Morning
BSAC Research Overview

Recent Research Results and New Directions
September 2003

Albert ("Al") P. Pisano, Ph.D.
Director, Electronics Research Laboratory
Director, Berkeley Sensor and Actuator Center
FANUC Chair of Mechanical Systems
Professor of Mechanical Engineering
Professor of Electrical Engineering & Computer Science
appisano@me.berkeley.edu

MORNING POSTER SESSION

- Wireless Communications & RF Devices (15)
- Smart Dust (8)
- Micro Robotics (3)
- Physical Sensors & Devices (17)
- Packaging Processing & Microassembly (12)
RF Dielectric Fluid Immersed Silicon MEMS Tunable Capacitors

Daniel T. McCormick
Prof. Norman Tien

Project Description
- Dielectric fluid is employed to electrically and mechanically enhance RF MEMS components

Recent Results
- Multi-line TRL based fluid characterization method
- Low frequency and microwave regime model verification
- Reliability testing of tunable capacitors, distributed elements and active devices

Next Six Months
- System level demonstration
Tunable Inductors and Transformers Utilizing Electro-Thermal Vibromotors

Wen-Pin Shih, Zhihong Li
Prof. Norman Tien

Project Description
- Development of tunable inductors and transformers utilizing electro-thermal vibromotors
- High tuning ratio, high tuning speed, and low temperature process
- Applications in wireless communication, magnetic microsensors, and micromagnetic power devices

Recent Results
- Tunable inductors and transformers have been fabricated.
- Fabricated tunable inductors have been characterized.
- Measured maximum tuning ratio is 18:1 at 10kHz.

Next Six Months
- Characterization of tunable transformers.

A Variable Inductor Array Using Lateral-Contact Microrelays

Ye Wang, Zhihong Li
Prof. Norman Tien

Project Description
- A lateral-contact microrelay for RF applications
- A 4-bit variable inductor switched by the RF microrelays

Recent Results
- Microrelay DC: 2.5-3.5 V driving voltage, >1 million cycles under cold switching
- Microrelay RF: -20 dB isolation at 40 GHz, -0.1 dB insertion up to 50 GHz
- Inductor array successfully switched by the microrelay to provide 3.34-14.54 nH

Next Six Months
- Microrelay: extensive reliability study
- Inductor array: testing on packaged device
**GHz Nano-Mechanical Resonators**

*Project Description*
- Design, fabricate, and test resonators with GHz frequencies
- Fabricate RF MEMS on top of CMOS for low-power telecom

*Recent Results*
- Low temp process: fabricated 80-100 nm gaps on 2.4 µm poly-SiGe film (a)
- Films after release in 90°C peroxide for: 2 mins (a), 1 hr (b), and 6 hrs (c)
- Etch rate in peroxide of B-doped:
  - poly-SiGe is: ~ 40Å/min
  - poly-Ge is: > 1 µm/min

*Next Six Months*
- High temperature, sidewall spacer fabrication process in progress

---

**High Frequency MEMS Resonator for Wireless Communication Applications**

*Project Description*
- This research aims to develop and characterize a high frequency MEMS resonator for wireless communication application with CMOS compatibility.

*Recent Results*
- Demonstration of a frequency-tunable microactuator with a specially designed comb width profile
- Effective stiffness reduction: 80%
- Resonant frequency reduction: 55%

*Next Six Months*
- Reduce the tuning voltage
**Electrostatic Transduction for GHz Resonators**

**Sunil A. Bhave**  
*Prof. Roger Howe*

**Project Description**
- Demonstrate the advantages of fully-differential, 2-port electrostatic transduction for RF MEMS resonators

**Recent Results**
- Devices fabricated. Unable to test due to oversight in capacitive feed-through

**Next Six Months**
- New fab run, test and graduate

---

**Integrated Nano Mechanically-Regulated Atomic Clock: 3.4 GHz Resonator**

**James M. Porter Jr.**  
*Prof. Al Pisano*

**Project Description**
- Nano-mechanical magnetic flux chopper for atomic clock
- Use resonance mode of Mumetal® plate to modulate permanent magnetic field

**Recent Results**
- Test structure design and preliminary fabrication
- Finite element modal analysis

**Next Six Months**
- Fabrication and characterization
- Continue suspension and resonator array analysis
- Next generation mask set

< FEM done with ANSYS v.5.7.1 >
**Integrated Nano Mechanically-Regulated Atomic Clock: Thin-Film AlN Piezoelectric Nano-Resonators**

*Gianluca Piazza*

*Prof. Al Pisano*

**Project Description**
- Fabrication of piston–motion and shear–motion aluminum nitride piezoelectric actuators operated at 3.4175 GHz
- Nano–resonators to be used in a 6.835 GHz Rb⁸⁷ resonance cell for a chip–scale atomic clock

**Recent Results**
- Successful sputter–deposition of AlN on Si and Pt substrates
- Started fabrication of VHF and UHF resonators

**Next Six Months**
- Complete fabrication of VHF and UHF resonators
- Test resonators
- Characterize piezocoefﬁcients and residual stress for AlN

---

**Piezoelectric Bulk Mode Resonators for RF Filtering**

*Philip Stephanou*

*Profs. Al Pisano and Roger Howe*

**Project Description**
- Develop high Q, GHz frequency micromechanical resonators
- Piezoelectric actuation and sensing of bulk extensional vibration mode

**Recent Results**
- Performed numerical simulation of coupled electromechanical system
- Derived analytical solution of equivoluminal mode shape

**Next Six Months**
- Derive equivalent electrical circuit of piezoelectric resonators
- Identify suitable material/process for fabrication
- Investigate anchoring losses
**Project Description**
- Drive and sense interface electronics are integrated on the same die as the nanoresonators.
- Promises improvements in signal quality by avoiding pad and cable parasitics.
- Resonator structures provided by low-temperature SiGe post-processing (Project RTH39).

**Recent Results**
- Low-noise trans-impedance amplifiers are designed in STMicroelectronics' 0.13um process. The useful bandwidth of the amplifiers is expected to be over 3GHz.
- The same circuits are adapted for National Semiconductor’s 0.25um process, with estimated 900MHz useful bandwidth.

**Next Six Months**
- Testing of fabricated amplifier circuits.
- Evaluation of device degradation after post-processing.

---

**Nanoresonator Interface Electronics**

Peter (Jeng-Wen) Chen, Emmanuel Quevy, Maryam Ziaei-Moayyed
Prof. Roger Howe

Figure 1: Testing Nanoresonators with On-chip Amplification

Figure 2: Example of On-chip Trans-impedance Amplifier

---

**Novel SiGe Processes for Electrostatically actuated MEMS Resonators**

Carrie W. Low
Prof. Roger Howe

**Project Description**
- Optimize the SiGe film deposition process with Excimer Laser Annealing (ELA) and build post-CMOS RF MEMS.
- ELA is being used to tune stress / stress gradient, and to reduce surface roughness.

**Recent Results**
- Process Temperature = 400 °C
- Stress Gradient = 1.3E-5 μm⁻¹
- Stress = -7 MPa (Assume E = 1.5 GPa)
- Surface Roughness = 10 nm

**Next Six Months**
- Study the effect of ELA on quality factor.
- Fabricate MEMS structure on top of CMOS.
### Post-process of GHz-range SiGe Resonators

**Over Standard RF CMOS Circuitry for Transceiver Applications**

Emmanuel Quévy  
Profs. Roger Howe, Tsu-Jae King

**Project Description**
- Exploiting MEMS resonators capabilities to demonstrate a Fully Integrated Microwatt Transceiver (IMT)

**Recent Results**
- Reconstitution of a 4” wafer with .18µm CMOS on-going
- New design of support circuitry

**Next Six Months**
- Demonstrate postprocess of SiGe structures over Deep Submicron RF CMOS circuits

---

### Silicon Carbide-Based Nanomechanical Filter Arrays

Di Gao, Carlo Carraro, Jingchun Zhang, Christopher S. Roper  
Profs. Roya Maboudian, Roger Howe

**Project Description**
- Design, fabricate and test silicon carbide-based nanoelectromechanical filter arrays

**Recent Results**
- Fabricated SiC Lamé resonators
- Scaled up SiC LPCVD (in Tystar 15)
- Doped SiC with both N- and P-type dopants

**Next Six Months**
- Test SiC Lamé resonators
- Metallization of SiC
- Evaluate thermal conductivity of SiC
**Integrated Nano Mechanically-Regulated Atomic Clock:**

**Thin Film Magnetic Shielding Alloy**

Carolyn D. White  
Prof. Al Pisano

---

**Project Description**
- Low power modulation of magnetic fields by mechanical resonators

**Recent Results**
- Thin film (10 nm) NiFe deposited by evaporation on silicon substrates.
- Magnetic saturation levels of 0.45 T and a relative permeability of $3.7 \times 10^3$ have been achieved and are within range of the desired film properties.
- Magnetic test structures designed.

---

**Next Six Months**
- Sputter Mumetal (NiFeMoCu) films
- First Magnetic field modulation tests

---

**3-D Millimeter-Wave Beam-Formers**

Firas Sammoura and Yu-Chuan Su  
Prof. Liwei Lin

---

**Project Description**
- Develop low-cost, fluidic-based, and reconfigurable electromagnetic-wave beam-formers for high-frequency communication applications.

**Recent Results**
- Demonstration of 3-D waveguide network with integrated antennas.
- Process development.
- Device design and analysis.

---

**Next Six Months**
- Device characterization.
- Process optimization.
- Development of phase-shifter.
MORNING POSTER SESSION

- Smart Dust (8)

**Laser Beam Steering for MEMS Optical Communication Systems**

Baris Cagdaser  
Prof. Bernhard Boser

**Project Description**
- Laser steering with MEMS
- +/- 10 deg optical range
- .25 mrad (.0143 deg) resolution

**Recent Results**
- Resonant drive demonstrated with $Q \sim 40$, and $f_{res,el}$ changing with position
- Conventional capacitive sense for mirrors implemented

**Next Six Months**
- Closed loop control with resonant drive and sense
- Closed loop control with conventional drive and sense

Rsusp $\sim 1$ kΩ

$C_d(0) = 4.4$ pF

$L, 10$ mH

$V_d = Q \cdot V_1$

$V_{el, f_{res,el}}$

TransR Amplifier

Resonant Drive

BEB16  BSAC ©2003. Confidential Information. Not to be made public without permission from UC Regents.
**Steered Agile Laser Transmitter (SALT)**

Matthew Last, Lixia Zhou  
Prof. Kris Pister

**Project Description:**
- Micromirror for steered laser wireless communication between two unmanned aerial vehicles

**Specific Results Since Last IAB:**
- Mechanical modeling agrees with Ansys simulation
- T-bar shaped torsional beam substitutes rectangular torsional beam to minimize cross-coupling rotation in 2-axis scanner

**Direction for the Next 6 Months:**
- Finish 2-axis scanner fabrication with T-bar torsional beams
- Package and Test

---

**CMOS Imaging Receiver for Free-Space Optical Communication**

Brian Leibowitz, Jonathan Choy  
Prof. Kris Pister

**Project Description:**
- Integrated CMOS optical receiver array for 1Mbps @ 5km in broad daylight

**Recent Results:**
- Tested analog electronics in single pixel receiver
- Designed digital electronics, 256 element imaging receiver (1.6 million transistors – in fab)

**Next 6 Months:**
- Optical assembly, board design, test receiver array
Ultra-Low-Power Radio for Sensor Networks

System level targets:
- 900MHz ISM Band
- 1mW power consumption
- Design in 0.25um CMOS
- Off-chip: crystal, RF inductor, 3V Li-ion coin cell.

Recent Results/Activities
- Full transmitter works with ~20% efficiency consuming 1.2 mW
- Receiver functions but with increased power consumption (~2mW)
- Final version of transciever designed. Should have reduced receiver power consumption and better performance.

Next Six Months
- Final testing of full transceiver.

Ivy – A Sensor Network Infrastructure for the College of Engineering

Project Description
- Research infrastructure of networked sensors

Recent Results
- Made a wireless ICM sensor which measures air speed and ambient / radiant temperature.
- It consists of ICM box, a mica2dot mote and a ICM interface that bridges the box and the mote.
- With calibration, different motes and interface boards produce the same reading within a small error (at most 0.2 deg C).

Next Six Months
- Plan to set up the 10~40 wireless ICM sensors to monitor the campus environment.
**Location Estimation Using RF Time of Flight**

*Steven Lanzisera*

*Prof. Kris Pister*

**Project Description**
- Wireless measurement of distance
- Three distances give 2D location
- Measurement algorithm similar to GPS
- Enhance capability of sensor networks

**Recent Results**
- System simulations in Matlab show promising results
- IC designed and currently in fab

**Next Six Months**
- Test new IC
- Integrate with off chip electronics

---

**Algorithms for Position and Data Recovery in Wireless Sensor Networks**

*Lance Doherty*

*Prof. Kris Pister*

**Project Description**
- Design/evaluate network algorithms
- Develop theory for large networks
- Feedback to sensor node design

**Recent Results**
- Analysis of asymptotic networks
- Simulation of simple algorithms
- Graph theoretic analysis

**Next Six Months**
- Completion of project
- Graduation
Chemical Sensing with Smart Dust

Justin P. Black
Prof. Richard White

Project Description
- Couple electrochemical vapor sensors to Smart Dust.

Recent Results
- Designed and tested Mica mote sensor board
- Calibrated sensors for carbon monoxide and hydrogen sulfide - linear response.

Next Six Months
- Improve sensitivity
- Investigate solid-state electrolytes

MORNING POSTER SESSION

- Micro Robotics (3)
Off-the-Shelf Distributed Robots (COTS-BOTS)

Project Description
- Use off-the-shelf components to develop an inexpensive and modular mobile robot platform
- Research distributed algorithms such as mapping and exploration

Recent Results
- Designed and tested CMOS Imager for localization
- Designed control loop for robot diffusion

Next Six Months
- Tape-out new iteration of CMOS Imager
- Test the robot diffusion algorithms on the CotsBots Platform

Microrobots

Project Description
- 10mg walking microrobots
- High force, large displacement actuators
- 3-chip hybrid for power, computation, and actuation

Recent Results
- New tooth designs to prevent “slipping” in motors
- High-voltage, polymer robots

Next Six Months
- New Inchworm motor designs
- Continue testing feasibility of polymer robots
Design of A Smart Universal Game Board

Xuchun Liu, Ming Li, Avinash Kane
Prof. Norman Tien

Project Description
- Develop a smart universal game board, which have three components: actuation, control and display.
- MEMS technology is used for actuation, control is accomplished through a microcontroller, and Organic LED is fabricated on top of the MEMS device as the display.

Recent Results
- MEMS fabrication has been further optimized for OLED fabrication.
- Masks for OLED been made, OLED fabrication is in progress
- Software of the Microcontroller is update for controlling the OLED display.

Next Six Months
- Finish the OLED fabrication.
- Testing of all three components as one system.

MORNING POSTER SESSION

- Physical Sensors & Devices (17)
### Memes Strain Gauge on Steel: Resonant Sensor Design and Fabrication

**Julian Lippmann**  
Prof. Al Pisano

**Project Description**
- Use resonant MEMS structure to sense μstrain

**Recent Results**
- Began In-house resonator fabrication  
- Performing Process development – specifically characterizing PR accuracy and resolution and Etch behavior

**Next Six Months**
- Complete Process Characterization  
- Complete fabrication of in-house resonators  
- Characterize Side-Pull and Center-Pull resonators

---

### Memes Strain Gauge on Steel: Capacitance Sensor Design and Fabrication

**Babak Jamshidi**  
Prof. Al Pisano

**Design Difficulties:**
- Cross-axis sensitivity  
- Structural component warping  
- Multi-Mask layer demand

**Recent Results**
- Analysis of different alternatives  
- Latest design shows good signs of cross-axis effect isolation

**Next Six Months**
- Design will be finalized  
- Mask Layout  
- Elaboration on Micro-Fabrication

---

**BSAC ©2003. Confidential Information. Not to be made public without permission from UC Regents.**
### Strain Gauge on Steel: Selective Strain Isolation

**Iyang Chen**  
Prof. Al Pisano

**Project Description**
- Design strain isolation trenches into sensor package to reduce cross-axis sensitivity

**Recent Results**
- Designed test structure to validate ANSYS analysis on strain isolation trenches
- Fabrication of test structure starting

**Next Six Months**
- Complete fabrication of test structure
- Begin characterization
- Refine ANSYS models

---

### MEMS Strain Gauge on Steel: Non-Linear Thermoelastic Elastic Analyses of a Resonant Sensor

**Todd Lauderdale**  
Prof. Oliver O'Reilly, Al Pisano

**Project Description**
- Understanding the dynamics of a single-crystal silicon double-ended tuning fork (DETF)
- Modeling natural frequencies as functions of strain, temperature, and other dependences

**Recent Results**
- Included anisotropic effects in DETF models
- Analyzed the effects of cross axis strain using FEM

**Next Six Months**
- Model the coupling of electromagnetic and mechanical effects in the comb drive
MEMS Strain Gauge on Steel: Compliant Packaging

Robert Azevedo
Prof. Al Pisano

Project Description
- Integrate a flexible package with a SOI strain sensor and CMOS chip
- Initial work will look at corrugated membranes

Recent Results
- ANSYS simulations indicate corrugated membranes have the potential to reduce membrane stress when subjected to static deflection
- Fabrication of MEMS static test structures in progress

Next Six Months
- Continue refining ANSYS models
- Fabricate static and fatigue test structures for corrugated membranes

Strain Gauges on Steel:
Electronic Interfaces for Resonant Sensors

Ken Wojciechowski
Prof. Bernhard Boser

Project Description
- The goal of this project is to develop a system for measurement of strain in automobile roller bearings.

Recent Results
- DETFs have been resonated in air with measured resolution of 0.1 microstrain in 10Hz-20kHz BW!

Next Six Months
- Complete characterization of DETF sensors.
- Design of electronics for frequency measurement.
Background Calibration for Low-Power High-Performance A/D Conversion

Project Description
- Goal: Reduce Power of High Performance A/D Converters
- Key: Relax Analog Precision, Correct Errors in Digital Domain

Recent Results
- Successfully Demonstrated 12-bit, 75MS/sec Proof-of-Concept Prototype in 0.35µm CMOS
- ADC Achieves 75% Power Savings in Critical Analog Blocks
- Projected Completed. Continuation Work: Project BEB19

Digitally Assisted Analog-to-Digital Converters

Project Description
- Leverage digital processing to enable low-power, high performance A/D converters in deep sub-micron
- Utilize digital background calibration to relax analog requirements

Recent Results
- Finalizing converter architecture
- Development of necessary calibration schemes

Next Six Months
- Complete circuit design and layout for March 2004 tape out
- Begin preparing test bench
**Phase Noise Considerations of a MEMS Oscillator**

*Manu Seth*

*Prof. Bernhard Boser*

**Project Description**

- Determine whether MEMS oscillator can be used as reference in PLL
- Measure phase noise of PLL with MEMS reference

**Recent Results**

- -70 dBc/Hz phase noise at 1 Hz offset for 32 kHz MEMS oscillator

**Next Six Months**

- Put 32 kHz oscillator into 1.8 GHz PLL
- Measure phase noise of PLL system
- Redesign oscillator for lower noise performance

**Electronic Interface for Micromachined Gyroscope Sensors**

*Vladimir Petkov*

*Prof. Bernhard Boser*

**Project Description**

- High-order sigma-delta interface for inertial sensors.

**Recent Results**

- Interface measured with a lateral accelerometer (150µg/√Hz resolution)
- Interface measured with a gyroscope (1deg/sec/√Hz resolution)
- Continuous-time sigma-delta architecture investigated and modeled on a system level.

**Next Six Months**

- Publish results.
- Continue work on the continuous-time sigma-delta concept.
**Micromachined Electrodes for Capacitive Sensors**

*Noel Arellano*

*Prof. Roger Howe*

**Assembled Capacitive Sensor**

- Membrane Assembled on Electrode
- Oxide Isolation
- Si Bulk of Electrode
- Aluminum Backside Contact
- Top of wafer

Through hole etch cross-section: sts recipe = Aaron6A

**Project Description**

- Precise and Repeatable Fabrication of Electrodes
- Assemble Capacitive Sensors

**Recent Results**

- Finalized Electrode Process
- Tested Assembled Sensor
- Results on Poster

**Next Six Months**

- Project Complete

---

**Scanning Microscopy Probe for Nanomechanical Resonators**

*Xuchun Liu, Alvaro San Paulo*

*Prof. Jeff Bokor*

**Project Description**

- To extend the probe technique by combining it with optical excitation to characterize the nanomechanical (NM) resonators without electrical drive structures.

**Recent Results**

- The resonant frequencies and quality factors of FBAR were measured by AFM.
- The mode shape of FBAR at one of the resonate frequencies was mapped by AFM.
- The power-dependent response and frequency-dependent response of FBAR were measured with the interferometry-based system.

**Next Six Months**

- Try to map the mode shape of FBAR with the interferometry-based system.
Electrostatic Actuator Design for a Digital Output Gyroscope

Joe Seeger
Prof. Bernhard Boser

**Project Description**
- Design parallel-plate actuation and control for a 5-V, digital-output gyroscope operating in air

**Recent Results**
- Parallel-plate actuators were controlled to 98% of the gap using a negative capacitance circuit.

**Next Six Months**
- Implement gyroscope control algorithm using an FPGA
- Measure gyroscope performance

Microfabricated Torsional Actuator by Self-Aligned Plastic Deformation

Jongbaeg Kim
Prof. Liwei Lin

**Project Description**
- Goal: To develop vertically driven out of plane motion micro actuator with improved performance
- Designed simple fabrication process utilizing plastic deformation of silicon

**Recent Results**
- Novel fabrication process for localized heating was developed
- Improved performance of microactuator

**Next Six Months**
- Reliability test for actuators made by localized heating
- 2D scanning mirror demonstration
**Nanostructure-Based Nanoactuator**

*Maggie Chau*

*Prof. Liwei Lin*

---

**Project Description:**
- Application of in-house nanostructures
- Thermal actuation of Si nanowires
- Thermal actuation of carbon nanotubes

**Specific Results Since Last IAB:**
- Computer simulations agree with experimental data
- Development of analytical model

**Direction for the Next 6 months**
- Materials investigation
- Design modification

---

**Bi-directional Electrothermal Electromagnetic Actuator**

*Andrew Cao, Jong Baeg Kim*

*Prof. Liwei Lin*

---

**Project Description**
- Actuator using both electrothermal and electromagnetic forces.
- Capable of high force output and large displacement at non resonant frequency.
- Operates at low voltage compared to electrostatic Actuators.

**Recent Results**
- Fabricated actuators using both surface micromachining process and 50µm SOI process.
- Performed various tests on devices.

**Next Six Months**
- Continue testing actuators.
- Design more complex systems using this actuator.
- Build second generation of actuators using metal process.
FLEMS: FLoating Electro Mechanical Systems

Jason Vaughn Clark
Profs. James Demmel, Sanjay Govindjee, Kris Pister

Project Description
- Create FLEMS
- Characterize them
- Develop applications

Recent Results
- Discovered FLEMS applications:
  - GHz filters, 360°x360° scanners,
  - RF inductors, Quantum gyros,
  - Batteries, Magnetometers,
  - Electrometers, Optical relays, etc.

Next Six Months
- Simulate
- Fabricate
- Measure

MORNING POSTER SESSION

- Packaging Processing & Microassembly (12)
Reversible Bonding Process Development

Ning Chen, Matthew Wasilik
BSAC Engineering Staff

Project Description
- Develop reliable, reversible bonding process for wafer and equipment protection in various processes.
- Adaptation of 4” device wafers in 6” only processing equipments.

Recent Results
- Total of six different reversible bonding processes investigated
- Four are successfully demonstrated in both bonding and debonding process.

Next Six Months
- Improve reliability
- Investigate other potential reversible bonding processes.

Process Investigated
- 3 Drops of PR
- 2 µm spin-on PR
- SOG
- Si-SiO₂ Prebond
- PolyGe Prebond
- PSG anodic bond

Cost and Process Time

- SOG Si-Si prebond
- PR method
- PSG PolyGe Si-SiO₂ prebond
- PolyGe Prebond
- PSG anodic bond

Selective Induction Heating for MEMS Packaging

Andrew Cao
Prof. Liwei Lin

Project Description
- Induction Heating is very selective with respect to material and geometry
- Heating is non contact and does not require a transport medium
- The goal is to achieve hermetic packaging of MEMS devices

Recent Results
- Fabricated Pb/Sn bonding rings and MEMS devices to be encapsulate
- Achieved Pb/Sn to Au encapsulating

Next Six Months
- Continue bonding and reliability testing
**Strain Gauge On Steel: Rapid Bonding**

Andrew Cao, Jong Baeg Kim  
Profs. Al Pisano, Liwei Lin

**Project Description**
- Design a rapid bonding process to attach MEMS strain gauge to the edge of bearing races
- Must withstand wide temperature range in a oily environment for several years
- Bonding process should not introduce residual stress or strain

**Recent Results**
- Fabricated Pb/Sn bonding samples
- Bonded chips to copper thin film, which could serve as adhesion layer to steel

**Next Six Months**
- Perform tensile and fatigue testing on bonded samples
- Cook bonded sample in motor oil and test for delamination and corrosion

---

**Stiction in MEMS**

Elizabeth Parker, Bob Ashurst  
Prof. Roya Maboudian

**Project Description**
- Expand on previous adhesion studies:
  - Investigate vapor phase coating with FDTS
  - Investigate adhesion in fluidic environments

**Recent Results**
- Vapor phase results comparable to liquid phase results
- Manual testing methodology developed for fluid environments

**Next Six Months**
- Develop electrostatic testing methodology for fluidic environments
**Nickel Nanocomposite Film for MEMS Applications**

**Kwok-Siong Teh**  
**Prof. Liwei Lin**

*Project Description*
- Low temperature, low stress deposition of nickel-nanodiamond film as MEMS structural material.

*Recent Results*
- Characterized nickel-nanodiamond composite microresonator:
  - Thermal stress decreases w/ particles (diamond) incorporation

*Next Six Months*
- Project is completed.

**Dedicated SiC MEMS LPCVD Reactor for Access through the DARPA MEMS Exchange Program**

**Christopher S. Roper**  
**Profs. Roya Maboudian, Roger Howe**

*Project Description*
- Deposit SiC on 4” and 6” wafers
- Make SiC thin films available to MEMS designers

*Recent Results*
- Multiple Depositions of SiC  
  Performed in Tystar15
- Good uniformity achieved with closed boat

*Next Six Months*
- Deposit Doped SiC Films
- Characterize reactor with Design of Experiments
- Release to MEMS community
**Project Description**
- Measures etch depth during DRIE process
- Ability to measure multiple film stacks

**Recent Results**
- System installed at Microlab’s STS
- Initial etch depth / resist mask thickness correlation study
- Incorporation of new optimized software

**Next Six Months**
- More data collection / correlation
- SOI wafer metrology study
- Extraction of Ge content in Silicon-Germanium films

**Integration of NEMS and MEMS by Localized Growth of Nanowires**

**Project Description**
- A selective synthesis process is used to integrate nanostructures with larger scale systems
- A self-assembled system can be fabricated for sensing applications
- Such a system takes advantage of the high surface to volume ratio of nanowires, while eliminating post assembly steps

**Recent Results**
- Begun TEM analysis – confirmed synthesis mechanism
- Illustrated intrinsic silicon nanowire’s response to the presence of an electric field

**Next Six Months**
- Continue TEM assisted characterization
- Synthesis of doped nanowires
- Test system functionality as a gas sensor
**Room-Temperature Synthesis of Carbon Nanotubes**

**Dane Christensen**

**Prof. Liwei Lin**

**Project Description**
- Microelectronics-compatible CNTs
- Incorporate with MEMS to form manufacturable sensors/transducers

**Recent Results**
- CNT growth directed to connect microbridges

**Recent Results (cont.)**
- Preliminary electrical, mechanical, structural characterization performed
- Dry N₂ pressure sensor demonstrated

**Next Six Months**
- Further mat’l characterization
- Single-walled CNTs
- Biological, gaseous sensing

---

**On-Chip Cryopreservation of Cells**

**Sha Li**

**Prof. Liwei Lin**

**Project Description**
- On-chip cryopreservation of cells with the potential applications to sperm or embryo preservation, single cell manipulation or lab-on-a-chip

**Recent Results**
- In the proof-of-concept experiment, about 7 times better survival rate has been achieved as compared with experiments without using the on-chip environmental control

**Next Six Months**
- Improve the heater and chamber design to get better uniformity of the heating inside the cell culture
**Electrical Interconnect of Components Transferred by Fluidic Microassembly Using Capillary Forces**

Karen L. Scott  
Profs. Roger Howe, Clay Radke

**Project Description:**
- Extend the understanding of fluidic microassembly using capillary forces
- Obtain single to multiple electrical interconnects between the micropart and substrate

**Specific Results Since Last IAB:**
- Microassembly and testing of inductors for RF applications  
  - Q ~ 60 at 6 GHz
- Project inception and research for monolayer adhesives

**Direction for the Next 6 Months:**
- Process development and testing for monolayer adhesives

---

**Fluidic Microassembly for Microfluidic Applications**

Frank J. Zendejas  
Prof. Roger Howe

**Project Description:**
- To extend the capillary-based fluidic self-assembly to the assembly of silicon micro-parts on polydimethylsiloxane (PDMS) films.

**Recent Results:**
- Using a shadow mask we demonstrated the patterning of gold binding sites on PDMS.  
- We successfully coated the Alkanethiol SAM on gold with hexadecane.
- Our newest fabrication technique has demonstrated the ability to selectively coat hydrophobic binding sites on PDMS without the use of a SAM.

**Next 6 Months:**
- Demonstrate self-assembly of "Dummy Parts".
- Begin modeling capillary forces involved in self-assembly using Surface Evolver.
We will now recess to begin the

MORNING POSTER SESSION

Return at 11:15 A.M.