Student: Narek Akopyan  
Professor/Sponsor: Professor Liwei Lin  
Mentor: Dr. Ryan Sochol  
Research Project Title: Micropost Traction Force Quantification

Abstract:  
Microfabricated posts were designed to advance cell handling techniques, which is useful for research in biology. By creating stiffness and interpost spacing gradients along the micropost array, bovine aortic endothelial cells (BAECs) were observed to unidirectionally migrate. The cells migrated in directions of increasing micropost stiffness and decreasing interpost spacing. The goal was to quantify the forces that the cell pushed or pulled on the microposts in order to move in one direction. These forces were calculated by taking microscopic images of the immovable bottom of the micropost array which was stuck to the substrate and the top of the micropost array which moved due to the forces applied by the cell. By applying the general Hooke’s Law, forces were related by the displacement each micropost moved since each cantilever could be approximated as a spring. With aid of image processing software, micropost traction forces were quantified, and the edges of the cells were found to pull more strongly on the microposts compared to the center of the cell. The forces were found to pull inwards towards the center of the cell causing unidirectional cellular migration due to the variable stiffness and spacing gradients.

Student: Eugene Chao  
Professor/Sponsor: Professor Lydia Sohn  
Mentor:  
Sub Area: Biomechanical Engineering & Health  
Research Project Title: Single Cell Analysis Using Microfluidic Devices

Abstract:  
This semester, I have participated in the single cell analysis using microfluidic devices project at the Sohn lab. The major goal of the project is to fabricate microfluidic devices that are capable of screening multiple biological markers on single cells such as CTC and stem cells. In particular, I am responsible for data analysis and instrumentation. I familiarize myself with data acquisition and analysis software like LabVIEW and write routines that are capable of analyzing cell characteristic signals. I tried out various filters to strengthen the signal to noise ratio and wrote LabVIEW algorithms that can detect and analyze the filtered signals. I have started transitioning our LabVIEW routine into FPGA format, which would make real time data acquisition and analysis much more efficient. I also worked on the instrumentation this semester. Tasks include fixing and replacing broken circuit parts, and exploring methods to facilitate parts such as pump.

Student: Yongkeun Choi  
Professor/Sponsor: Professor Liwei Lin  
Mentor: Dr. Nazly Pirmoradi  
Subarea: Bioengineering  
Research Project Title: Magnetic Actuation System for an Implantable Micro Drug Delivery System
Abstract:
The main goal of this project is to manufacture a Magnetic Actuation System for an Implantable Micro Drug Delivery System. This Micro Drug Delivery System is a MEMS device which is attached to a rabbit eye. In order to actuate this MEMS device, the gradient of 0.016 T/mm is needed to be "on" and "off" on the MEMS device for 2 hours of experiment with 10 seconds of each state ("on" state means 0.016 T/mm on the device and "off" state means the value close 0 T/mm on the device). To achieve the gradient of 0.016 T/mm, a pair of coils with equal currents running in opposite direction is used in order to generate uniform magnetic field gradient between two coils. Each of a coil has 1000 turns of copper wires and one of them has a magnet at the center of it. To achieve the gradient to be "off" state, a coil with magnet simply is moved away from the MEMS device.

The Magnetic Actuation System consists of two components: a platform to hold a rabbit and a stand to hold two coils. Those two were carefully designed in order to cover all possible degrees of freedom. The challenging part in manufacturing the system was that it must be designed with only non-magnetic materials which sometimes were not strong to hold heavy weights. In addition, thermal analysis was performed on two coils to anticipate the temperature from the current going through the copper wires. Also, a circuit was designed for its automation process. As a result, 2 Amp of current was needed to achieve the gradient of 0.016 T/mm, which was "on" state, on the device and a coil with magnet was moved away by 1 cm from the MEMS device to achieve the gradient of 0.0055 T/mm, which was "off" state.

Student: Yongkeun Choi
Professor/Sponsor: Professor Liwei Lin
Mentor: Dr. Nazly Pirmoradi
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Abstract:
Developing microfluidic components capable of autonomously operating at ultra-low Reynolds numbers (e.g., Re<0.2) is necessary for the advancement of microfluidic circuitry for "lab-on-a-chip" applications in the biological and chemical fields. Previous work has been performed using poly(ethylene glycol) diacrylate (PEGDA) for both the operating fluid (in liquid form) and as the material for the microfluidic components (when cured using a photoinitiator). For use in most biological applications, however, such systems must be tested with water-based fluids, such as phosphate buffered saline (PBS). Prior studies have found swelling and stiction to occur when PEGDA-based microfluidic components are exposed to such water-based fluids. To overcome such problems in this study, we studied the use of differing combinations of PEGDA, polysorbate 20, and the photoinitiator 2,2-dimethoxy-2-phenylacetophenone as the material for various microfluidic components, namely spring, domino, and snap-open diodes. Additionally, the effects of different exposure intensities and times were also studied. All components were fabricated in situ via an optofluidic lithography process. Experimental results found that a mixture in which a PEGDA to polysorbate ratio of 60:40 by volume was cured using photoinitiator that was 35% of the mass of the initial PEGDA/polysorbate 20 mixture performed the best in PBS. Additionally, pressures of around 40 to 100 millibars were necessary for the functioning of the microfluidic components.

Student: Jimmy Huang
Professor/Sponsor: Professor Hayden Taylor
Research Project Title: Chip-Scale Imprinter with Integrated Optical Intereference for Calibrating Models of NIL Resists

Abstract:
Traditional techniques in collecting rheological information from sub-micron thickness polymers involve imprinting each resist material at several temperatures and then having the resist undergo optical profilometry, a time-consuming procedure.

To enable faster and more thorough characterization of many resist and stamp material combinations, we are interested in the development of a compact imprinting device that can be placed under an optical microscope to visualize the nanoimprinting processes in real time and extract rheological information about the films being imprinted.

Multiple reflections from the top and bottom of the deformed resist layer result in distinct colored interference patterns that can be captured by the microscope and subsequently analyzed using computer software. These color patterns can then be used to map a given location's red green and blue (RGB) light composition to the location's residual layer thickness (RLT). The mapping of colors to layer
thicknesses depends on the refractive indices of the stamp, substrate and resist materials, and contrast may be enhanced by depositing a semi-reflective coating on to the transparent stamp.

The focus of this paper is the development of software that predicts thicknesses based off of an area's RGB composition. The software contains two major sections: The first is the creation of a 4D reference matrix based off of a calibration stamp with known topography. This matrix will be able to take in 3 RGB inputs to predict a single RLT output. The second is the fitting algorithm that takes in unknown video topography and outputs RLT estimates based on the calibration matrix.

References:

Student: Seoho Jung
Professor/Sponsor: Professor Liwei Lin
Mentor: Alina Kozinda
Research Project Title: Aligned Canbon Nanotube Forests for Energy Storage Devices

Abstract:
Electrochemical capacitors, or supercapacitors, are energy storage devices whose advantages include high power density, fast charging, and long cycle life. Carbon nanotubes (CNTs) have been expected to be excellent capacitor electrode materials due to their large surface area, sufficient storage spaces for electrolyte ions, and high electrical conductivity. This study analyzes the performances of densely aligned CNT forests with built-in bottom metal electrodes when CNT growth length and type of electrolyte are varied. In 1-ethyl-3-methylimidazolium tetrafluoroborate (EMIM-BF4) ionic liquid, when the CNT growth length of a 10 mm x 10 mm electrode changed from 9 µm to 30 µm, capacitor charge time increased from 1.3 s to 8 s, approximately by 520 %. The effects of different electrolytes - aqueous and ionic liquid - on electrode performances have also been examined.

Student: Seoho Jung
Professor/Sponsor: Professor Liwei Lin
Mentor: Alina Kozinda
Research Project Title: Canbon Nanotube Supercapacitor Electrode in Ionic Liquid

Abstract:
This study builds and tests electrochemical capacitors that consists of aligned carbon nanotube (CNT) forests as the electrodes and 1-ethyl-3-methylimidazolium tetrafluoroborate (EMIM-BF4) ionic liquid and the electrolyte. Aligned CNTs have been expected to make better capacitor electrode materials than activated carbons (ACs) because they have large surface area, sufficient storage spaces for electrolyte ions, and high electrical conductivity and because they provide better conducting paths to ions and electrons. In addition, ionic liquids are considered to have advantages over aqueous and organic electrolytes in terms of power and safety. When the CNT growth length of a 10 mm x 10 mm electrode changed from 9 µm to 30 µm, capacitor charge time increased from 1.3 s to 8 s.
Abstract:
Circulating Tumor Cells found in the blood stream have shown to be a dependent biomarker for many Cancers. There have been numerous approaches in the isolation of CTC's as a cancer diagnostic, most with some form of active sorting requiring the use of functionalized antibodies. This is both expensive, and slow, as the flow rate needs to be low so that cells have enough time to interface and bind with the antibodies. Furthermore, most groups also do not use whole blood, thus adding another barrier to real patient application. Our group looks at using a multistage multistep sorting system. Whole blood is first put into a hydrodynamic focusing step that utilizes inertial and dean flow to filter out red blood cells from white blood cells and the CTC's. The white blood cells and CTC's are then sent through a device that has a structural impedance that resembles a weir, which sorts the white blood cells from the CTC's. Though the process is still slow overall due to the nature of microfluidics, this process can easily be implemented in a parallel manner. We have seen 98% efficiency in the past which is comparable if not better than current methods.

Abstract:
The most lethal of gynecology cancers, ovarian cancer is one of the most difficult to study, due to its extreme heterogeneity. This heterogeneity is due to its increased likelihood of undergoing epithelial-mesenchymal transition (EMT), a progression towards malignancy through loss and gain of epithelial and mesenchymal characteristics, respectively. Cells undergoing EMT not only seem to evade detection, but also are resistant to chemotherapeutic drugs. In order to better understand EMT in ovarian cancer, I will evaluate the relative gene expression of selected epithelial and mesenchymal markers throughout the phases of EMT. I will induce EMT in ovarian epithelial cells, SKOV-3, through the introduction of either transforming growth factor β (TGF-β) or thrombin, both of which have been shown to induce EMT in SKOV-3 cells. The respective phenotype of the cell, at a specific stage of EMT, can be determined via expression of specific markers, including E-cadherin (CDH1), pan-cytokeratin (PCK), and vimentin (Vim). I will sort the cells via fluorescence-activated cell sorting (FACS) or magnetic-activated cell sorting (MACS) based on expression levels of CDH1, CDH2, and KRT19. The latter two are selected for the cell sorting section instead of PCK and Vim because they are surface markers whereas Vim/PCK are cytoplasmic. I will utilize quantitative real time polymerase chain reaction (qRT-PCR) to quantify gene expression levels of genes specific to ovarian cancer (e.g. BRCA1, BRCA2, HNF1B, MUC16), which will be selected based on our collaborator's, Professor Haiyan Huang's, HiSeq analysis on SKOV-3. Through this more comprehensive understanding of how ovarian cancer cells change phenotypically and genotypically throughout EMT, my work could potentially allow for earlier diagnosis, improved treatments, and a basis for new therapies.
Abstract:
My research this semester has been focused on creating a robust testing device for the harsh environment sensors that we design in BMAD as part of our integrated Microelectromechanical Systems (MEMS). Specifically, we needed to be able to test the capabilities of inclinometers at high temperatures with 600 °C being our target temperature. Additionally, this testing device would be capable of mounting on an inclinometer test-stand that was previously used in the lab to measure the accuracy of the inclinometers independent of temperature. Previous attempts to test these sensors at temperature included a high temperature IR-lamp and a vacuum chamber, however, neither of these two set-ups gave us the ability of measuring inclination while being at temperature. The device that we constructed needed to achieve a 600 °C operating temperature on the sensor surface, be compatible with the inclinometer test stand, and be able to house our sensor and sense data from it.

The device that we designed and manufactured consists of two boxes. The first one is an aluminum electric box fitted with a 120 W strip heater which goes to temperature and houses the sensor. Holes for thermocouples and high-temperature wires allowed us to perform characterization on the box and will allow us to connect to the sensor for data acquisition. The second box is a control box fitted with a Fuji controller that allows us to regulate the temperature of the box to desired levels. We characterized the heater box using four thermocouples connected to various parts of the set-up and a LabView VI to analyze the behavior of the box as we tried to reach temperature. The first test was not promising; the box fell far short of our target temperature at 340 °C. We proceed to modify the box to increase the temperature, eliminating heat loss and taking advantage of certain materials' lower coefficients of thermal conductivity, such as steel and ceramic. We were able to finally achieve 600 °C on the sensor surface. For the first time, we will be able to measure inclinometers at the high temperature they were designed for.

Recently, testing has been slowed by malfunctions with the gold wire-bonder. To avoid having experimentation being reliant on NanoLab equipment, we have begun developing our own probe-pin station that is compatible with this set-up (inclination and temperature). This will allow us to sense data from our sensors without wire-bonding them to our ceramic plates which run our high-temperature data wires. What we have concluded is that it is possible for us to now test harsh-environment sensors at high temperature and with inclination. Furthermore, our probe-pin set-up will give us full testing capabilities without being reliant on the NanoLab equipment. Pursuant to the work done so far, we will begin characterizing the sensors at temperature intervals using the set-up to analyze their behavior and correlate it to theoretical work.

Student: Edgar Ramos
Professor/Sponsor: Professor Liwei Lin
Mentor: Dr. Nazly Pirzoradi
Subarea: Bioengineering
Research Project Title: Implantable Micro Drug Delivery System

Abstract:
An actuation device for an implantable micro drug delivery system was designed and fabricated. The design called for the use of nonmagnetic components. This limited the design materials to aluminum
and various polymers. The design parameters were obtained with the use of Finite Element Method Magnetics (FEMM) simulations. A series of simulations were performed in order to ensure similar results after the fabrication process. During hardware testing, it was found that there were noticeable discrepancies between simulation and experimental material properties. However, the design was modified to adapt to the new properties. Through experiments and simulations, it was found that the actuation device would theoretically actuate the drug delivery system. From this, it can be concluded that the actuation device is ready for in-vivo experimentation.

Student: Andrius Raulinaitis  
Professor/Sponsor: Professor Liwei Lin  
Mentor: Dr. Ryan Sochol  
Research Project Title: 3D Printed Microbead Arraying for Microfluidic Reactors

Abstract:
Microfluidic reactors utilizing microbeads are ideal for multi-stage mixing processes due the benefits of small-scale microfluidics. This report presents the design considerations and results of attempting 3D printed prototyping of these "lab-on-a-chip" devices as opposed to the traditional soft lithography techniques. Our testing revealed that the support wax deposited by the 3D printer could not be removed from the interior channels of the devices designed for 74.6 µm and 100 µm beads. Support wax was successfully removed from the devices designed for 196 µm beads - allowing the further testing and development of designs with this process. Preliminary testing of this size of device, however, indicated the failure of beads to enter the devices. This prompted a redesign of the device. The new device design implements larger channels for bead flow, as well as using equations for microfluidic resistance to ensure bead trapping. At the time of this report, testing has not yet been conducted on the new design of the device.

Student: Niloofar Shahmohammadhamedani  
Professor/Sponsor: Professor Liwei Lin  
Research Project Title: Electrical Integrated Circuits and Lab On Chips

Abstract:
Electrical integrated circuits and their application is wide known to us. Same concepts can be used to make fluidics circuits in which the carries instead of electric charge, is fluid. In these devices pressure difference is used to control the flow; the same way as in electrical circuits where difference in voltage causes charge to flow. The very same concepts can be used in fluidics circuits. For example just as in circuits where we can build logic gates, we can build binary states in fluidics circuits to perform Boolean logics. Doing so, we can build any function that we wish with fluidics circuits. For instance, we can build functions such that they perform as a Diode, or transistors.

In order to make such device, the microfluidic system was fabricated by optofluidic lithography method. The process contained soft-lithography process using PDMS and glass slides bonded with them. First the device is loaded with PEGDA (1% photo initiator) and a photo mask is aligned with the device. Then a short amount of UV exposure creates the channels inside. The same way that integrated circuits revolutionized the field of electricity, the fluidic circuits can revolutionize biology and chemistry field.
One major application of this idea is building "Lab-on-chips". These devices are portable labs in which manipulation and mixing of the fluids can take place on. Eventually "Lab-on-chips" are hoped to replace the expensive labs and reduces the costs dramatically. This can be very beneficial first because the cost of having lab on chips is substantially less than having lab both cost wise and also in terms of transportation and accessibility especially to countries where transporting medicine is problematic. One limitation in this technology however in this case, controlling the pressure is problematic. The devices to change the pressure and control the flow are expensive and not as accessible.

Student: Jessica Sun
Professor/Sponsor: Professor Liwei Lin
Mentor: Dr. Nazly Pirmoradi
Subarea: Bioengineering
Research Project Title: Use Of Flow-Focusing Devices To Generate Microcapsules With Magnetic Nanoparticle-based Shell And Fluorescent Aqueous Core For Drug Delivery Applications

Abstract:
We carried out a method to create successful magnetic core-shell particles using microfluidic devices, which can be used for remote delivery of therapeutic drugs. Using a consecutive flow-focusing device, a surface modification method to control the surface energies of the reagents, and various surfactants, we were able to initially form double emulsions with polyethylene diacrylate (PEGDA) shells and aqueous cores. Building upon that, we present three specific accomplishments: (1) the formation of a magnetic PEGDA-based magnetic composition with the incorporation of 10 wt % iron oxide coated nanoparticles (10nm diameter), (2) the use of the device to generate magnetic capsules (206 μm diameter, 13 μm standard deviation) with fluorescent cores (95 μm diameter, 7 μm standard deviation) via selective polymerization with red fluorescent water (250 nm nanobeads) as the continuous phase and a 5 wt% surfactant background water environment, and (3) UV curation of the magnetic microcapsules and subsequent manipulation via an external magnetic field.

Regarding surfactants, polysorbate (Tween) 20 was found to be the most successful to incorporate into the PEGDA-based magnetic composition and poloxamer 406 (Pluronic F127) into the water environment. Regarding flow rates, the most successful capsules were generated via syringe pumps with flow rates of 2.0 µL/min, 7.0 µL/min, and 22.0 µL/min for aqueous core, magnetic PEGDA shells, and water environment, respectively. The flow rate ratios at the T junction of the device were pertinent in determining optimal droplet sizes.

The magnetic microcapsules created have implications in controlling the transport of therapeutic agents to target sites in the human body as well as on-demand rupturing via application of a magnetic field, which releases the aqueous payload into the body or other site. This novel class of microcapsules offers great potential for an alternative to traditional organism-based vaccines.

Student: Eric Sweet
Professor/Sponsor: Professor Liwei Lin
Mentor: Dr. Ryan Sochol
Subarea: Bioengineering
Research Project Title: Design and Manufacturing of 3D-Printed Microfluidic Channel Screw Connectors
Abstract:
3D printing technology is rapidly improving every year in resolution, diversity of materials and lower cost of operation, and with it arise new viable applications in the field of micro-scale mechanical device manufacturing.

In this research we employ a high-resolution photolithographic 3D printer to design and manufacture compact working 3D-printed three-dimensional microfluidic channel geometries and chip components for lab-on-a-chip biological testing devices.

The objective of my research project, the specific subject of this is report, is to design a micro-scale threaded screw connection design for the linking of microfluidic channels together end-to-end at as small of a scale as a high-resolution 3D printer is capable of producing. The primary goals are thus to both produce a viable screw connection design as well as to explore the capabilities and limitations of 3D-printing to produce sufficient detail at micro-scales. Smaller successful screw connections can allow for smaller microfluidic channels and more compact and space-saving chips. The latest stages of testing are yielding successful connections for microfluidic channels smaller than predicted and previously produced.

This innovatively small channel connection design will allow for more flexibility in placement of linkages, which can permit, for example, the creation of modularly-designed microfluidic channels, circuits or chips, or to connect microfluidic channels post-manufacturing. This in-turn can expand the capabilities and applications of microfluidic devices.

Student: Eric Sweet
Professor/Sponsor: Professor Liwei Lin
Mentor: Dr. Ryan Sochol
Subarea: Bioengineering
Research Project Title: Development of 3D Printed Microfluidic Capacitors

Abstract:
Self-regulating microfluidic circuitry components capable of ultra-low Reynolds number (Re < 0.1) operations in on-chip applications allow the advancement, improvement and optimization of integrated microfluidic circuitry used for a variety of biological and medical applications. The M3B 3D-Printing lab group's overarching goal is to revolutionize the manufacturing of aforementioned microfluidic components with the use of ultra-high resolution 3D printing. Suspended structures impossible to construct using standard manufacturing processes, such as sinusoidal membranes, springs, pistons and hollow three-dimensional cavities, are manufactured with ease using dissolvable wax support material as a foundation using a 3D printer. The motivation behind the development of 3D printed capacitors is to create a three-dimensional circuitry component capable of storing a predictable and reliable amount of fluid under pressure. When integrated into a larger microfluidic system as one component, this powerful device can behave akin to its electrical counterpart, the electrical capacitor, storing fluid for timed-release and allowing the customization of fluid flow parameters over the entire circuit.

The most successful capacitor design was found to have an optimal sinusoid 150 microns thick, 250 microns in amplitude and has eight periods, with an overall diameter of roughly 20 mm. This capacitor is capable of 450 cubic millimeters of fluid storage and a numerical relationship between pressure and displacement of the sinusoid has been created. Said model can be used to operate this specific capacitor
design under specific pressures to produce a desired volume change and displacement. Future applications of the flexible sinusoidal membrane include use in isolated channel transistors, gates, fluid regulators and a customizable capacitor. From a qualitative and qualitative standpoint, a functional microfluidic capacitor has been successfully manufactured and adheres well to a numerical model.

Student: Sunita Venkatesh
Professor/Sponsor: Professor Liwei Lin
Mentor: Dr. Ryan Sochol
Research Project Title: 3-D Printed Integrated Microfluidic Circuitry

Abstract:
Autonomous fluidic components are critical to the advancement of integrated micro/nanofluidic circuitry for lab-on-a-chip applications. The standard method of fabrication for these devices involve the soft lithography process which demands extreme precision and is constrained by the 2-D masking process. A novel way to fabricate microfluidic structures and self-regulating microfluidic circuitry components is to use 3D printing. 3D printing has evolved to have resolutions better than 20 microns and can quickly and accurately fabricate a desired device. 3D printing also allows devices to have 3-dimensional features including springs, balls and hinges. This semester, the primary point of investigation was characterizing the ProJet 3D printer in the Sutardja Dai Invention Lab and beginning to fabricate integrated microfluidic components.

The most common microfluidic circuitry component is the diode. It allows fluid to travel in only one direction. We created several designs for fluidic diodes in SolidWorks before 3D printing them. Over the past semester, an optimal design was chosen. Figure [1] shows the spring diode, which pushes outward when fluid travels right through the channel but closes the channel when fluid travels the other direction. The spokes on the outside edge of the channel are guides to keep the spring head from falling too far from the channel entry point.

Student: Ki Tae Wolf
Professor/Sponsor: Professor Liwei Lin
Mentor: Dr. Fatemah N. Pirmoradi
Sub Area: Bioengineering
Research Project Title: Finite Element Analysis of Remotely-Controlled Drug Delivery via Magnetically-Responsive Membrane

Abstract:
The current project continues from previous semester’s progress on finite element analysis (FEA) techniques to modela magnetically-responsive elastomeric composite membraneactuated to deliver drug compounds in various ocular layers from sclera to retina by means of diffusion and convection. Previous semester's work included 2D axis-symmetric FEA modeling based on diffusion of drug compound inside the reservoir, cavity enclosed by the membrane and eye tissue, and eye layers. This semester work combines Fluid-Structure Interaction (FSI) and Transport of Diluted Species modules. By combining two physics modules together, the simulation produces calculated values from a setup that is more comparable to actual physical process of drug delivery, thus giving a better understanding towards drug delivery device’s interaction with ocular layers under microfluidic environment. The simulation is constructed to simulate a drug delivery device in 2D axis-symmetric environment with dimensions given
from the standard manufacturing procedure or the actual device used on the experiment with major interaction in composite membrane that is composed of silicone elastomer, poly(dimethylsiloxane) (PDMS), incorporated with iron-oxide nanoparticles. (Pirmoradi et al., IEEE MEMS 2013) By applying uniform forces (originated from the magnetic field) with varied magnitude on the membrane, deflection of the membrane and the fluidic velocity and pressure profile caused by the deflection can be obtained. Obtained fluidic velocity profile is then applied in drug diffusion and convection process, creating drug concentration profile in the model. The model also addresses methods in coupling of FSI and Transport of Diluted Species in COMSOL with focus on computational elements such as meshing, conditional re-meshing, and coupled solver settings. Typical errors and warnings during the particular model as well as methods to minimize them are addressed. Then, possible methods and design modifications are suggested from the simulation to optimize drug delivery in the actual device. Finally, inclusion of extra physics module and modification of current physics module to give a drug delivery process that resembles actual ocular drug delivery are discussed.

Student: Ki Tae Wolf  
Professor/Sponsor: Professor Liwei Lin  
Mentor: Dr. Fatemah N. Pirmoradi  
Subarea: Bioengineering  
Research Project Title: Finite Element Analysis of Magnetically Controlled Osmotically Powered Drug Delivery System

Abstract:
This semester's project focused on finite element analysis of a novel version of osmotic pump. Instead of typical applied pressure-based pumps, osmotic pumps utilize osmotic pressure from concentration difference across a semi-permeable membrane, motivating a fluid flow towards region of higher salt concentration. The pump's relative simplicity in design and operation provides advantage in creating cheap and effective implantable pumps for drug delivery. Typical micro-scale osmotic pumps have been widely available and well studied. However, this novel version of osmotic pump, which has been designed, manufactured, and tested by researchers from King Abdullah University of Science and Technology in Saudi Arabia (KAUST) utilizes a magnetically and temperature responsive semi-permeable membrane to add an extra degree of fluid control. This extra degree of fluid control is aimed to mitigate one of the major disadvantages of osmotic pumps; as an osmosis-driven pump, fluid can be infused when osmosis occurs, but once osmosis occurs, amount of fluid inflow cannot be directly controlled within the pump. Although osmotic pumps have been well studied, new addition of fluid control and extreme geometric constraints applied to test the pump's performance create a need to utilize finite element analysis of the model to better understand the pump's operation. Finite element analysis was run by COMSOL Multiphysics, commercially available multiphysics software. The simulation was constructed in 2D-axisymmetric environment. Due to complex nature of the entire osmotic pump system, simulations were divided into several sections for more effective analysis of pump's operation. Fluid-Structure Interaction physics module has been used to perform the major analysis of the main section of the pump. The model also focuses on addressing any computational issues such as mesh inversion and quality loss due to changing geometry of the model over time. The model includes the analysis of osmotic influx of fluid and semi-permeable membrane and study of drug release rate through the membrane. The finite element analysis of the model suggests possible design and method modifications for the osmotic pump to optimize fluid flow through the device for disease applications.