CNF Cornell NanoScale Science and Technology Facility

2004 CNF ANNUAL MEETING

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Cornell NanoScale Facility
Annual Meeting

Tuesday, October 5th, 2004
Statler Hotel, Cornell University, Ithaca NY

8:00-8:45 **Registration & Continental Breakfast**
Outside Statler Amphitheater

8:45-9:00 **Welcome: Prof. Sandip Tiwari, Lester B. Knight Director, CNF**
Statler Amphitheater

Session Chair: Lynn Rathbun

10:15-10:30 **Break**

Session Chair: Daniel Woodie

12:00-1:15, Lunch, Statler Ballroom

Announcement of Nellie Yeh-Poh Lin Whetten Memorial Award Winner

Session Chair: Rob Ilic

2:30-2:45, Break

Session Chair: Michael Skvarla

4:00, CNF & Duffield Tours

5:00-7:00, Poster Session & Reception .... ***Posters Listed Page 22***

Statler Ballroom & Ballroom Foyer

Integration of C_{60} into CMOS Gate Stack

Udayan Ganguly, Dept. of Materials Science and Engineering, Cornell University
CNF Project # 715-98
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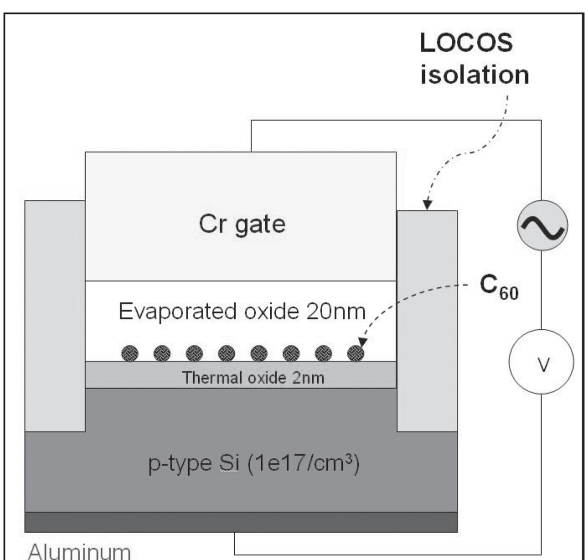
The integration of low dimensional carbon molecules, like fullerenes and nanotubes, in the gate stack of CMOS technology is a promising approach to fabricate structures with novel functionality within the CMOS technology. Carbon with its rich chemistry can be used on the CMOS platform to enrich CMOS applications such as nonvolatile nanocrystal memory (with monodisperse storage) [1-3] and CνMOS (with nanoscale tip resolution) [4].

Fullerenes are single walled molecules that are prone to structural damage through chemistry and mechanical interactions e.g. sonication. CMOS is very susceptible to material contamination. Material and process compatibility are important concerns towards integration. After some processing study, a compatible process has been designed and structural damage has been investigated through different techniques [5].

An ultra thin oxide, of thickness 2-3 nm, is thermally grown on silicon wafers. Fullerenes are thermally evaporated for sub-monolayer coverage. A control-gate SiO_2 of thickness 20-40nm is then deposited by evaporation. Top metal is deposited and patterned to produce MOS capacitors. The MOS capacitors are subjected to CV measurement. Surface contamination and traps are monitored to investigate the CMOS compatibility. Low temperature measurements are used to quench the trap-assisted Frenkel-Poole conduction in the evaporated oxide to study charge injection in the C_{60} molecules. Step-charging observed provides evidence of the integrity of C_{60} molecules in the CMOS gate stack, which is equivalent to observing molecular redox in a dielectric medium. Step heights provide a measure of the surface density of C_{60} of 2×10^{11} cm^{-2}. The highest occupied molecular orbital (HOMO) energies of anions can be extracted from the step-charging width and corroborated with calculated values [6].

References:

[1] Z.Liu, C.Lee, G.Pei, V.Narayanan and E.C.Kan, (MRS) Mat. Research Symp., Boston, MA, Nov. 26-30, 2001, Proc. Vol. 686, A5.3.
[2] Z. Liu, C. Lee, V. Narayanan, G. Pei and E. C. Kan, IEEE Trans. Electron Devices, vol. 49, no. 9, p.1606-1613, Sept. 2002.
[3] C. Lee, Z. Liu and E. C. Kan, (MRS) Material Research Symposium, Boston, MA, Dec. 2002, Proc. Vol. 737, F8.18.
[4] Y. N. Shen, Z. Liu, B. A. Minch, and E. C. Kan, Transducers'03: The 12th International Conference on Solid-State Sensors, Actuators and Microsystems, June 8-12, 2003, Boston, MA.
[5] U. Ganguly, C. Lee and E. C. Kan, (MRS) Material Research Symposium, Boston, MA, Dec. 1-5, 2003, Proc. Vol. 789, N16.3.
[6] W. H. Green Jr., M. G. G. Fitzgerald, P. W. Fowler, A. Ceulemans and B. C. Titeca, J. Phys. Chem. 100, 14892 (1996)



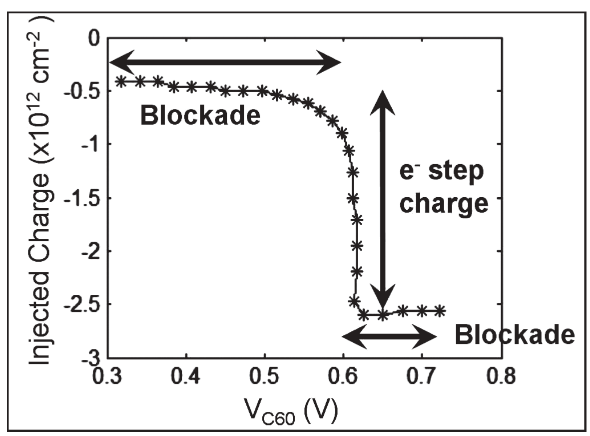


Figure Caption: "Electron injection into C_{60} molecules vs potential on C_{60} relative to the Si conduction band in a MOS capacitor structure extracted from CV measurements at T=10K showing step-charging."

Lambda Repressor Oligomerization Kinetics at High Concentrations using Fluorescence Correlation Spectroscopy in Zero Mode Waveguides

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CNF Project # 551-95
PI: Harold Craighead, Applied and Engineering Physics, Cornell University
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Fluorescence Correlation Spectroscopy (FCS) has demonstrated its utility for measuring transport properties and kinetics at low fluorophore concentrations. We demonstrate that simple optical nanostructures, known as Zero Mode Waveguides, can be used to significantly reduce the FCS observation volume. This, in turn, allows FCS to be applied to solutions with significantly higher fluorophore concentrations. We derive an empirical FCS model accounting for one dimensional diffusion in a finite tube with a simple exponential observation profile. This technique is used to measure the oligomerization of the bacteriophage lambda repressor protein at micromolar concentrations. The results agree with previous studies utilizing conventional techniques. Additionally, we demonstrate that the Zero Mode Waveguides can be used to assay biological activity by measuring changes in diffusion constant as a result of ligand binding.

Spin Transfer Effects In Magnetic Multilayer Nanopillars

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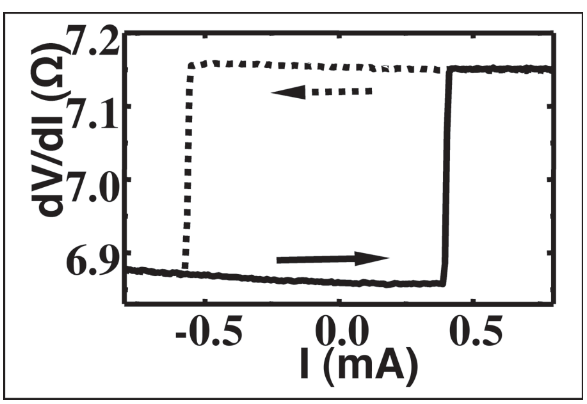
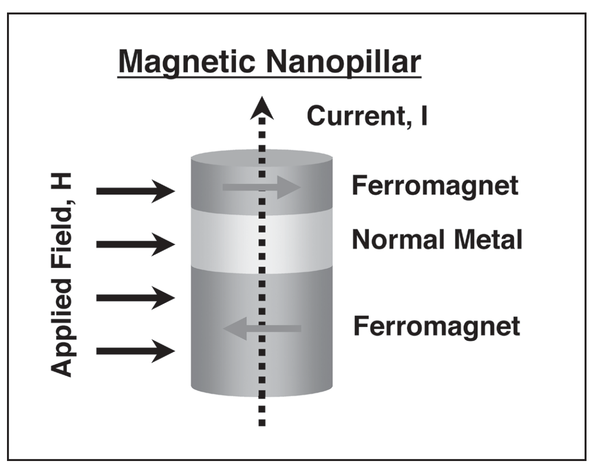
It is now well established that a spin-polarized DC current I applies a spin torque at a non-magnet (N)/ferromagnetic (F) interface that can excite the magnetization of the ferromagnet, a process known as the spin transfer effect. The origin of the spin torque can be understood as a simple matter of spin angular momentum conservation, where the spin-dependent scattering of a spin-polarized current by a non-collinear F layer applies a torque to change the current polarization direction [1]. In F/N/F trilayer nanopillars, this spin torque can induce magnetization reversal [2] or, for large external fields H, dynamical magnetization precession of the thinner, free F layer [3]. Although a matured field of academic interest, spin transfer must still overcome significant challenges in order for there to be serious industrial attention to spin-switched non-volatile magnetic memory applications.

I present work focused on understanding how the magnitude of the switching currents may be controlled by careful engineering of the nanopillar layer composition, including the incorporation of synthetic antiferromagnetic layers (SAF) into the fixed layer of the nanopillar. The SAF reduces undesirable dipole fields on the free layer but can also reduce the spin polarization of the electron current passing through the nanopillar, leading to increased critical currents for spin-transfer excitation. Other studies include the effect of reducing the magnetization of the free layer through alloying and the effect of rare-earth impurity doping to tune the damping of the free layer excitations. I also present recent results from an experiment probing the GHz-frequency dynamical behavior of the free layer, where power from the device is measured as a function of I, H, and frequency. We find that the dynamical behavior agrees qualitatively very well with the single-domain simulations of the Landau-Lifshitz-Gilbert (LLG) equation assuming the spin-torque term derived by Slonczewski [1].

References:

[1] J. C. Slonczewski, J. Magn. Magn. Mater., 159, L1 (1996).
[2] J. A. Katine, F. J. Albert, R. A. Buhrman, E. B. Myers, and D. C. Ralph, Phys. Rev. Lett. 84 3149 (2000).
[3] S. I. Kiselev, J. C. Sankey, I. N. Krivorotov, N. C. Emley, R. J. Schoelkopf, R. A. Buhrman, and D. C. Ralph, Nature (London) 425, 380 (2003).





Silicon Based Ultrasonic Microprobes for Cardiac Signal Recording

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Three dimensional mapping of physioelectrical activities in *in-vitro* cardiac tissues is highly desired for the study of mechanism and development of cardiac arrhythmias. Silicon based microprobes have been reported for electrical activity recording in neural tissues. They provide high spatial resolution, reduced tissue damage, and ease to integrate with microelectronics. However, these thin probes do not have enough rigidity to go in the much denser and harder cardiac tissues. Thicker probes provide greater rigidity but the increased probe size causes more damage to the tissue being investigated and may affect their physioelectrical activities. In this paper we present ultrasonically actuated silicon microprobes to reduce insertion force and minimize tissue damage. Probe tips with multiple recording sites were successfully inserted into canine heart tissue and cardiac signals in two dimensions were recorded. Integrating ultrasonic actuator with silicon microprobe preserves all the advantages of microprobes while reduces the force required to penetrate and cut cardiac tissues, enabling use of thinner and less invasive microprobes.

The device was fabricated with combined DRIE and single side KOH etching. The device consisted of a silicon ultrasonic horn actuator with a longitudinal $\mu/2$ resonance at 75kHz. Two microprobe tips (100 μm wide, 70 μm thick, 5 mm long) were defined at the small end of the horn to be actuated ultrasonically. Au/Cr electrode arrays were deposited on the two microprobes for potential recordings. Penetration and cutting force measurements show that both forces reduced as ultrasonic driving voltage increased. The probes successfully penetrated the isolated and perfused canine heart at 6~10Vpp driving voltage and both spontaneous fibrillation and externally stimulated rhythmic signals were recorded with qualities comparable to those obtained by conventional metal wire probe. Signals from different recording sites were compared and phase/morphology difference can be used for later reconstruction of physioelectrical wave propagation in the heart.

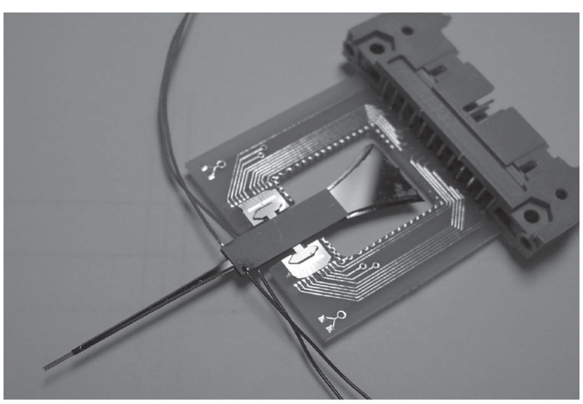

Figure 1. Fabricated and packaged device

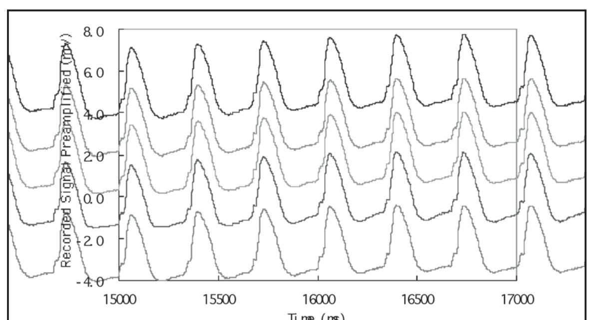

Figure 2. Five channel signal recorded from isolated and perfused canine hear, with external pacing

Nanoscale Organic Thin Film Transistors

Yuanjia Zhang, Materials Science and Engineering, Cornell University

CNF Project # 775-99

PIs: George G. Malliaras [1], Daniel Ralph [2]

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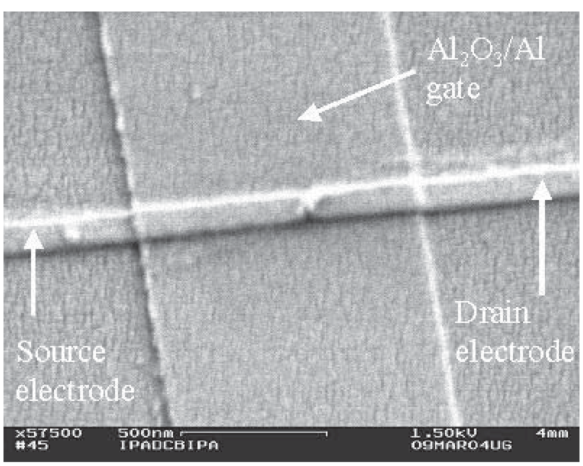
Organic thin film transistors OTFTs have attracted a large interest in emerging electronic technologies where large area coverage and low cost is required. The current delivered by the OTFT is inversely proportional to the channel length L, which motivated studies of OTFTs with submicron channel lengths. We have successfully fabricated functional organic transistors with channel lengths down to 30 nm and found their characteristics to scale gracefully with channel length and width [1]. Those devices used 30 nm silicon oxide as the gate insulator. To further scale down the channel length of organic transistors, even thinner gate insulator is required in order to achieve better gate coupling.

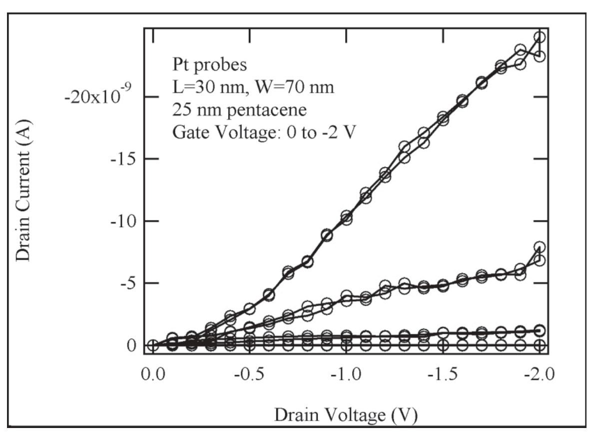
This can be achieved using aluminum oxide as the gate insulator. The gate consists of a patterned Al wire with a native Al oxide insulating layer (Figure 1). The thickness of this Al oxide layer is just a few nm [2]. The current-voltage characteristics of a 30 nm channel length pentacene transistor exhibited the behavior of p-channel TFTs, but showed injection limited behavior compared with previous nano-transistors using a SiO_2 gate insulator (Figure 2). We are currently optimizing the processing to improve the performance of these transistors.

References:

[1] Y. Zhang, J. T. Petta, D. Ralph and G. G. Malliaras, “30 nm channel length pentacene transistors,” Adv. Mater. 15, 1632 (2003).

[2] A. Bachtold, P. Hadley, T. Nakanishi, C. Dekker, “Logic circuits with carbon nanotube transistors,” Science, 294, 1317 (2001).





Magnetic Resonance Force Microscopy With Ultrasensitive Cantilevers

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CNF Project # 863-00
Authors: Sean R. Garner, Seppe Kuehn, Jahan M. Dawlaty, Neil E. Jenkins, John A. Marohn
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Magnetic resonance force microscopy (MRFM) is a technique in which magnetic resonance is detected as a deflection of a microcantilever, and which we are pursuing as a possible route to three-dimensional, single molecule imaging. Using highly sensitive cantilevers fabricated at the Cornell NanoScale Science & Technology Facility, we have demonstrated a new type of MRFM, detecting thermal magnetization of Ga nuclei in GaAs at 4 kelvin. Due to favorable spin-relaxation characteristics, our approach is applicable to a much wider array of samples than previous methods, and has allowed us to mechanically detect nuclear magnetic resonance at unprecedented sensitivity.

A Side-Gated Silicon nMOSFET for Field Effect Transistor Based Sensing

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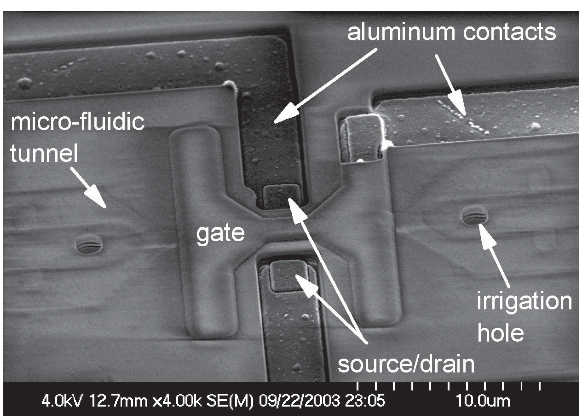
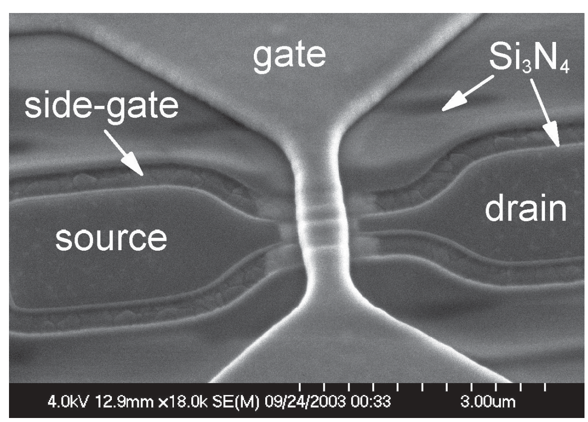
We have developed a process flow to monolithically integrate an ultra-narrow-channel air-gap field effect transistor (FET) with electrically isolated micro-fluidic tunnels using silicon nitride shallow trench isolation. The channel widths of the fabricated FETs go down to sub-10 nm range. The gate of the FET is suspended 10 to 30 nm above its channel. The FET is designed to detect local charge variations along the denatured biomolecules to reveal the sequence information by monitoring the variations in drain current as the sample travels between gate and channel of the FET.

In order to satisfy the charge and spatial resolution requirements, we have developed a side-gated FET structure which can be integrated with the fluidic process for increased sensitivity via suppression of the leakage currents below 50 fA and electrostatic channel width control.

We have observed electrostatic threshold voltage tuning in a range greater than 1.5 V at with a sensitivity of 0.75 V/V ($\mu V_t/\mu V_{side}$) to the side-gate bias. Side-gated devices at small device widths show transconductance oscillations with the application of a strong side-gate bias because of the narrow features. Small process variation in the fabrication of side-gated FET structure results in excellent transistor characteristics, with maximum drive currents exceeding 0.8mA/μm, I_{on}/I_{off} exceeding $1x10^{10}$ and subthreshold slope of 80 mV/dec for an effective gate length (L_{eff}) of 150 nm. Devices with L_{eff} of 260 nm show sub-threshold slopes down to 69mV/dec and drain induced barrier lowering (DIBL) below 14 mV/V.

The achieved device characteristics demonstrate that the side-gated ultra-narrow channel device structure and fabrication process can be used for high-density, low power logic and memory applications as well as sequencing of biomolecules and chemical sensing.





Patterned Self-Assembled Monolayers: Synthesis, Fabrication and Biosensors

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CNF Project # 640-97
PI: Christopher K. Ober, Materials Science & Engineering, and Nanobiotechnology Center, Cornell University
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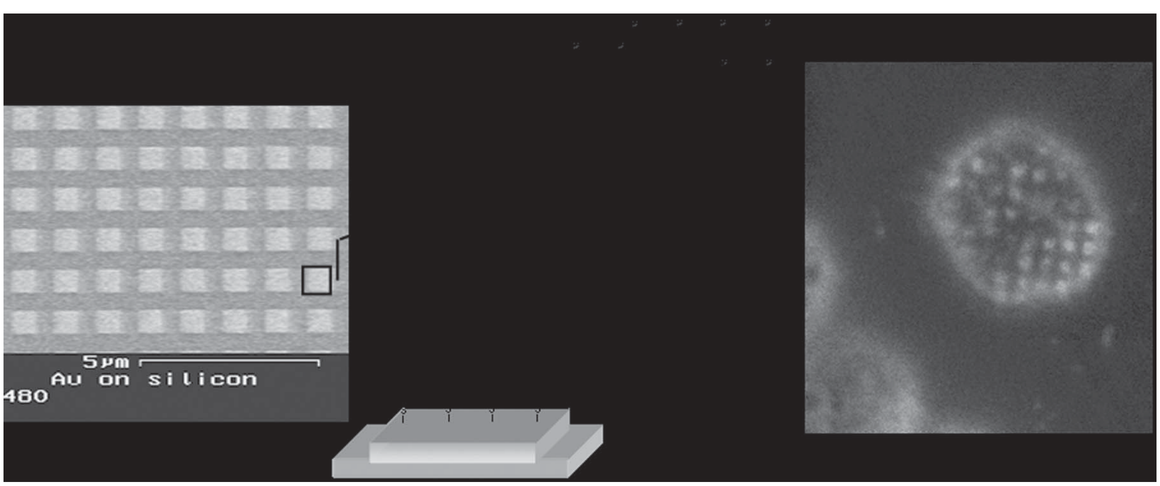
An important problem in cell biology is how surface topography and chemistry affects cellular response. This is of fundamental importance for any situation where living systems encounter device surfaces as in medical implants, tissue engineering and cell based sensors. In order to understand these biological processes on surfaces there is a vast interest and need placed upon materials, surface chemistry as well as advanced engineering tools. We utilize self-assembled monolayers (SAMs) as molecular templates to engage and cluster IgE-receptors on RBL mast cells with sub-micron scale spatial resolution. Bioactive templates were fabricated using electron beam lithography, and these consisted of gold arrays on silicon with patterns from 1 μm down to 45 nm. These gold arrays served as molecular tethering sites, enabling covalent binding of functionalized self-assembled monolayers of alkanethiols. The free ends of the monolayers were functionalized with 2, 4-dinitrophenyl(DNP)-caproate-based ligands which interact specifically with anti-DNP IgE bound to its high affinity cell surface receptor, FcεRI on RBL mast cells. Present results indicate that these patterned SAM arrays can function as a powerful tool for visualization and systematic characterization of IgE receptor mediated immune cell signaling at submicron scale.



Self-Biased Electrostatic MEMS Resonator

Shyi-Herng Kan, Electrical & Computer Engineering, Cornell University

CNF Project # 1078-02

PI: Amit Lal, Electrical & Computer Engineering, Cornell University

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Micro-Electro-Mechanical-Systems (MEMS) resonators [1, 2], have shown the potential to replace the current off-chip technology with on-chip versions of high quality factor (Q) resonators used in wireless communication systems for frequency generation and signal filtering. Recent works [1, 2] have addressed issues of achieving an operating frequency in the gigahertz range and the need for vacuum to attain a high Q. However, there are several barriers that remain for the acceptance of such devices in transceivers. They are high input impedance, potentially large size, and the need for high DC bias.

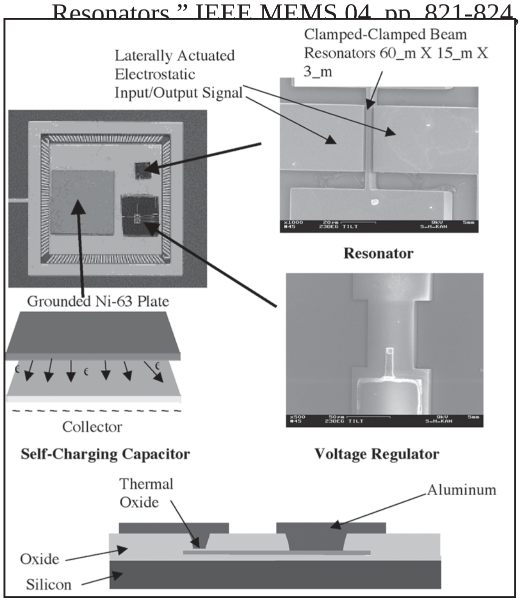
This paper shows that through a high polarization voltage the series input resistance of the electrostatic MEMS resonator could be reduced to 50 Ω, without adverse effect on the power consumed from the battery supply. One of the key achievements of this paper is to demonstrate method for implementing a radioactive powered DC bias for these resonators, self-biasing MEMS resonator. The self-biasing MEMS resonator comprise of three main components, namely, 1) the radioactive self-charging capacitor that proves the high voltage bias, 2) silicon oxide thin-film that regulates the voltage bias at breakdown voltage and 3) the electrostatic MEMS resonator. A parallel plate capacitor plate is formed by placing an electroplated radioactive Nickel-63 plate (source) across an aluminum plate (collector), as the beta particles (electrons) from the Nickel-63 source collect across the parallel plate capacitor, the capacitor voltage increases. Voltage regulation is controlled at the breakdown voltage of a silicon dioxide thin film. The high voltage and low power provided by the self-charging capacitor is ideal for the electrostatic MEMS resonator, since no power is consumed by the device during operation.

In this paper a general description of each component is made and experimental results are shown and analyzed to proof the concept of the self-biased MEMS resonator.

References:

[1] Jing Wang, Zeying Ren and T.-C. Nguyen, “Self-Aligned 1.14GHz Vibrating Radial-Mode Disk Resonators,” Transducers ’03, Vol. #2, pp.947-950, Boston, June 8-12, 2003.

[2] Sheng-Shian Li, Yu-Wei Lin, Yuan Xie, Zeying Ren and Clark T.-C. Nguyen, “Micromechanical “Hollow-Disk” Ring Resonators,” IEEE MEMS 04, pp. 821-824, Maastricht, Netherlands, January 25-29, 2004.



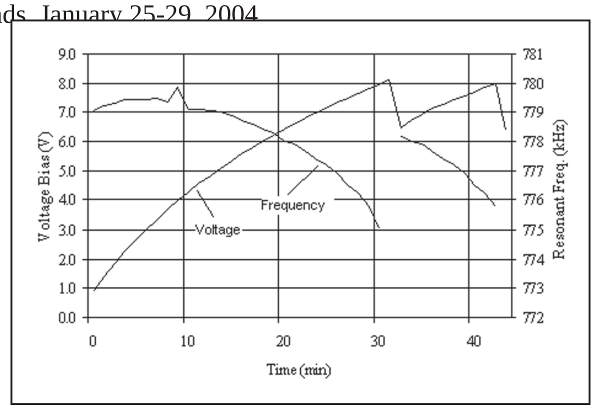


Figure 1: Self-biased electrostatic MEMS resonator.

Figure 2: As the self-generated DC bias increases, the beam resonant frequency decreases due to electrostatic spring softening. When the voltage bias reaches 8.1V, the beam touches the polysilicon electrode and the circuit is shorted. Once the electrostatic force is reduced the clamped-clamped beam springs back and voltage bias starts charging process again.

Ultra-Short SONOS Memories

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Obtaining non-volatile, low power, and fast memories at short dimensions is a key challenge in electronics. Among the approaches being adopted are use of storage of single or few electrons such as in nano-crystal memories, and other modifications such as the use of silicon-oxide-nitride-oxide-silicon (SONOS) or back-floating gates. All these approaches, in different ways, address the gate-stack thickness and voltage issues while attempting to achieve reproducibility and reliability. Silicon nitride and its interface with silicon dioxide provides an alternative for this charge storage where the highly localized storage of charge at increased number of sites may allow a further scaling of the insulator thickness. A higher scalability of the injector thickness, due to the reduced trapping cross-section of defects and of the nitride thickness due to deposition techniques employed, may provide SONOS structures with attractive power and scalability characteristics for the smallest dimensions. In this work, we report the operational characteristics of ultra-short SONOS memories down to ~30 nm effective gate length. Good sub-threshold swing, good DIBL (~120 mV/decade), and ~2.4 V of memory window down to the smallest dimensions demonstrate the improvements arising from electrically short insulator gate stack and large trapping center density. The use of distributed defects and thin oxide is reflected in a memory window that is stable up to at least 10^5 cycles for the smallest devices. The smallest structures tested employed ~75 electrons for memory storage which allows for reproducibility. The capture and emission process asymmetries point to the differences in the energy parameters of the two processes. The smallest structures however, do show loss of retention compared to the bigger structures, for the same ONO stack thickness, but devices show excellent endurance characteristics.

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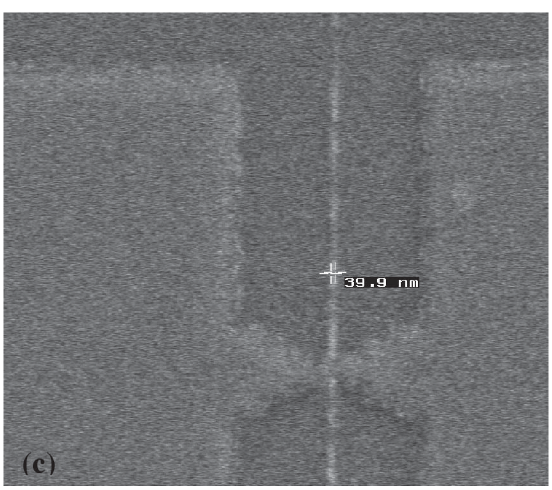
** This manuscript is based on work presented at the 2003 IEEE Silicon Nanoelectronics Workshop.



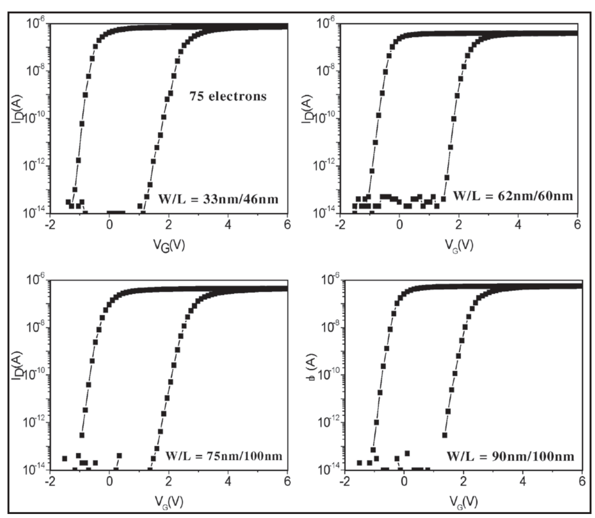


Figure 1: SEM images of a device with width and length of 33 nm and 46 nm.

Figure 2: Memory window at various channel widths and lengths. ONO stack is 2, 7, and 9 nm respectively and the size of the device is identified in the figure.

Integrated Microfluidic Biosensor for Bacterial Detection

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There is a need for rapid and accurate methods to detect pathogenic bacteria, viruses and other disease-causing agents. Devices designed to meet this need incorporate multiple laboratory processes in a semi-automated, miniaturized format. Sample preparation for these devices is often carried out off-line which complicates the entire process. We sought to develop a microchip-based detection system capable of purifying DNA from complex samples and performing real-time PCR to detect bacterial pathogens. Therefore, a portable, fully-automated, PCR-based detection system has been developed for the rapid detection of bacterial pathogens. The detection platform with integrated microprocessor, pumps, valves, thermocycler and fluorescence detection modules was used to detect bacteria by real-time PCR amplification. This system is portable, making it ideal for the detection of bacterial pathogens in the field or other point-of-care environments. Silicon based microchips which purify DNA and PCR amplify target were fabricated and tested for their ability to detect the food pathogens Listeria monocytogenes and Salmonella typhimurium. Using monolithic, silica-coated microstructures, DNA was bound, washed and eluted for subsequent real-time PCR. These microstructures are part of a microchip containing two distinct regions for DNA purification and real-time PCR. The system was tested with intact cells and between 10^3 and 10^7 bacterial cells could be detected. Complete analysis from sample loading to endpoint analysis could be completed in less than 1 hour.

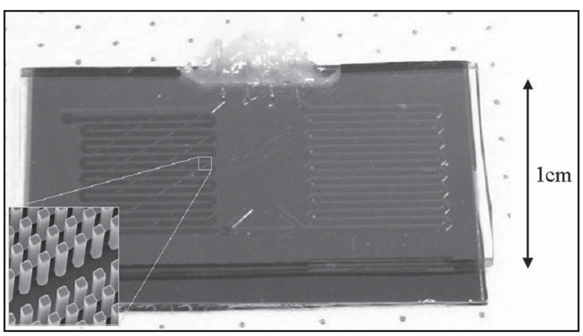

Figure 1. An integrated microchip for DNA purification and real-time PCR. The inset SEM image shows 10 μm square pillars etched 50 μm into silicon. The pillars are coated with SiO_2 for DNA binding.

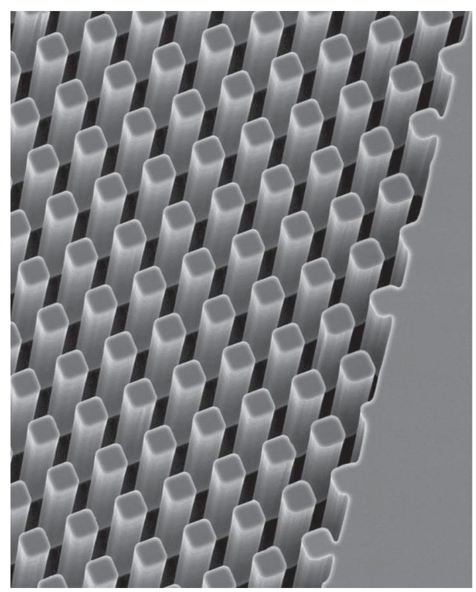

Figure 2. An SEM image of the DNA purification pillars is shown. Pillars are 10 μm square by 50 μm tall and are coated with SiO_2 for DNA binding. The array of pillars creates a large surface area for maximum binding of DNA.

A Tunable Carbon Nanotube Oscillator

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CNF Project #900-00
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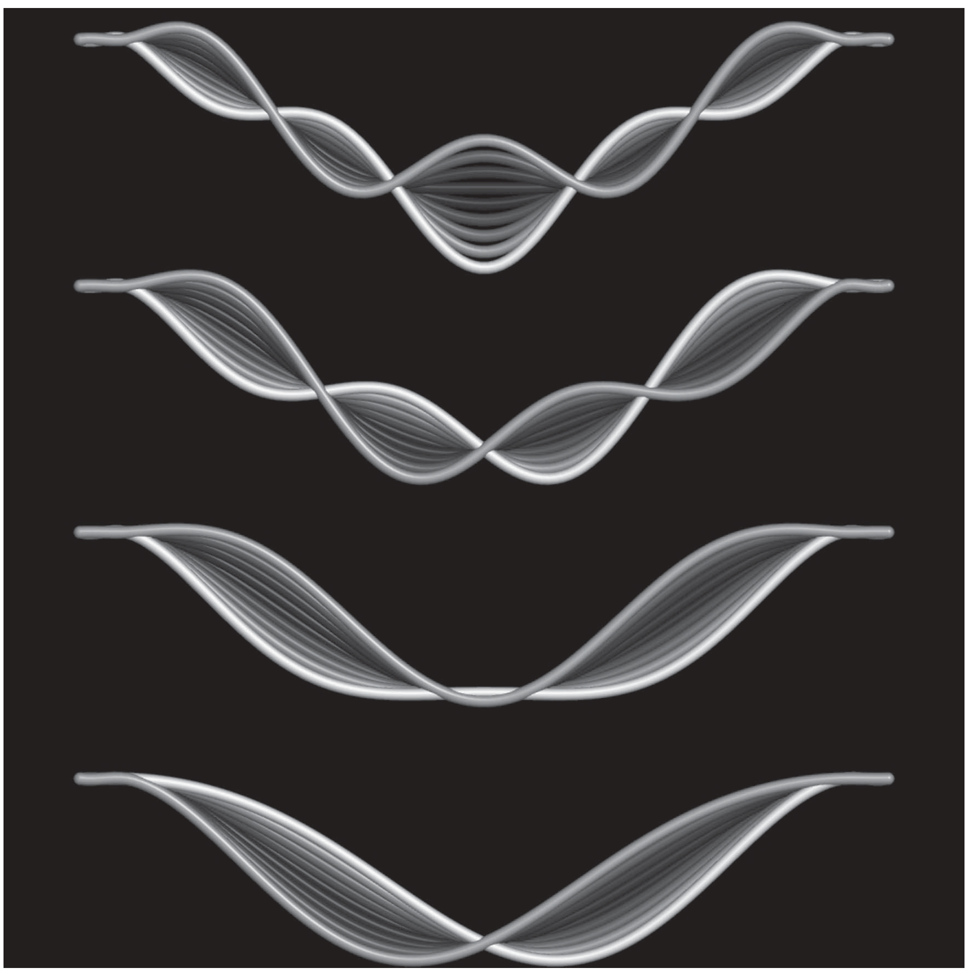
Nanoelectromechanical systems (NEMs) hold promise for a number of scientific and technological applications. In particular, NEMs oscillators have been proposed for use in ultrasensitive mass detection, RF signal processing, and as a model system for exploring quantum phenomena in macroscopic systems. Perhaps the ultimate material for these applications is a carbon nanotube (NT). They are the stiffest material known, have low density, ultrasmall cross sections and can be defect-free. Equally important, a nanotube can act as a transistor and thus may be able to sense its own motion. We report the electrical actuation and detection of the guitar-string oscillation modes of doubly-clamped NT oscillators. We show that the resonance frequency can be widely tuned and that the devices can be used to transduce very small forces.



Micro Fuel Processor for a Micro Fuel Cell Application: Building a Micro Scale Hydrogen Purification System

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CNF Project # 972-01
PI: Mayuresh V. Kothare, Chemical Engineering Department, Lehigh University
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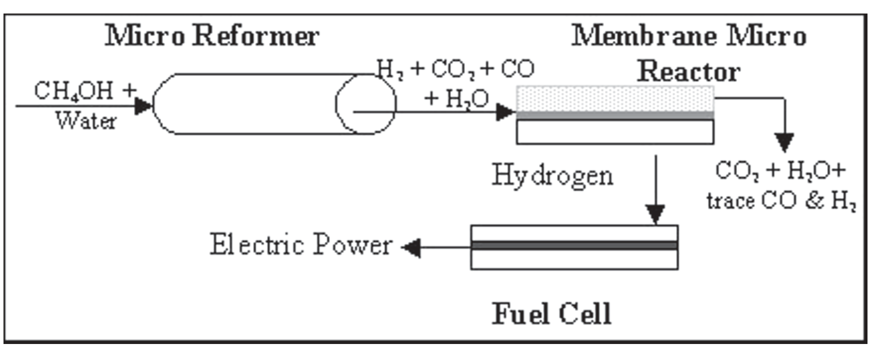
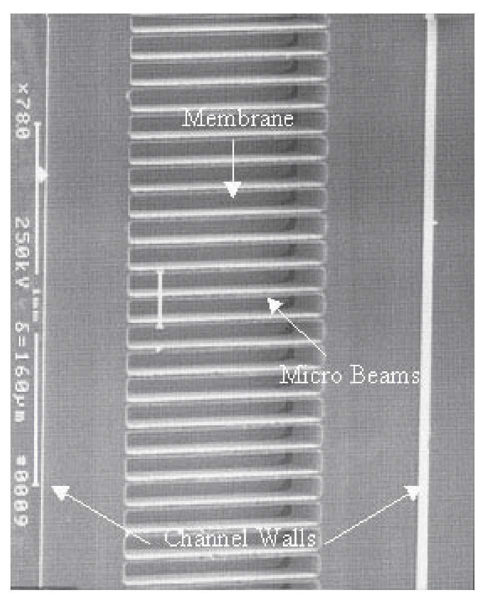
Micro fuel cells are a new and exciting alternative to lithium ion batteries used today to power portable electronics. Fuel cells run best on pure hydrogen. However, hydrogen has low energy density and hence is not suitable for storage and distribution. Methanol has a much higher energy density and can be converted to hydrogen at point-of-use. The aim of our research group is to convert methanol to pure hydrogen in a micro scale which can then be fed into a fuel cell. This research is part of a wider effort to build chemical plants on a chip for a variety of applications.

The conversion of methanol to hydrogen is a 2 step process. Firstly, in a reforming reaction, methanol and water are reacted at 170-230°C over catalyst to produce carbon dioxide and hydrogen. Unfortunately 1-8 % carbon monoxide (CO) is also formed. Fuel cells poison in the presence of 20 ppm CO and therefore a second step involving the removal of CO is required. In this research, a micro scale membrane reactor is being built for the purification of hydrogen and the removal of CO. The membrane reactor consists of a metal membrane to separate hydrogen and a water-gas-shift reaction to react carbon monoxide with steam to produce useful hydrogen.

A freely suspended metal membrane has been built for hydrogen separation. The membrane material is a palladium-tantalum-palladium thin film. The membrane is housed in silicon and glass. The membrane was subsequently tested for hydrogen permeation.

A glass reactor for testing water gas shift reaction has also been built and tested. A novel macro-micro fluidic connector has been fabricated successfully as well.





Highly-Confined Optical Devices on SOI Platform

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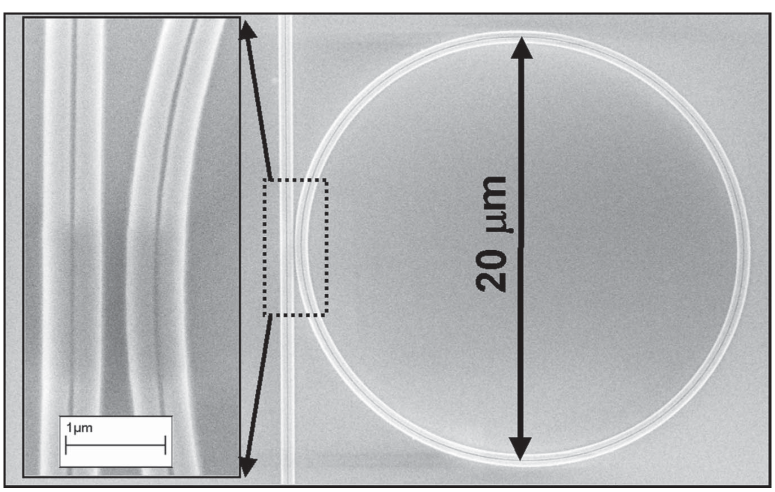
Silicon-on-insulator (SOI) waveguide provides ultra-high optical confinement and the potential of monolithically integration with electronics. We designed and fabricated various optical devices on SOI platform targeting optical switching, amplification, and sensing applications.

We present a novel silicon waveguide structure, called slot-waveguide, that can guide and confine light in nanometer-wide low-index material. With this structure, we can obtain high-intensity optical field in the low-index material because of the discontinuity of the electric field at high-index-contrast interfaces. We measure a 30% reduction of the effective index of light propagating in slot waveguide due to the presence of the nanometer-wide low-index region, evidencing the guiding and confinement of light in the low-index material. We fabricate ring resonators based on the structure and show that the structure can be implemented in highly integrated photonics, enabling very compact optical sensing, optical amplification, and optical switching devices to be monolithically integrated with electronic circuits.

We build electro-optical switch on silicon based on the free-carrier dispersion effect. The refractive index of silicon changes with the carrier density. With 10^{18} cm^{-3} electron and hole densities, the refractive index changes about $^{-}3 \times 10^{-3}$. The carrier density in the waveguide is controlled by the bias of a p-i-n junction build across the waveguide. In order to convert this index change to the switching operation in a compact device, we use a ring resonator structure. From the simulation, we estimated a bandwidth of 775 MHz with modulation depth of 90%. With the fabricated device, we measured 0.1 nm resonance shift with 10-V driving voltage, corresponding to 50% modulation depth.



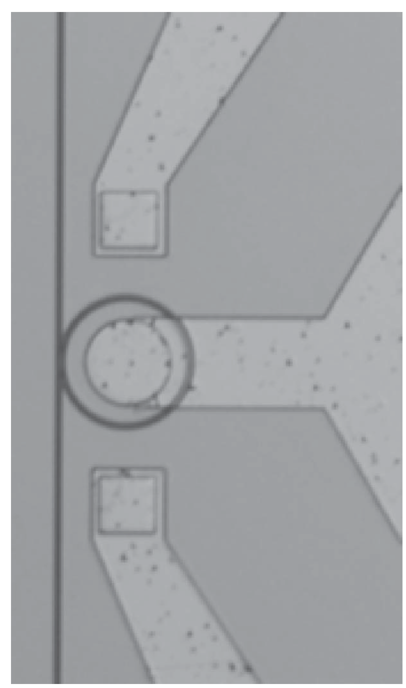


Figure 1: Top-view SEM picture of a ring resonator made of slot-waveguide.

Figure 2: Microscope image of fabricated optical modulator with electrical contacts.

Statics and Dynamics of DNA Confined in 35-400 nm Nanochannels

Walter Reisner, Physics, Princeton University
Authors: W. Reisner, K. Morton, R. Riehn, Y. M. Wang, S, Chou, R. Austin
PI: Robert Austin, Physics, Princeton University

This talk presents measurements of the equilibrium and dynamic properties of λ and T2 phage DNA molecules confined in quartz nanochannels of 35 nm to 400 nm diameter. Such measurements serve a two-fold purpose: (1) we hope to assist in the design of future nanofluidic devices by quantifying the behavior of semiflexible polymers in confined environments and (2) we hope to test existing theories for confined semiflexible polymers. For each channel width, we extracted the average extension of the molecule along the channel axis and the relaxation time of the fluctuations. These measurements are shown to be qualitatively (but not quantitatively) consistent with existing scaling theories.

Mechanically-Adjustable and Electrically-Gated Single-Molecule Transistors

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CNF Project # 598-96
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A primary challenge in the field of single-molecule electronics is to develop adjustable devices that can enable well-controlled, systematic experiments. If one uses techniques that measure only a current-voltage (I-V) curve, it can be difficult to determine even whether a molecule is present between electrodes, because nonlinear transport across tunnel junctions or metallic shorts can easily be mistaken for molecular signals. Previous efforts to overcome this difficulty have employed two separate strategies for systematically adjusting a molecular device in situ to make changes that can be compared with theory. Electrostatic gating permits control of electron transport through a molecule by shifting its energy levels. Mechanical adjustability, using scanning probes or mechanically-controlled break junctions, enables manipulation of the device structure and the strength of bonding to electrodes.

Here we report the implementation of both electrostatic gating and mechanical adjustability within the same single-molecule device. This combined capability enables a detailed characterization of electrical transport in molecules, providing understanding that is not possible with just gating or mechanical adjustability separately. We demonstrate the devices' performance using C_{60} molecules.

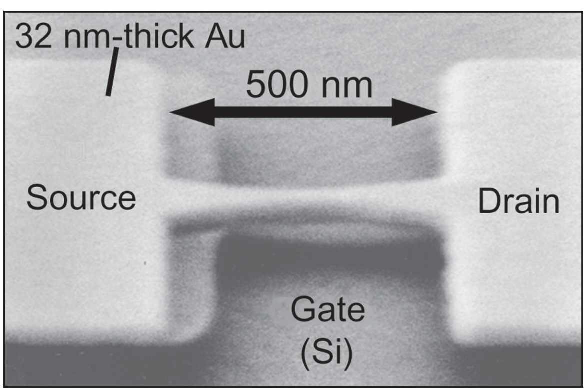
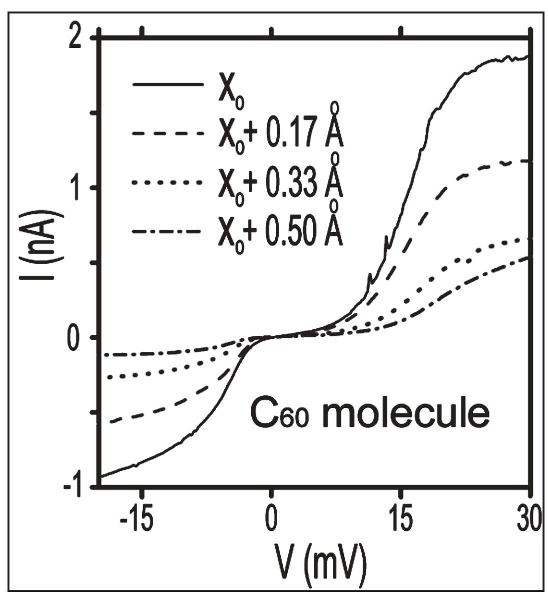


Figure 1: SEM image of a gated-mechanical-break junction before breaking.

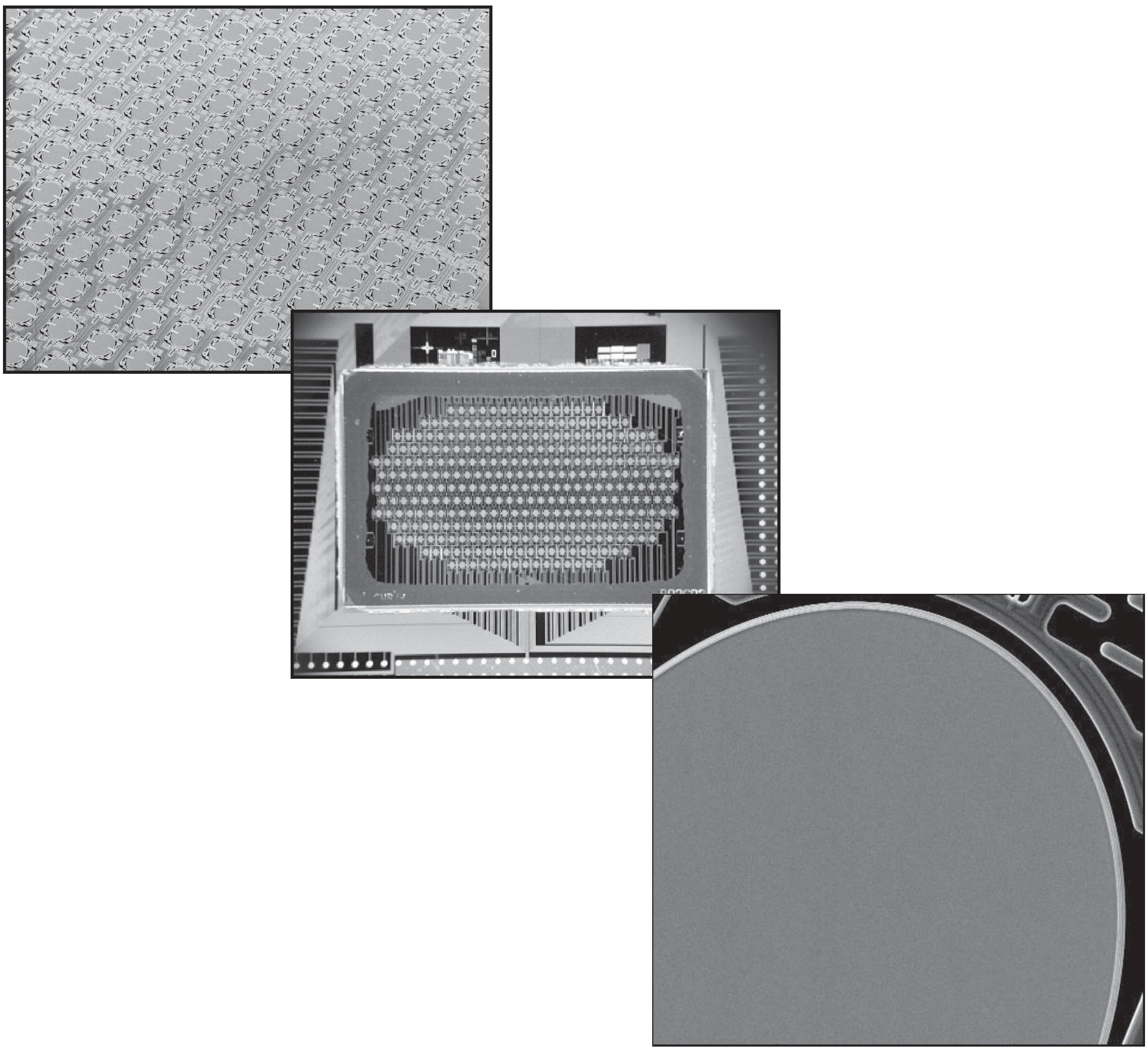
Figure 2: I-V characteristics for a single-C_{60} molecule transistor at different source-drain spacing.



From CNF to Production: Development of the Calient Optical 256 Mirror MEMS Array

Kevin A. Shaw, Calient Optical Components

We will discuss the development of the MEMS optical switch used in the Calient Diamondwave PXC 256 x 256 fiber optic switch. This switch is in production and carrying live telecom traffic in companies throughout the world. The core switch is a 256 mirror array of 2-axis gimbaled mirror components driven by electrostatic drives. The mirror can rotate independently in both axes for more than 20 degrees of mechanical motion. The MEMS were designed and are fabricated here in Ithaca at Calient Optical Components, a subsidiary of Calient Networks, at the Cornell Technology Park. The underlying technology of these devices is based on the plasma micromachining techniques developed at the Cornell Nanofabrication Facility in the mid-nineties and is an outstanding example of technology transfer from academia to commercial production.

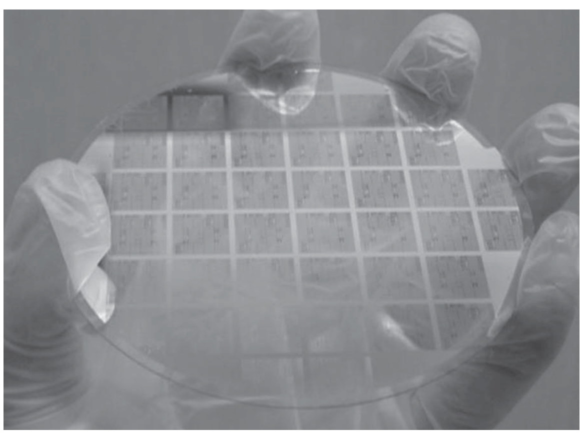


Three-Dimensional CMOS Systems: Technology and Architecture

Christianto C. Liu, Electrical and Computer Engineering, Cornell University
Authors: Christianto C. Liu, Sang (Kevin) Kim, and Sandip Tiwari,
School of Electrical and Computer Engineering, Cornell University

3-D CMOS allows scaling of circuits and systems that is unattainable with conventional device scaling, and has two fundamental advantages: increased packing density and reduction of global wire lengths. Digital and mixed-signal systems can both take advantage of the three-dimensional integration approaches. Mixed-signal, e.g., can reduce cross-talk and allow a significant increase in dynamic range of analog circuits. Digital systems can combine approaches that allow high-speed, low power, and high noise margin at the circuit level, while global optimization of systems allows for incorporation of ground planes (for mixed-signal design) and dramatic reductions in interconnect length between different modules on a complex processor.

In our work, we have developed technology for achieving integration for such systems. For mixed-signal applications, our measurements show 5 to 8 dB suppression of cross-coupling. For digital systems, we have developed techniques that allow attractive device -level performance in multiple device stacking layers. For digital applications, in 3D designs, optimization is possible at a variety of levels of scale. At circuit level, the properties of silicon-on-insulator or bulk can be judiciously utilized to achieve improvement in characteristics beyond that possible by either. At systems level, placement and block-level optimization can be used to achieve performance under the variety of constraints - in power, speed, cost, etc. We will discuss and show the characteristics of the hierarchy of technology and design optimization in this talk.



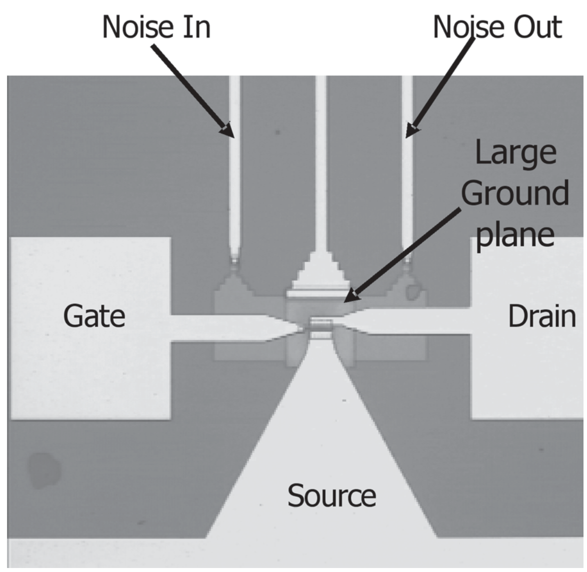


Figure 1: A device layer transplanted onto a glass wafer.

Figure 2: Top-view of a transistor with underlying 3D structure.

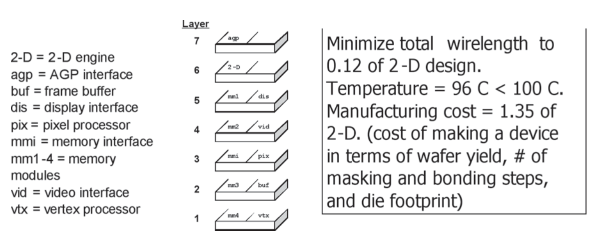


Figure 3: 3 D optimization with constraints of design. A graphic processor is optimized for 3D.

Cornell NanoScale Facility
Poster Session & Reception

Tuesday, October 5th, 2004
5-7 p.m., Statler Ballroom, Cornell University, Ithaca, NY

(Partial Listing)

Tuncay Alan
ta39@cornell.edu, CNF Project: 1154-03, Cornell University, PI: Alan Zehnder
Poster Title: STM/SEM Method to Test Bending Strength of MEMS Materials

Christopher Alpha
alphac@advion.com, CNF Project: 740-98, Advion BioSciences, Inc., PI: Thomas Corso
Poster Title: A Microchip-Based, Multi-Nozzle Nanoelectrospray Device

Anthony Annunziata
aannunziata@mail.colgate.edu, CNF Project: 689-97, Colgate University, PI: Beth Parks
Poster Title: High Frequency Properties of Carbon Nanotubes

M.Kursad Araz
mka22@cornell.edu, CNF Project: 1193-04, Cornell University, PI: Prof. Amit Lal
Poster Title: Ultrasonic Focusing at Microscale

Serhan Ardanuc
sma34@cornell.edu, CNF Project: 1121-03, Cornell University, PI: Amit Lal
Poster Title: A 2D Ultrasonic Array for Off-chip Actuation of MEMS

Hailing Bao
hb48@cornell.edu, CNF Project: 1130-03, Department of Chemistry, PI: Prof. Melissa Hines
Poster Title: Using Micromachined Test Patterns to Investigate Aqueous Silicon Etching

Nathaniel Cady
ncc4@cornell.edu, CNF Project: 884-00, Cornell University, PI: Carl Batt
Poster Title: An Integrated, Microfluidic Biosensor For Bacterial Detection

Alexandre Champagne
ac236@cornell.edu, CNF Project: 598-96, Cornell University, PI: Dan Ralph
Poster Title: Mechanically-Adjustable And Electrically-Gated Single-Molecule Transistors

Kee-Chul Chang
kc53@cornell.edu, CNF Project: 317-87, Cornell University, PI: Jack Blakely
Poster Title: Formation of Ridges on Patterned Mesas and Their Role in Evolution of Step Arrays on Mesas

Xi Chen
xc35@cornell.edu, CNF Project: 1122-03, Cornell University, PI: Amit Lal
Poster Title: Silicon Ultrasonic Microprobe for Cardiac Signal Recording

Jamie Cohen
jlc222@cornell.edu, CNF Project: 1173-03, Cornell University, PI: Prof. Hector Abruna
Poster Title: Ordered Intermetallics for Fuel Cell Applications

Anuja De Silva
ead35@cornell.edu, CNF Project: 386-90, Cornell University, PI: Chris Ober
Poster Title: Molecular Glass Resists for EUV lithography

Shahyaan Desai
sd51@cornell.edu, CNF Project: 1241-04, Cornell University, PI: Anil Netravali & Michael Thompson
Poster Title: Fibers for MEMS applications

Nathan Emley
nce2@cornell.edu, CNF Project: 111-80, Cornell University, PI: Robert A. Buhrman
Poster Title: Spin Transfer Switching in Magnetic Nanopillars: The Effects of Temperature and Materials Modifications

Nelson Felix
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Poster Title: Solventless Lithography: Supercritical CO2 for Resist Development

Gregory Fuchs
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Poster Title: Spin Transfer in Nanoscale Magetic Tunnel Junctions

Sean Garner
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Poster Title: Magnetic Resonance Force Microscopy With Ultrasensitive Cantilevers

Marcus Gingerich
mdg37@cornell.edu, CNF Project: 106102, MIT/Harvard/VA, PI: Douglas Shire
Poster Title: Assembly and Packaging Developments for an Ab-Externo Retinal Prosthesis
Poster Title: Design and Fabrication of An Ab-Externo Retinal Prosthesis

Nicholas Glassmaker
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Poster Title: Study of the Mechanism of Adhesion in Geckos

Ali Gokirmak
agg6@cornell.edu, CNF Project: 804-99, Cornell University, PI: Prof. Sandip Tiwari
Poster Title: Quantum Confinement Effects In Electrically Confined Narrow Channel Silicon Mosfets

Vasiliy Goral
vg44@cornell.edu, CNF Project: 802-99, Cornell University, PI: Prof. A.J. Baeumner
Poster Title: Dengue Virus Detection: From Membrane Strip Assays to a Highly Integrated Microfluidic Device

Janice Guikema
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Poster Title: Implementing Optical Studies of Single-Molecule Transistors

Joshua Henry
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Poster Title: Supressing Mechanical Energy Dissipation in Microresonators Through Surface Chemistry

Valerian Ignatescu
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Poster Title: The Influence of Interfacial Atomic Steps on the Leakage Current in MOS Capacitors

Kassandra Kisler
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Poster Title: Exocytosis of Docked and Undocked Vesicles

Ilya Krivorotov
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Poster Title: Time-Resolved Measurements of Magnetization Dynamics Induced by Spin-Polarized Current

Chungho Lee
CL249@cornell.edu, CNF Project: 715-98, Cornell University, PI: Edwin Kan
Poster Title: Double Layer Nanocrystal Memories

Lori Lepak
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Poster Title: Development of Devices for Nanofiltration of Biomolecules

Connie Lew
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Poster Title: Imprint and Fatigue Behavior in Ferroelectric Poly(vinylidene fluoride-trifluoroethylene) (P(VDF-TrFE)) Thin Films

Hui Li
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Poster Title: Radioactive Micro Power Generation

Yuxin Liu
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Poster Title: Plastic Microchip for Nucleic Acid Purification

Yizhi Meng
ym20@cornell.edu, CNF Project: 935-01, Cornell University, PI: H.C. Hoch
Poster Title: The Use of Microfluidic Devices to Elucidate Upstream Twitching Motility by Bacteria

Samrat Mukherjee
samd@lehigh.edu, CNF Project: 972-01, Lehigh University, PI: Prof. Mayuresh Kothare
Poster Title: Micro Fuel Processor for a Micro Fuel Cell Application: Building a Micro Scale Hydrogen Purification System

Tse Nga Ng
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Poster Title: Magnetic Measurements on Individual Submicron Particles by Cantilever Magnetometry

Shankar Radhakrishnan
sr265@cornell.edu, CNF Project: 1121-03, Cornell University, PI: Amit Lal
Poster Title: In-Channel Flow Sensors for Feedback Control of Flow & Recent Results on Rubidium Chip-Scale Atomic Clocks

Brad Schmidt
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Poster Title: Optical Modulators based on Silicon Photonic Resonators

Keyur Shah
kshah5@stevens.edu, CNF Project: 1184-04, Stevens Institute of Technology, PI: Prof. Ronald S. Besser
Poster Title: Silicon Based Microchemical Concepts for Miniature Fuel Processor

Helena Silva
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Poster Title: Back Gate SONOS non-volitile memories

Scott Stelick
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Poster Title: Fun with Nanotechnology: Creation of the Nanoflag

David Tanenbaum
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Poster Title: Interactions Between Topographic Features and Carbon Nanotubes

Robert Thorne
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Poster Title: Microfabricated Tools for Structural Genomics

Burak Ulgut
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Poster Title: Molecular Electronics

Tobias Wheeler
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Poster Title: Vascular Materials Via Microfabrication In Gels

Joe Woody
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Poster Title: Colloidal Self-Assembly of Nano-fabricated Particles

Yanou Yang
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Poster Title: Coupling Microchip To Mass Spectrometry Through On-Chip Electrospray Tips

Tao Yin
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Poster Title: Lateral Coupling SiGe Photodetectors For On-Chip Optical Interconnects

Norimasa Yoshimizu
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Poster Title: Self-powered Photon Source

Natalya Zaytseva
nvz2@cornell.edu, CNF Project: 802-99, Cornell University, PI: Prof. Antje J. Baeumner
Poster Title: Dengue Virus Detection: From Membrane Strip Assays To A Highly Integrated Microfluidic Device

Yuanjia Zhang
Cornell University, PIs: George Malliaras, Daniel Ralph, CNF Project: 775-99, yz56@cornell.edu
Poster Title: Nanoscale Organic Thin Film Transistors

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