294. <https://doi.org/10.1038/s41598-023-51040-0>.
- (3) Zaaba, N. I.; Foo, K. L.; Hashim, U.; Tan, S. J.; Liu, W.-W.; Voon, C. H. Synthesis of Graphene Oxide Using Modified Hummers Method: Solvent Influence. *Procedia Eng.* **2017**, *184*, 469–477. <https://doi.org/10.1016/j.proeng.2017.04.118>.
- (4) King, A. A. K.; Davies, B. R.; Noorbehesht, N.; Newman, P.; Church, T. L.; Harris, A. T.; Razal, J. M.; Minett, A. I. A New Raman Metric for the Characterisation of Graphene Oxide and Its Derivatives. *Sci. Rep.* **2016**, *6* (1), 19491. <https://doi.org/10.1038/srep19491>.

Investigating Synthesis and Structure of Alumina-supported CoO_x Catalysts for Oxidation of Carbon Monoxide

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In the past few decades, researchers have studied organometallic precursors as starting material for synthesis methods like Atomic Layer Deposition (ALD) and Chemical Vapor Deposition (CVD). The synthesized CoO_x catalysts are of great interest in the industry for CO oxidation and preferential CO oxidation (PROX). Another important aspect is that preparation of catalysts plays a vital role in its performance. Herein, we try to study synthesis and structure-related properties of CoO_x/γ-Al₂O₃ catalysts, applying CO oxidation as a model reaction.

One-Pot Chemical Vapor Deposition (OP-CVD)¹ has emerged as a facile synthesis method, offering a strong control over dispersion. However, the mechanism for OP-CVD is not completely understood. This study analyzes ex situ step IR and Raman spectroscopy after each intermediate stage to propose a synthesis mechanism. This is also the first study to test the activity of catalysts with different precursor oxidation states at varying metal loadings (eg., 1, 3, and 5 wt%). Synthesis mechanisms were derived using 3 wt% of the precursor Co(acac)₂ or Co(acac)₃ on γ-Al₂O₃.

For the synthesis mechanism involving the precursor Co(acac)₂, based on the similarity in Raman spectra of physically mixed and post dispersion (Fig. 1a), it is concluded that Co(acac)₂ fails to vaporize and react with the γ-Al₂O₃ surface. However, post calcination data shows a broad peak at 690

cm⁻¹ indicating formation of CoO_x. FTIR shown in Fig. 1b further indicates that the acac ligands were decomposed after the calcination step with the acac bands between 1350 and 1650 cm⁻¹ disappearing.

In determining the synthesis mechanism involving the precursor Co(acac)₃, the Raman spectra of the physically mixed sample differ clearly from the post dispersion sample (Fig. 1c). As Co(acac)₃ is coordinatively saturated, it is assumed to vaporize with Co-O bonds decomposing at the dispersion temperature¹. The precursor is then expected to simultaneously undergo ligand exchange and an associative reaction precursor and support to anchor the CoO_x over alumina.

The activity results of the synthesized supported CoO_x catalysts are shown in Fig 2. The future scope includes: testing the catalysts for S-XRD, H₂-TPR and ICP-OES to understand crystal structure, redox properties, and achieving target metal loadings, respectively. will help lay the foundation for establishing how precursor oxidation state and metal loading can guide precursor selection.

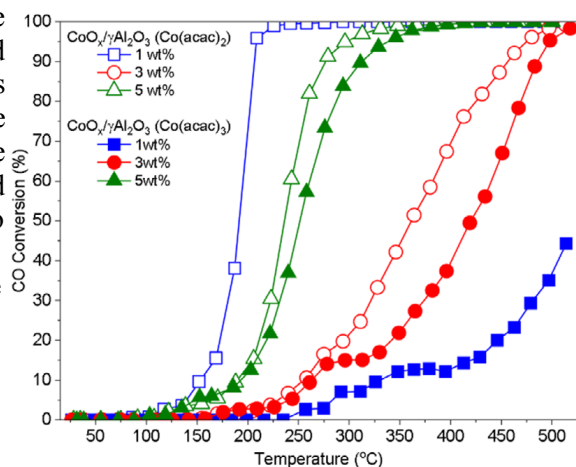
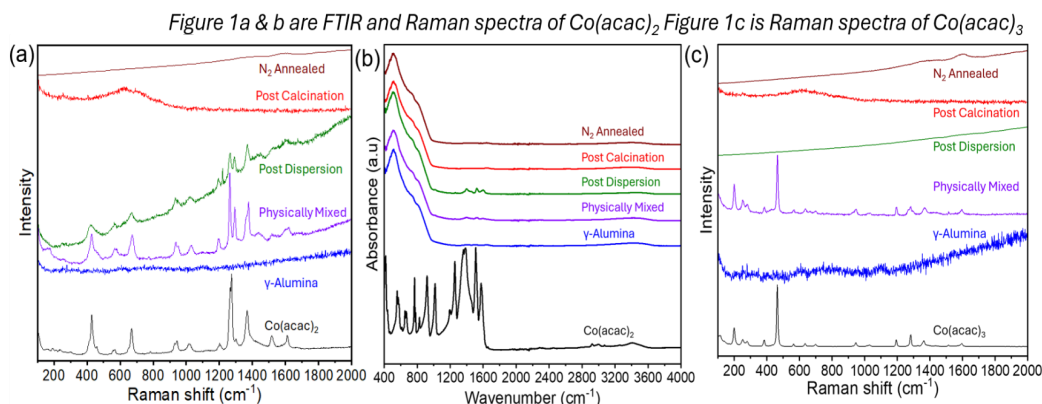


Figure 2 shows the catalytic activity of 1, 3, 5 wt% supported CoO_x catalysts for CO oxidation

- (1) Pophali, A.; Shimogawa, R.; Zhang, L.; Kwon, G.; Yoon, K.; Roh, J.; Kim, D. H.; Song, H.; Frenkel, A. I.; Kim, T. Development of Ceria-Supported Metal-Oxide (MO_x/CeO₂) Catalysts via a One-Pot Chemical Vapor Deposition (OP-CVD) Technique: Structure and Reverse Water Gas Shift Reaction Study. *Chem. Eng. J.* **2025**, *504*, 158726. <https://doi.org/10.1016/j.cej.2024.158>

Engineering Cu-Based Bimetallic Nanoparticle-Nafion Interfaces for Enhanced Performance and CO Tolerance of PEM Fuel Cells

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Proton-exchange membrane fuel cells (PEMFCs) are an active area of research due to their immense power output, efficiency, and portability. Additionally, their only byproduct of water vapor renders them promising alternatives amid concerns of fossil fuel combustion.¹ Despite these advancements, one significant bottleneck that inhibits widespread deployment is poisoning via carbon monoxide (CO), which reduces durability and performance. To address this issue, the present study deposited Cu-Ag and Cu-Zn nanoparticles onto a Nafion 117™ membrane to investigate the hypothesis that CO adsorption to the platinum catalyst is mitigated with bimetallic interfacial layers.

Both Cu-Ag and Cu-Zn nanoparticles were synthesized via a modified Brust-Schiffrin method, which utilizes dodecanethiol to cap the size of metal nanoparticles.² For the zinc-based alloy, an unexpected third phase led to an investigation using Cu-Zn ratios of 3:1 and 1:3. A Langmuir-Blodgett (LB) trough was used to coat the Nafion 117™ membrane with a nanoparticle monolayer, and the gas diffusion layers were prepared using carbon papers sprayed with platinum ink to catalyze the reactions at the electrodes.

For the Cu-Ag alloys, deposition of nanoplatelets at 2, 4, 6, and 8 mN/m surface pressures displayed a percent increase of 6.67%, 26.10%, 34.36%, and 15.55% respectively in power mass density compared to the control (Fig. 1). The ideal performance occurred at 6 mN/m, so this value was selected for a durability test of 30,000 cycles which demonstrated a 12.1% improvement in maximum power density (MPD) retention relative to the control. After fuel cell testing, nanoparticles were also examined by transmission electron microscopy (TEM), which revealed the median particle size to be 6.38 ± 1.07 nanometers (nm) and verifying minimally agglomerative qualities regarding the layer's morphology (Fig. 2). However, it was also found that certain nanoparticles were rendered in structures analogous to filaments, a likely effect of the alloying process.

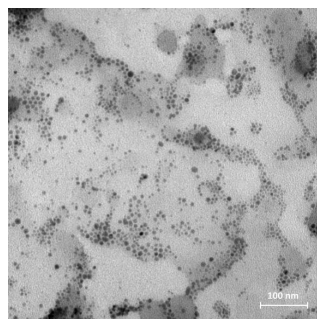


Fig. 2. TEM of CuAg at 6 mN/m.

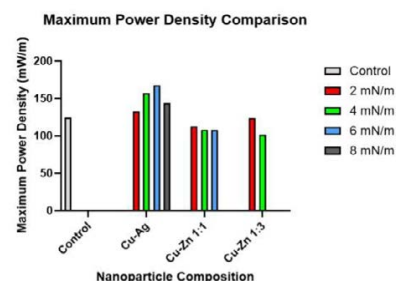


Fig. 1. MPD Comparison.

Expanding upon prior studies on Au-Nafion nanoplatelet interfaces³, we additionally synthesized gold nanoparticles, deposited them using the LB Trough, then submerged the membrane in liquid nitrogen under cryogenic conditions to grind it in a brittle state. Diffuse reflectance infrared Fourier transform spectroscopy (DRIFTS) testing was conducted to analyze CO oxidation behavior for Au nanoparticles⁴, and further TEM, X-ray diffraction, DRIFTS, and durability tests are planned to verify the impact of a copper-alloy layer on PEMFCs.

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Investigation of Synergy Effect on Alkaline Exchange Membrane Fuel Cell (AEMFC) by using ALD Coated TiO₂ and Gold Nanoparticles

Aidan He¹, Brian Xiong², Daniel Lim³, Haoyan Fang⁴, Yuzhuo Li⁴, Miriam Rafailovich⁴

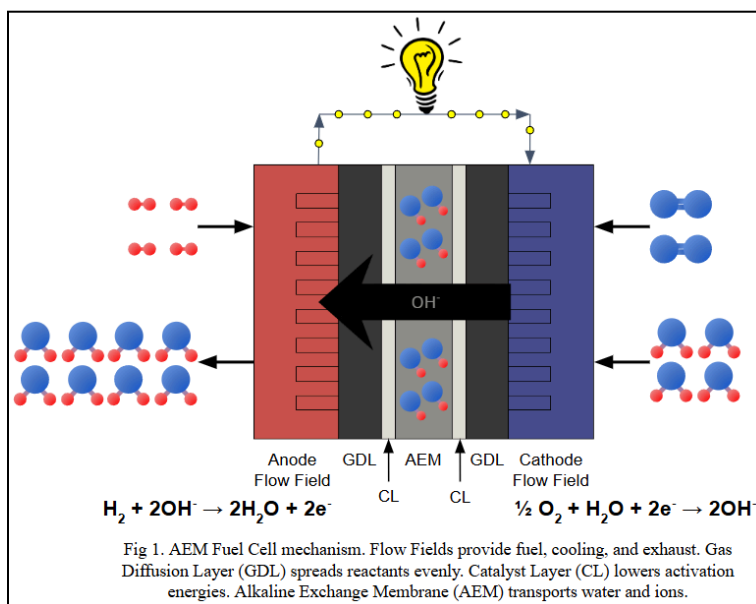
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In the ongoing energy transition, hydrogen fuel cells have been steadily gaining attention for being a clean energy alternative to fossil fuels, as these cells release water as exhaust instead of greenhouse gases. Alkaline Exchange Membrane Fuel Cells (AEMFCs) are a type of hydrogen fuel cell that uses an alkaline solution as an electrolyte in order to balance the difference in charges generated from the reduction-oxidation reactions [1]. Alkaline solutions operate over a larger range of temperatures and pressures than acidic solutions due to lower corrosivity and more favorable reactions, allowing for the use of more unique materials. In particular, AEMFCs can use nickel or silver as a catalytic material rather than traditional hydrogen fuel cells which use platinum. This allows for cheaper fuel cells that have commercial potential [1]. A diagram of an AEMFC is below (Figure 1).

While current hydrogen fuel cells are relatively efficient, there are still many improvements that can be made. There are 4 main losses of power in AEMFCs: Activation losses, fuel crossover and internal currents, Ohmic losses, and mass transport or concentration losses [1]. This research focuses on mass transport loss, which relates to molecule transport across the membrane. This study tests the effects of depositing TiO₂ and Au nanoparticle (NP) coatings onto the membrane surface in boosting cell performance, and whether synergy exists when both are present.

To coat our membranes with even TiO₂ nanolayers, thermal atomic layer deposition was used, with varying number of cycles to control TiO₂ layer. To coat our membranes with even gold nanolayers, the Brust method was used to synthesize well-dispersed gold nanoparticles. The nanoparticles were then deposited using a Langmuir-Blodgett trough, adjusting the number of gold nanolayers by maintaining the surface pressure at calibrated values with the barriers. 5.0 cm² square GDL were cut from a sheet of carbon paper, then sprayed with 12.66 mg of a Platinum Carbon (Pt-C) catalyst ink. The membrane and GDL were immersed in KOH for an hour in order to saturate them with OH⁻, then tested for maximum power density across varying current densities.

Our results for TiO₂ showed a significant increase in performance up to 60 cycles, with maximum power density of 0.399 W/cm², 87% higher than the control membrane at 0.213 W/cm². Our Au NPs also increased performance, but we did not find a trend with the number or density of layers. Maximum power density was 0.305 W/cm², 43% higher than the control. We theorize that the TiO₂'s superhydrophilicity allows for enhanced water transport, and the Au's conductivity allows for enhanced ion transport. After measuring possible synergy effects, future research could be done on the synergistic effects of other coatings or membrane types.



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² Yang, W., Son, M., Rossi, R., Vrouwenvelder, J. S., & Logan, B. E. (2019). Adapting Aluminum-Doped zinc oxide for electrically conductive membranes fabricated by atomic layer deposition. *ACS Applied Materials & Interfaces*, 12(1), 963–969. <https://doi.org/10.1021/acsami.9b20385>

Session 5: Energy Materials

Mentors:

Rebecca Isseroff

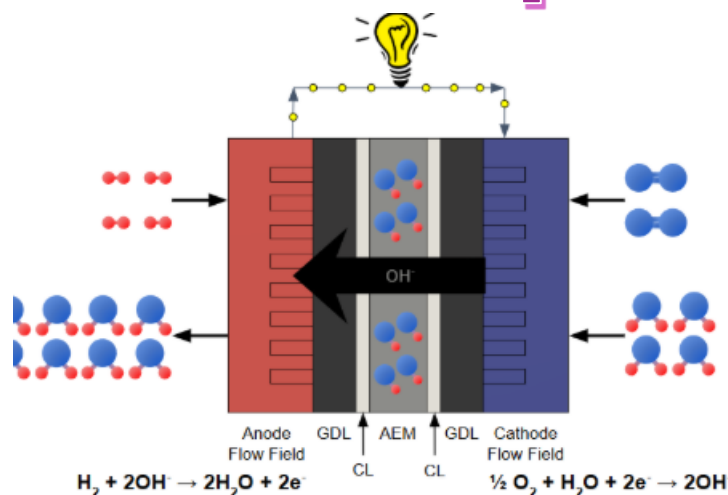
Haoyan Fang

Yuzhuo Li

Md Ashraful Islam

Niamul Hassan

Amol Pophali



Lecithin Retinol Acyltransferase Alters Cytoskeletal Structure and Young's Modulus in Squamous Cell Carcinoma Cells

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¹Biotechnology High School, Freehold, New Jersey, ²Shanghai Starriver Bilingual School, Shanghai, China, ³Salanter Akiba Riverdale High School, Bronx, New York, ⁴Department of Biomedical Engineering, Stony Brook University, Stony Brook, New York, ⁵University of Connecticut, Storrs, Connecticut, ⁶Department of Materials Science and Chemical Engineering, Stony Brook University, Stony Brook, New York, ⁷Department of Oral Biology and Pathology, Stony Brook University, Stony Brook, New York

Lecithin Retinol Acyltransferase (LRAT) is a major enzyme involved in retinol metabolism. It catalyses esterification of retinol into retinyl esters, a biologically inactive form of retinol, for retinol storage and to modulate retinoic acid production. LRAT expression is significantly downregulated in multiple cancers, including squamous cell carcinomas (SCC) [1]. LRAT downregulation reduces conversion of retinol to retinyl esters, leading to an increase in retinoic acid. Retinoic acid is a transcription factor ligand that suppresses keratinocyte differentiation markers and cornified envelope formation [2]. This study investigates the effect of the misregulation of retinol metabolism on the mechanical properties of cancer cells. Mechanical properties like modulus influence cancer cell behavior and determine invasive capacity. Cancer cells that are softer have increased metastatic potential [3].

Functional copies of LRAT, along with the gene for green fluorescent protein (GFP), were inserted into two squamous cell carcinoma strains, SCC-12B (RRID:CVCL_4027) and SCC-13 (RRID:CVCL_4029). SCC-12B and SCC-13 with and without LRAT were cultured with and without 3T3 feeder cells at 37°C and 7% CO₂. Normal keratinocytes, which naturally contain LRAT and require 3T3 cells to grow, were cultured in the same conditions. Both SCC-12B and SCC-13 share a common mutation (TP53); however, SCC-12B has an extra mutation (HRAS). This is consistent with SCC-12B having a higher metastatic potential, and an expected lower modulus.

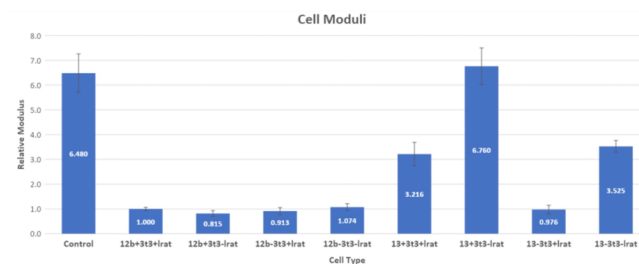


Figure 1. AFM measurements depicting moduli and standard error for all samples.

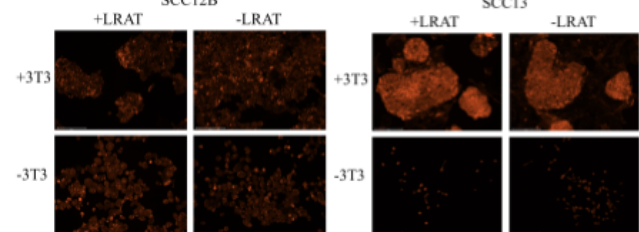


Figure 2. EVOS fluorescence microscopy images under red fluorescent lighting at 10x magnification to depict actin stain.

Atomic force microscopy (AFM) was used to measure Young's modulus when cultures were pre-confluent. This allowed measurements of single cells at the edge of colonies. Figure 1 suggests that SCC-12B cells have a low modulus independent of the expression of LRAT or the presence of 3T3 cells, the SCC-12B cells' state further into the epithelial-mesenchymal transition [4]. In contrast, the presence of LRAT led to a decrease in cell modulus in SCC-13 cells. The specific impact of LRAT on cell modulus is being assessed.

Cells were fixed while pre-confluent, stained for actin with ActinRed 555 (ThermoFisher), and imaged with an EVOS microscope to visualize actin and GFP (LRAT expression). In SCC-13, actin was localized at the plasma membrane. In contrast, in SCC-12B there was less actin, which appeared punctate. Punctate actin in SCC-12B cells likely led to the lower modulus observed by the AFM. In order to determine the effect of LRAT on gene expression, RNA was isolated for assessment by RNA-seq (RT-qPCR will be carried out to verify RNA-Seq findings).

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Investigating the Effects of TiO₂ Nanoparticles on Angiogenesis in HUVEC-EGFP Cultures

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Skin grafts are widely used to promote wound healing in burn, diabetic, and trauma patients; however, graft survival depends heavily on the speed at which vascular perfusion is reestablished in the new tissue. Delayed perfusion is a leading cause of graft necrosis, where transplanted tissue dies¹. Human umbilical vein endothelial cells (HUVECs) seeded on Matrigel are a standard in vitro model of angiogenesis, self-assembling into networks that mimic early steps of vascular formation. Titanium dioxide (TiO₂) nanoparticles have been reported to promote wound healing and tissue regeneration by adsorbing blood serum proteins and accelerating the coagulation cascade². TiO₂-nanostructured surfaces have separately been shown to enhance HUVEC proliferation, VEGF secretion, and capillary-like tube formation relative to untreated controls³. However, TiO₂ has also shown anti-angiogenic effects in other cell types at higher exposure levels⁴, suggesting its influence on endothelial network formation may depend on both dose and duration of exposure.

HUVEC cells expressing EGFP (HUVEC-EGFP) were cultured and expanded in EGM2 medium and subcultured to confluency. Experimental wells were treated with 0.1mg/mL TiO₂ for 24 hours. Cells were then seeded onto Matrigel; excess TiO₂ was removed during plating, so networks formed without continued contact with free nanoparticles. An EVOS microscope recorded images every 5 minutes for 16 hours. Modulus was measured by atomic force microscopy (AFM). RNA was extracted with the RNeasy Universal Mini Kit (Qiagen); poly(A)-selected libraries were sequenced by Azenta on an Illumina NovaSeq.

TiO₂-treated samples formed vasculature faster than the control samples, shown in Fig. 1, but also degraded at a faster rate. The volcano plot in Fig. 2 shows a strong upward bias (612 up / 198 down). The most significantly up-regulated genes are lipid/cholesterol-biosynthesis genes (HMGCS1, INSIG1, ACAT2, TLR2, CH25H), while the most down-regulated are proliferation genes (MKI67). This indicates a shift towards membrane remodeling and a decrease in cell proliferation. We used atomic force microscopy (AFM) to observe cells at 16 hours and found no significant difference in cell modulus after p-value analysis.

In the future, we plan to observe vascular network morphology via AFM at 1, 4, 8, and 16 hours post-plating to track the time course of TiO₂'s effect on endothelial network structure. This data will provide insight into cell modulus, stiffness, and networking, helping us quantify the effectiveness of vascularization when treated with TiO₂.

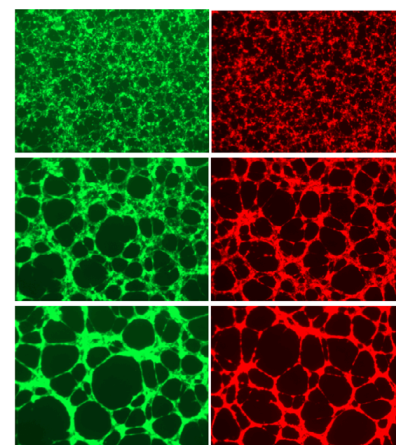


Fig 1. EVOS imaging at 1hr 45min, 8hr, and 15hr 45min respectively for control (green) and TiO₂ treated (red) HUVEC samples

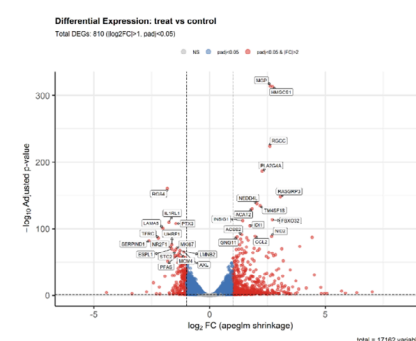


Fig 2. Volcano plot of RNA sequencing data, showing certainty and the up- and down-regulation of genes

¹ Pinho, A., Brinca, A., & Vieira, R. (2024). Exploring the Role of Perfusion in Skin Graft Viability on the Scalp and Lower Limb: An Analysis of Graft Bed, Margin, and Donor Skin Using Laser Speckle. *Journal of Clinical Medicine*, 13(24), Article 7671. <https://doi.org/10.3390/jcm13247671>

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⁴ Kirkland, D., Burzlaff, A., Czich, A., Doak, S. H., Fowler, P., Pfuhrer, S., & Stankowski, L. F. (2024). Updated assessment of the genotoxic potential of titanium dioxide based on reviews of in vitro comet, mode of action and cellular uptake studies, and recent publications. *Regulatory Toxicology and Pharmacology*, 154, Article 105734. <https://doi.org/10.1016/j.yrtph.2024.105734>

Session X:

JESTI

Chairs:
Marie Kouzmine
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**Welcome to the Journal of Ethics in Scientific
and Technological Innovations (JESTI).**

Kiruna, 2021: A Case Study into Moral Hazard and a Test for Moral Hazard

Objections to Research

Sean Minjune Park¹ Luke Zhang²

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Some research is restricted because of what it might release. In February 2021 the Saami Council and three Swedish environmental organizations demanded cancellation of a balloon flight (SCoPEX) near Kiruna because of what it might reveal.¹ The test was merely an equipment test, would have released no material, and was cleared by independent reviews^{2,3} but the Saami objected, stating stratospheric aerosol injection constitutes a moral hazard;^{1,4} essentially, an objection to producing knowledge, a recurring theme in many virology and nuclear weapons studies. **This paper examines whether knowledge makes action more likely, whether that justifies restricting inquiry, and proposes a three-part framework for evaluating the morality of conducting research.** Existing review frameworks like the Fink criteria⁵ and HHS P3CO,⁶ ask simply whether knowledge confers capability, necessary but insufficient, since it doesn't directly address the issue of a moral hazard objection.

Restriction is warranted only where all three conditions hold: (1) producing the knowledge reduces effort on the problem it addresses; (2) restricting it prevents the work rather altogether; (3) research enables the harmful act. SCoPEX satisfies none. (1) Recent experimental evidence find little evidence that awareness of solar geoengineering reduces support for cutting emissions.⁷ (2) Cancelling the flight did not stop the research; it moved it toward state and private actors.³ (3) The indication of a potential danger of a deployment of a stratospheric aerosol injection is separate from the issue of outlining how to deploy it.² The 2011–2012 H5N1 controversy^{8,9} is routinely cited as the precedent for restricting research on moral hazard grounds, yet it fails the first condition: transmissibility research does not reduce effort on pandemic preparedness. Failing the moral hazard test does not clear a project and leaves other objections standing: for H5N1, published methods would have shown others how to make a transmissible virus.¹⁰ Restriction on capability-based biosecurity grounds was warranted, but not on moral hazard grounds.

None of the three conditions held at Kiruna. Therefore, moral hazard objections did not justify stopping the flight. More broadly, the case leaves behind a test for distinguishing when concerns about the consequences of knowledge justify restricting research and when they do not. If an objection fails this test, it may justify safeguards such as disclosure, registration, siting, or community consent, but not prohibition. Only when all three conditions are met is a ban on moral hazard grounds justified.

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The Ethics of Preserving Identity During Awake Craniotomy

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Awake brain mapping during craniotomy is used to identify and determine which areas need to be preserved during tumor resection. During an awake craniotomy, the patient performs tasks while electrodes placed on the exposed cortex record neural activity through electrocorticography (ECoG) (Almairac and Duffau). Neurosurgeons may also use direct electrical stimulation to briefly disrupt small cortical areas and, as resection progresses, underlying white matter pathways. If stimulation causes the patient to falter, the stimulated tissue is identified as essential and preserved. Traditionally, intraoperative mapping has focused on preserving motor and language functions (Rossi et al.). However, there are ethical implications in that there is a blurred line between basic functions like movement or speech and higher order functions such as memory, emotion—ie. personal identity. These functions related to identity do not exist in one identifiable brain region, so there might be possible identity-related changes post surgery. This introduces ethical considerations. This paper will first describe the scientific and technical basis of awake brain mapping. It then examines ethical implications. In particular, particular attention is given to the onco-functional balance between maximizing tumor resection and preserving meaningful functioning, as well as questions concerning autonomy, informed consent under uncertainty, beneficence, neurological harm, etc. (Kirsch and Bernstein). This discussion is especially relevant given the recent progress in connectome-guided surgery that emphasises preserving critical cognitive function, as well as longitudinal outcome assessments that can track the results of such procedures (Tykocki and Rakasz). Overall, there has been a shift from preserving isolated neurological abilities toward preserving broader elements comprising personal identity, which brings the aforementioned ethical concerns. To maintain ethics in awake craniotomy, future research must improve task validity, patient-specific assessment, professional standards, and accessibility in order to avoid the reduction of personal identity to purely cognitive performance.

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The Space Race's Second Lap!

An Ethical Analysis of the Modern Space Revitalization

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With the rise and recent success of private space-oriented companies over the past few years like SpaceX and Blue Origin¹ along with the United States' rejuvenated efforts to explore the moon through the Artemis program, space travel has been at the forefront of scientific discourse only comparable to the first Space Race in the 1960s. However, in comparison to the previous political motivations of the Cold War, the modern day "race" has a significantly higher focus on the potential economics and settlement of outer space.² Most notably, through tourism programs,³ interplanetary colonization efforts,² and the ever-growing satellite industry.⁴ The shifted focus of the current space-related excitement calls for the assessment of the ethical implications surrounding the topic- such as concerning the people and companies who have more selfish motivations to traverse space,⁴ the potentially harmful and wasteful methods and issues of said space traversal relative to other methods,⁶ and whether major economic incentives, like a moon base, satellites, and Mars exploration, outweigh the incredible costs and risks involved in their production and implementation. Overall, this article seeks to answer the overarching question "Is space worth it?" from a moral perspective, exploring whether humanity's pure technological prowess or out-of-this-world hubris has truly been bringing us closer to the stars with each new innovation.

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Session 6: Materials Engineering

Mentor:
Kevin Kayang

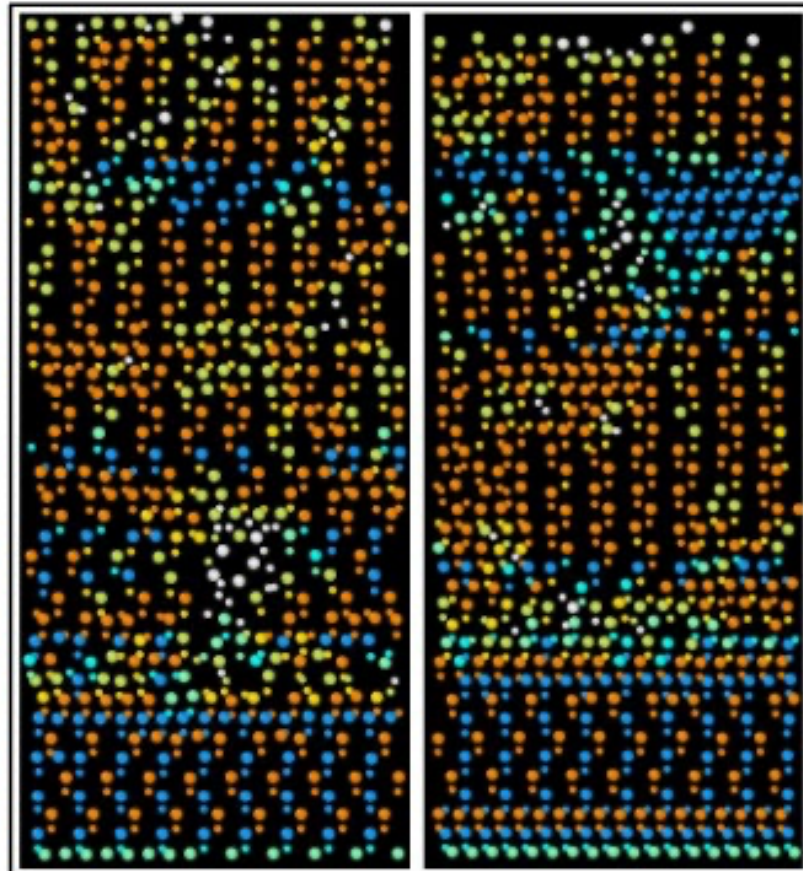


Figure 1: Stacking sequence of full step (left) and half step (right) substrates

Grain Boundary Characterization of Carbide Ceramics for Fusion First-Wall Applications

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Nuclear fusion offers a promising pathway towards clean and high-density energy generation; however, the extreme conditions required to harness this energy hinder its practical feasibility. Ultra-high temperature ceramics (UHTCs) are therefore being studied for potential first-wall applications because of their stability under harsh conditions. Their performance, however, depends strongly on their microstructural properties, particularly grain boundaries. These interfaces between differently oriented crystals can weaken the material and serve as preferential sites where defects can accumulate. This work investigates the properties of grain boundaries and their relationships to material properties in four carbide-based ceramics: VC+SiC, VC+SiC+CF, WC+SiC+CF, and WC+ZrC+Ta+CF.

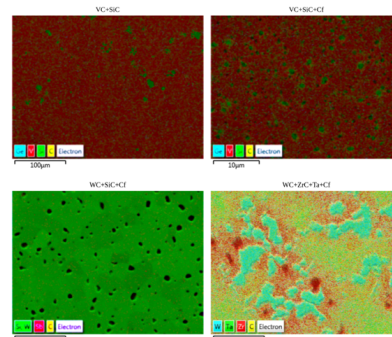


Figure 1 – Layered SEM-EDX elemental maps comparing four carbide composites.

Previous work by Lin et al. showed that the most compromising swelling of the irradiated ¹¹B-enriched ZrB₂ came from cracks along the grain boundaries¹. Samples with larger grains (approx. 18 μm) exhibited five times more grain-boundary cracking than samples with smaller grains (approx. 7 μm). In a related study, the same group found that adding fibers to similar ceramic materials could reduce cracking and swelling². These findings reveal grain boundaries as a key feature in understanding the strength of materials under extreme conditions.

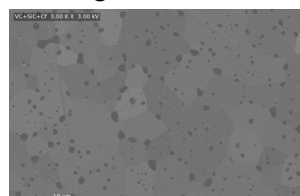


Figure 2 – SEM image of a VC composite with finely dispersed silicon carbide.

Simulations and experiments were used to characterize the microstructure of carbide materials and examine features that may influence their response to extreme thermal and radiation conditions. Molecular simulations with RustBCA modeled radiation-induced atomic damage, and optical microscopy identified large-scale microstructural features and selected regions of interest for further analysis. These regions were imaged at higher resolution using scanning electron microscopy, and energy-dispersive X-ray spectroscopy mapped the spatial distribution of silicon carbide phases, including SiC particles located near or along grain boundaries (Figs. 1-2).

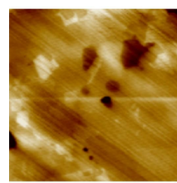


Figure 4 – AFM surface topography of WC.

Measurements of SiC particle size, spacing, grain size, and particle-boundary contact showed that finely dispersed second-phase SiC was associated with substantially smaller grains than agglomerated SiC, effectively restricting grain growth by producing a more stable microstructure with a greater density of interfaces (Fig. 3). Such interfaces can distribute deformation rather than allowing damage to concentrate within a small region of grains and boundaries. Atomic force microscopy was also used to obtain maps of surface friction and topography, corroborating the results from the SEM (Fig. 4).

Together, the results reveal how finely dispersed SiC can stabilize the grain structure and increase the density of interfaces that may act as sinks for radiation-induced defects.

Finely dispersed second-phase SiC may therefore provide a practical means of controlling grain structure for fusion first-wall applications. Future work can involve irradiating the samples to directly test whether finely dispersed SiC suppresses grain coarsening and preserves microstructural stability for fusion first-wall applications.

	VC+SiC+CF dispersed	VC+SiC agglomerated
SiC second phase		
Mean particle radius, r (μm)	0.26	2.44
Mean spacing (μm)	1.3	10.9
Particles on grain boundaries (%)	29	90
Grains		
Measured grain size, d (μm)	10.5	82.6
Boundary density (μm ⁻¹)	0.80	0.06

Figure 3 – Comparison of vanadium carbide with dispersed & agglomerated SiC.

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[2] Lin, Yan-Ru, et al. "Comparative Neutron-Irradiation Effects on Thermal Conductivity Degradation and Dimensional Stability of TiC, TiB₂, and ZrB₂ at 200–1000 °C." *Journal of Nuclear Materials*, vol. 632, 2026, article 156897, <https://doi.org/10.1016/j.jnucmat.2026.156897>.

Effects of Substrate Microsteps on SiC Growth

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In recent years, silicon carbide (SiC) has become a material of great interest in the fields of semiconductors, optoelectronics, automobiles, and energy due to useful properties like a wide bandgap and high thermal conductivity¹. However, the manufacturing process currently faces numerous challenges, suffering from low growth rates and high defect rates². Quality SiC crystals must be grown in high temperature environments, making experimental observation of the growth process difficult. Thus, computational modelling is needed to gain a greater understanding of the growth mechanism and improve manufacturing methods. In this study, we use molecular dynamics (MD) simulations to investigate the impact of substrate microsteps on SiC growth.

The modified embedded atom method (MEAM) was utilized through the large-scale atomic molecular massively parallel simulator (LAMMPS) program. Three 4H-SiC substrate models all prepared with a 4 degree offset were then engineered with either no steps, a half step, or a full step with OVITO Pro. These substrates were then equilibrated at 300K then heated to 2400K under NPT and equilibrated again through the use of the Nose-Hoover thermostat and barostat. Physical Vapor Deposition (PVD) was simulated by depositing Si₂C, SiC₂, and Si above the substrate, at rates of 0.469ps⁻¹, 0.935ps⁻¹, and 0.466ps⁻¹, respectively, inside a box with base area 70.1nm². These preserve a 1:1 Si to C ratio. Periodic boundary conditions were employed along the x and y directions. The deposited molecules then formed Si and C atoms to form SiC crystals above the substrate under NVE at a timestep of 1fs for 11.052ns to deposit eight unit cells of SiC crystal. Finally, the deposited crystal is equilibrated again and the data was analyzed in OVITO using modifiers such as Dislocation Extraction Algorithm (DXA), Slice, and Identify Diamond Structure.

The results for half step and full step are shown in Fig. 1. We see a majority of the deposited atoms form a hexagonal stacking sequence (completely orange). The 4H-SiC structure (alternating blue and orange bilayers) is exhibited in the substrate as engineered, and we observe promotion of its growth near the step, while higher layers (grown on top of a smoother step surface) manifest largely in hexagonal geometry. The full step substrate exhibits a large amount of basal slips, which are then forced up into the crystal by the full step and become threading edge dislocations. These results contribute to developing an understanding of SiC growth, which we will further by comparing our results with unstepped substrates and different step widths.

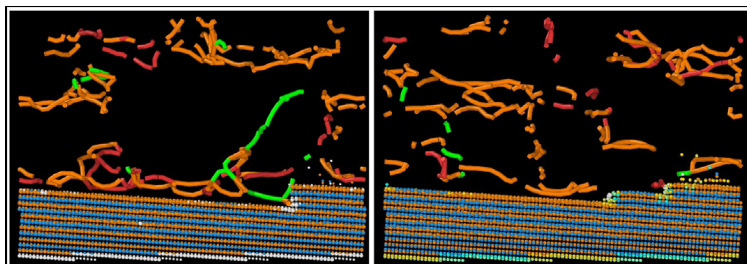


Figure 2: Dislocation analysis of full step (left) and half step (right) substrates

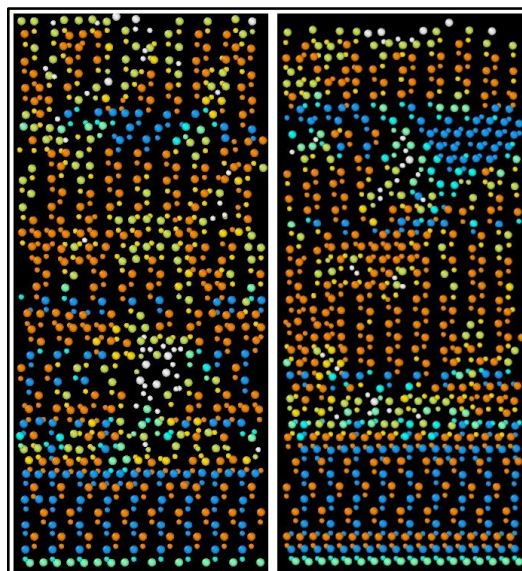


Figure 1: Stacking sequence of full step (left) and half step (right) substrates

¹ F. Roccaforte et al. Emerging trends in wide band gap semiconductors (SiC and GaN) technology for power devices, *Microelectronic Engineering*, Volumes 187–188, 2018, Pages 66–77, ISSN 0167-9317, <https://doi.org/10.1016/j.mee.2017.11.021>.

² H. Tsuchida, T. Kanda, Advances in fast 4H-SiC crystal growth and defect reduction by high-temperature gas-source method, *Materials Science in Semiconductor Processing*, Volume 176, 2024, 108315, ISSN 1369-8001, <https://doi.org/10.1016/j.mssp.2024.108315>.

Session 7:

Nanotoxicology

Mentors:

Muyun Cui

Fernando Aguilar Perez

Said Yashaev



Topology-based Analysis of TiO₂ Effects on Endothelial Cell Network Formation

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Titanium dioxide (TiO₂) nanoparticles are widely used in consumer products and can readily enter the bloodstream via inhalation, ingestion, or dermal absorption, raising critical concerns over their potential vascular toxicity. Within the bloodstream, these nanoparticles interact with endothelial cells, which rely on Vascular Endothelial (VE)-cadherin-based adherens junctions to link neighboring cell membranes to the cytoskeleton and coordinate network assembly during angiogenesis [1]. Because these junctions provide the mechanical stability necessary for coordinated network assembly during angiogenesis, disrupting them can compromise vascular integrity. Indeed, TiO₂ exposure induces reactive oxygen species (ROS) that destabilize these junctions and impair endothelial cell viability [2]. However, most prior work exploring the effects of TiO₂ measures local morphological measures, such as viability, migration, and vessel length, which cannot capture the resulting network's organization holistically. Standard image-based network analysis also typically relies on binarizing the image at a single fixed intensity threshold, discarding real structural information that exists at other threshold levels.

We addressed both limitations by combining deep-learning segmentation with topological analysis across a sixteen minute timelapse of control and TiO₂-treated (0.1 mg/mL) Human Umbilical Vein Endothelial Cell (HUVEC) cultures. Networks were segmented with Cellpose's pretrained cyto3 model—using image inversion so enclosed loops matched cyto3's training distribution—then skeletonized into a graph for structural (density, spline length, thickness) and topological (connectivity, fragmentation, loop count/area) metrics. To complement this with a threshold-independent approach, we incorporated persistent homology. Unlike traditional binarization, persistent homology characterizes network structure across the full spectrum of brightness intensity thresholds simultaneously, a methodology of established value in vascular network analysis [3].

TiO₂-treated networks showed more branch points and greater total length than controls, metrics that alone suggest a larger network. Topological analysis showed the opposite: TiO₂ networks were ~53% more fragmented, less connected (0.53 vs. 0.67), and formed loops ~26% smaller on average despite similar loop counts. Co-culture wells with swapped fluorophore labeling showed lower spatial overlap in TiO₂-containing wells, consistent with impaired consolidation, though the swapped replicate pair only partially agreed.

These results show TiO₂ does not suppress branching but disrupts its consolidation into a unified network. This distinction is invisible to count-based metrics but is captured by topological metrics. Persistent homology also offers a more complete, threshold-independent characterization of this disruption, supporting topological analysis as a sensitive biomarker for nanoparticle-induced vascular dysfunction.

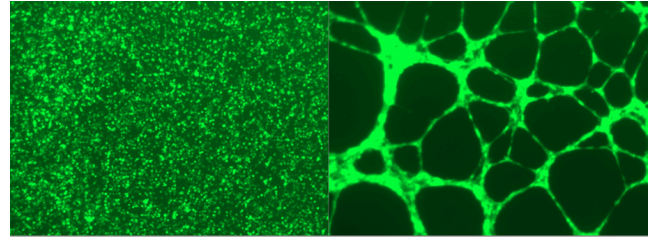


Figure 1. First (left) and last (right) frame of a 16-minute timelapse showing control-group endothelial cell network formation, from initial sparse cell distribution to a fully consolidated network.

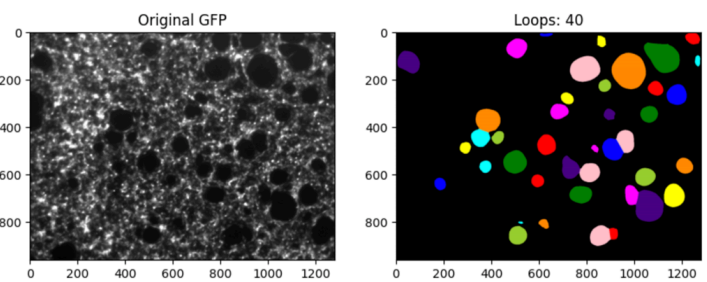


Figure 2. Cyto3-based loop detection on a GFP frame (control). *Left*: original grayscale image. *Right*: individual network loops segmented by inverting image and applying the pretrained cyto3 model, with each loop shown in a distinct color.

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[3] Nicponski, J., & Jung, J.-H. (2020). Topological data analysis of vascular disease: A theoretical framework. *Frontiers in Applied Mathematics and Statistics*, 6, 34. <https://doi.org/10.3389/fams.2020.00034>

Evaluating Titanium Particles Released During Dental Implant Placement

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Dental implants, typically made out of titanium, are commonly drilled into the jawbone. As the TiO₂ layer degrades over time, metallic particles are released onto the surface of the bone. These particles can cause inflammation, peri-implantitis, and compromised osseointegration [1, 2]. This study aims to evaluate the size, amount, and location of Ti, Ca, and P particles released by different implant placement techniques.

Synthetic bone and *ex vivo* pig bone were used to mimic human bone. Titanium-vanadium alloy (Ti-V) implants and calcium phosphate coated titanium (CaP-Ti) implants were implanted into synthetic bone, and full-drilled into the pig bone alongside a standard sandblasted, large-grit, acid-etched-surface-treated titanium (SLA-Ti) implant. The implants were inserted using two different implant placement techniques (half vs. full drilling) in synthetic bone for torque-related stability.

After implant placement, the synthetic bone samples were demounted to separate the two sides of the synthetic bone surface. For the pig bone samples, the bone surrounding the implants was sectioned following the implant's main axis to expose the implant-bone interface. Under the Keyence microscope, each third of the implant site (gingiva, middle, apical) was imaged, and elemental analysis was conducted. The proportion of images with the element over the total number of images taken were compared under different parameters like implant third, implant type, and full vs. half-drilling.

In synthetic bone, Ti particles were found in 11.8% of the Ti-V implant site images and 28.6% of the CaP-Ti implant site images. In pig bone, Ti particles appeared in 16.7% of the Ti-V implant images, 50.0% of the CaP-Ti implants, but in none of the SLA-Ti implant sites (Fig. 1). CaP-Ti implants continued to

leave higher proportions of particles for Ca and P. Additionally, Ti particles were discovered in 37.5% of gingiva images in both synthetic and pig bone and in 16.7% of pig bone's middle third, but no Ti was found in either

apical third (Fig. 2). Similarly, in both bone types, the majority of Ca and P particles were found in the gingiva third. In the synthetic bone samples, half drilling had a higher proportion of Ti and Ca particles but a lower proportion of P particles.

These preliminary findings support titanium release during dental implant placement, especially for CaP-Ti implants. For further

analysis, critical-point dried samples will undergo scanning electron microscopy with energy-dispersive X-ray spectroscopy, and transmission electron microscopy to confirm particle identity, characterize particle size and morphology, and distinguish detached particles from titanium signals originating from the implant surface.

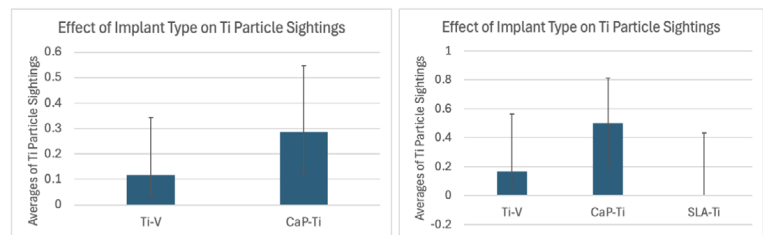


Fig 1. Effect of Implant Type on Ti Particle Sightings for Synthetic Bone and Pig Bone

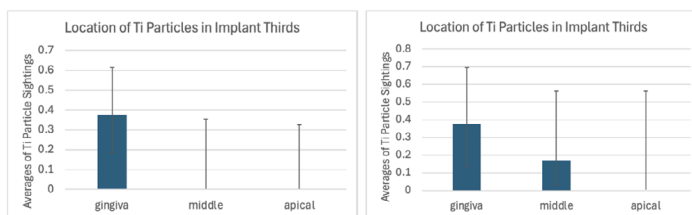


Fig 2. Location of Ti Particles in Implant Third in Synthetic and Pig Bone

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Substrate-Mediated Mitigation of TiO₂ Nanoparticle Effects on Osteoblast Mineralization

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Miriam Rafailovich⁷

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Titanium has been widely used in dental implants, particularly within the jawbone, due to a longstanding belief in its biocompatibility¹. However, recent research has revealed that TiO₂ nanoparticles can shed from the oxide layer during insertion and chewing, leading to impairment of osteoblast function, disruption of osteogenesis, periimplantitis, and implant failure¹. We aim to investigate how collagen and collagen-fibrin substrates, essential proteins that mimic the native bone environment and promote adhesion during wound healing, can mitigate the negative effect of TiO₂ nanoparticles on osteogenesis².

Osteoblasts were expanded in osteogenic growth medium and plated onto three substrates: tissue-culture plastic (TCP), collagen (Col), and collagen-fibrin (CF). Half of the wells in each group were exposed to 0.1 mg/mL rutile TiO₂ nanoparticles prior to differentiation in osteogenic induction medium. After 21 days, osteogenesis was evaluated by Alizarin red S staining, DAPI/F-actin fluorescence imaging, SEM-EDX, Raman spectroscopy, and qRT-PCR normalized to the GAPDH housekeeping gene.

On day 21, fluorescent staining characterized Col and CF osteoblasts as forming a 3D interconnected network regardless of TiO₂ exposure, contrasting with the 2D monolayer formed on TCP. (Fig. 1). ImageJ

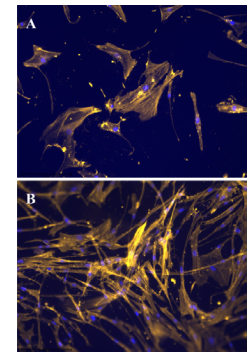


Figure 1. Immunofluorescence images of day 21 TiO₂-treated osteoblasts on TCP (A) and CF (B)



Figure 2. Percent area covered by ARS stain

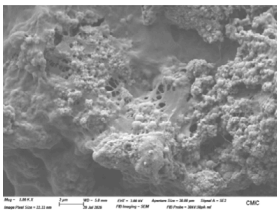


Figure 3. SEM image of TCP without TiO₂ biomimetic mineralization templated on collagen

quantification of Alizarin red S staining showed that TiO₂ treatment reduced calcium deposition area by approximately 99.8% on TCP (4.68% to 0.01%) and by 11.5% on collagen substrates (99.8% to 88.3%), while collagen-fibrin substrates showed no measurable reduction in stained area (100% vs. 100%) (Fig. 2). SEM-EDX confirmed calcium phosphate mineralization on all but TCP with TiO₂ in the form of biomimetic deposits. On TCP without TiO₂, phosphorus (33.4 Wt%) co-localized with calcium (66.4 Wt%) in ratios near the molar ratio of hydroxyapatite (5:3 Ca:P) (Fig. 3). For Col and CF, calcium phosphate biomimetic mineralization was both detected on the surface and visible within the substrate networks. Raman spectroscopy of the two highly networked CF samples also suggested calcium phosphate peaks for both. Upon analyzing osteogenic markers (RUNX2, BSP, ALP, OCN, DSPP, and DMP1), osteogenic gene expression was generally downregulated by TiO₂ on TCP,

downregulated to a lesser extent on Col, and upregulated on CF in relation to each control.

When considered together, these preliminary observations provide promising insight into the potential of biological substrates in the mitigation of titanium implant nanoparticle toxicity. The use of collagen-fibrin, in particular, aligns with clinical observations as to the benefits of blood on implant integration. To validate these findings, we intend to culture osteoblasts for a 28-day period, run additional Raman, and perform FTIR to further characterize mineral composition and clarify the substrate's preventative effects against TiO₂.

[1] Romanos, G.E.; Fischer, G.A.; Delgado-Ruiz, R. Titanium Wear of Dental Implants from Placement, under Loading and Maintenance Protocols. *Int. J. Mol. Sci.* 2021, 22, 1067. <https://doi.org/10.3390/ijms22031067>

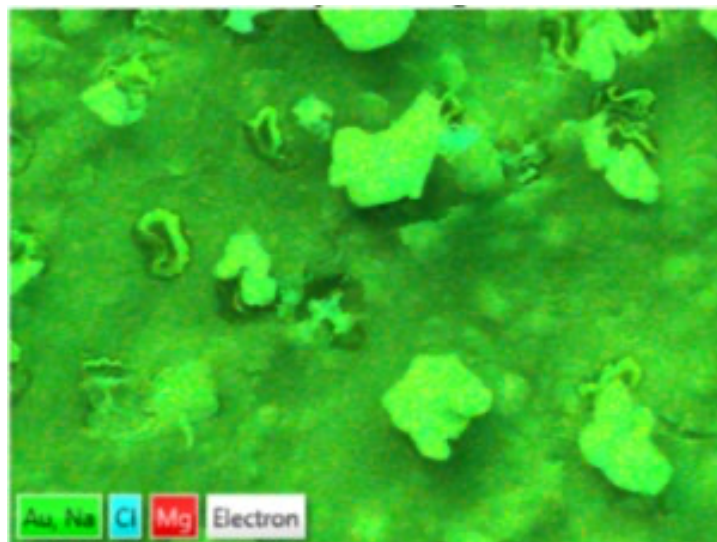
[2] Luo, H., Fu, S., Cui, M., Feng, K.-C., Wong, R., Hansen, A., Zaliznyak, T., Sprouster, D., Kleinerman, O., Singh, G., Cymerman, J., Simon, M., & Rafailovich, M. (2026). Structural analysis of a collagen-fibrin scaffold which promotes osteogenic differentiation and templated biomimetic mineralization of dental pulp stem cells. *Dental Materials*, 42(6), 1031–1042. <https://doi.org/10.1016/j.dental.2026.02.013>

Session 8: Hydrogels for Industrial Applications

Mentors:

Dezhao Meng

Aaron Sloutski

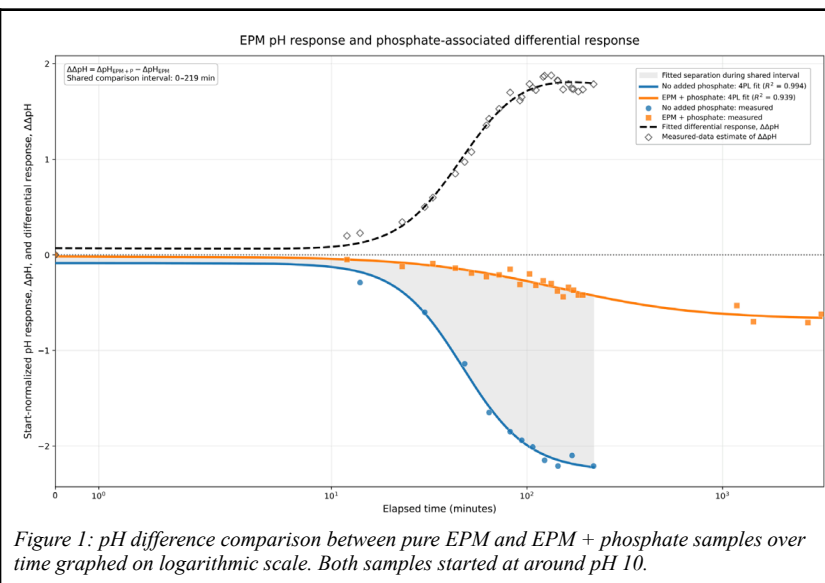


Determination of Ion Interactive Properties of Ethanol Precipitable Material from *Rhizobium tropici*

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Ethanol precipitable material (EPM), a biopolymeric material derived from the *Rhizobium tropici* CIAT 899 strain, is a promising material to enhance plant growth.¹ Previous research has pointed to EPM interactions with phosphate as a topic of interest, suggesting that EPM could improve the bioavailability of phosphate in soil.² Experiments showed that EPM preserved around 71% of total phosphorus content after water dialysis and 36% after step dialysis with NaCl, the highest retention rate of any ion present in bulk. Experiments also showed that *Arabidopsis*



thaliana treated with EPM grew similarly to those treated with extra phosphate (KH_2PO_4), and plants in both treatment groups grew significantly better than those in the control group lacking a significant phosphate source. These experiments indicated possible ion-specific interactions between phosphate and EPM. In our study, we attempted to shed light on possible mechanisms underlying these interactions.

As demonstrated in titration experiments, EPM functions as a buffer when a strong base such as NaOH is added, which is likely due to the charged functional groups on the polymer (e.g., $-\text{COOH}$). Further titration showed that EPM behaves differently as a buffer when Na_2HPO_4 is added to the solution, suggesting that EPM interacts with phosphate with its charged functional groups in ion-specific associations.

Based on the experimental results, two hypotheses were proposed about EPM-phosphate interactions: (1) EPM establishes cation-bridging with phosphate through multivalent ions attached to its charged functional groups and (2) EPM forms ether bonds with phosphate. Other theories such as the entrapment of phosphate within a polysaccharide matrix are less likely to be a primary mechanism based on previous compositional analysis post-dialysis. To assess these hypotheses, we attempted to chelate multivalent metal ions binding to the EPM with EDTA and measured the change in phosphate concentration through inductively coupled plasma optical emission spectroscopy (ICP-OES). We also performed Fourier transform infrared spectroscopy (FTIR) to identify phosphate bonding patterns.

[1] Metuge, J.A., Rugandirababisha, J., Havugimana, E., Cebert, E., Rutayisire, U.N. and Senwo, Z.N. (2025) Field Evaluations of *Rhizobium tropici* Extracellular Polymeric Substances on Soil Fertility Indices, Plant Growth, and Development. *Agricultural Sciences*, 16, 609-628. doi: 10.4236/as.2025.167039.

[2] Xinyun Xie, Trinity Stark, Huimin Zhang, Christian Lipe, Steve L. Larson, John H. Ballard, Liang Xiao, Xianchun Zhu, Fengxiang X. Han; Exopolysaccharides from *Rhizobium tropici* Enhance the Solubility of Soil Legacy Phosphorus. *ACS Earth Space Chem.* 19 February 2026; 10 (2): 592–602. <https://doi.org/10.1021/acsearthspacechem.5c00377>

Investigating the pH Buffer Properties of *Rhizobium Tropici* Exopolysaccharides

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Rhizobium tropici exopolysaccharide (RT-EPS) is a biopolymer with numerous potential applications in soil remediation, wastewater treatment, and nanoparticle synthesis. RT-EPS exhibits pH-responsive behavior, which may arise from ionizable functional groups that accept or release protons.¹ In this study, we explore the pH buffering effect of RT-EPS and evaluate the effects of temperature on its acid-base response.

The initial pH of non-dialysed RT-EPS solutions was measured as slightly basic, between pH 7 and 8. To evaluate the effect of temperature on pH stabilization, aqueous mixtures of RT-EPS and NaOH were calibrated to an initial pH of approximately 10 and incubated in water baths at 25, 40, and 60 °C. The pH was recorded every 15 minutes. At all temperatures, pH decreased toward approximately 8, with higher temperatures producing a more rapid initial decrease (Figure 1). Potentiometric titration was subsequently used to estimate the titratable charge density of RT-EPS. Two aqueous pH 3 solutions were prepared: one control and one containing 25 mg of dialysed RT-EPS. Both solutions were titrated with 0.01 M NaOH, and the additional base consumed by the RT-EPS solution relative to the control was used to estimate its blank-corrected titratable charge. RT-EPS exhibited charge densities at approximately 1.14 mEq/g at pH 7.5 and 1.46 mEq/g at pH 8.0.

A differential titration curve, dq/dpH vs. pH, was constructed to identify regions of rapid charge development. The peaks on this curve indicate possible ionizable functional groups on RT-EPS that underwent substantial deprotonation at that pH level. The apparent peak at pH 7.29 likely indicates a phosphate-containing group; the peak at around pH 8 likely indicates amine or other groups in specific chemical environments.

In conclusion, RT-EPS demonstrated measurable and effective pH-regulating behavior, with faster effects under higher temperatures and substantial titratable charge under slightly basic conditions. Further studies should compare dialyzed and non-dialyzed RT-EPS under identical temperature conditions, and utilize additional methods such as conductometric titration to improve charge density estimations and ionizable functional group identification.

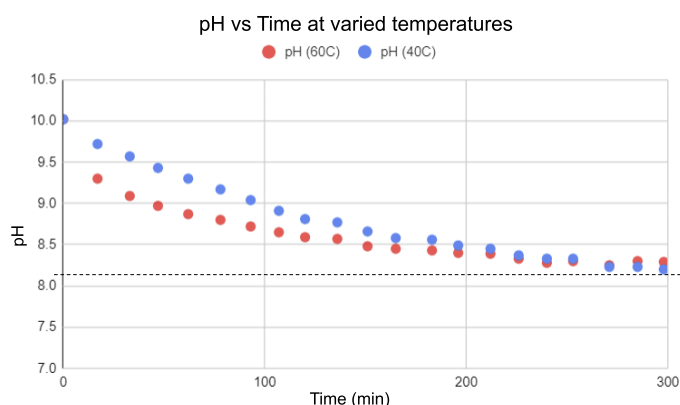


Figure 1: Effect of temperature on the pH of RT-EPS solutions over time. The dashed horizontal line indicates pH 8.1.

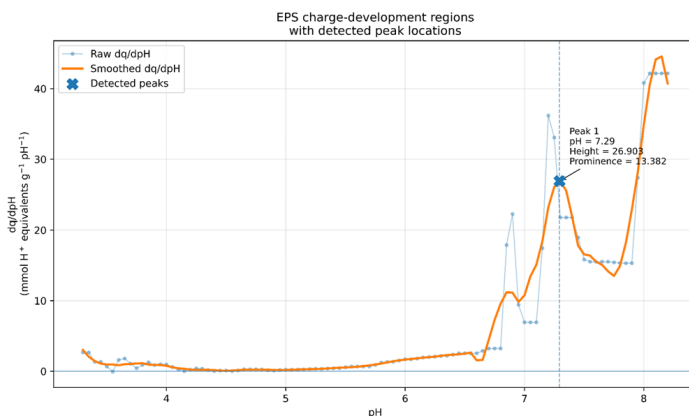


Figure 2. pH-dependent development of titratable charge in RT-EPS.

¹ Jeon, S., Haynie, T., Chung, S., & Callmann, C. E. (2024). Bioinspired, Carbohydrate-Containing Polymers Efficiently and Reversibly Sequester Heavy Metals. ACS Central Science. <https://doi.org/10.1021/acscentsci.4c01010>

Sustainable Metal Nanoparticle Synthesis via Rhizobial Exopolysaccharides

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Gold and copper nanoparticles (Au NPs and Cu NPs) have a variety of applications including drug transport, medical diagnostics, and energy harvesting due to their high biocompatibility, unique localized surface plasmon resonance properties, and electrical conductivity. However, traditional methods of synthesizing Au and Cu NPs involve harsh chemicals that generate waste and raise concerns for medical usage. Thus, the synthesis of Au and Cu NPs using polysaccharides or other organic materials have been increasingly investigated for their environmental sustainability, low cost, and biocompatibility.^{1, 2} In this study, we investigate the use of exopolysaccharides secreted by *Rhizobium tropici* (RT-EPS) for the synthesis of Au and Cu NPs. We propose that the hydroxyl and carboxyl groups on RT-EPS allow for the reduction of these metals into nanoparticles.

Nanoparticles were synthesized by mixing varying concentrations of potassium gold(III) chloride (KAuCl₄) with varying concentrations of dialyzed and non-dialyzed RT-EPS. Samples were mixed with 0.01 M NaOH until the solution was brought to pH 12. Afterwards, samples were placed in a hot bath at 80 degrees celsius until a stable color shift from a clear solution to a dark pink color and a brown color for Au NPs and Cu NPs respectively were observed.

A variety of characterization techniques were utilized to qualitatively and quantitatively analyze the formation of Au NP synthesis. Firstly, scanning electron microscopy images (SEM) with energy dispersive x-ray spectroscopy (EDS) mapping showed the synthesis process reduced gold precursors into solid gold microstructures. Additionally, x-ray absorption fine structure spectroscopy (XAFS) was conducted on precursor gold solution to form a reference baseline and on synthesized Au NP solutions. Spectroscopy results revealed a mixture of precursor salts and synthesized nanoparticles remained in the solution, while simultaneously confirming the reduction of Au³⁺ into neutral atoms in the synthesis process.

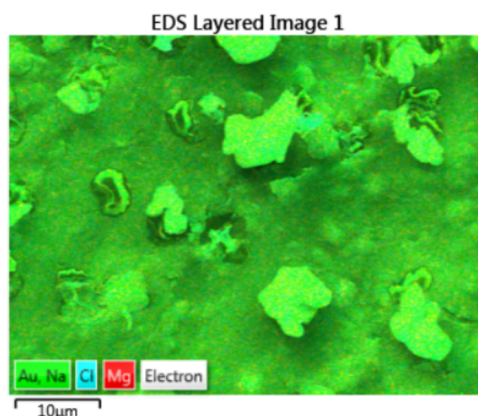


Figure 1: Scanning Electron Microscopy (SEM) images with Energy Dispersive X-Ray Spectroscopy Mapping of Gold Nanoparticles Synthesized by RT-EPS

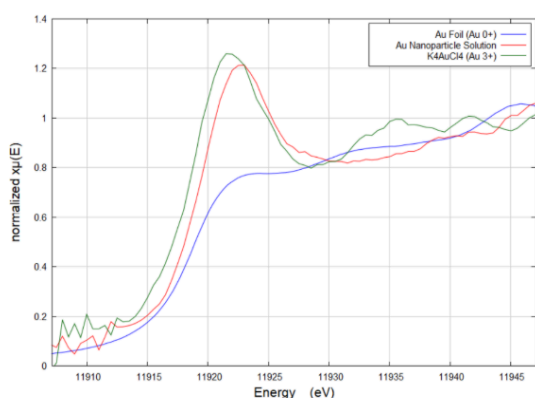


Figure 2: XAFS scanning of Au NP solution formed from RT-EPS compared to Au foil and KAuCl₄ precursor solution

In conclusion, RT-EPS show high potential to be effective facilitators of Au and Cu NP synthesis without the toxic byproducts of traditional methods. However, further work needs to be done on the characterization of Au NP formation using XAFS in order to understand the ratio of reduced to non-reduced gold. Additionally, characterization of Au NPs with SEM and XAFS will be repeated with the Cu NPs to evaluate the effectiveness of EPS in forming Cu NPs and to determine if EPS has higher affinity with one metal over another. Furthermore, we plan to apply EPS synthesized Au and Cu NPs to AEM fuel cell films to evaluate possible improvements in power density.

¹ Liu, Haoqiang, et al. "Polysaccharide-Based Gold Nanomaterials: Synthesis Mechanism, Polysaccharide Structure-Effect, and Anticancer Activity." *Carbohydrate Polymers*, vol. 321, Elsevier BV, Aug. 2023, pp. 121284–84, <https://doi.org/10.1016/j.carbpol.2023.121284>.

² Krishna, Anand G, et al. "Green Synthesis of Copper Nanoparticles: A Promising Solution for Drug Resistance and Cancer Therapy Challenges." *Journal of the Egyptian National Cancer Institute*, vol. 36, no. 1, Springer Nature, Dec. 2024, <https://doi.org/10.1186/s43046-024-00254-y>.

Controlled High-Efficiency Removal of Heavy Metals via Rhizobial Exopolysaccharides for Sustainable Water Treatment

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Conventional heavy metal water pollution treatment methods such as chemical precipitation, ion exchange, and electrochemical removal are disadvantageous when considering energy requirements, efficiency, and toxicity.¹ In this study, we explored an emergent method of heavy metal contamination remediation using *Rhizobium tropici* exopolysaccharides (RT-EPS). RT-EPS is a biopolymer that occurs naturally, and previous works have noted its ability to chelate metal ions in water.² We tested the effectiveness of RT-EPS for removing iron and lead in water and observed efficient precipitation and removal of the metal ions. RT-EPS showed promising results as a bio-based polymer for eco-friendly and efficient removal of heavy metal contaminants in water.

Initial experiments mixing Fe(III) and RT-EPS produced visible, cloudy aggregates, and these solutions were incubated overnight, vortexed, and separated using centrifugal filtration. Dissolved Fe remaining in the filtrate was quantified by inductively coupled plasma spectroscopy (ICP), and removal efficiency was calculated as the percent of Fe ions removed from the solution relative to the initial, prepared concentration. Fe removal increased with RT-EPS concentration and decreased as Fe(III) concentration increased. Next, the effects of RT-EPS processing and reaction conditions were evaluated. At varying Fe (III) concentrations, the dialyzed RT-EPS produced higher removal than non-dialyzed RT-EPS, because dialysis removed low molecular-weight polysaccharides that interfered with metal aggregation. Finally, scanning electron microscopy images with energy-dispersive X-ray spectroscopy mapping revealed the structural and elemental composition of RT-EPS.

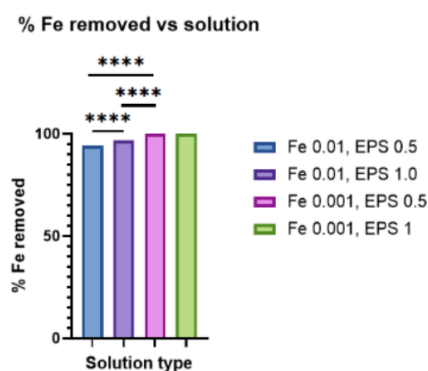


Figure 1: Percentage of Iron Removed From Samples after Addition of RT-EPS, Centrifugation, and Filtration

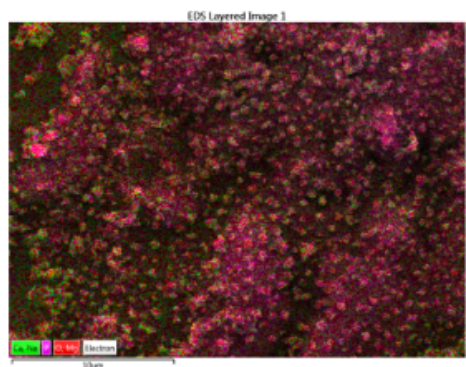


Figure 2: SEM-EDS images of Pure RT-EPS

Overall, the results demonstrate that RT-EPS can promote high-efficiency removal of dissolved metal ions through metal association, aggregation, and filtration, with performance strongly dependent on RT-EPS and metal concentrations, reaction conditions, and metal identity. Future studies will explore RT-EPS's ability to chelate other heavy metals, such as cadmium, chromium, lead, and tungsten. Chelation when different types of heavy metals are simultaneously present in a solution will also be tested. Additionally, X-ray absorption fine structure (XAFS) spectroscopy scans can clarify the moieties that interact with heavy metal ions and allow us to understand the mechanisms behind RT-EPS and its chelation capabilities. In conclusion,

RT-EPS shows great potential as a non-toxic, biodegradable, and environmentally friendly solution for treating heavy metal-contaminated water.

¹Zamora-Ledezma, C., Negrete-Bolagay, D., Figueroa, F., Zamora-Ledezma, E., Ni, M., Alexis, F., & Guerrero, V. H. (2021). Heavy metal water pollution: A fresh look about hazards, novel and conventional remediation methods. *Environmental Technology & Innovation*, 22, 101504. <https://doi.org/10.1016/j.eti.2021.101504>

²Moretto, C., Castellane, T. C. L., Leonel, T. F., Campanharo, J. C., & de Macedo Lemos, E. G. (2022). Bioremediation of heavy metal-polluted environments by non-living cells from rhizobial isolates. *Environmental science and pollution research international*, 29(31), 46953–46967. <https://doi.org/10.1007/s11356-022-18844-5>

Engineering a Stable Emulsion Formulation for a Fragrance & Mineral-Based Insect Repellent

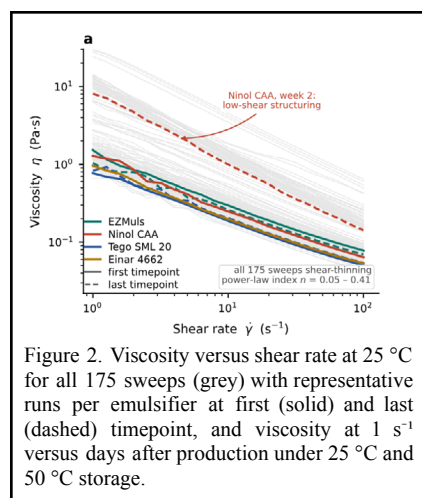
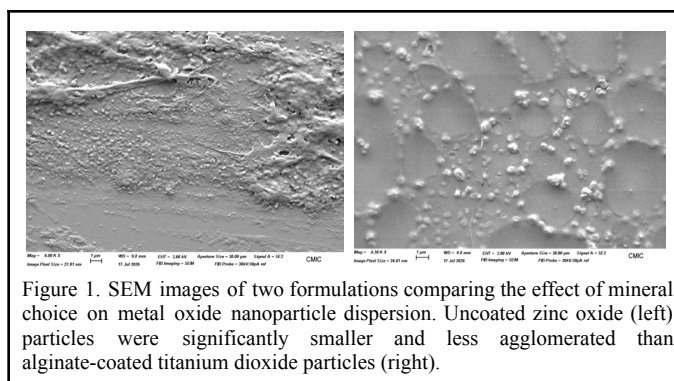
Audrey Tan¹, Luke Zhang², Hunter Maguire³, Cyrus Sedgh⁴, Julianna Vrabec⁵, Sophie Xu⁴, Dezhao Meng⁴, Bicheng Wu⁴, Aaron Sloutski⁴, Miriam Rafailovich⁴

¹James Madison High School, VA, 22180; ²Southfield Christian High School, MI, 480342; ³Columbia College, Columbia University, NY, 10027; ⁴Department of Materials Science and Chemical Engineering, Stony Brook University, NY 11794; ⁵Davidson School of Chemical Engineering, Purdue University, IN, 47906

Mosquitoes orient themselves towards human hosts through multiple sensory cues, including body odor, CO₂, moisture, and heat¹. DEET, N-diethyl-m-toluamide, is the most common active ingredient in topical mosquito repellents, but plant-derived alternatives like citronella oil and eucalyptus oil are gaining popularity due to environmental concerns.² Both repellent groups work by interfering with mosquitoes' odor detection; however, essential oils have a low molecular weight, are highly volatile, and oxidize quickly, making them unstable in repellent formulations. Several encapsulation and emulsification techniques have been thus developed to overcome these challenges.³

This study aimed to develop an effective emulsion formulation to stabilize both metal oxides and essential oils within a polymer-based colloidal system by evaluating the effects of different minerals, antioxidants, chelating agents, and emulsifiers on formulation stability. After identifying the best ingredient of each category, further testing was done to optimize the concentrations of each ingredient.

Formulations were stored at different temperature levels, following the standard accelerated testing conditions set by the International Federation of the Societies of Cosmetic Chemists (IFSCC)⁴, and characterized at set time intervals through rheology and qualitative visual observations to determine how dispersion uniformity, viscosity, and oxidation changed over time. In addition, optical microscopy, SEM, and EDS



analyzed elemental composition and dispersion of the metal nanoparticles. Rheological measurements showed that all 175 sweeps were shear-thinning, with power-law indices between 0.05 and 0.41. Among the emulsifiers tested, glyceryl oleate citrate changed the least over two weeks at 25 °C (1.53 to 1.07 Pa·s at 1 s⁻¹), while dimethyl lauramide/myristamide with alginate-coated titanium dioxide, by week 2, rose ninefold in low-shear viscosity with little change at high shear; a formulation paired with zinc oxide instead remained comparable. Formulations with butylated hydroxytoluene and ethylenediaminetetraacetic acid showed the least oxidation and discoloration under accelerated storage, suggesting these were the most stable chelating agent and antioxidant, respectively. Both uncoated zinc oxide and alginate-coated titanium dioxide were more stable than dimethicone-coated titanium dioxide, though sedimentation was more prevalent in the zinc oxide. No mosquito bioassays were performed;

additional testing is needed to confirm the particles' ability to irritate mosquito proboscises. These findings provide a framework for engineering a stable, DEET-free repellent base capable of suspending essential oils and metal nanoparticles, though commercialization would require long-term stability testing.

¹McMeniman, C., Corfas, R., Matthews, B., Ritchie, S., & Vossell, L. (2014). Multimodal integration of carbon dioxide and other sensory cues drives mosquito attraction to humans. *Cell*, 156(5), 1060-1071. <https://doi.org/10.1016/j.cell.2013.12.044>

²Diaz, J. H. (2016). Chemical and plant-based insect repellents: Efficacy, safety, and toxicity. *Wilderness & Environmental Medicine*, 27(1), 153-163. <https://doi.org/10.1016/j.wem.2015.11.007>

³Farina, P., & Conti, B. (2024). Liabilities of essential oils as insect repellents. *Current Opinion in Environmental Science & Health*, 40, 100564. <https://doi.org/10.1016/j.coesh.2024.100564>

⁴Kirkbride, L., Humphries, L., Kozielska, P., & Curtis, H. (2021). Designing a Suitable Stability Protocol in the Face of a Changing Retail Landscape. *Cosmetics*, 8(3), 64. <https://doi.org/10.3390/cosmetics8030064>

Session 9: Biomedical Hydrogels

Mentors:
Robert Wong
Aaron Sloutski

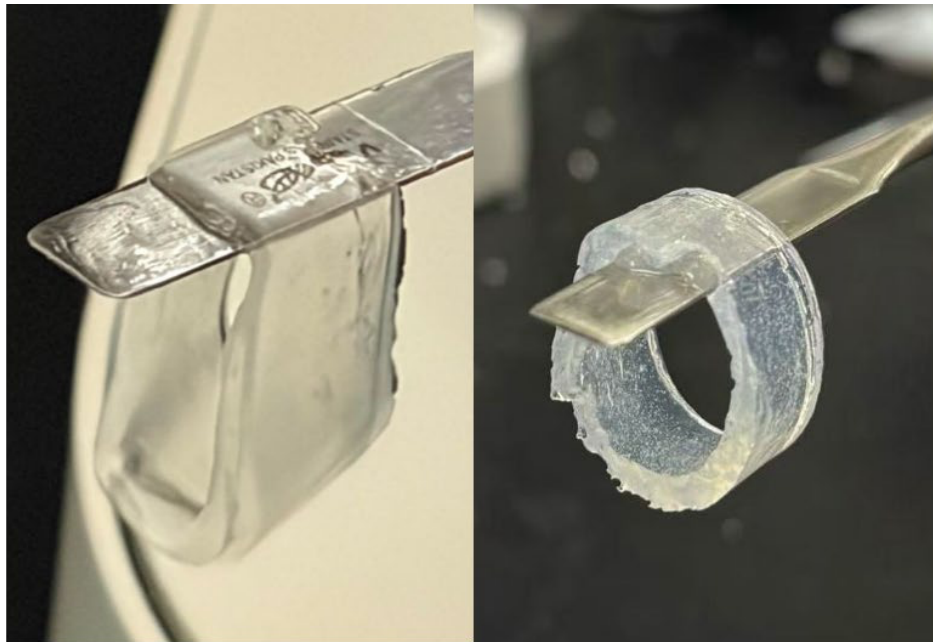


Figure 2: Comparison between UV-cured gel rigidity (left) and APS/TEMED crosslinked gel rigidity (right) when picked up with a spatula

Engineering Poly(vinyl alcohol)-based Vascular Graft and Aneurysm Model Systems

Ian Jake Kim¹, Megan Li¹, Nicole Lin¹, Grace Zeng¹, Adithya Santhosh², Issac Varghese², Jian Chen², Jashmin Gill², Aaron Sloutski³, Robert Wong³, Miriam Rafailovich³

¹West High School, Salt Lake City, UT, ¹Zhengzhou Middle School, Zhengzhou, Henan, CHN, ¹BASIS Independent Fremont (Upper School), Fremont, CA, ¹International School, Bellevue, WA, ²Stony Brook University, Stony Brook, NY, ³Department of Materials Science and Chemical Engineering, Stony Brook University, Stony Brook, NY

Brain aneurysms are localized dilations of intracranial arteries that pose the risk of rupturing and causing hemorrhagic stroke. Current models of brain aneurysms have highly simplified vascular morphologies compared with the more complex anatomies found in human aneurysms. Modeling of complex brain aneurysm morphologies both in vitro and in vivo would improve treatment in patient-specific aneurysms.¹

Previous modeling methods relied on an acrylonitrile butadiene styrene-based negative mold, which is then turned into a positive mold made of beeswax. The structure is coated with PVA, and the wax is melted out. However, this method is time-consuming and imprecise for complex aneurysm models.

Poly(vinyl alcohol) (PVA) is a promising biomaterial for the manufacture of artificial vascular grafts due to its biocompatibility, moldability, and tunable mechanical properties.² Existing aneurysm models involve drawbacks such as low resolution accuracy, fabrication time, reproducibility for in vitro or preclinical testing. This study aims to engineer and synthesize a suitable PVA-based solution that rapidly crosslinks both under the 3D-biprinter's UV light and chemically within molds.

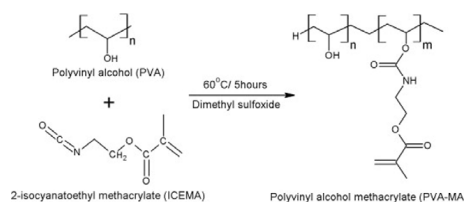


Figure 1: Synthesis of PVAMA

PVA was reacted with isocyanatoethyl methacrylate to synthesize PVAMA (Fig. 1), confirmed using NMR and IR spectroscopy. The polymers were dissolved in water to form aqueous PVAMA solutions at 20 wt%.

Compared with pure PVA, PVAMA gels crosslinked with ultraviolet (UV) light exhibited improved shape retention and crosslinking properties due to their grafted methacrylate double bonds. Pluronic F127-dimethacrylamide (F127DMA) was added to increase the storage modulus of the crosslinked gels and the viscosity of the PVAMA aqueous solutions to enable precise 3D-printing. Under 365-nm irradiation, the formulation containing 3 wt% F127DMA and 2 wt% Irgacure 2959 underwent gelation within 30 seconds under the tested conditions.

During chemical crosslinking, PVAMA was reacted with ammonium persulfate (APS) and tetramethylethylenediamine (TEMED) in silicone molds. The gels crosslinked rapidly (<30 sec) and displayed superior mechanical properties compared to the UV-cured ones (Fig. 2).

The PVAMA crosslinked rapidly (<2 min) via both APS/TEMED and UV light (365 nm), a marked improvement over traditional crosslinking methods, such as drying and freeze/thaw methods (>2 days). Tubular gel structures were successfully fabricated using mold-based crosslinking; however, the biomaterial ink's low viscosity limited multilayer printability due to insufficient filament stability before UV crosslinking. Future work includes optimizing printing parameters of the developed inks, validating mechanical performance with Young's modulus and swell tests, and evaluating cytocompatibility and hemocompatibility followed by in vivo studies.

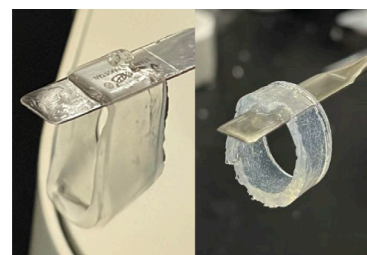


Figure 2: Comparison between UV-cured gel rigidity (left) and APS/TEMED crosslinked gel rigidity (right) when picked up with a spatula

[1] Gopal, M., Gopal, M., Wong, R., Sloutski, A., Dashti, R., Rafailovich, M., & Sadasivan, C. (2023). Abstract Number-127: Poly (vinyl alcohol) grafts of brain aneurysms with patient-specific morphologies. *Stroke: Vascular and Interventional Neurology*, 3, e12555.

[2] Liu, Y., Gao, Z., Yu, X., Lin, W., Lian, H., & Meng, Z. (2024). Recent advances in the fabrication and performance optimization of polyvinyl alcohol based vascular grafts. *Macromolecular Bioscience*, 24(9), 2400093.

Fundamental Characterization Studies of Injectable Pluronic-Based Polymer Coils for Embolization of Brain Aneurysms

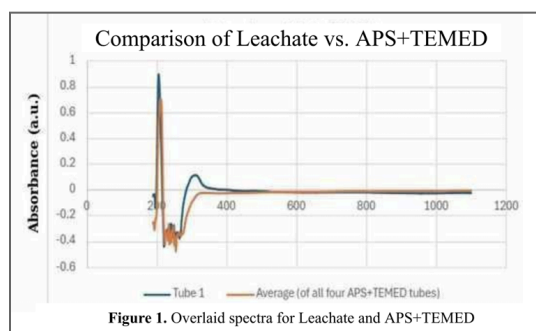
Audrey Chin¹, Advik Kishore², Bella Lin³, Lelin Tsai⁴, Camilie Wang⁵, Amber Zhang⁶, Justin Wightman, Kaniz Fatema, Robert Wong, Chander Sadasivan, Miriam Rafailovich

¹Palos Verdes Peninsula High School, Rolling Hills Estates, California, ²Flower Mound High School, Flower Mound, Texas, ³Island Trees High School, Levittown, New York, ⁴Greenwich High School, Greenwich, Connecticut, ⁵Keystone Academy, Beijing, China, ⁶The Bishop's School, San Diego, California

Brain aneurysms are characterized by dilations in cranial blood vessels that can pose a high risk of hemodynamic rupture, leading to potentially lethal effects. Currently accepted treatment methods involve the insertion of agents in or around the aneurysm to slow or block blood flow¹. We present PluCoil, a biocompatible, injectable, two-part pluronic coil system for the treatment of brain aneurysms. PluCoil is comprised of a preliminary F127DMA physical gel followed by the F88DMA coil, which is crosslinked via an APS/TEMED redox system. As a novel formulation, a thorough understanding of the fundamental properties of PluCoil components is crucial. In this study, we have characterized the various constituents of this system through UV-visible spectroscopy, cytotoxicity assays, and coiling efficiency analysis.

APS and TEMED are known to be cytotoxic; therefore, analysis was required to determine the amount and identity of the components that leach out of the crosslinked F88DMA. Initially, UV-vis was performed on each of the individual components present in the PluCoil system to generate spectra and detection limits: F127DMA, F88DMA, APS, TEMED, and Iohexol. These were then compared to the spectra of the leachate.

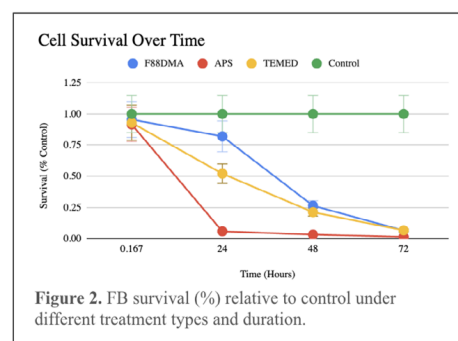
Since the leachate spectra displayed a prominent dip before the absorbance peak that wasn't observed in any of the component spectra, an APS and TEMED solution was created to generate another spectrum. Interestingly enough, this solution displayed a similar dip before peaking, lining up with the leachate. However, the absorbance peaks of APS and TEMED essentially overlapped, making it impossible to differentiate between the two. Following this experiment, analysis of leaching over various times (10min, 1h, 2h, 1d, 2d) was



performed to determine whether leaching occurred in a short burst or a prolonged period. Spectra showed that leaching plateaus some time between 2h and 1d.

We also performed a cell proliferation assay on fibroblasts (FBs) treated with relevant concentrations of F88DMA, APS, or TEMED in DMEM+ for varying durations (n=4) in order to quantify cytotoxicity. Overall, we observed similar cell morphology and density across samples for short treatment times. F88DMA and TEMED demonstrated moderately reduced cell growth for the duration of the experiment, their key difference being abnormal morphology for TEMED. APS displayed a sharp drop in survival by 24h. Because the leaching experiment revealed the 2h-1d window where the majority of crosslinker leaching occurs, low cytotoxicity observed within a short exposure window is very important for biocompatibility.

Coiling efficiency, or packing density, is another important factor for the efficacy of an aneurysm treatment, as higher density reduces the risk of the aneurysm reopening. We printed an ABS aneurysm model and measured the water volume of the sac, then injected crosslinked F88DMA gel into the model while submerged in a water bath. Our data revealed an average coiling efficiency of 83%, which is roughly fourfold higher than commonly used platinum coils². These effects, likely due to the flexibility of PluCoil as a hydrogel, support PluCoil as a promising alternative to the current industry standard and a novel asset to brain aneurysm treatment.



[1] Deshmukh, A. S.; Priola, S. M.; Katsanos, A. H.; Scalia, G.; Costa Alves, A.; Srivastava, A.; Hawkes, C. The Management of Intracranial Aneurysms: Current Trends and Future Directions. *Neurol. Int.* 2024, 16 (1), 74–94. <https://doi.org/10.3390/neurolint16010005>

[2] Hassankhani, A.; Ghozy, S.; Bilgin, C.; Kadirvel, R.; Kallmes, D. F. Packing Density and the Angiographic Results of Coil Embolization of Intracranial Aneurysms: A Systematic Review and Meta-Analysis. *Interv. Neuroradiol.* 2024, 30 (3), 721–731. <https://doi.org/10.1177/15910199231155288>.

Integrated Mechanical Characterization and Optimization of PluCoil Hydrogels for Endovascular Treatment of Intracranial Aneurysms

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Intracranial aneurysms are localized dilations of cerebral blood vessels that may rupture and cause life-threatening hemorrhage. Endovascular embolization aims to isolate the aneurysm from blood flow while preserving the parent vessel, but conventional coil-based treatments may be limited by several factors. PluCoil is a two-component, injectable pluronic hydrogel system combining a reverse thermoresponsive F127DMA physical gel with a crosslinked F88DMA component that provides coil-like mechanical stability. Due to its novelty, characterization and optimization of PluCoil's mechanical properties are necessary to improve performance. In this study, a series of experiments exploring viscoelasticity, swelling, and injection pressure were integrated to evaluate the various components of PluCoil and identify areas requiring further optimization.

Rheological temperature sweep (2°C–40°C) was conducted under constant stress or rate for 13%, 15%, 17%, and 20% F127DMA. Analysis of shear viscosity against temperature revealed a lack of sol-gel transition for 13% F127DMA and an inverse relationship between concentration and transition temperature for all other concentrations, consistent with previous literature¹. There is also an increase in post-gelation shear viscosity of F127DMA as concentration increases. These findings are critical to balancing sol-gel transition and injectability for F127DMA. Besides, amplitude sweep rheology at 37°C showed that increasing F127DMA concentration increased G' , G'' , and flow-point stress, indicating a stronger gel network with greater resistance to stress-induced flow.

A major concern during PluCoil injection is the high injection pressure risk from premature gel crosslinking. Manual injection and automated injection experiments were conducted to measure pressure change over the course of an injection. For manual injection, a pressure transducer was connected to a syringe and catheter and the results were recorded through an arduino, with data collected for three types of catheters with varying diameter size. Automated injection was controlled via an Instron machine, tested for two catheter sizes. Analysis of PSI data over time showed a consistent increase in pressure as injection progressed, and peak and average pressure increased as catheter diameter decreased. These findings contribute to evaluating and developing injection and application methods during treatment.

Another concern regarding PluCoil was its tendency to swell after injection. To improve dimensional stability, 1% or 2% MB partially replaced F88DMA at a constant total polymer concentration, followed by a parallel tetramer study using the same formulations. Both additives caused early swelling, which was greater with tetramer, but improved long-term mass retention. MB groups showed a sharp late-stage volume decrease, whereas tetramer-containing groups retained volume better than the control. Overall, tetramer provided stronger long-term mass and volume retention than MB despite greater initial swelling.

Comparison of Average Masses of Control and Experimental Groups

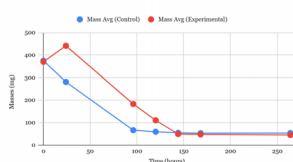


Figure 2. Plot of average masses of control and experimental groups over time.

To address confusion about why the mass of the F88DMA gel balls increased and then decreased in saline solution, another experiment was conducted to determine the root cause of the mass changes. Eight F88DMA gel balls were synthesized and split into two groups, each with four balls. The control group was left to dry immediately. The experimental group, on the other hand, was first soaked in saline solution for 1d. Each group was weighed 0h, 24h, 96h, 120h, 144h, 168h, and 264h from synthesis. Analysis then revealed a plateauing of masses by the 144th hour, with the experimental group having consistently lower masses than the control, suggesting some of the polymer was leaching out into the saline solution.

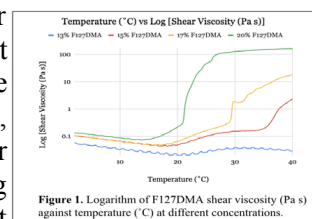


Figure 1. Logarithm of F127DMA shear viscosity (Pa s) against temperature (°C) at different concentrations.

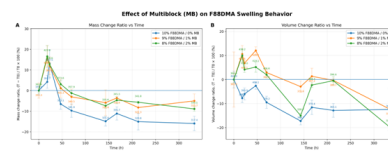


Figure 3. Effect of Multiblock (MB) on F88DMA Swelling Behavior.

Injectable Crosslinking Calcium Hydroxide/Salicylic Acid (CASA) Hydrogel for Antibacterial Delivery in Endodontic Therapy

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Endodontic infections caused by bacteria such as *Enterococcus faecalis* (*E. faecalis*) pose a significant challenge in root canal treatment, often causing tooth pain, reinfection, and degradation of surrounding bone tissue. Calcium hydroxide, applied intracanal, currently serves as the standard antimicrobial for endodontic infections. However, it lacks efficacy against *E. faecalis*, its alkalinity results in structural damage to dentin with long-term use,¹ and it can result in severe necrosis and nerve damage upon apical extrusion.² A novel salicylic acid and calcium hydroxide drug (CASA) enhances calcium hydroxide's antimicrobial properties and limits cytotoxicity.³ Encapsulating CASA in the pluronic polymer F127-DMA and adding the photoinitiator Lithium phenyl-2,4,6-trimethylbenzoyl phosphinate (LAP) produces a thermoreversible, UV-crosslinking hydrogel optimal for compound delivery and retrieval. With its injectability, stability, and hydrophilicity, it offers a stronger alternative to current root canal treatments. This study aims to determine the optimal concentration of CASA within the hydrogel by evaluating the efficacy of various concentrations against *E. faecalis* and their injectability.

CASA powder was prepared by combining calcium hydroxide and salicylic acid in a weight ratio of 1:6. The powders were combined with deionized water at 1g/mL ratio to obtain a paste-like consistency. The mixture was then vortexed for 30 seconds to ensure homogeneity. To form the polymer-CASA composite at the six final composite concentrations of 0%, 5%, 10%, 15%, 20%, and 25% CASA, six aqueous solutions of F127-DMA were prepared with total composite-to-water ratios of 1:4, including the water previously added to the CASA paste. The 20% F127-DMA aqueous solution was refrigerated overnight at 4°C to ensure full dissolution. LAP was added at a concentration of 0.1% and kept refrigerated. 250 µl of each solution was pipetted into a well of a 24-well plate and cured with UV light for 1 minute. Disks of 15.2 mm in diameter were prepared for each concentration. To test the antimicrobial efficacy of the CASA, disks of each concentration were placed in triplicate on inoculated agar Petri dishes using sterilized tweezers and gently pressed to ensure full contact. The plates were incubated at 30°C for 48 hours. After incubation, the antibacterial efficacy was determined by evaluating the diameter of the zone of inhibition for each disk on the agar plates. To test the antibacterial activity of the CASA disks upon direct contact with *E. Faecalis*, the disks that had been placed for the zone of inhibition test were removed and placed onto uninoculated agar plates, one for each concentration in triplicate, and gently pressed to ensure full contact. After one minute, the disks were removed. Plates were then incubated at 30°C for 24 hours.

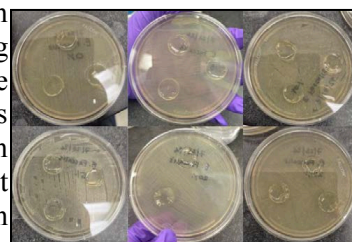


Figure 1. CASA disks at increasing concentrations after 48 hours of incubation.

For the initial zone of inhibition experiment, none of the concentrations of crosslinked CASA disks exhibited clear zones of inhibition for the *E. Faecalis*.

After incubation, all of the areas where the disks had been placed exhibited bacterial growth, indicating that the CASA disks did not eliminate the *E. Faecalis* on contact. These failures could be attributed to the slow diffusion of the CASA compound. The crosslinking process results in sustained drug release that prevents rapid activation of antimicrobial properties due to physical enmeshment of the compound within the polymer chains. While this diffusion is optimal for long-term treatment and healing, it can inhibit rapid disinfection as expected in the contact test. The failures could also potentially be a result of biofilm formation. The CASA disk could have killed the initial layer of bacteria, creating a protective shield that enabled other bacteria to grow on top of neutralized ones.

Future work would include characterizing F127-DMA's thermal transitions using differential scanning calorimetry to determine the storage and usage temperatures of the CASA-polymer compound. Rheology testing would also assess the compound's injectability for endodontic use.

¹Fariborz Moazami, Safoora Sahebi, Jamshidi, D., & Alavi, A. (2014). The Long-Term Effect of Calcium Hydroxide, Calcium-Enriched Mixture Cement and Mineral Trioxide Aggregate on Dentin Strength. *Iranian Endodontic Journal*, 9(3), 185.

²Koosha, F., Cymerman, J., Manders, T., Simon, M., Walker, S., & Rafailovich, M. (2022). Non-cytotoxic root canal dressing with improved antimicrobial efficacy. *Journal of Endodontics*, 49(2), 205–211. <https://doi.org/10.1016/j.joen.2022.11.007>

³Mohammadi, Z., Shalavi, S., & Yazdizadeh, M. (2012). Antimicrobial activity of calcium hydroxide in endodontics: a review. *Chonnam Medical Journal*, 48(3), 133. <https://doi.org/10.4068/cmj.2012.48.3.133>

In-Situ Crosslinking Calcium Hydroxide/Salicylic Acid (CASA) Drug Delivery System for Rapid Wound Disinfection in Austere Environments

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Bacillus atrophaeus (*B. atrophaeus*) is a widespread soil bacteria that acts as an opportunistic invader in deep wounds and severe burns. It is capable of causing bacteremia, sepsis, and localized infections.^{1, 2} While previous studies have demonstrated that a calcium hydroxide and salicylic acid compound (CASA) exhibits antimicrobial properties against certain bacteria,³ its particular effect against *B. atrophaeus* remains unknown. Adding the pluronic polymer F127-DMA and a photoinitiator produces a thermoreversible, UV-crosslinking hydrogel optimal for antibiotic delivery and retrieval. With its injectability, retrievability, and hydrophilicity, CASA/F127-DMA may provide an optimal antibiotic dressing for use in situations such as natural disasters and military conflict. Such austere environments leave populations susceptible to unique risk from otherwise innocuous ailments like cuts and scrapes. This study aims to characterize the effect of CASA/F127-DMA on *B. atrophaeus*, as well as to determine the optimal concentration to maximize efficacy against *B. atrophaeus*.

CASA powder was prepared by combining calcium hydroxide and salicylic acid in a weight ratio of 1:6. The powders were combined with deionized water at 1g/mL ratio to obtain a paste-like consistency. To form the polymer-CASA composite at the six final composite concentrations of 0%, 5%, 10%, 15%, 20%, and 25% CASA, six aqueous solutions of F127-DMA were prepared, with total composite-to-water ratios of 1:4, including the water previously added to the CASA paste. The 20% F127-DMA aqueous solution was refrigerated overnight at 4°C to ensure full dissolution. LAP was added at a concentration of 0.1%. 250 µl of each solution were pipetted into a 24-well plate, and cured with UV light for 1 minute. To test the antimicrobial efficacy of the CASA, CASA disks of each concentration were placed in triplicate on the inoculated plates and gently pressed to ensure full contact. The plates were incubated at 30 °C for 48 h. After incubating, the antibacterial efficacy of the CASA concentrations was determined by evaluating the diameter of the zone of inhibition of each disk. The 0% and 5% CASA disks exhibited no zones of inhibition (Fig. 1). The 10% CASA disks exhibited zones with slight discoloration, indicating partial inhibition where the CASA had diffused but had not fully eliminated the *B. atrophaeus*. The 15%, 20%, and 25% CASA disks exhibited mean zones of inhibition of 4.02 mm, 8.89 mm, and 9.67 mm, respectively.

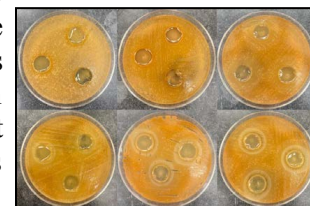


Figure 1. Zones of inhibition of CASA disks at increasing concentrations

To test the antibacterial activity of the CASA disks upon contact with *B. atrophaeus*, the disks that had been plated for the zone of inhibition test were moved onto uninoculated agar plates and gently pressed to ensure full contact. After one minute, the disks were removed. The plates were then inverted and incubated at 30°C for 24 hours. After incubating, the areas where the disks had been placed exhibited significant bacterial growth, indicating that the CASA disks did not eliminate the *B. atrophaeus* upon contact. This could be attributed to the slow diffusion of the CASA compound, as the crosslinking process results in sustained drug release that prevents rapid activation of antimicrobial properties due to enmeshment of the compound within the polymer chains. While this diffusion is optimal for long-term treatment and healing, it can inhibit rapid disinfection as expected in the contact test. The failure could also potentially be a result of biofilm formation. The CASA disk may have killed the initial layer of bacteria, creating a protective shield that enabled other bacteria to grow atop the neutralized ones.

Future work will include testing the liquidity of the F127-DMA/CASA solutions in simulated skin tissue and examining its crosslinking properties while atop simulated skin. Future studies would also include characterization of F127-DMA's thermal transitions using differential scanning calorimetry, to determine the storage and usage temperatures for the CASA-polymer compound. Rheology testing would also assess the compound's injectability for endodontic use.

¹Saleh, F., Kheirandish, F., Azizi, H., & Azizi, M. (2014). Molecular diagnosis and characterization of bacillus atrophaeus isolated from burn wound in Iran. *Research in Molecular Medicine*, 2(2), 40–44. <https://doi.org/10.18869/acadpub.rmm.2.2.40>

²Chassagne, F. (2022). Medicinal Plants as Anti-infectives. Academic Press.

³Koosha, F., Cymerman, J., Manders, T., Simon, M., Walker, S., & Rafailovich, M. (2023). Non-cytotoxic root canal dressing with improved antimicrobial efficacy. *Journal of Endodontics*, 49(2), 205–211. <https://doi.org/10.1016/j.joen.2022.11.007>

Chlorine Concentration in Commercial Hypochlorous Acid Compound Correlates to Efficacy as a Bacterial Sporicide

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Disinfecting operating rooms is crucial to maintaining the health of doctors and patients. Bacterial spores present a unique challenge to disinfect due to their protective coat and ability to withstand extreme conditions, including high temperature or radiation.¹ Therefore, finding an effective cleaning method and material is integral for numerous healthcare applications. This study examines the efficacy of commercial hypochlorous acid as a bacterial sporicide by evaluating chlorine concentration, pH, and conducting broth microdilution.

The chlorine concentrations and pH levels of six separate containers of hypochlorous acid were tested. Each container of hypochlorous acid ranged in age and time elapsed from opening. The chlorine content of the acid compound was tested using iodometric titration. After adding 2 mL of the hypochlorous acid disinfectant to 50 mL of demineralized water, packets of potassium iodide and dissolved oxygen were added to the solution. To ensure complete dissolution of all the particles, the flasks were placed into a rotary incubator for 24 hours. Using a digital titrator, small amounts of sodium thiosulfate solution were added until the mixture shifted from bright to pale yellow. Once this occurred, 7 drops of starch indicator solution were added so that the mixture turned a dark purple to black. Digital titration continued, with continuous swirling, until the solution became transparent. The value displayed on the titrator represented the mg/L of chlorine in 5 mL of acid, so the number was multiplied by 2.5 in order to find the total chlorine concentration in the acid, in parts per million (ppm). The pH of each container was found using standard pH test strips.

The chlorine concentration of the bottles was 275, 307.5, 367.5, 395, 442.5, and 480 ppm, respectively, with a negative correlation between the acid's age and its chlorine content. The pH level of the containers demonstrated weak acidity, maintaining approximate pH levels from 4 to 5.

A broth microdilution was conducted to test the efficacy of the hypochlorous acid against *Bacillus atrophaeus*. The testing was conducted using the 395 ppm bottle. Eight sterile tubes were filled with 10 mLs of Brain Heart Infusion (BHI) medium and labeled from 0 through 7. 100 μ L of the bacterial suspension (10^6 per mL concentration in phosphate-buffered saline) was combined with 900 μ L of hypochlorous acid in a microvial. At 1-minute increments from 0-7 minutes, 100 μ L of the solution was micropipetted into the corresponding tubes containing BHI. After all eight tubes were filled with the solution at their respective time intervals, the samples were placed in a rotary incubator to shake at 160 RPM at 30°C.

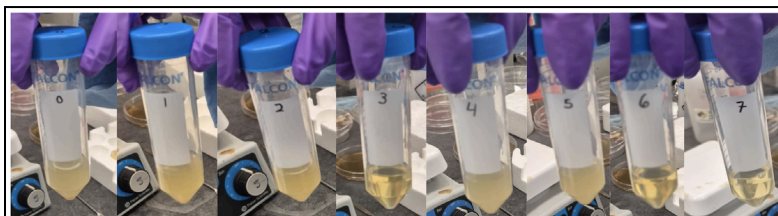


Fig. 1. Turbidity of *Bacillus atrophaeus* Broth after Incubation with Increasing Exposure Time to Hypochlorous Acid Disinfectant

The turbidity of the broth following incubation served as the evaluation metric for the acid's success. Cloudiness indicated the spores survived and experienced vegetative outgrowth, while transparency demonstrated that the disinfectant prevented bacterial growth. After 24 hours, 3, 6, and 7 minutes of exposure time showed no clouding, while the rest of the tubes did, demonstrating that after 6 minutes, the 395 ppm disinfectant successfully eradicated the bacterial spores (Fig. 1). Tube 3's absence of clouding could be a result of insufficient vortexing before pipetting the sample into the broth. The bacteria may have settled at the bottom of the microvial, preventing enough bacteria from arriving in, and therefore proliferating in the BHI following exposure to the hypochlorous acid.

Future work includes retesting the hypochlorous acid with a new titration kit to validate the current chlorine content measurements, and evaluating the hypochlorous acid's efficacy against other bacterial spores.

¹ Setlow P. Spores of *Bacillus Subtilis*: Their Resistance to and Killing by Radiation, Heat and Chemicals. *Journal of Applied Microbiology*. 2006;101(3):514-525. doi:10.1111/j.1365-2672.2005.02736.x

Optimization of F127DMA Hydrogel Crosslinking and Bioprinting Parameters for Aneurysm Model Fabrication

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Endovascular treatment planning for aneurysms currently relies extensively on animal models, particularly rabbits, for procedural training and device testing^[1]. Three-dimensional bioprinting of hydrogel-based aneurysm models offers a patient-specific alternative for endovascular device testing and procedural training, with the long-term goal of integration into rabbit vasculature for more physiologically relevant studies. Pluronic F127 dimethacrylate (F127DMA) is a biocompatible, thermosensitive hydrogel suited to this application^[2], liquefying at reduced temperatures and gelling near room temperature to facilitate extrusion while retaining printed geometry.

Fabrication was performed using a CELLINK BIO XTM bioprinter equipped with a temperature-controlled printhead. Three crosslinking systems were evaluated: N,N,N',N'-tetramethylethylenediamine (TEMED) with ammonium persulfate (APS), 2-hydroxy-4'-(2-hydroxyethoxy)-2-methylpropiophenone (Irgacure 2959) dissolved in N-Methyl-2-pyrrolidone (NMP), and lithium phenyl-2,4,6-trimethylbenzoylphosphine (LAP). Optimal values for all variables are summarized in Table 1.

Table 1: Variables		
Parameter	Optimal Value	Effect of Deviation
Crosslinker	3% (w/v) Irgacure in NMP	TEMED/APS: crosslinks pre-extrusion, cytotoxic. LAP: effective but \$208/100 mg ^[3]
F127DMA	25% (w/v)	Higher: premature gelation in syringe; lower: inadequate gelation
Extrusion Pressure	70-100 kPa	Higher: uncontrolled deposition; lower: insufficient extrusion
Nozzle Temperature	8–13°C 30–37°C	Lower range for Irgacure 2959 to prevent spoiling Higher range for no crosslinker to approximate physiological conditions
Pre-flow Time	300-400 ms	Higher: premature flow out of syringe; lower: print failure at beginning
Print Speed	10-20 mm/s	Faster: discontinuities/breaking; slower: excessive line thickness
UV wavelength & exposure	365 nm, 3 mins	405 nm is less efficient, and lower time results in incomplete crosslinking
Nozzle Gauge	22 gauge	Premature gelation in 27 gauge

The present approach employs a sacrificial scaffold strategy, in which Pluronic F127 dissolved in Dulbecco's Phosphate-Buffered Saline (F127/DPBS) is printed as a structural template for subsequent F127DMA infilling. Because F127/DPBS does not crosslink, print errors can be corrected without material loss. Printing without a crosslinking agent improved extrusion consistency, as Irgacure 2959 was observed to partially crosslink within the nozzle despite full light shielding.

A reliable protocol has been established for printing F127/DPBS using a nozzle temperature of 34°C, bed temperature of 27°C, extrusion pressure of 98 kPa, print speed of 17 mm/s, and 22-gauge nozzle (Figure 1). A consistent method for printing F127DMA with Irgacure 2959 without reliance on a sacrificial scaffold has not yet been established.

These preliminary findings establish a foundation for the development of a three-dimensional hydrogel-based model of a blood vessel with an aneurysm using F127DMA.

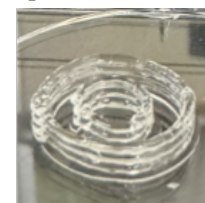


Figure 1:
Sacrificial F127/DPBS scaffold

[1] T. A. Altes et al., "Creation of saccular aneurysms in the rabbit: A model suitable for testing endovascular devices," *Am. J. Roentgenol.*, vol. 174, no. 2, pp. 349–354, 2000.

[2] Y. Lai et al., "Photocrosslinkable Biomaterials for 3D Bioprinting: Mechanisms, Recent Advances, and Future Prospects," *International Journal of Molecular Sciences*, vol. 25, no. 23, pp. 12567–12567, Nov. 2024, doi: 10.3390/ijms252312567.

[3] "TissueFab® Photoinitiator," Sigmaaldrich.com. Accessed: Aug. 03, 2026. [Online]. Available:

<https://www.sigmaaldrich.com/US/en/product/aldrich/940704?srsltid=AfmBOoqIK1Q3rEM5oemyMbxgoMdrmuzS5p8c9aZ1gcxSSUAVIwQswCi>.

Optimization of Polyvinyl Alcohol (PVA) Dip-coated Vessels for Aneurysm Model Fabrication

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Dip coating is a layer-by-layer fabrication technique where a substrate, such as a glass rod or a 3D-printed support, is repeatedly immersed into a liquid polymer solution to form a thin, uniform film upon withdrawal. It is revolved around the midpoint of the rod for an extended period of time in order to distribute the solution lengthwise. Small caliber (<6 mm) vessels are a particular focus in vascular research due to their clinical significance and high complication rates such as higher graft occlusion rates due to either thrombosis or intimal hyperplasia [1]. This study is motivated by the need for a scalable and reproducible method to fabricate hollow, anatomically relevant vascular structures. Specifically, the method aims to produce small-diameter vessels with a wall thickness of 250 μm and complex branched geometries that more closely resemble native vasculature. These models provide clinically relevant platforms for medical device evaluation including aneurysm treatments. The research primarily investigates the optimization of parameters for hydrogel-based synthetic vessels using polyvinyl alcohol (PVA) crosslinked with Sodium Hydroxide (NaOH) and sodium trimetaphosphate (STMP).

Fabrication of PVA varied based upon PVA concentration, number of layers, drying time, temperature, and rotational speed. PVA concentrations of 8%, 10%, and 12% were tested and the results are shown in Figure 2. As shown, 8% PVA achieved superior radial uniformity, while 10% PVA showed by far the least linear standard deviation (with mean layer thickness at 260 μm). Conversely, 12% PVA exhibited high axial and radial standard deviations due to high-viscosity with wall irregularities reaching 660 μm . Additional variables were investigated such as heating the PVA to 60 to reduce viscosity and promote even coating, wiping excess gel, and raising the RPM to 80 between coats. Heating the PVA did not produce promising results, while varying the RPM produced thinner vessels, but with increased linear consistency while maintaining similar radial variance. Future trials should investigate if increasing the number of coats at 80 RPM produces vessels with the correct thickness and improved linear consistency. Furthermore, technological innovations such as developing a biaxial rotation model shown in Figure 1, which utilizes a gear train to transfer revolution motion into rotational motion within the rod, were implemented to improve cross-sectional uniformity.

Future work will focus on optimizing the biaxial model to find a gear ratio which provides the ideal ratio of the two different movement types to allow for a good balance of centripetal and gravitational accelerations. This would correct the accumulation of PVA on the ends of the rods.

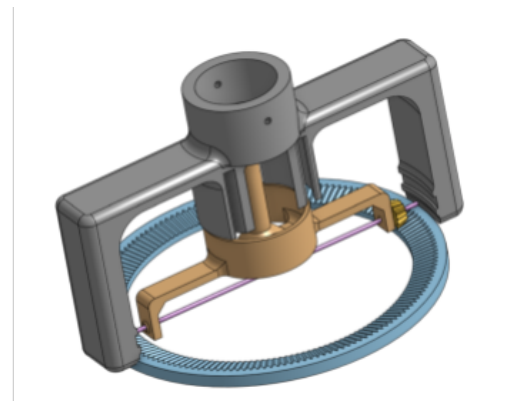


Figure 1: Biaxial Rotation Model

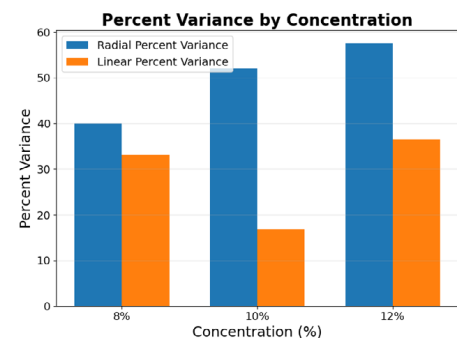


Figure 2: Comparison of Variance at Various Concentrations

[1] Weekes A, Bartnikowski N, Pinto N, Jenkins J, Meinert C, Klein TJ. Biofabrication of small diameter tissue-engineered vascular grafts. *Acta Biomater.* 2022;138:92-111. Epub 2021/11/16. doi: 10.1016/j.actbio.2021.11.012. PubMed PMID: 34781026.

[2] T. A. Altes et al., "Creation of saccular aneurysms in the rabbit: A model suitable for testing endovascular devices," *Am. J. Roentgenol.*, vol. 174, no. 2, pp. 349-354, 2000.

[3] Y. Lai et al., "Photocrosslinkable Biomaterials for 3D Bioprinting: Mechanisms, Recent Advances, and Future Prospects," *International Journal of Molecular Sciences*, vol. 25, no. 23, pp. 12567-12567, Nov. 2024, doi: 10.3390/ijms252312567.

[4] "TissueFab® Photoinitiator," Sigmaaldrich.com. Accessed: Aug. 03, 2026. [Online]. Available:

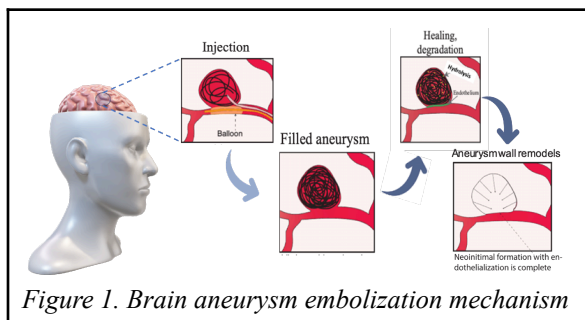
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Biodegradable Hydrogel Agents for Endovascular Embolization of Brain Aneurysms

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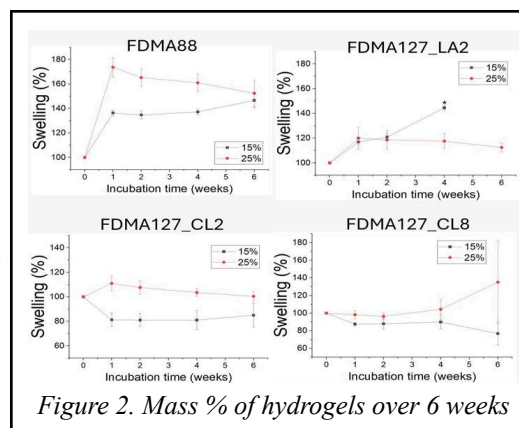
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Brain aneurysms are localized, abnormal dilations on a cerebral arterial wall. Most current treatments are permanently implanted, which can lead to many long-term complications. Previous work developed a mechanically stable liquid embolization agent (LEA), but this plug was non-degradable by design.¹ To develop a degradable version of this agent, we aim to create an ideal hydrogel embolic that is injectable through a catheter, remains mechanically stable during the healing period, and biodegrades once stable occlusion and tissue remodeling have occurred (Fig. 1). Here we develop a library of polymers with tunable degradation rate based on Pluronic F127, a thermoresponsive triblock copolymer.



Pluronic F127 was extended with polyester segments and reacted with 2-isocyanatoethyl methacrylate (IEMA) to introduce terminal methacrylate groups, enabling permanent chemical crosslinking with ammonium persulfate (APS) and tetramethylethylenediamine (TEMED). We synthesized a library of polymers with varying polyester composition (caprolactone or lactide), segment lengths, and polymer concentrations (15% vs 25%). Nuclear magnetic resonance (NMR) and Fourier-transform infrared (FTIR) spectroscopy confirmed the chemical nature of the synthesized polymer. The polymers were dissolved in deionized water at 15% and 25% concentrations, and crosslinked with APS and TEMED in silicone molds. Crosslinked gels were incubated in deionized water at 37°C and at 45°C for simulation of accelerated degradation. Gels in the 37°C incubator were measured to study degradation and swelling behavior, while those incubated at 45°C were dried to isolate the mass change of the polymer independent of swelling. Storage modulus of the gels was measured through rheology right after crosslinking and at day 1 and week 7 of degradation to study mechanical stability over time, while complex viscosity of uncrosslinked polymer solutions was measured by a temperature sweep to analyze gelation properties.

Degradation behavior of the 37°C gels was studied throughout 6 weeks and was generally consistent with predicted polymer behavior. LA2 gels at 15% concentration degraded completely by week 6, with continuous swelling suggesting bulk erosion, while LA2 gels at 25% concentration and CL-containing gels exhibited less swelling with lower changes in mass (Fig. 2). Measurement of storage modulus through rheological studies demonstrated that CL4 and LA4 gels had similar stiffness after crosslinking, with storage modulus reducing by half in both after a day of degradation. By seven weeks, LA4 gels showed significant decrease of storage modulus from roughly 35 kPa at day 1 to around 10 kPa, while CL4 gels retained their stiffness better.



These findings demonstrate how polyester incorporation can control degradation rates and mechanical stability, showing potential for a tunable platform in which hydrogel degradation can be controlled in clinical contexts. Future work includes extended degradation studies, surface and structural characterization of gels through XPS and contact angle measurement, and injectability testing in vitro and in vivo, with a focus on advancing these agents toward clinical translation.

[1] Wong, R., Sloutski, A., Gopal, M., Dashti, N., Li, J., Rai-Gersappe, D., Pandey, I., Guo, J., Tsai, E., Freychet, G., Peselev, Z., Cohn, D., Sadasivan, C., & Rafailovich, M. (2024). Engineering a biopolymer for vascular embolization based on fundamental polymer principals. *Polymer*, 309, 127437. <https://doi.org/10.1016/j.polymer.2024.127437>

Engineering a Glycation-Resistant Scaffold to Promote Cell Migration and Differentiation in Diabetic Wound Healing

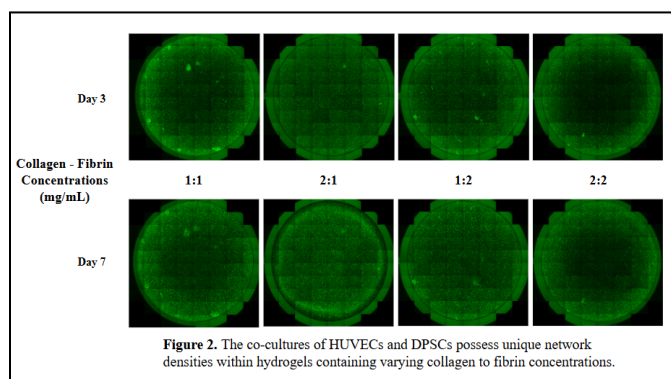
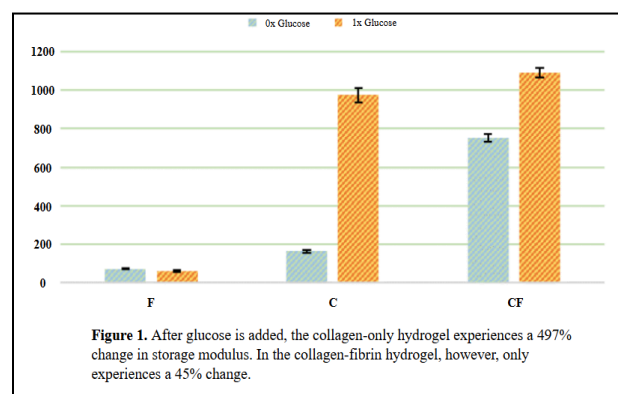
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Hyperglycemia leads to nerve damage, poor blood circulation, and immune dysfunction, contributing to a higher incidence of slow-healing and chronic wounds in diabetic patients. In previous research, engineered skin scaffolds were explored to facilitate angiogenesis and wound healing¹. However, the aggressive oxidative environment generated by the high glucose concentrations leads to the formation of advanced glycation end products (AGEs) and crosslinks on collagen.² This will increase the vascular wall stiffness, which in turn reduces cell adhesion, migration, matrix remodeling, and tissue regeneration.³ In this study, we incorporate fibrin into collagen matrices, exploring whether this may modulate glucose-induced mechanical dysfunction. Additionally, we observe the effect of collagen-fibrin ratios on the network formation of co-cultures of human umbilical vein endothelial cells (HUVECs) and dental pulp stem cells (DPSCs), a crucial step in skin tissue engineering.

The storage moduli of collagen-only, fibrin-only, and collagen-fibrin hydrogels were analyzed as a function of shear stress with and without glucose. The collagen-only hydrogels experienced drastic changes in storage modulus when glucose was added, especially compared to the fibrin-only hydrogels. However, the collagen-fibrin blends experienced mitigated alterations in storage modulus, affirming the role of fibrin in preserving the ECM's mechanical properties in hyperglycemic environments.

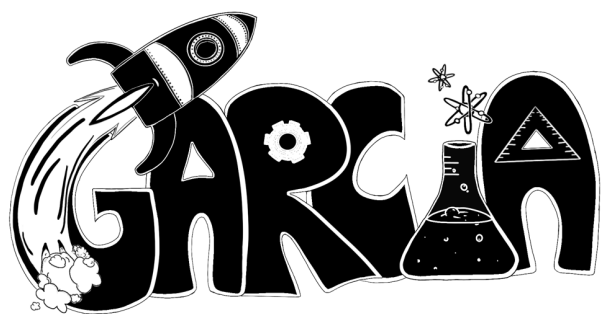


Co-cultures of HUVECs and DPSCs within hydrogels also provide insight into how distinct concentrations of collagen and fibrin impact angiogenesis. Using EVOS imaging and GFP fluorescence, it was observed that the networks appeared most dense in the 2:1 and 1:2 cultures, while the 1:1 and 2:2 cultures performed relatively worse. These results indicate a potential correlation between concentration of collagen and fibrin in the hydrogels of engineered skin scaffolds and offer a direction of further research.

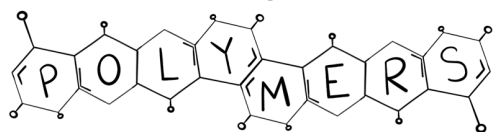
¹Liao, Jie et al. "Applications of decellularized materials in tissue engineering: advantages, drawbacks and current improvements, and future perspectives." *Journal of materials chemistry. B* vol. 8,44 (2020): 10023-10049. doi:10.1039/d0tb01534b

²Dhulekar, J., & Simionescu, A. (2018). Challenges in vascular tissue engineering for diabetic patients. *Acta Biomaterialia*, 70, 25–34. <https://doi.org/10.1016/j.actbio.2018.01.008>

³Van Putte, L., De Schrijver, S., & Moortgat, P. (2016). The effects of advanced glycation end products (ages) on dermal wound healing and scar formation: A systematic review. *Scars, Burns & Healing*, 2. <https://doi.org/10.1177/2059513116676828>



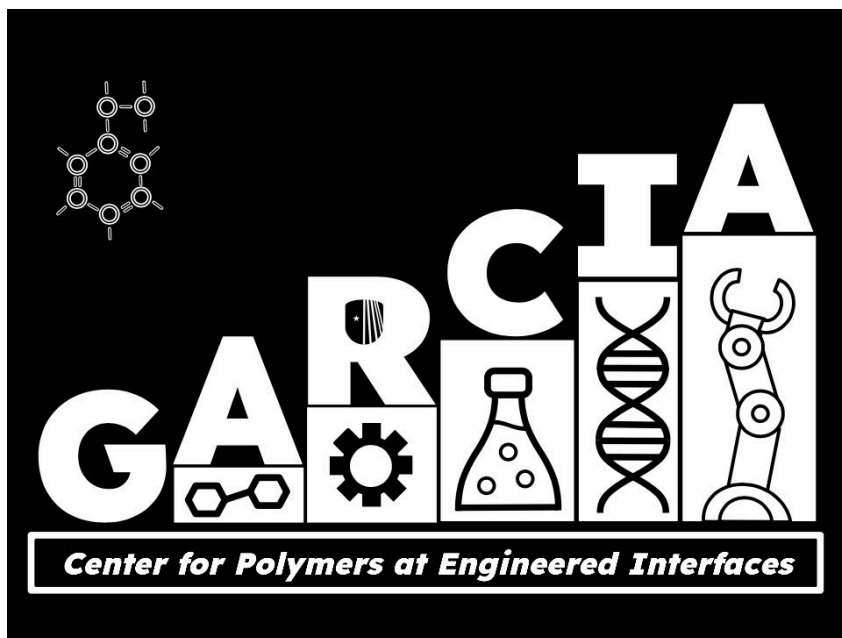
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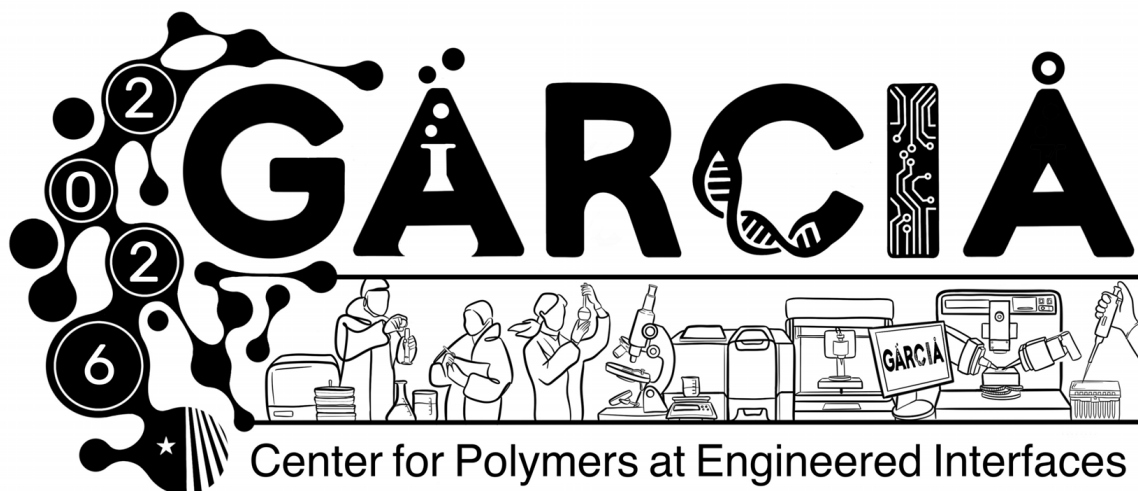
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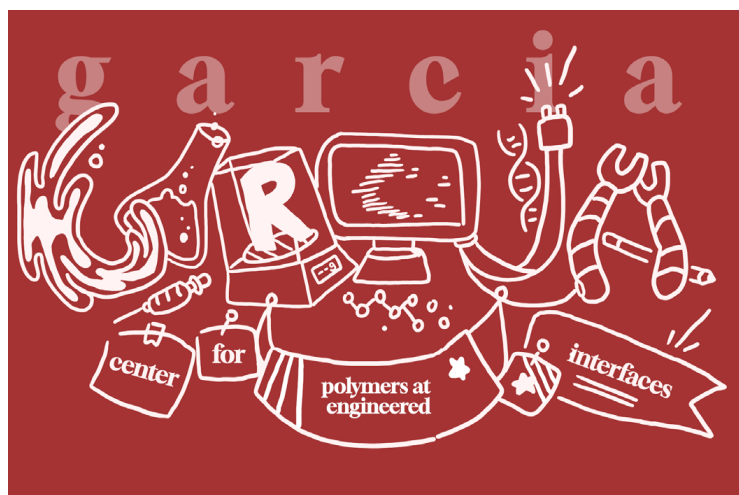


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