Dr. Navajit Singh Baban

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My Academic and Professional Journey thus far: I am a passionate researcher and a dedicated educator who loves teaching. My multidisciplinary research spans bioinspired engineering, computational biomechanics, and the security of biochips and additive manufacturing. As a firm supporter of nature-based innovation, I deeply value the inscrutable wisdom of natural solutions, aiming to discover and incorporate them into my research. Below is the brief overview of my academic and professional journey:

- ***Bachelor of Technology (B.Tech.),* MECHANICAL ENGINEERING, VIT UNIVERSITY, 2008-2012:** Developed a strong foundation in mechanical engineering, combining hands-on capstone projects with rigorous theoretical knowledge.

- ***Master of Technology (M.Tech.),* MATERIAL SCIENCE, IIT KANPUR, 2012-2014:** Gained expertise in materials science through a two-year program, combining intensive coursework in the first year with focused research in the second. Specialized in composites, which became the foundation for the M.Tech. thesis.

- ***Assistant Professor,* MECHANICAL ENGINEERING, LOVELY PROFESSIONAL UNIVERSITY PUNJAB, 2014-2015:** I garnered substantial experience in academia, with significant engagement in teaching and research. Throughout my tenure, I provided guidance for numerous capstone projects undertaken by final year B.Tech. students specializing in Mechanical as well as Materials Science and Engineering.

- ***Manager, Planning, and Scheduling,* RELIANCE INDUSTRIES LIMITED (RIL), JAMNAGAR, GUJARAT, 2014-2015:** Gained project management experience as a manager at Reliance Industries Limited (RIL), leading teams to efficiently execute tasks, meet tight deadlines, and perform under pressure.

- ***Global Ph.D. Fellow, Mechanical Engineering,* NEW YORK UNIVERSITY (NYU), 2016-2021:** Striving to transform into a results-oriented academic professional, I embarked on a journey that culminated in the successful completion of my Ph.D. in Mechanical Engineering at the esteemed New York University (NYU) under the effective guidance of Prof. Yong-Ak (Rafael) Song. This accomplishment underscores my unwavering dedication to honing problem-solving skills through the lens of critical thinking. My research delved into the intricacies of micro- and nanoscale soft interfacial fracture mechanics, harnessing bioinspired engineering models. This specialized investigation further solidified my knack for innovative and exacting problem resolution.

- ***Postdoctoral Associate,* DEPARTMENT OF ENGINEERING, CENTER FOR CYBER SECURITY (CCS) AND BIOENGINEERING, NYU/NYUAD, 2021-PRESENT:** In a committed effort to broaden my expertise horizontally, with a particular focus on the domains of cybersecurity and artificial intelligence, I have taken on the role of a Postdoctoral Associate under the mentorship of Prof. Ramesh Karri at CCS NYUAD since September 2021. My ongoing research revolves around the cyber-physical security aspects of security critical biochips (lab-on-a-chip devices). I am actively delving into potential vulnerabilities within these biochips to preempt cyber-attacks, with the ultimate goal of proposing robust defensive solutions.

ACADEMIC CREDENTIALS

Doctor of Philosophy (Ph.D., Mechanical Engineering): New York University (NYU), 2021, *CPI - 3.7/4*
Master of Technology (M.Tech., Materials Science): IIT Kanpur, 2014, *CPI - 9.45/10*
Bachelor of Technology (B.Tech., Mechanical Engineering): VIT University, Vellore, 2012, *CGPA - 8.58/10*
Higher Secondary: Modern School, Kota, 2007, Percent - *86.4%*
Senior Secondary: Kendriya Vidyalaya No. 1, Surat, 2005, *Percent - 87.4%*

GRANTS

- Received a **Postdoc Collaborative Research Grant** of $5,000 from NYU Abu Dhabi. This esteemed award enabled my visit to New York University's campuses in New York in July 2023, providing a valuable opportunity for collaboration with peers, delivery of academic presentations, and further enhancement of my research.

- Received a **SEED Research Grant** from IIT Kanpur, in collaboration with NYU. The grant supports the project "*NSF-DST: Unconventional Physically Unclonable Functions for Micro-fluidics and Supply Chain Fingerprinting*," with a tripartite collaboration between NYU, NYUAD, and IIT Kanpur. Funded with $20,000 from NYU and ₹1,500,000 from IIT Kanpur, the grant period spans from April 1, 2024, to March 31, 2025, focusing on advancing security technologies in bioengineering.

JOURNAL PAPERS

- Peer Reviewed Paper (Published, First Author): Baban, N.S., Orozaliev, A., Stubbs, C.J. and Song, Y.A., Understanding interfacial fracture behavior between microinterlocked soft layers using physics-based cohesive zone modeling. *Physical Review E*, *102(1), p.012801*, 2020.

- Peer Reviewed Paper (Published, First Author, Cover Page Article): Baban, N.S., Orozaliev, A., Kirchhof, S., Stubbs, C.J. and Song, Y.A., Biomimetic fracture model of lizard tail autotomy. *Science*, *375(6582), pp.770-774*, 2022.

  Media Coverage:
  - "The Paradox of the Lizard Tail, Solved," (The *New York Times*, by Jack Tamisiea, 2023).
  - "Study finds how lizard tails are sturdy at regular times but detach easily when needed," (*Independent, UK Edition*, by Vishwam Sankaran, 2023).
  - In total, more than 20 media outlets publicized the research findings worldwide in different languages as per the Altmetrics' scoring (Present Altmetrics Score for the article = 308).
  - Moreover, the Science (AAAS) media team made a separate dedicated video on the research, which was published on Youtube, which records more 324K views thus far.

- Peer Reviewed Paper (Published, First author): Baban, N.S., Orozaliev, A., Stubbs, C.J. and Song, Y.A., Biomimicking interfacial fracture behavior of lizard tail autotomy with soft microinterlocking structures. *Bioinspiration & Biomimetics*, *17(3), p.036002*, 2022.

- Perspective Article (Published, First author): Baban, N.S. and Song, Y.A., Rational design of bioinspired tissue adhesives. *Clinical and Translational Medicine*, *12(4)*, 2022.

- Perspective Article (Published, First author): Baban, N.S. and Song, Y.A., The Mystery of the Lizard Tail. *The ScienceBreaker*, 8(4), 2022.

- Peer Reviewed Paper (Published, Corresponding author): Baban, N.S., Saha, S., Orozaliev, A., Kim, J., Bhattacharjee, S., Song, Y.A., Karri, R. and Chakrabarty, K., Structural attacks and defenses for flow-based microfluidic biochips. *IEEE Transactions on Biomedical Circuits and Systems*, *16(6), pp.1261-1275*, 2022.

- Peer Reviewed Paper (Published, Co-author): Abdelhameed, M., Elbeh, M., Baban, N.S., Pereira, L., Matula, J., Song, Y.A. and Ramadi, K.B., High-yield, one-pot upcycling of polyethylene and polypropylene waste into blue-emissive carbon dots. *Green Chemistry*, *25(5), pp.1925-1937*, 2023.

- Peer Reviewed Paper (Published, Corresponding Author, Cover Page Article): Baban, N.S., Saha, S., Jancheska, S., Singh, I., Khapli, S., Khobdabayev, M., Kim, J., Bhattacharjee, S., Song, Y.A., Chakrabarty, K. and Karri, R., Material-level countermeasures for securing microfluidic biochips. *Lab on a Chip*, *23(19), pp.4213-4231*, 2023.

  Media Coverage:
  "Putting Medical Tests to the Test," (Arizona State University, ASU News by Thomas Triolo, 2023).
  "NYU Abu Dhabi Post-Doc Scores Cover Story for Securing Biochips Paper," (NYU Tandon School of Engineering Center for Cyber Security, by Lois Anne DeLong, 2023).

- Peer Reviewed Paper (Published, Corresponding Author, Cover Page Article): Baban, N.S., Zhou, J., Elkhoury, K., Bhattacharjee, S., Vijayavenkataraman, S., Gupta, N., Song, Y.A., Chakrabarty, K. and Karri, R., 2024. BioTrojans: viscoelastic microvalve-based attacks in flow-based microfluidic biochips and their countermeasures. *Scientific Reports*, *14*(1), pp.1-13.

CONFERENCE PAPERS

- Conference paper (Published, First Author): Baban, N.S., Orozaliev, A. and Song, Y.A., 2018, January. Mechanistic approach to mimic lizard tail autotomy using deformable microstructures as biological interlock in the soft tissue. *In 22nd International Conference on Miniaturized Systems for Chemistry and Life Sciences, MicroTAS 2018, Kaohsiung, Taiwan, pp. 1670-1672)*, Chemical and Biological Microsystems Society (CBMS).

- Conference paper (Published, Co-Author): Chaturvedi, N., Baban, N.S., Sofela, S.O., Orozaliev, A., Giakoumidis, N., Kim, J., Gunsalus, K.C. and Song, Y.A., 2018, January. A single pressure pulse-actuated 3D-printed microfluidic tip for high throughput dispensing of C. elegans worms. In *22nd International Conference on Miniaturized Systems for Chemistry and Life Sciences, MicroTAS 2018, Kaohsiung, Taiwan,* (pp. 1557-1559). Chemical and Biological Microsystems Society (CBMS).

- Conference paper (Published, First Author): Baban, N.S., Orozaliev, A., Stubbs, C.J. and Song, Y.A., 2019. Bioinspired micromechanical interlocking structures for enhanced adherence between soft elastomeric layers. In *23rd International Conference on Miniaturized Systems for Chemistry and Life Sciences, MicroTAS 2019, Basel, Switzerland, (pp. 1130-1131)*. Chemical and Biological Microsystems Society (CBMS).

- Conference paper (Published, First Author): Baban, N.S., Orozaliev, A., Song, Y.A., Chatterjee, U., Bose, S., Bhattacharjee, S., Karri, R. and Chakrabarty, K., 2023, October. Biochip-PUF: Physically Unclonable Function for Microfluidic Biochips. In *2023 IEEE International Test Conference (ITC), Anaheim, California, USA,* (pp. 166-175).

- Conference paper (Published, First Author): Baban, N.S., Saha, S., Jancheska, S., Zhou, J., Vijayavenkataraman, S., Bhattacharjee, S., Song, Y.A., Chakrabarty, K. and Karri, R., 2023, October. Bio-FP: Biochip Fingerprints for Authentication. In *2023 IEEE Biomedical Circuits and Systems Conference (BioCAS) (pp. 1-5).*

- Conference poster paper (In Press, First Author): Baban, N.S., Zhou, J., Bhattacharya, S., Chatterjee, U., Bhattacharjee, S., Sanjairaj, V., Song, Y.A., Mukhopadhyay, D., Chakrabarty, K., and Karri, R., 2024, March. Physically Unclonable Fingerprints for Authentication. In 22nd International Conference on Applied Cryptography and Network Security (ACNS).

BOOK CHAPTERS

- Book Chapter (Published, Co-Author): Pramanik, S., Cherusseri, J., Baban, N.S., Sowntharya, L. and Kar, K.K., 2017. Metal matrix composites: Theory, techniques, and applications. *Composite Materials: Processing, Applications, Characterizations*, pp.369-411, Springer Berlin Heidelberg.

- Book Chapter (Published, Co-Author): Stubbs, C.J., Baban, N.S., Robertson, D.J., Alzube, L. and Cook, D.D., 2018. Bending stress in plant stems: models and assumptions. *Plant Biomechanics: From Structure to Function at Multiple Scales*, pp.49-77, Springer International Publishing.

- Book Chapter (Published, Co-Author): Sofela, S., Feng, Y., Baban, N.S., Stubbs, C.J., Song, Y.A. and Wang, W., 2021. Biophysical phenotyping of C. elegans in a microfluidic chip for high-throughput drug screening. In *Micro and Nano Systems for Biophysical Studies of Cells and Small Organisms* (pp. 261-293), Academic Press.

POSTER PRESENTATIONS

- Poster presentation (MicroTAS 2018, First author): Presented a research poster with the topic "Mechanistic approach to mimic lizard tail autotomy using deformable microstructures as biological interlock in the soft tissue" during *MicroTAS 2018 held in Kaohsiung, Taiwan.*

- Poster presentation (NYUAD Annual Research Conference, First author): Presented a research poster with the topic "A Study on the Releasable Microinterlocked Soft Elastomeric Model Bioinspired from Lizard Tail Autotomy Process"during *Annual Research Conference at NYUAD, Abu Dhabi, UAE.*

- Poster presentation (MicroTAS 2019, First author): Presented a research poster with the topic "Bioinspired micromechanical interlocking structures for enhanced adherence between soft elastomeric layers" during *MicroTAS 2019, held in Basel, Switzerland.*

- Poster presentation (BEMS 2019, *Co-author*): Christopher J Stubbs, Samuel O Sofela, *Navajit S. Baban*, Yong-Ak Song, "MechanoCellCAD: A Generalized Computational Modelling Approach for Analyzing Traction Forces on a Soft Micropillar Array", *Biomedical Engineering Society Annual Meeting, October 16 - 19, 2019. Philadelphia, PA.*

- Poster presentation (3rd NYU Bioengineering Conference, First author): Presented a research poster with the topic "Human-skin inspired micromechanical interlocking structures for enhanced adherence between soft layers" during *3rd NYU Biomedical and Biosystems Conference, 2020, Abu Dhabi, UAE.*

- Poster presentation (*Co-author*): Christopher J Stubbs, Samuel O Sofela, *Navajit S. Baban*, Yong-Ak Song, "MechanocellCAD: Analyzing Cell Traction and C. Elegan Thrashing Forces on Micropillar Arrays", *New York University Biomedical and Biosystems Conference, January 12 - 14, 2020. Abu Dhabi, United Arab Emirates.*

- Poster presentation (MicroTAS 2020, *Co-author*): Christopher J. Stubbs, Samuel O. Sofela, *Navajit S. Baban*, Yong-Ak Song, "A Generalized Semi-Automated Rational Design of Micropillar Arrays for Mechanobiological Studies", *MicroTAS, October 4-9, 2020. Online.*

- Poster presentation (Gordon Conference, First Author): Navajit S. Baban, Christopher J. Stubbs, Samuel O. Sofela, Yong-Ak Song, "MechanoBioCAD – An Automated Computational Design Tool for Mechanobiological Studies", *Gordon Research Conference: Physics and Chemistry of Microfluidics*, Barga, Italy, June 4-9, 2023.

- Poster presentation (IEEE Biomedical Circuits and Systems, First Author): Navajit S. Baban, Sohini Saha, Sofija Jancheska, Jiarui Zhou, Sanjairaj Vijayavenkataraman, Sukanta Bhattacharjee, Yong-Ak Song, Krishnendu Chakrabarty, and Ramesh Karri, "Bio-FP: Authentication through Biochip Fingerprints", *IEEE Biomedical Circuits and Systems*, Toronto, Canada, October 2023.

- Poster presentation (Applied Cryptography and Network Security, First Author): Navajit S. Baban, Jiarui Zhou, Sarani Bhattacharya, Urbi Chatterjee, Sukanta Bhattacharjee, Vijayavenkataraman Sanjairaj, Yong-Ak Song, Debdeep Mukhopadhyay, Krishnendu Chakrabarty, and Ramesh Karri, "Physically Unclonable Fingerprints for Authentication", *22nd International Conference on Applied Cryptography and Network Security*, Abu Dhabi, UAE, March 5th-8th, 2024.

ORAL TALKS

- Early Engineers Research Forum, EERF, NYU Abu Dhabi, 2022: P my Ph.D. research on the "Biomimetic Fracture Model of Lizard Tail Autotomy" at the Early Engineers Research Forum (EERF) at NYU Abu Dhabi. The session was highly interactive, and introducing this novel research to a curious audience was incredibly rewarding, with their engagement and insightful questions enriching the discussion.

- Center for Cybersecurity Seminar Series, CCS-AD, 2023: delivered a talk at NYU Abu Dhabi on the platform of the Center for Cybersecurity (CCS)-NYUAD Seminar series, focusing on the cyber-physical security of flow-based microfluidic biochips (FMBs) in the context of global pandemics. The presentation aimed to enhance inclusion, engagement, and awareness among researchers about the crucial security aspects of biochip security.

- Department Speaker, Research and Industrial Conclave, IIT Guwahati, 2023: Delivered a talk at the 2023 Research and Industrial Conclave at IIT Guwahati on 'Biomimetic Fracture Model of Lizard Tail Autotomy and Its Possible Use in Bioinspired Tissue Adhesives.' It focused on fracture mechanisms that can inspire scientists and engineers, addressing challenges related to synthetic adhesives, including effective adherence in wet environments, residue-free removal, and rapid mode-dependent adhesion tuning.

- The City College of New York, CCNY, 2023: Delivered a talk at the City University of New York, CCNY, addressing the topic of 'Cyber-Physical Security of Biochips.' The presentation centered around the examination of cyber-physical vulnerabilities and the exploration of possible countermeasures to enhance the security of these critical devices against potential attackers.

- ICDAMMI conference, Jaipur, 2023: Delivered a talk on 'Material-Level Cyber-Physical Biochip Vulnerability at the International Conference' on Digitization and Advancements in Materials and Metallurgical Industries (ICDAMMI), held in Jaipur on August 19th and 20th, 2023. The conference, hosted by The Institutions of Engineers India (IEI) in collaboration with New York University, New York University Abu Dhabi, Indian Institute of Technology, Roorkee, and Malaviya National Institute of Technology Jaipur, offered a valuable platform for knowledge exchange on Industry 4.0 and networking with fellow researchers.

- Department Talk, CSE and Mechanical Engineering, IIT Kharagpur, 2023: Delivered a talk at the Indian Institute of Technology, Kharagpur, CSE Department, focusing on cyber-physical security for microfluidic biochips (lab-on-a-chip devices). We discussed their growing demand amid global pandemics and their role in point-of-care tests. Engaged in insightful dialogues, dissecting challenges and threats from malicious attacks and IP theft. A key focus was innovating Physically Unclonable Functions (PUFs) to enhance authentication and security for these life-saving devices.

- IEEE International Test Conference, ITC, 2023: Delivered a talk at the prestigious International Test Conference in Anaheim, California, USA. The talk emphasized the vital role of Physically Unclonable Functions (PUFs) in authenticating microfluidic biochips, which are essential in medical diagnostics. These biochips confronted threats like intellectual property theft and counterfeiting, with direct consequences for patient health. The presentation introduced the Bio-PUF, a device-level authentication scheme tailored for biochips, marking a significant advancement in enhancing their security.

- ICSEC, Doha, Qatar, 2023: Delivered an oral talk on bioinspired fracture mechanics of lemon peels and lizard tails, along with their finite element-based computation, at the fourth International Computational Science and Engineering Conference (ICSEC) 2023 in Doha, Qatar last week. The event facilitated engagement with experts from various computational research fields, fostering valuable collaborations and knowledge sharing.

- Department Talk, CSE and Mechanical Engineering, IIT Kanpur, July 2024: As part of the NYU-IITK Seed Grant project, where I serve as Co-PI, I delivered a talk focused on using Physically Unclonable Functions (PUFs) to enhance the security of microfluidic biochips. I had an engaging discussion with the IIT Kanpur PI (Prof. Urbi Chattterjee) and her group, exploring innovative solutions for cyber-physical security in lab-on-a-chip devices.

- Departmental Talk, Mechanical Engineering, IIT Ropar, July 2024: Presented my research on lizard tail autotomy at IIT Ropar, Mechanical Engineering Department, focusing on the biological mechanisms and its potential for biomimetic applications in engineering. Engaged in a stimulating discussion with faculty and students on how these insights could inspire the design of innovative materials and systems, particularly in the fields of robotics and adhesion technology.

- Departmental Talk, Biological Sciences and Bioengineering (BSBE), IIT Bombay: Delivered a presentation on lizard tail autotomy at BSBE Department IIT Bombay, emphasizing the underlying biological mechanisms and their potential applications in bioengineering. Engaged in an enriching discussion on how this natural phenomenon could inspire biomimetic advancements, particularly in wound healing and wet environment adhesives.

- Departmental Talk, Mechanical Engineering, IIT Patna: Presented my research on lizard tail autotomy at Mechanical Engineering Department IIT Patna, emphasizing the soft fracture mechanics governing the detachment process. The discussion focused on applying biological insights from soft fracture mechanics to engineering, particularly in developing biomimetic materials inspired by traction-separation laws and adhesive mechanisms.

PEER REVIEW DONE

- Journal Name: **IET Nanobiotechnology**, Publisher: IET and Wiley, IF = 2.3
- Journal Name: **PLOS ONE,** Publisher: Public Library of Science, IF = 3.7
- Journal Name: **IEEE Transactions on Biomedical Circuits and Systems (TBioCAS)**, IEEE, IF = 5.2

PATENTS

- **Provisional Patent Filed, USA**, **SYSTEM, METHOD AND COMPUTER-ACCESSIBLE MEDIUM FACILITATING BIOCHIP FINGERPRINTS FOR AUTHENTICATION,** NYU Code: 20, Your Ref.: P. BAB01-01PRO, Our Ref.: 300694.US.01-109197-0000109

AWARDS

- Received a **Travel Grant Award** from New York University Abu Dhabi to attend **MicroTAS 2018** conference in **Kaohsiung, Taiwan.**
- Received a **Travel Grant Award** from New York University Abu Dhabi to attend **MicroTAS 2019** conference in **Basel,Switzerland.**
- Received a **Travel Grant Award** from The **Chemical and Biological Microsystems Sociery (CBMS)** for the research presented in **MicroTAS 2019 in Basel, Switzerland**.

TEACHING

- ***Teaching Assistant (TA),* BIOMECHANICS, NEW YORK UNIVERSITY ABU DHABI (NYUAD), 2020:** In the spring of 2020, I assumed the role of Teaching Assistant for Dr. Jeremy Teo's Biomechanics course at NYU Abu Dhabi (NYUAD). In this capacity, my duties encompassed experiment design, the creation of the laboratory manual, and the formulation of lab report evaluation criteria. Simultaneously, as the global pandemic took hold, NYUAD transitioned to remote learning. To address this shift, I developed instructional lab experiment videos and gathered sample data, which were then distributed to students. This initiative enabled them to conduct data analysis and fulfill their lab assessment requirements from a distance, ensuring the uninterrupted continuity of their educational journey.

- ***Teaching Assistant (TA),* QUANTITATIVE SYNTHETIC BIOLOGY, NEW YORK UNIVERSITY ABU DHABI (NYUAD), 2023:** In spring 2023, I served as a Teaching Assistant for the Quantitative Synthetic Biology course, under the mentorship of Dr. Yong-Ak Song at NYUAD. My role encompassed a wide range of responsibilities, including teaching the class, designing experimental procedures, authoring the laboratory manual, and establishing lab report evaluation criteria. Additionally, I was entrusted with the task of assessing student test scores and leading recitation classes, which significantly enhanced my teaching proficiency.

TECHNICAL PROFICIENCY

Programming Languages and Packages: Python, C/C++, CNC, Matlab, Stata, Bash, Latex.

CAD Design Software: Solidworks, AutoCAD®, Fusion 360.

Simulation Package: ABAQUS, COMSOL Multiphysics, ANSYS, OpenFOAM.

Machines and Gadgets: Instron®, ThermoFischer Quanta 3D Scanning Electron Microscope, Bruker Micro-CT and Atomic Force Microscopy (AFM), Leica and Nikon Bright-field and Fluorescence Microscopes, Chronos High-speed camera, Leica SP8 Confocal Microscope, Nanoscribe 3D Printer, Optical Coherence Tomography Microscopes, Agilent Nanoindenter, Arduino, Raspberry Pi, Elveflow, Mecmesin Universal Testing Machine (UTM), Cellscale UTMs, Ocean Insight Spectrometers, Harrick Plasma Cleaners.

Others: MS Office®, OriginPro, Mendeley, EndNote, Finalcut Pro, Shotcut, TecPlot, Overleaf.

M.TECH. THESIS: 2D NUMERICAL SIMULATION OF MATERIAL PROPERTIES OF CARBON-CARBON (C-C) COMPOSITES DURING CARBONIZATION IN THE FABRICATION PROCESS BY RESIN APPLICATION METHOD. My Master's thesis focused on simulating the impact of grid size and heating rate on gas pressure during the carbonization of C-C composites. I explored how temperature and porosity gradients influence elasticity, thermal conductivity, gas molecular weight, and specific heat capacity, ultimately affecting the final fabrication. Utilizing the Finite Difference Method (FDM) and custom C++ code on a Linux platform. This experience ignited my interest in simulations, leading me to pursue my Ph.D. in computational finite element-based studies.

PH.D. WORK

(1) HUMAN SKIN INSPIRED SOFT MICROINTERLOCKS AND THEIR APPLICATIONS (LEAD): I focused on the fracture mechanics of human skin's dermal-epidermal microinterlocks using a physics-based cohesive zone finite-element model. Cohesive zone modeling revealed that in areas with microinterlocks, primary cracks are arrested and secondary cracks initiated, leading to significant energy dissipation, a phenomenon absent in plain interfaces. These insights are crucial for designing sutureless skin grafts and electronic skin. The initial findings were presented as a poster at the MicroTAS 2019 conference in Basel, Switzerland, and the final work was published in Physical Review E, 2020.

(2) LIZARD TAIL AUTOTOMY INSPIRED TISSUE ADHESIVES (LEAD): I developed a biomimetic model based on lizard tail autotomy using multiscale hierarchical structures that mimic the micro- and nanostructures on lizard tails. Experiments and physics-based simulations demonstrated enhanced adhesion with nanoporous surfaces and flexible micropillars, especially under wet conditions due to energy dissipation aided by capillarity and mechanisms similar to Cook-Gordon and Lake-Thomas effects. This research, which advances biomimetic solutions for adhesion, was featured on the cover of the prestigious Science journal and discussed in a perspective article in the Clinical and Translational Medicine Journal.

(3) LIZARD TAIL AUTOTOMY INSPIRED SOFT ROBOT (LEAD): I developed a soft robot inspired by lizard tail autotomy, featuring a pneumatically actuated soft bilayer patch with tunable microinterlocks. This innovative design markedly enhanced the adjustability of adhesion, demonstrating promising applications in soft robotics and prosthetics. The preliminary findings were showcased at MicroTAS 2018 in Kaohsiung, Taiwan, and the comprehensive results were later published in the Bioinspiration & Biomimetics journal in 2022.

PH.D. THESIS: UNDERSTANDING MICRO-AND NANOSCALE SOFT INTERFACIAL FRACTURE MECHANICS THROUGH BIOINSPIRED ENGINEERING MODELS. My Ph.D. thesis focused on bioinspired interfacial designs to modify fracture and adhesion mechanics in soft interfaces, drawing inspiration from human skin and lizard tails. The thesis, spanning three chapters, provided biomimetic design guidelines for electronic skin, bioinspired tissue adhesives, and soft robotics. The first chapter examined the dermis-epidermis microinterlocks in human skin, while the latter chapters explored lizard tail autotomy. This work contributed valuable insights for innovative bioinspired designs, advancing our understanding of nature's solutions for complex engineering challenges.

PROJECTS IN COLLABORATION DURING PH.D.

(1) CORN STALK LODGING, CROP BIOMECHANICS (IN COLLABORATION): During my Ph.D. coursework at NYU, I collaborated with Prof. Douglas Cook's group at NYU Abu Dhabi to study corn stalk failures under heavy wind. We combined material characterization and beam bending models to uncover mechanisms behind these failures and suggested countermeasures for plant biologists. This work led to a Springer-published book paper, focusing on bending stress in plant stems. The reference details are provided below in the book chapters section.

(2) DISPENSING TIP DESIGN FOR C. ELEGANS (IN COLLABORATION): In collaboration with a team member at NYU Abu Dhabi, we developed a high-throughput, 3D-printed microfluidic dispensing tip for C. elegans worms, utilizing COMSOL Multiphysics for simulations. This automated solution, driven by single pressure pump pulses and enhanced with a 3-axis stage and imaging system, significantly improved the dispensing process in terms of reliability and speed. Our collaborative work was presented at MicroTAS 2018 in Taiwan and is documented in the conference proceedings, as detailed in the proceedings section.

(3) C. ELEGANS BASED MECHANOBIOLOGICAL STUDIES (IN COLLABORATION): Collaborating with a colleague at NYU Abu Dhabi, we developed a method to measure muscle force in Caenorhabditis (C.) elegans using elastomeric micropillars, essential for drug testing in hyperglycemia. We created MechanoBioCAD (MBC), a finite element-based tool for error analysis and design optimization for elastomeric micropillar based force sensing. My contribution involved data analysis using MBC, establishing design guidelines, and error quantification in muscle force measurement. This work has been featured in a book chapter and presented at various prestigious conferences, seen below in the relevant sections.

POSTDOC PROJECTS

National Science Foundation (NSF), USA, Secure and Trustworthy Cyberspace (SaTC) Projects.

(1) STRUCTURAL ATTACKS AND DEFENSES FOR FLOW-BASED MICROFLUIDIC BIOCHIPS (FMBS), LEAD: As the team lead, I worked on the cyber-physical security of FMBs, addressing structure-level threats. We successfully demonstrated the initial structure-based (SB) attack by reducing chamber heights to generate false negatives. Validation through fluorescence microscopy revealed a robust height-fluorescence intensity correlation (R2 = 0.987) for DNA amplification. Detecting SB attacks involved using deep learning anomaly detection algorithms, achieving approximately 96% accuracy. Additionally, we proposed a device-level watermarking method based on intensity-height correlation to counter IP theft. These safeguards shield FMBs from SB and IP theft threats, especially in the age of global pandemics and personalized medicine. The research was published in IEEE TBioCAS in 2022.

(2) MATERIAL-LEVEL COUNTERMEASURES FOR SECURING MICROFLUIDIC BIOCHIPS (MBS), LEAD: As team lead, I worked on the cyber-physical security of MBs, addressing material-level threats. We presented a dynamic material-level watermarking scheme for PDMS-based FMBs with microvalves, using a fluorescent dye. Experimental validation showed a strong correlation ($R^2 = 0.971$) between excimer intensity changes and mechanical strain in actuated microvalves. We also employed machine learning models to detect curing ratio-based attacks, achieving over 99% accuracy. These measures proactively protect FMBs from material-level threats, particularly in the context of global pandemics and POCT-based diagnostics. The research was published in Lab-on-a-Chip journal in 2023.

(3) PHYSICALLY UNCLONABLE FUNCTIONS FOR MICROFLUIDIC BIOCHIPS (BIOCHIP-PUFS), LEAD: I spearheaded a project focused on developing physically unclonable functions (PUFs) for authenticating FMBs by utilizing their associated microvalve responses, considering the inherent variability resulting from diverse fabrication parameters. To support our Bio-PUF characterization, we conducted simulations of the FMB's microvalves using Comsol Multiphysics, aligning them with observed parameter distributions in actual FMBs. Additionally, we introduced a scheme that utilizes the transient response of microvalve actuation to enhance Bio-PUF authentication. The work was presented as an oral talk at the esteemed IEEE International Test Conference (ITC) held in Anaheim, California, USA.

(4) BIOCHIP FINGERPRINTS FOR AUTHENTICATION (BIO-FP), LEAD: I led a project that introduced a groundbreaking biochip authentication scheme using material-level fingerprints. We employed a melt electrospinning printer to produce unique biochip fingerprints with polycaprolactone ink. To ensure security and tamper resistance, we added a protective layer of polydimethylsiloxane over the fingerprints. For authentication, we utilized various deep learning-based image processing techniques, achieving 99.9% classification accuracy, and experimented with incorporating a fluorescent dye into the ink for spectral scanning, adding an extra layer of material-level security. This research was presented as a poster at the 2023 IEEE BioCAS conference and a provisional U.S. patent has been filed.

(5) QUANTUM DOT BASED BIOCHIP AUTHENTICATION, LEAD: I have been leading a project focused on developing a state-of-the-art fingerprinting and authentication system for biochips, harnessing the potential of quantum dots. In our innovative approach, we have devised a biochip authentication method using carbon quantum dots (CQDs) to create fluorescent stickers, fingerprinting signatures, and QR codes. These inconspicuous stickers, synthesized from COVID-19 masks, are discreetly integrated into the biochips, remaining invisible to the naked eye. However, they become visible under UV light, revealing their distinctive emission properties. To enhance security further, we have added an additional layer by imprinting UV-detectable QR codes infused with CQDs onto the biochips.

(6) VISCOELASTIC TROJAN VALVES IN MICROFLUIDIC BIOCHIPS, LEAD: In this project, we investigate the cyber-physical security vulnerabilities associated with microvalves typically constructed from PDMS. These critical components in bio-protocols can be compromised by deteriorative solvents, chemicals, or alterations in the curing ratio. Our current focus is on assessing performance degradation and intentional rupture caused by these attacks, aiming to understand how they render microvalves viscoelastic. Simultaneously, we characterize the material properties of both original and attacked valves to create a trade-off map for attack evasion and detection. The preliminary research results were presented as an oral talk at the International Conference on Digitization and Advancement in Materials and Metallurgical Industries in 2023 in Jaipur, India.

(7) BIOHACK3D, LEAD: In this project, we are investigating vulnerabilities associated with the 3D printing of biochips. Specifically, we are exploring various types of attacks at different levels, including structural, material, G-code, firmware, software, hardware and STL file generation, with the potential to bypass quality control checks. As the use of 3D printing technology in the manufacturing of security-critical biochips has significantly increased, our objective is to enhance the security of this supply chain. We aim to identify vulnerabilities and propose respective countermeasures.

(8) DIGITAL MICROFLUIDIC BIOCHIPS (DMFBS) SURFACE WETTABILITY ATTACKS AND DEFENSES, LEAD: In this project, we are investigating potential vulnerabilities associated with tampering with the wetting characteristics of droplets in digital microfluidic biochips. We are using smart hydrogels capable of altering their contact angle behavior in response to external stimuli such as temperature, light, pH, and more. These smart hydrogels can be discreetly coated onto the superhydrophobic layer of the electrodes. This effort involves modifying the superhydrophobic layer using smart hydrogels, which can trigger changes in surface properties, leading to denial-of-service attacks.

BIOENGINEERING PROJECTS DURING POSTDOC TENURE AT NYU ABU DHABI:

(1) BIOINSPIRED FRACTURE MECHANICS OF LEMON PEEL, LEAD: Leading the team, I focus on unraveling why peeling lemons proves more challenging compared to fruits like mandarins and oranges. Our approach involves using diverse techniques: light microscopes, scanning electron microscopes, and micro-CT scans, to explore the intricate multiscale hierarchical structures within lemons. We also employ hardness, indentation, and piercing tests for material characterization. Our objective is to integrate data from these assessments to develop a biomimetic model using physics-based finite element analysis techniques. Preliminary findings were recently presented in an oral talk at the Fourth International Computational Science and Engineering Conference in Doha, Qatar, 2023.

(2) MECHANOBIOCAD (MBC), LEAD: We are currently developing MechanoBioCAD (MBC), a finite element-based tool for error analysis, design optimization, and data analysis in elastomeric micropillar-based force sensing, utilizing both cells and animal models such as C. elegans. As the team lead, my responsibilities include utilizing MBC for data analysis, establishing design guidelines, and quantifying errors in muscle force measurement. Our recent findings were presented as a poster at the prestigious 2023 Gordon Conference on the Physics and Chemistry of Microfluidics in Tuscany, Italy.

(3) LUNG-ON-A-CHIP, IN COLLABORATION: In collaboration with Prof. Mostafa Mobasher, an assistant professor in civil engineering at NYU Abu Dhabi, we are developing lung-on-a-chip using polydimethylsiloxane (PDMS) membrane and microfluidic chips where the aim is to understand the inherent mechanism of oxygen transport through lung's alveoli via biomimetic means. My role is in mechanical characterization of the fabricated membranes with alveoli like features and experiments using a controlled pressure source, the finding of which will be utilized in devising an effective physics-based finite element model.

(4) ORGANOID-ON-A-CHIP, IN COLLABORATION: In collaboration with a group member from Prof. Yong-Ak (Rafael) Song's laboratory, I am involved in a project focused on growing organoids on a chip using stem cells from autistic patients. My role in this project is to simulate the microlevel flows that govern nutrient transport to the organoids, as well as to analyze fluid-structure interactions. This helps us understand the expected shear stress that can potentially affect the growth behavior of these challenging-to-cultivate organoids on the chip.

WORKSHOPS/HACKATHONS ORGANIZED AND OUTREACH

- Biochip Security Workshop and Hackathon, 2022: organized and conducted the first-ever microfluidic biochip event at NYUAD that comprised a half-day workshop and a 24-hour biochip hackathon.
  - The event was aimed and dedicated to familiarizing the students with the working and fabrication of microfluidic biochips, as well as highlighting the need for biochip cybersecurity to ensure trustworthy biochip-based diagnostics.
  - In total, 40 students participated from different universities and high schools in UAE, where they got hands-on experience with the biochips and associated applications such as COVID-19 detection using Fluidigm 192.24 Integrated Fluidic Circuit (IFC) Biochip and Biomark HD tools.
  - Provided the evaluation points, along with other judges, after going through the teams' presentations as my contribution to decide on the winners.

- BioHack3D, Workshop and Hackathon, 2023: organized and conducted the first-ever workshop and hackathon event dedicated to 3D printing of security critical biochips or medical diagnostic devices.
  - Orchestrated the planning and execution of BioHack3D, a CSAW'23 workshop and hackathon on Biochips and 3D Printing Cyber-Physical Security at NYU Abu Dhabi, emphasizing cybersecurity awareness.
  - Highlighted the vital role of biochips in diagnostics, emphasizing their vulnerability to cyber-physical threats, with strong support from NYUAD's Advanced Manufacturing, iGEM team, and Bioengineering Department.
  - Received applications from 20 teams (comprising approximately 100 participants) from across the UAE and selected the top 5 teams to advance to the final round, while guiding the iGEM team for necessary logistics.

MENTORSHIP

- Mentored *Sohini Saha*, a Duke University Electrical and Computer Engineering Ph.D. candidate, in our biochip security project. Sohini has co-authored the cover page article titled "Material-level Countermeasures for Securing Microfluidic Biochips" in the Lab-on-a-Chip journal, as well as "Structural Attacks and Defenses for Microfluidic Biochips" in the IEEE TBioCAS journal, along with several other IEEE conference papers.
- Mentored *Sofija Jancheska*, a Ph.D. candidate in Electrical and Computer Engineering at NYU, focusing on machine learning strategies and academic writing. Sofija co-authored the cover page article titled "Material-level Countermeasures for Securing Microfluidic Biochips" in the Lab-on-a-Chip journal.
- Mentored *Maksat Khobdayev*, an undergraduate bioengineering student at NYUAD, in conducting experiments related to material-level attacks and defenses. Developed his skills in sample preparation, spectral analysis, and the utilization of a confocal microscope. Maksat was a co-author of the cover page article titled "Material-level Countermeasures for Securing Microfluidic Biochips" in the Lab-on-a-Chip journal.
- Mentored *Saleha Firdouse*, an NYUAD Bioengineering undergraduate, in a project involving the development of a Python-based graphic user interface for controlled pressure pump usage in bioengineering and microfluidic applications.
- Currently mentoring *Rayan Alnaqbi*, an NYUAD Civil Engineering undergraduate, in a project focused on bioinspired fracture mechanics of lemon peel.
- Currently mentoring *Mauricio Lamoyi*, an NYUAD Bioengineering undergraduate, in a project involving the development of a lung-on-a-chip using polydimethylsiloxane. The role of Mr. Lamoyi lies in conducting mechanical characterization for finite element simulation on which I have been mentoring him.

REFERENCES

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I certify that the details provided in this CV are accurate and have been personally compiled by me.

Date: 28th August 2024

Place: Abu Dhabi

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