

NSF (#15) Community Stuff

Although scholarly pursuits have been the priority for most of my academic career, interacting positively with my community is what brings me the most satisfaction. Using what I've learned to help raise the standard of living for those around me is a necessary part of my development as a person, and as a member of the community I participate in.

During high school, I was a volunteer tutor during my lunch break for math, physics and English. I continued tutoring during my undergraduate studies in solid state chemistry and was thankful for the opportunity to both learn the material well enough to teach it and to help several students pass their final exams. During college I was able to actively participate in decisions made regarding the departmental community by serving as an elected official of the Society of Undergraduate Materials Students (SUMS). I helped to organize advertising and recruiting events that shared the concepts of materials science and engineering with undecided freshman and the MIT community in general. The other officers and I also planned social events to allow students to interact with professors on a social plane. As an avid pole vaulter, I also coach beginning vaulters at the college level, and was thrilled to be able to apply my knowledge of computational modeling to create an ideal pole bending simulation based on the mass and speed of the vaulter. Thus, I was able to analyze my students' vaults by comparing digital recordings of their vaults to the simulation.

There have also been several opportunities, entirely outside of academia, through which I have been able to contribute. During high school, I worked weekly at St. Anthony's soup kitchen located in the 'tenderloin,' one of the San Francisco's most neglected neighborhoods. I also served as a member of Advocates for the Future, a political awareness group for high school students, through which I published an article concerning affirmative action in California universities. In addition, during the summer of 2001 I volunteered for the Urban Forest, a non-profit organization created to guide the stewardship of local trees to benefit all San Franciscans while ensuring public health and safety.

To merge my desire for community outreach with my research aspirations during graduate school, I will serve as a graduate teaching assistant for undergraduate engineering classes. I also plan to share my research interests and engineering perspective with elementary and high school students through campus-based programs including the Edgerton Center and the Society of Women Engineers chapter. Finally, in gratitude toward the many professionals who have offered academic and career advice throughout my academic development, I will participate in local youth mentorship programs so that I, too, may pass on my experiences in materials engineering and help other young adults cultivate their goals.

Since my earliest memories, math and science have been interwoven with my perceptions of the world. In elementary school I put myself to sleep by doubling numbers in my head until they became exhaustingly large. Nothing suited me more than constructing sturdy teepees in the back yard before lounging around in the grass with a book of logic puzzles. I was excited to push myself in math and science and thus I taught myself geometry before high school so that I could take calculus my sophomore year. At that time, I recognized calculus as just the beginnings of mathematics and not the end, as most high schoolers then believed. This spurred me to supplement my high school math studies at San Francisco State, where I met with a mathematics professor who probed my affinity for math. These interactions prompted me to realize that it was the physical applications of math – engineering – that energized me most.

My engineering explorations began formally at MIT, and favorite classes such as thermodynamics and quantum mechanics reminded me of the logic puzzles I enjoyed a decade earlier. Seeing the concepts for the first time required flexibility and the willingness to view the systems through very different frameworks. The framework of thermodynamics fascinated me especially; it was nearly as limber as reality, but was entirely created by human minds.

In the frenzy of learning that characterized my undergraduate studies, I completed my Bachelor of Science degree in three years. However, my appetite for research had only been heightened throughout my undergraduate career and thus entering graduate school was a natural decision. Nevertheless, I would only resolve to pursue a doctoral degree once I found an advisor under whom a project could become the zenith of my enthusiasm and motivation. Although my interests were still broad during my third year at MIT, I had determined several criterion for the project I would choose: I wanted an advisor who I could interact with closely, a multi-disciplinary project that would allow me to apply my materials science background to a complex problem involving knowledge of several fields, and most importantly a project that strives to directly improve the human state.

After a rigorous search, I chose to work with Krystyn Van Vliet, a new faculty member at MIT. I have selected a project investigating the effects of global and local strain on enzymatic activity of endothelial cells. I am currently taking preparatory classes for the qualification exam and therefore have not begun my research yet. However, it is with great anticipation that I look forward to beginning. I feel that my fertile and vibrant relationship with science, combined with my academic and personal goal of contributing to humanity, compel me to make graduate research my next endeavor. I desire to take part in engineering at its most noble, which strives to characterize and rationalize the natural world with the purpose of increasing scientific knowledge and then to develop technology that benefits others.

NSF (previous research)

My research experiences, in conjunction with the [academic](#) program at MIT, have exposed me to a broad range of fields that I have synthesized to foster a rounded understanding of materials science. Throughout my three years of undergraduate study, I continually increased [my involvement in](#) scientific research, [and](#) I now feel well-prepared to begin original and meaningful research leading to a PhD thesis.

My undergraduate research experience [began during](#) my sophomore year, in the MIT Air-Sea Interaction Laboratory under Dr. Moshe Alamaro. I [applied](#) thermodynamic and fluid mechanics principles to investigate hurricane mitigation possibilities by [developing and conducting](#) experiments that measured [evaporation rates of](#) hexadecanol monolayers [from](#) salt water. Hexadecanol was tested for several variables, including evaporation resistance, spreading rate, lifespan and durability under turbulence. My results suggested that while hexadecanol could spread easily over the sea water and [remain intact for](#) 30-60h, the monolayer did not reform after being disturbed, indicating that hexadecanol was not a feasible option for hurricane control. I was given significant responsibilities on such a small research team and got to know my supervisor and colleagues, who opened my eyes to the diverse research possibilities at MIT and in industry.

During the summer after my second year at MIT, I worked for 3M in the Film and Light Management Technology Center under Dr. Chiu Ping Wong. My project encompassed generating a temperature-dependent mechanical behavior database for several multilayer optical films. I generated many of the tested samples [under a thermally controlled biaxial deformation via a commercial instrument. I then quantified mechanical properties of these film samples via](#) Dynamic Mechanical Analysis (DMA), through which I was able to analyze trends in the collected data as a function of film orientation, film stretch ratio, frequency of oscillations during DMA and post-strain heat treatment. My results, which thoroughly tracked [elastic](#) modulus E and glass transition temperature T_g for all the aforementioned variables, were used in computational models for a new pilot plant and were able to [optimize the processing conditions](#) (temperature [and biaxial strain](#)) for the various materials. During the three months I worked on the project, I developed an intuitive sense for the viscoelastic properties of the polymers I worked with, as well as an understanding of the other engineering components involved in designing a feasible film processing line for a specific product. [Through this independent project,](#) I learned how important it is to network within a company to be as effective as possible.

In my materials processing laboratory [course](#), during my third year of undergraduate studies, I was the group leader of [a four-person](#) team. With the guidance of several faculty, our group designed and fabricated prototypes of polymer-based track spikes. [Computational](#) analysis [via finite element modeling](#) suggested that uniaxially aligned carbon fibers surrounded by an epoxy filler would [achieve](#) the most durable design. The processing challenge was to attain [a sufficiently large volume fraction of](#) carbon fibers. By using a close-packed cylinders model, we calculated the maximum packing density and came within 5% of this theoretical maximum using the method of pull-trusion. We used a lathe to shape the spike and applied a spin-on glaze for a smooth finish [to prevent](#) delamination. Our polymer-based spikes were lighter than any [commercially](#) available spikes and were less likely to cut an athlete's legs than steel spikes. During the second term, I pursued a track and field project related to safety. I decided to create a computational model for the bending of a pole vault pole, during a technically solid jump, based on the athlete's speed at takeoff and mass. Each year there are serious, if not fatal, injuries in pole vault [that may be avoided by improvements in](#) coaching. The purpose of my project was to create a tool to help coaches analyze their vaulters' jumps by comparing them to an ideal model. The initial simulations [successfully predicted](#) pole progressions of Olympic athletes, [and also aided my coaching of novice vaulters.](#)

This past summer I worked at IBM under Dr. Timothy Dalton and Dr. Nicholas Fuller. I [worked with](#) the reactive ion etch (RIE) team [which included](#) two research engineers and one process engineer. Dr. Nicholas Fuller, my direct supervisor, assigned [to](#) me an ambitious sub-project involving the effects of various photoresist ash chemistries on interlayer dielectric (ILD) sidewalls. The purpose of this project was to help facilitate the transition from SiO₂ interconnects to enhanced [silicon](#) (Si, O, C, H) interconnects. To establish a baseline, I first measured blanket photoresist ashing [\(stripping\)](#) rates with various N₂/H₂ and CO/O₂ ash chemistries. However, these results only provided relative data, as the ion bombardment on

horizontal surfaces is far greater than that on the vertical sidewalls. The main obstacle in characterizing sidewall damage done by the photoresist ash chemistries was that angular resolved x-ray photoelectric spectroscopy (AR XPS) was not possible on standard patterned wafer geometries. To overcome this hurdle, I helped to develop a grating lithography pattern for trenches with a critical dimension (CD) of 250 nm, wide enough to perform the analytical tests on the sidewalls. In addition to using AR XPS, I was able to analyze electron energy-loss spectroscopy (EELS) data conducted on several samples. The EELS analysis indicated that the CO/O₂ ash chemistries stripped the photoresist faster but depleted carbon in the sidewalls to a lesser depth than the N₂/H₂ ash chemistries. In addition, I created a design of experiment (DOE) computational analysis to evaluate thoroughly the same effects for a second ILD. I varied several chemistries as a function of gas flow, temperature, pressure and power and found that while power had the greatest effect on ash rates, these alternative chemistries could not provide significantly improved ash rates and therefore were not viable production options. Although this was a short-term project, I was able to gather a significant amount of data and to develop an experimental procedure for characterizing ILD sidewall damage for future researchers. On the whole, my research experience at IBM enabled a tremendous leap in my development as a research scientist and developed my ability to coordinate my plans within a team with a common timeline and set of goals.

Throughout my research experiences and undergraduate studies, I have not only confirmed my enthusiasm for science, but have begun to learn how to be a researcher. I have learned how to model problems, ask the right questions and test hypotheses efficiently. I relish implementing creative ideas in the lab and look forward to laboratory problem solving as part of my daily life. My involvement in long-term projects has taught me about the need for patience and innovation in science, and has convinced me that I am ready to develop and execute a graduate-level research plan.

NSF (research plan)

Through the evolution of my interests, my undergraduate research experiences have included methods for hurricane mitigation, mechanical properties of multilayer optical films, processing and computational modeling for sports applications and reactive ion etch process development. Although I have sampled a non-similar group of research disciplines, I have found that I approach each new project with more confidence in my ability to learn the tools necessary to answer new questions. To continue applying my academic and research skills to my graduate studies, I plan to use my background in mechanical behavior of materials and computational modeling to execute a multidisciplinary project involving biology and mechanics. For these reasons, I aspire to begin graduate level research at the interface among biology, materials and mechanics, with Professor Krystyn Van Vliet in the Department of Materials Science and Engineering.

The research question that I am most enthusiastic about concerns the effects of mechanical stimuli on the enzymatic activity of endothelial cells that line capillaries. The question that my graduate research seeks to answer is the following: Does mechanical strain imposed on cells impact angiogenic potential? Angiogenesis is the sprouting of new capillaries from existing vasculature, and mechanical stimuli may arise due to the mechanical properties of/defects in the vessel or to the deformation of that vessel. Matrix metalloproteases (MMPs) are enzymes of particular interest in this mechanical-biochemical coupling, in that MMPs promote angiogenesis by degrading the extracellular matrix (ECM) that surrounds these cells. Although there is significant interest in biochemical/pharmaceutical control of ECM degradation through MMP regulation, the role of mechanics in this process is largely unexplored. By explicitly coupling mechanical stimuli with biochemical responses of the cell, my research could impact those fields that seek to promote angiogenesis in applications such as cardiac tissue repair and wound healing, as well as those that seek to inhibit this process in order to starve nutrient-dependent growths such as cancerous tumors.

I would approach this question by setting up preliminary experiments that deal with a relatively controlled facet of the problem in order to gain experience with many of the molecular biology techniques that are new to me, such as substrate gel electrophoresis, zymography and western blot analyses. A pilot set of experiments will consist of measuring MMP activity for endothelial cells on a substrate, both as a function of applied strain on the substrate and as a function of the mechanical properties of that substrate. The substrates I would characterize and utilize would include (bioinert) silicone and (biodegradable) poly(glycerol sebacic acid), an elastomer developed by Professor Robert Langer (MIT) and Professor Yadong Wang (Georgia Tech). Through discussions with Professor Van Vliet and current literature on the topic, it has become apparent that designing a device that can simultaneously impose mechanical strain, facilitate visual observation and sustain in vitro culture conditions would significantly contribute to the impact of my research.

In addition to the experimental components of this project, I will develop computational models to validate my hypotheses and form testable predictions of cell response. Professor Doug Lauffenburger (MIT), is developing a computational model based on signaling network properties to predict phenotypic cell decisions. It is my hope that my mechanical-biochemical coupling experiments will facilitate the modification of this model to simulate this signaling pathway accurately. I will also use this computational modeling effort as one indication of which experimental directions hold the most promise for meaningful discovery, and thus will be able to formulate a mature research plan.

I intensely anticipate the inception of my graduate school research and the opportunity to use scientific research principles to explain this, or a similar, phenomena. I realize that any doctoral research project will require perseverance, patience and the implementation of an effective research strategy.