AGENDA

Tuesday May 10, 2016 – Center for Integrated Manufacturing Studies –CIMS

8:00 am    Registration and Continental Breakfast, Upper Lobby – SLA Hall – 2210/2240

8:30 am    Opening Remarks, Ryne Raffaelle, Vice President for Research at RIT.

Invited Talks

Session Chair: Robert Pearson

8:40 am    Can applied electric fields control colloidal deposition on polymer surfaces?
Michael Schertzer, KGCOE Mechanical Engineering, RIT, 2015 RIT-TI Douglass Harvey Faculty Development Award.

9:10 am    Bayesian Analysis for Photolithographic Models, Andrew Burbine (’13, ’16 µE), RIT.

9:40 am    Coffee Break

10:00 am   Magnetic Nanocomposite Smart Skin, Ahmed Alfadhel (’10 EE), Computer, Electrical and Mathematical Sciences and Engineering Division (CEMSE), King Abdullah University of Science and Technology (KAUST).

10:30 am   Silicon Photonics Processing Challenges for an Advanced Node Foundry, Jeremiah Hebding (’03, ’08 µE), Derivatives Integration Engineering, SUNY Polytechnic Institute.
11:00 am Low-temperature Heterojunction Solar Cells and Advanced RF Switches, Ken Nagamatsu ('10 µE), Northrop Grumman Corporation.

11:30 am Poster Session

noon Luncheon, Louise Slaughter Hall 2220 - Dinosaur Barbeque (a Rochester Tradition)

Invited Talk

Session Chair: Santosh Kurinec

1:30 pm Revolutionary Kerfless Wafer Manufacturing via the Direct Wafer™ process, Steve Hudelson, Director Growth at 1366 Technologies, Inc.

Talks from RIT Microelectronic Engineering Students

2:00 pm Ferroelectric HfO2 Thin Films for FeFET Memory Devices, Joe McGlone

2:12 pm Fabrication of Electrostatically Actuated MEMS Switch, Mattias Herrfurth

2:24 pm Directed Self-Assembly using PS-b-PMMA Block Copolymers, Jacob P. Kupernik

2:36 pm Direct Write Optical Waveguide Fabrication in organic films using a Heidelberg Laser Writer, Ryan Moss

2:48 pm Optimization of Transmission Line Measurement (TLM) Structures for Contact Resistivity Determination, Sidhant Grover

3:00 pm Coffee Break and Poster Session

Session Chair: Dale Ewbank

3:30 pm Process Development Challenges Associated with Gallium Nitride Materials, Eric Evangelou

3:42 pm Silicon Photonic Devices Manufactured Using Double-Patterned i-Line Lithography, Patsy Cadareanu

3:54 pm Fabrication of a MEMS Comb Drive Actuator, Adam Banees

4:06 pm CD Reduction through Annular Illumination and Sidewall Spacers, Corey Shay

4:18 pm Flash Lamp Annealing for Dopant Transfer and Activation in Low-Temperature Polycrystalline Silicon, Nicholas Hawkins

4:30 pm Poster Session
Can applied electric fields control colloidal deposition on polymer surfaces?

Michael John Schertzer¹ (collaborating with Kara L. Maki²)
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From 2012 to 2013, the global market for optoelectronic devices such as touch screens, liquid crystal displays, organic light emitting diodes, electroluminescent devices and solar cells, increased by 7.5% to $7.2 billion USD. Robust growth in this market is expected to continue with the development of flexible electronic circuits that can be used in many of the same applications. Transparent conductive films (TCFs) are a critical component in all of these devices. These films typically consist of a transparent conductive oxide. Unfortunately, patterning conductive oxides requires expensive fabrication techniques and their brittle nature makes them unsuitable for use in flexible electronics. As such, new fabrication methods are necessary to integrate TCFs in flexible electronics.

Inkjet printing of fluid containing conductive micro- or nanoparticles is one fabrication technique for flexible electronics. Recently, improvements in feature size have been achieved by exploiting microscale fluid mechanics referred to as the coffee-ring effect. Unfortunately, this method is restricted to simple shapes and surface defects can cause non-uniformities in the printed feature. The coffee-ring effect is generally the result of the interplay between evaporative and surface tension effects. Application of an electric field to a colloidal droplet as it evaporates has the potential to disrupt the interplay between these effects by introducing an electrowetting force at the contact line and an electrophoretic force on charged colloids in a droplet. This work will examine the effect of various parameters on colloidal depositions while asking whether applied electric fields can be used to control colloidal deposition in these cases.

Biography:

Michael J. Schertzer received the Bachelor of Engineering and Management and Master of Applied Science degrees from the Department of Mechanical Engineering at McMaster University in Hamilton, Ontario, Canada. He earned his Doctorate in the Department of Mechanical and Industrial Engineering at the University of Toronto for his work characterizing the motion and mixing of droplets in Electrowetting on Dielectric Devices. Before joining the Mechanical Engineering Department at RIT, Dr. Schertzer held a Postdoctoral Fellowship in the Department of Mechanical and Industrial Engineering at the University of Toronto where he focused on integrating his contributions into a point of care medical diagnostic device. During this time, he also had the opportunity to collaborate with a medical diagnostic company in the Toronto area while examining surface tension related phenomena in DNA Microarrays.

Dr. Schertzer’s Discrete Microfluidics Laboratory at RIT is focused on facilitating transformative technologies in advanced manufacturing, diagnostics, and energy by furthering the fundamental understanding of the interactions between fluids, particles, and electric fields.
Bayesian Analysis for Photolithographic Models

Andrew Burbine (’13, ’16 µE)

The use of optical proximity correction (OPC) as a resolution enhancement technique (RET) in microelectronic photolithographic manufacturing demands increasingly accurate models of the systems in use. Model building and inference techniques in the data science community have seen great strides in the past two decades in the field of Bayesian statistics. This work aims to demonstrate the predictive power of using Bayesian analysis as a method for parameter selection in lithographic models by probabilistically considering the uncertainty in physical model parameters and the wafer data used to calibrate them. We will consider the error between simulated and measured critical dimensions (CDs) as Student’s t-distributed random variables which will inform our likelihood function, via sums of log-probabilities, to maximize Bayes’ rule and generate posterior distributions for each parameter. Through the use of a Markov chain Monte Carlo (MCMC) algorithm, the model’s parameter space is explored to find the most credible parameter values. We use an affine invariant ensemble sampler (AIES) which instantiates many walkers which semi-independently explore the space in parallel, which lets us exploit the slow model evaluation time. Posterior predictive checks are used to analyze the quality of the models that use parameter values from their highest density intervals (HDIs). Finally, we explore the concept of model hierarchy, which is a flexible method of adding hyperparameters to the Bayesian model structure.
Magnetic Nanocomposite Smart Skin

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Recent progress in the development of artificial skin concepts is a result of the increased demand for providing environment perception (e.g. touch, vibration and flow sensing) to robots, prosthetics and surgical tools. Tactile sensors are the essential components of artificial skins and attracted considerable attention that led to the development of different technologies for mimicking the complex sense of touch in humans. Our approach to tactile sensing is inspired by microscale hair-like cilia receptors found in nature, which are attractive for sensing applications, due to extremely high sensitivity and outstanding performance.

We developed novel magnetic nanocomposite artificial cilia sensors, which exhibit a high performance in terms of sensitivity, power consumption and versatility. The nanocomposite is made of iron nanowires (NWs) incorporated into polydimethylsiloxane (PDMS). Iron NWs have a high remanent magnetization and coercivity, due the shape anisotropy; thus, they are acting as nanoscale permanent magnets. This allows remote device operation and avoids the need for a magnetic field to magnetize the NWs, benefiting miniaturization, integration and the possible range of applications. The magnetic properties of the nanocomposite can be easily tuned by the NWs concentration or by aligning the NWs during the fabrication process to define a magnetic anisotropy. The nanocomposite is easily patternable, corrosion resistant, biocompatible, and can operate in humid and high temperature environments. The stray field exhibited by the nanocomposite cilia is measured with an integrated magnetic sensor. When the cilia are bent by vertical or shear forces, their stray field changes and can be detected. The tactile sensor can operate in dry and wet environments with the ability to measure different properties with easily modifiable performance. Tactile sensors were realized on flexible and rigid substrates that can detect static and dynamic forces with tuned sensitivity, resolution, and operating range. Various dynamic studies were conducted with the tactile sensor demonstrating the detection of flow, moving objects, textured surfaces, and even Braille characters with extremely low power consumption of 80 nW.

Ahmed Alfadhel is a PhD candidate in electrical engineering and a research fellow at the Sensing, Magnetism and Microsystems research group, at King Abdullah University of Science and Technology (KAUST) in Saudi Arabia. He received his BS degree in Electrical Engineering from Rochester Institute of Technology (RIT), in 2010, and his MS degree in Electrical Engineering from KAUST in 2012. His research interests are in the fields of micro- and nano magnetic devices and sensors, nanofabrication, nanocomposites, and microfluidics. He is a member of the IEEE society. Ahmed is also a co-founder of SONATE Inc., a start-up company that fabricate high quality nanoporous membranes, and metallic nanowires. His research work and entrepreneurial activities led him to be nominated by the MIT technology review to be in the list of “2016 innovators of the year under 35 in the Middle East”.
Silicon photonics processing challenges for an advanced node foundry

Jeremiah Hebding ('03, '08 µE), Derivatives Integration Engineering, SUNY Polytechnic Institute.

Silicon photonics has moved forward to the point that it is emulating the dramatic successes seen in the CMOS electronics industry over past years. Challenges arise in development foundries when balancing the shared tooling and resources in the foundry to the unique photonic integrated circuit processing requirements and the more standard processes used in advanced CMOS nodes. The foundry at SUNY Polytechnic has proven highly capable at delivering state of the art silicon photonics for industry, government and academic communities while overcoming the challenges of a shared fab space. Rapid prototyping, aggressive scheduling and working with designers at all phases of the build to ensure quality deliveries are the keys to SUNY Poly’s success.

Jeremiah is a BS and MS graduate from the RIT microelectronics program. He spent several years at IBM in BEOL manufacturing and transitioned to development integration and RFCMOS engineering. He’s been with CNSE at SUNY Polytechnic Institute for 6 years working on CMOS Derivatives, 3D and Silicon Photonics. He’s currently the senior integrator leading development for the AIM Photonics initiative at SUNY Poly. He has multiple publications and patents in 3D and photonics integration.
Low-temperature Heterojunction Solar Cells and Advanced RF Switches

Ken Nagamatsu ('10 µE), Northrop Grumman Corporation.

Silicon-based solar cells are the mainstay of the industry. In order to support continued permeation of the technology, manufacturing costs must be continually brought down. To this end, research and development of low-temperature heterojunctions on silicon is motivated. In particular, the organic polymer PEDOT:PSS and titanium dioxide show promise in combining facile fabrication with good solar cell performance.

RF switches are a critical component of RF system architectures. The dependence of system performance on RF switch insertion loss and isolation has driven the development of high performance switch technologies. Northrop Grumman has developed a novel technology in the Super-Lattice Castellated Field Effect Transistor (SLCFET), which shows very high RF switch performance.

Ken Nagamatsu attended the Rochester Institute of Technology from 2005-2010. While at RIT he was engaged in many activities on campus, including the Men’s Track and Field team, Eight Beat Measure, and the Microelectronic Engineering Student Association. Upon completing his undergraduate degree in Microelectronic Engineering, he attended graduate school at Princeton University, where he was advised by Professor James Sturm. His PhD dissertation focused on low-temperature materials for silicon heterojunction photovoltaics. Since December 2015, Ken has worked as a microelectronics and semiconductor engineer at Northrop Grumman Corporation.
Silicon wafers made directly from the melt without sawing have long been recognized as a potentially transformative technology for photovoltaics, having the potential to:

- Double the efficiency of silicon utilization.
- Eliminate ingot cropping, squaring and blocking and associated consumables costs.
- Eliminate sawing – the most wasteful, highest-cost step in wafer production.
- Reduce the CAPEX requirement of wafer making and shrink the size of factories.
- Reduce labor content.

Until recently, no previous kerf-less wafer technology has met the stringent needs of the PV industry. A wealth of innovation and progress has been made to deliver first-of-its-kind wafer manufacturing approaches that promise to dramatically reduce costs, simplify wafer manufacturing and accelerate solar adoption. In this presentation, Mr. Hudelson will discuss a new approach, called the Direct Wafer™ process that makes standard-size silicon wafers directly from the melt with no sawing required. This disruptive technology has, in the span of a few years, achieved average solar cell efficiencies of 19% on an industrial PERC line. Additionally, the ability to work at the melt level allows for further innovation and opens up the potential for new wafer specifications impossible through conventional methods.

Steve Hudelson is the Director of Growth Operations at 1366 Technologies, and one of the inventors of the Direct Wafer™ process. Steve joined 1366 in 2009, working as part of the process development team where he helped to improve wafer efficiency, bringing Direct Wafer technology to parity with traditional multicrystalline silicon wafers. He has also focused on improving process productivity, bringing yield and uptime metrics to the level necessary for high volume manufacturing. Today he leads growth operations at the demonstration factory in Bedford, MA, and is beginning to assemble the production team for the planned factory in NY State.

Steve received his MS in Mechanical Engineering from MIT, working in the Photovoltaics Research Lab under Prof. Tonio Buonassisi. His thesis was “High Temperature Investigations of Crystalline Silicon Solar Cell Materials,” specifically studying defects in silicon at high temperatures by developing and using in situ characterization tools. His work focused on the effects and interactions of transition metals in silicon, as well as the effectiveness of solar cell processing steps (phosphorous diffusion gettering and hydrogen passivation) as defect engineering tools during solar cell processing.
Ferroelectric HfO$_2$ Thin Films for FeFET Memory Devices

Joe McGlone

Silicon-doped hafnium oxide has been shown to exhibit ferroelectric properties with certain small thicknesses with appropriate applied stress and annealing conditions. Utilizing Si:HfO$_2$ as the dielectric with a TiN capping layer in a FeFET is promising as a potential emerging memory device due to the ease in integration with standard CMOS process flows. The process developed at RIT was successful in fabricating n-channel FeFET memory devices. The work done here utilizes a 10 nm thick ALD Si:HfO$_2$ film that has a remnant polarization of 10.34 μC/cm$^2$ and an average memory window of 572.3 mV.
This project encompasses the process of designing and fabricating a series of MEMS switches. These devices are composed of a mechanical conductive polysilicon material being brought into contact with a signal line so as to rectify it. The parameters altered between each switch include the number of arms anchoring the mechanical polysilicon to the substrate and various dimensional constants. These dimensional constants include values for the width and length of the arms, and the area of the electrodes used in the electrostatic operation. Two sets of devices were fabricated for this project, and data was obtained for the advancement of the MEMS fabrication process. A new design rule was formulated for this process, and device layout considerations were made to optimize the design for making a DC contact switch.

*Index Terms* — MEMS – microelectromechanical systems; electrostatic actuation – the practice of applying opposing charges to materials in proximity of one another to cause them to attract.
Directed Self-Assembly using PS-b-PMMA Block Copolymers

Jacob P. Kupernik

The goal of this senior design project was to develop a DSA process for the RIT SMFL and enable further research and teaching opportunities. The objective of this project was to achieve lamellar structure formation using a PS-b-PMMA BCP annealed thermally and in solvent vapor. Thermal annealing of the samples resulted in destructive film oxidation. SVA was carried out on the samples using both toluene and THF and the polystyrene pattern was revealed using an oxygen RIE. No significant changes in pattern morphology were noted when comparing the toluene and THF SVA processes. Final patterns were observed using the RIT Nano-Imaging Lab SEM. Dense polystyrene pillar morphologies were observed for both blanket and resist patterned samples instead of the expected lamellar morphologies. The pillars were observed to form with a mean diameter of 16.8nm and a standard deviation of 2.3nm from a random sampling of 50 pillars from three separate SEM images.

Index Terms— Directed Self Assembly, Block Copolymers, Solvent Vapor Annealing.
Fabrication and characterization of mr-DWL photoresist buried channel waveguides on glass is carried out using the Heidelberg DWL 66+ (a laser direct write system). Waveguides are formed of mr-DWL-5 on glass with a spun on cladding material Norland Optical Adhesive-65(NOA-65). The optical waveguides are successfully coupled at 650nm, and resonance structures tested at 710nm. Ring resonators with nominal spacing of .9um and a radius of 350um have an approximate quality of 25-35k and 75-90k for the transverse electric and magnetic modes respectively.

Keywords—waveguide; direct write; negative resist.
Optimization of Transmission Line Measurement (TLM) Structures for Contact Resistivity Determination

Sidhant Grover

Low resistance ohmic contacts are of extreme importance to modern semiconductor devices. Transmission Line Measurement (TLM) structures are most commonly used to determine the specific contact resistivity ($\rho_c$). Inconsistencies have been observed in literature regarding the determination of $\rho_c$ for Integrated Circuit (IC) and Photovoltaics (PV) applications. Therefore, accurate determination of $\rho_c$ is essential for characterizing these devices. The influence of TLM dimensions on the extraction of $\rho_c$ was investigated. TLM structure widths were optimized based on least amount systematic error and TLM’s with optimum width dimensions were fabricated. A dependence of the transfer length ($L_T$) on TLM width ($W$) was observed. It was also observed that approximations used in $\rho_c$ extraction lead to overestimation for certain optimum TLM widths and the use of the general formula is recommended. Finally, a process to accurately determine $\rho_c$ from TLM structures is proposed.
Process Development Challenges Associated with Gallium Nitride Materials

Eric Evangelou

While attempting to fabricate low resistance Ohmic contacts to n-GaN and n-AlGaN, processing setbacks necessitated the development of new procedures within the Semiconductor and Microsystems Fabrication Lab (SMFL) at RIT. Photoresist coating recipes usable on GaN pieces were developed for OiR-620 and LOR-5A photoresists, and GaN was etched for the first time on the LAM4600 reactive ion etcher (RIE). The etch was successful, etched GaN at a rate of 187.2 Å/min, and exhibited selectivity between GaN and hard-baked photoresist comparable to an inductively coupled plasma (ICP) etch of the same chemical makeup. An Ohmic Ti to n-GaN contact was fabricated, but was not optimized for low resistance due to time constraints. These processing solutions will enable future GaN-based projects in the SMFL.
Silicon Photonic Devices Manufactured Using Double-Patterned i-Line Lithography

Patsy Cadareanu

The scope of this project is the realization of basic infrared integrated photonic waveguides and ring resonators in the RIT SMFL. Due to the requirements in spacing between the ring and waveguide for coupling, double patterned i-line lithography is used. The a-Si waveguides are intended to be 250nm thick, 500nm wide, and curved at distances of 75μm; the rings have 40μm diameters and the spacings between the two structures are varied from 200nm to 1000nm. The process development for the successful fabrication of these devices will be discussed in detail. Though more optimization is required, the finished process resulted in waveguides which appeared to be coupling and is thus considered a success.
Fabrication of a MEMS Comb Drive Actuator

Adam Banees

Comb drives are common in many microelectromechanical systems (MEMS) applications such as gyroscopes, accelerometers and resonators in different fields such as optical communication, wireless communication, and biomedical engineering. A comb drive actuator uses electrostatic forces between the combs to create capacitive actuation. The goal of these devices was to achieve a maximum displacement of the movable combs with the lowest amount of drive voltage. Comb drive actuators were designed and then fabricated. It was found that comb fingers were not defined properly as the fingers were either too skinny or have been completely destroyed. This was due to the STS etcher being down in the SMFL and using the Drytek Quad for the mechanical poly etch.
CD Reduction through Annular Illumination and Sidewall Spacers

Corey Shay

An investigation into CD reduction through the use of annular illumination and a sidewall spacer etch. The capabilities of ASML’s PAS 5500 5X reduction stepper to image dense critical dimensions below 300nm is of interest. The ASML stepper has a minimum resolution of 350nm as defined by i-line exposure. The focus of this project is to pattern mask features below 350nm into a hard mask of thermal oxide. The hard mask will act as a pitch defining feature for sidewall spacer formation. The lithographic materials for this project are 2600 A of OiR 620 photoresist with PGMEA 1:1 ratio and 1600 A of I-CON ARC 16 BARC as a bottom anti-reflective compound. Annular Illumination with σi equal to 0.45 and σo equal to 0.86 is used to expose features at 360mJ for a min CD of 325nm. A BARC and 4000 A Oxide etch with the Drytek Quad is performed to transfer pattern to the oxide hard mask. The sidewall spacer material is deposited with LPCVD for 2000 A of nitride. Using the Drytek Quad for anisotropic etch of the nitride, sidewall spacers are formed with a CD below 200 A.
Flash Lamp Annealing technology has become a recent research interest, particularly in the area of large format displays where it has the potential to exhibit good performance and at a much lower cost than Excimer-laser annealed LTPS. Flash Lamp Annealing is a method for heating or annealing materials to very high temperatures in a very short amount of time. This is done with short bursts of high intensity broad spectrum light from xenon flash lamps. The focus of this work was to demonstrate effective doping and activation in low temperature polycrystalline silicon. The doping technique investigated was with the use of spin on dopant as the dopant source because of the much lower cost as compared to ion implantation. Also some interesting discoveries were made where the silicon layer was effectively being doped by the glass substrate when these two materials were in direct contact. The scope of this work was to exploit this phenomenon. Both n-type and p-type spin on dopants were investigated and it was found that the n-type dopant, which uses Phosphorous as the impurity atom, yielded much better results as compared to the p-type material which used Boron. The n-type dopant source looks very promising as it gave low sheet resistances, majority of which being in the (1-2)kOhm/square range. They also showed very linear Current-Voltage characteristics. This work is still on-going as part of the research interest in the area of Flash Lamp Annealing of Polycrystalline silicon for Thin Film Transistor fabrication as part of the collaboration between Corning inc. and the Hirschman Research Group.