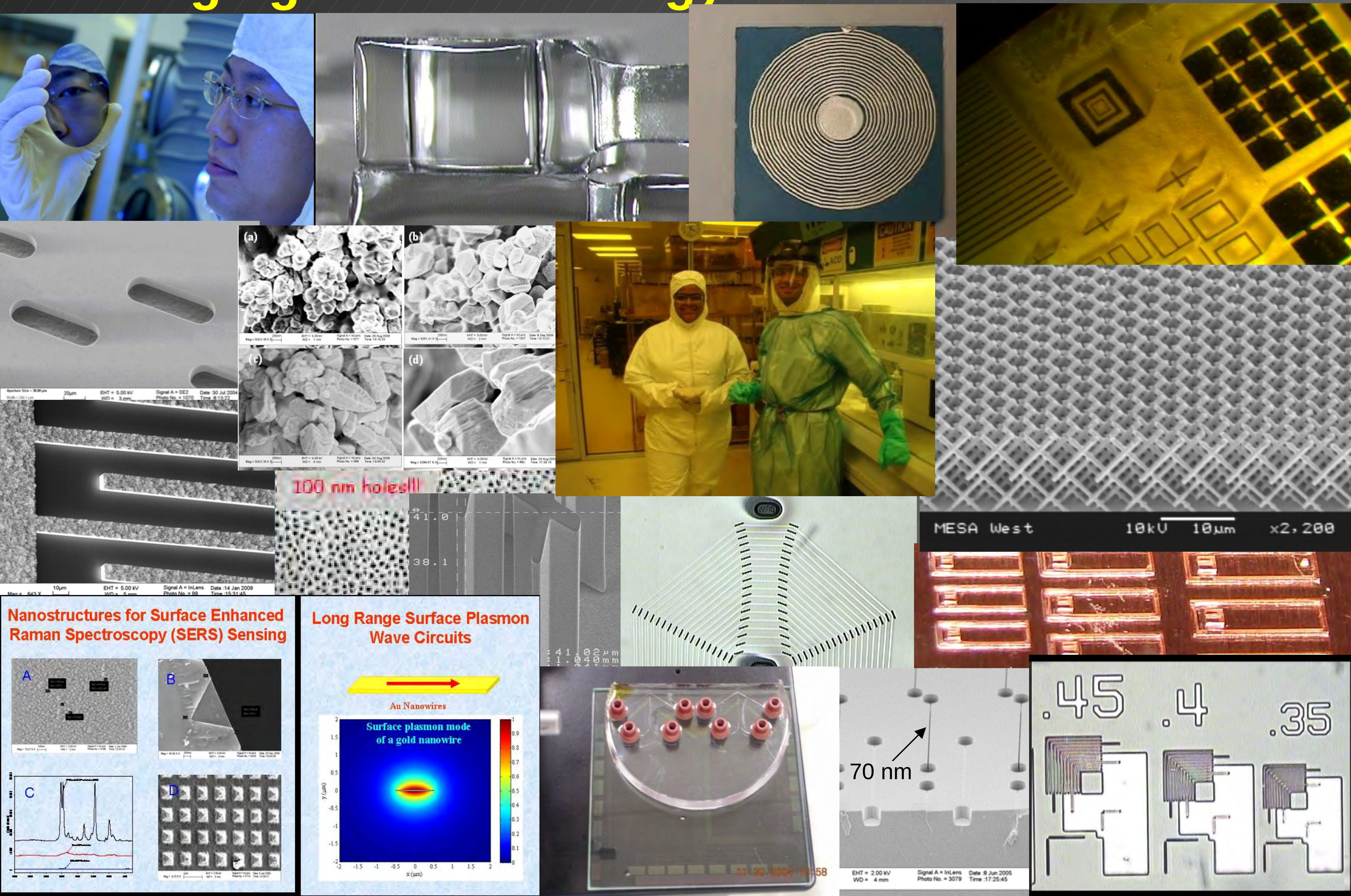
NANO AND MICRO DEVICES CENTER

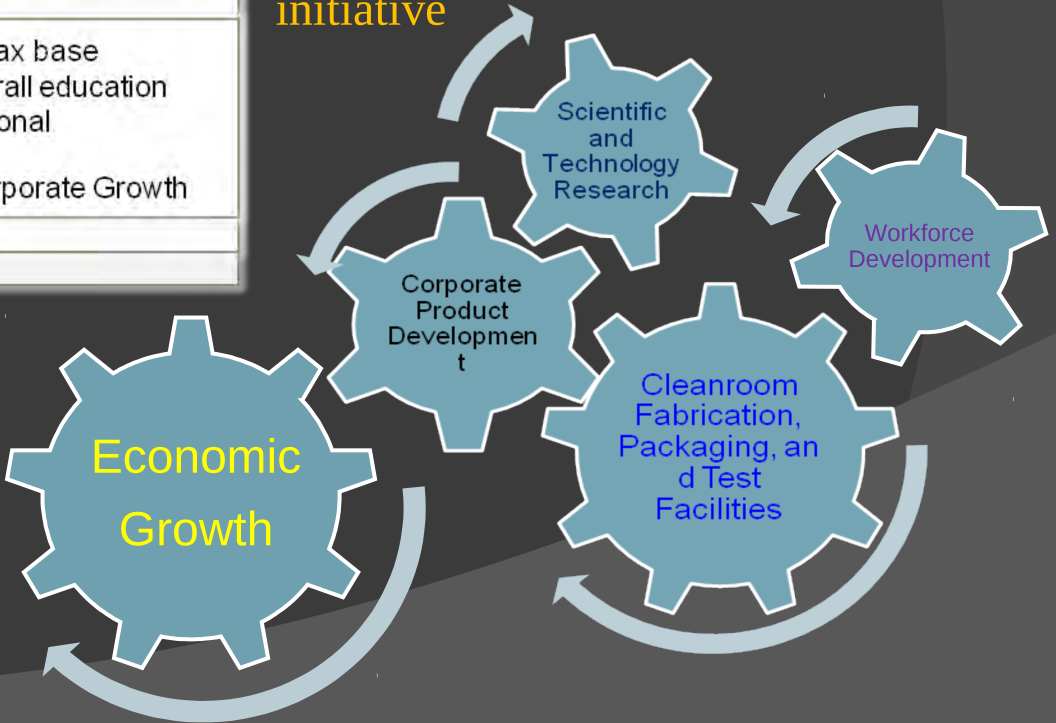
Bridging Nanotechnology to Device Realization



Growth Through Collaborative Research and Development

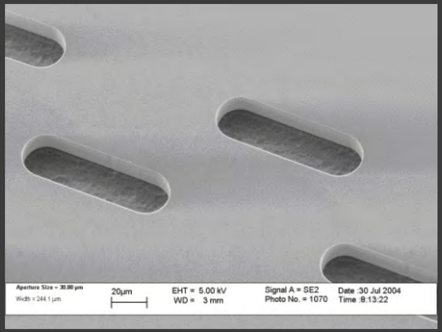
Question: If successful, can this model be implemented for a statewide network of research infrastructure?

Alabama's 5 year S&T Plan is attempting to develop just such an initiative

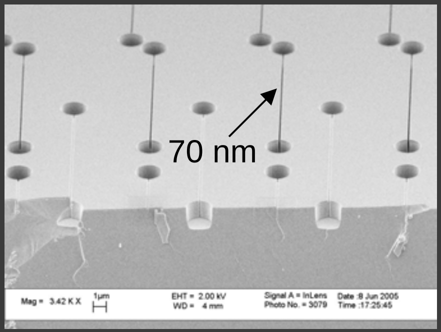


Example: San Jose, CA is teeming with collaborations between academic research and small business

NMDC Device Capability

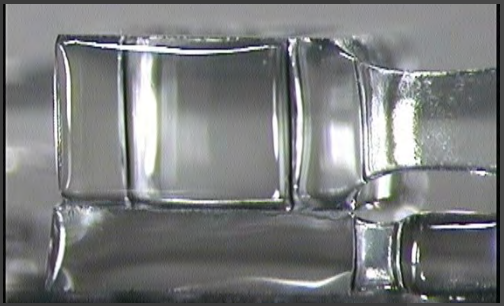


ICP Etching of PFCB

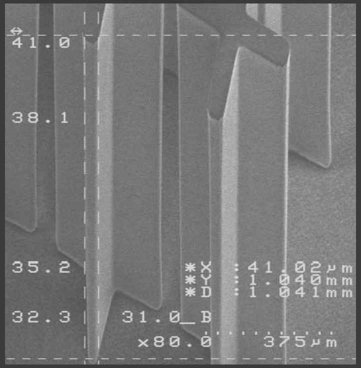


ICP Etching and anodic bonding of Si

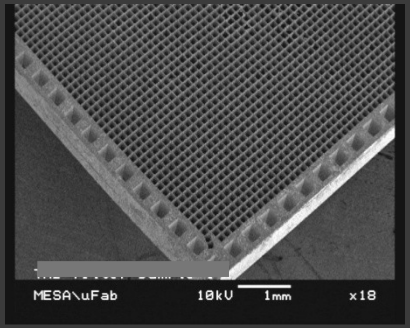
LTCC pressure sensors



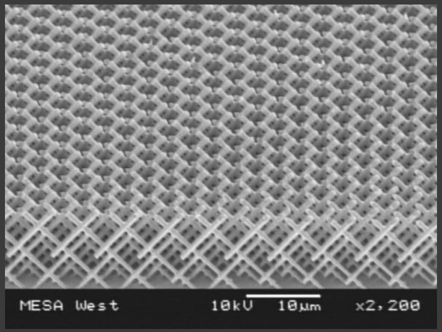
Transparent/ bonded Foturan glass



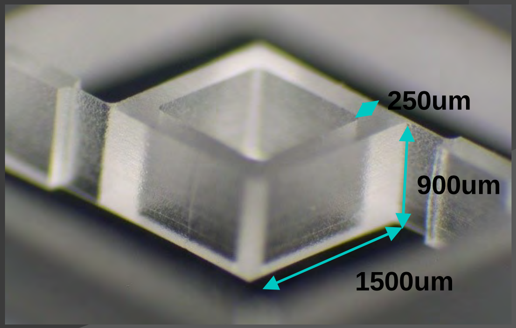
mm thick UV resist technology



75:1 Aspect ratio metallic MEMS



3-D Photonic Crystals



High aspect ratio glass MEMS

NMDC Cleanroom:
1st Floor Optics Building

Thin Film Deposition

Thin Film Deposition

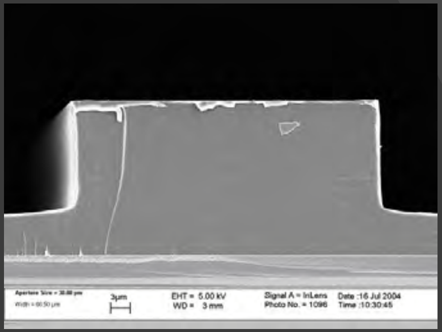
- Denton sputterer (RF, DC, pulsed-DC)
- Thermal evaporator
- Large chamber 4-pocket e-beam evaporator
- Thermal oxidation furnace
- 4 tube LPCVD

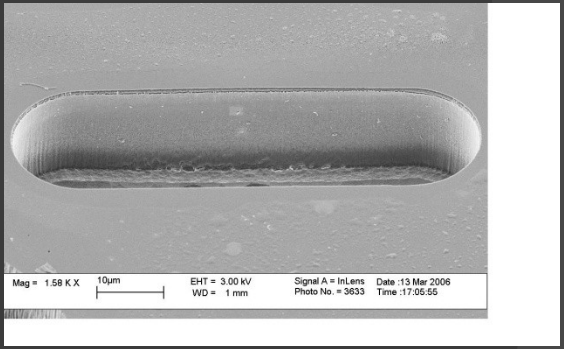
Etching


Class 1k
Class 10k
Class 100k
Service Chase
Not Clean
Support
HVAC EQUIPMENT
Support
Microfabrication Teaching Lab
Metrology
SEM & E-beam Litho
i-line Steppers
Photolithography
Chemicals
SERVICE CORRIDOR
DI Water
Interference Lithography
CMP
Wet Processing
Thin Film Deposition & Metrology
Plasma Processing
Ion Beam Milling
Packaging
Gowning
Sample Storage
Entry
First Floor
N

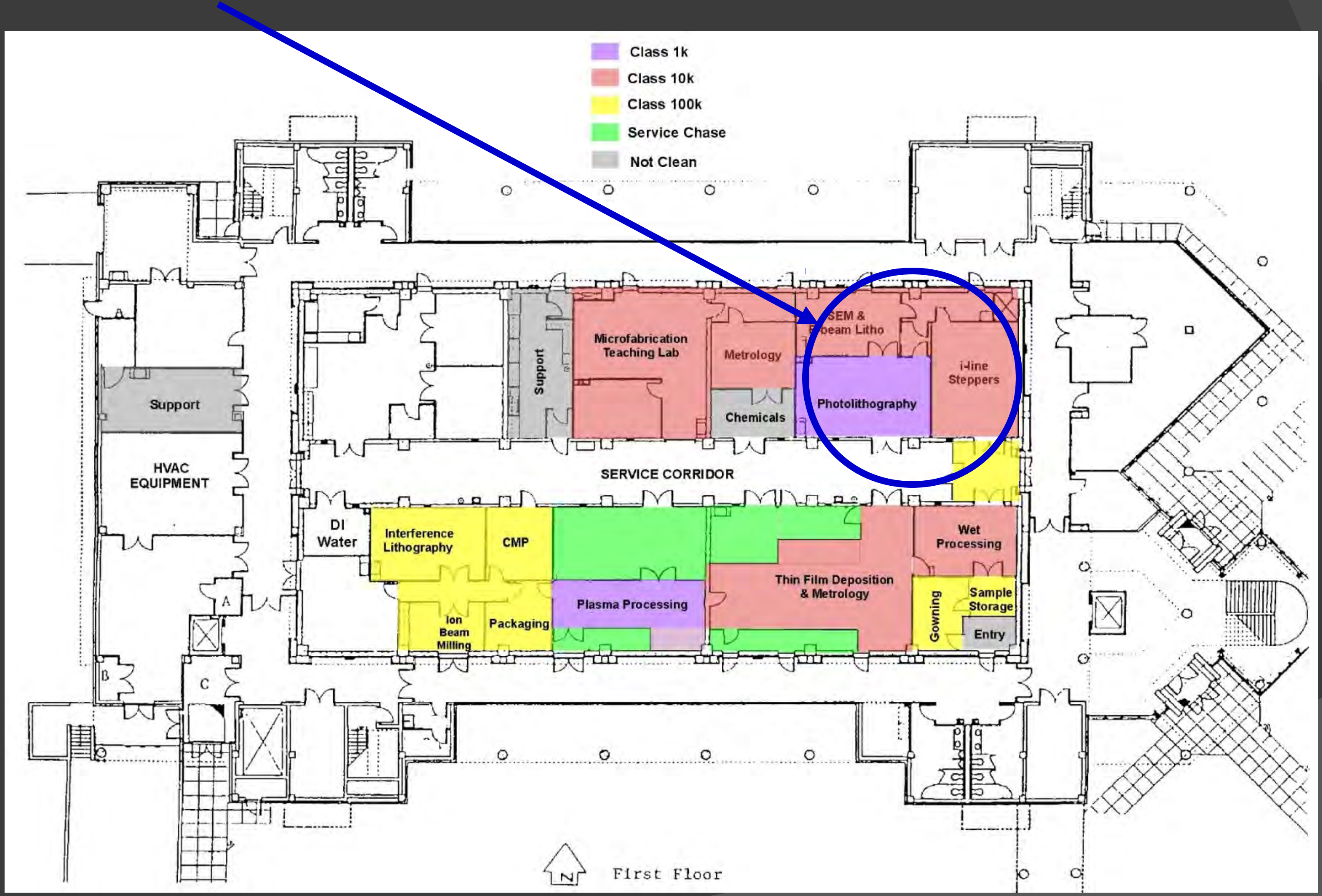
Etching

- Reactive ion etcher-F etch chemistries (PlasmaTherm System 790)
- Downstream plasma asher (Matrix 105)
- Wet etch/strip
- STS Inductively coupled plasma RIE, fluorine etch chemistries



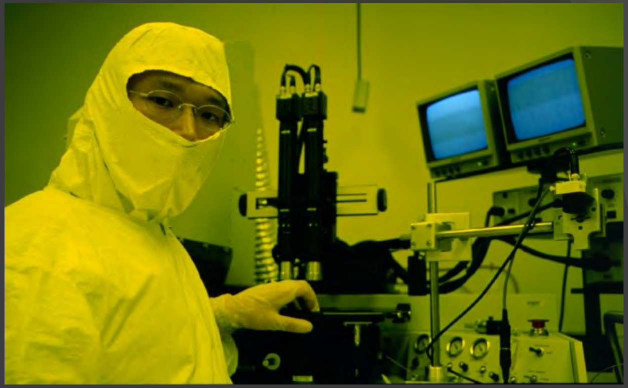


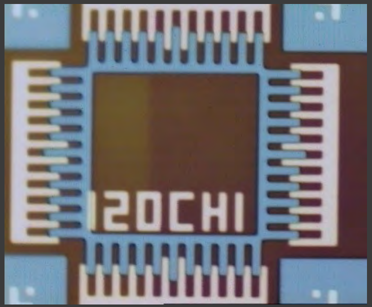
Lithography

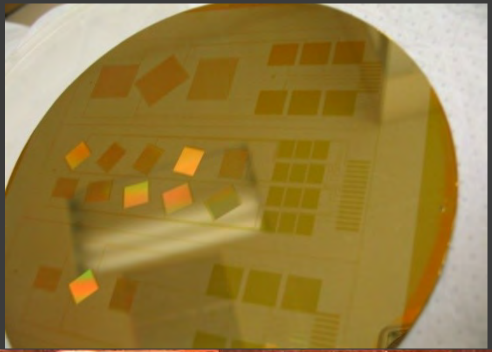


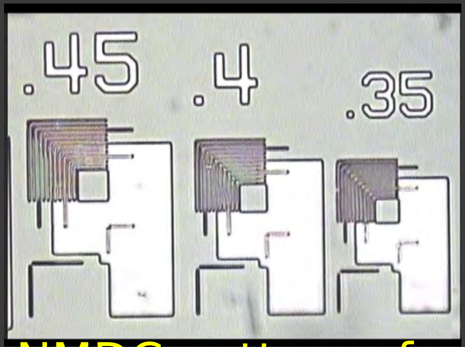
Lithography

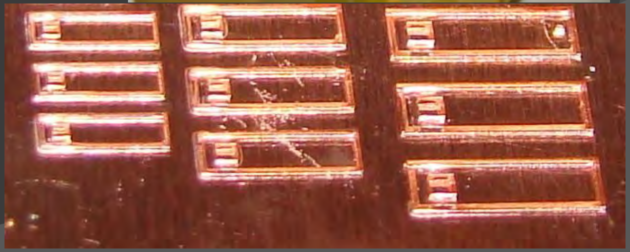
- Contact mask aligner (Near UV, Mid UV, and Deep UV)
- E-beam lithography, field-emission scanning electron microscope (FE-SEM) with EDAX
- Stepper, GCA XLS i-line





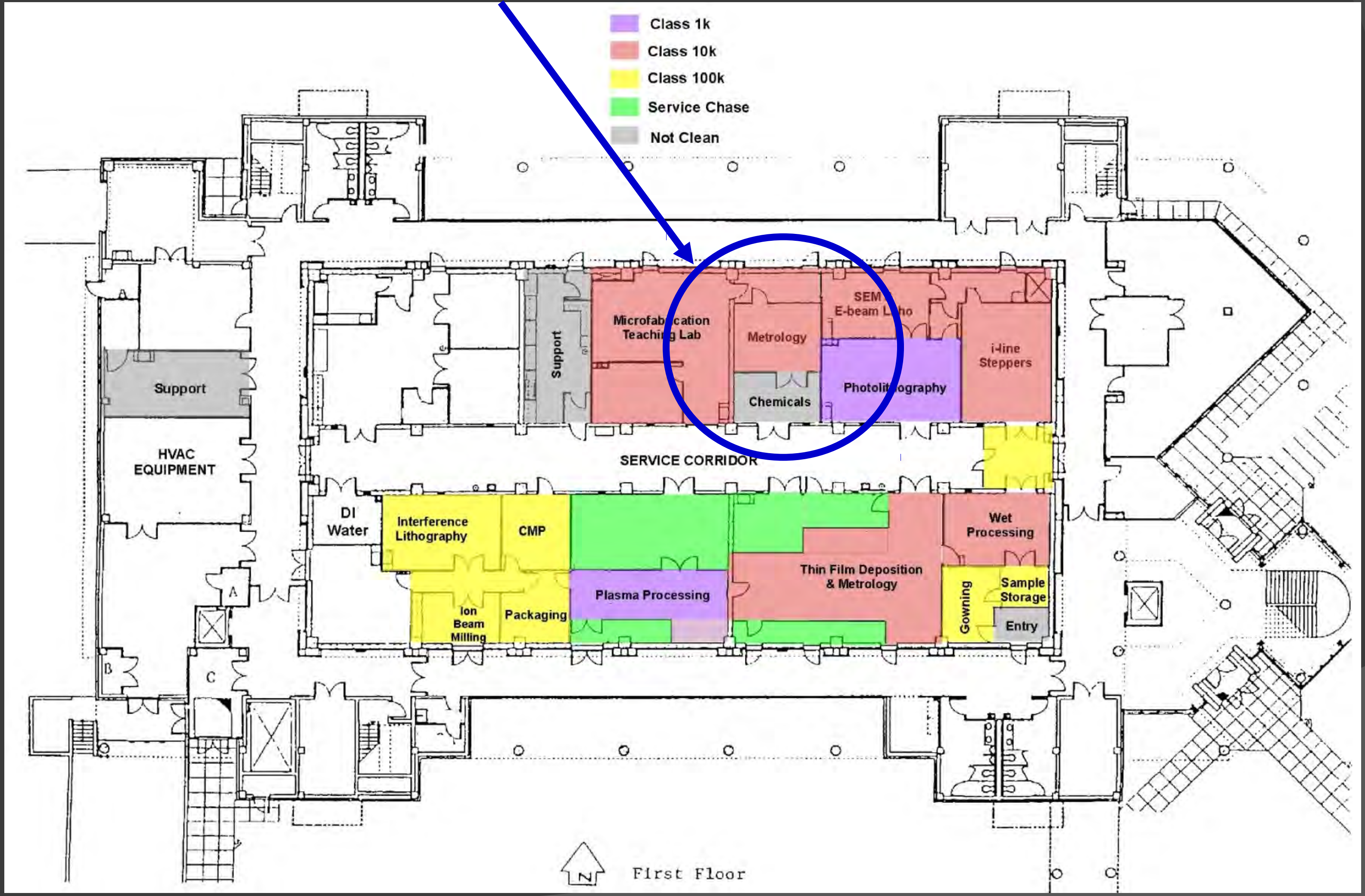






NMDC patterns features from 10’s of mm to 10’s of nm
On multiple substrates with aspect ratios from 1:10 to 40:1

Metrology and Test Equipment

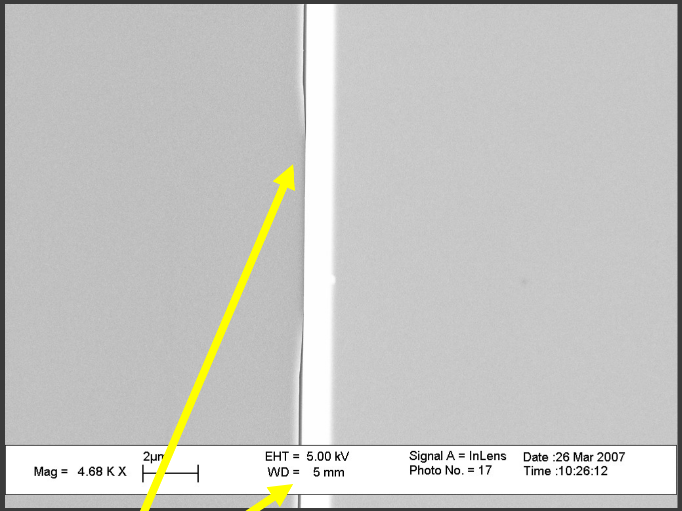


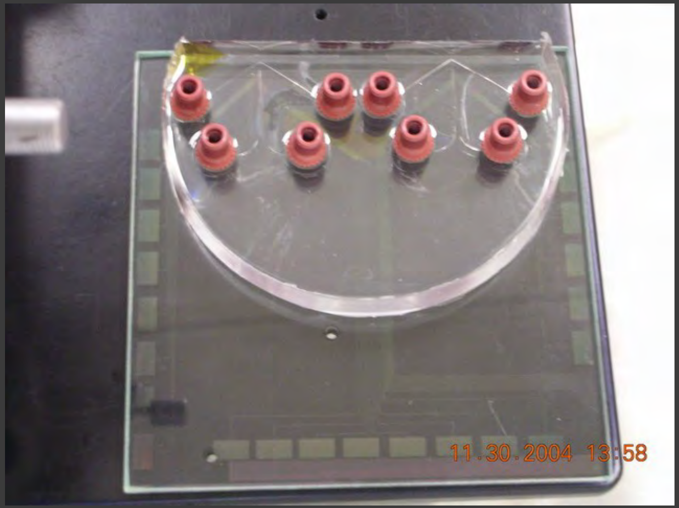
Metrology and Test Equipment

- Profilometer (KLA-Tencor P-10)
- Ellipsometer
- Wire bonders
- Wafer dicing saw (MicroAutomation 1100)
- Numerous optical microscope
- Probe Stations
- Thermal and Humidity Chambers
- Newport Auto-align System
- PM Fiber Fusion Splicers
- Agilent Network Impedance Analyzer

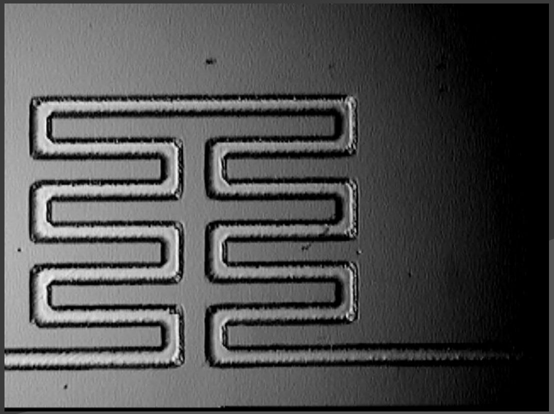
Nano and Micro-Fluidics

PDMS Microchannels



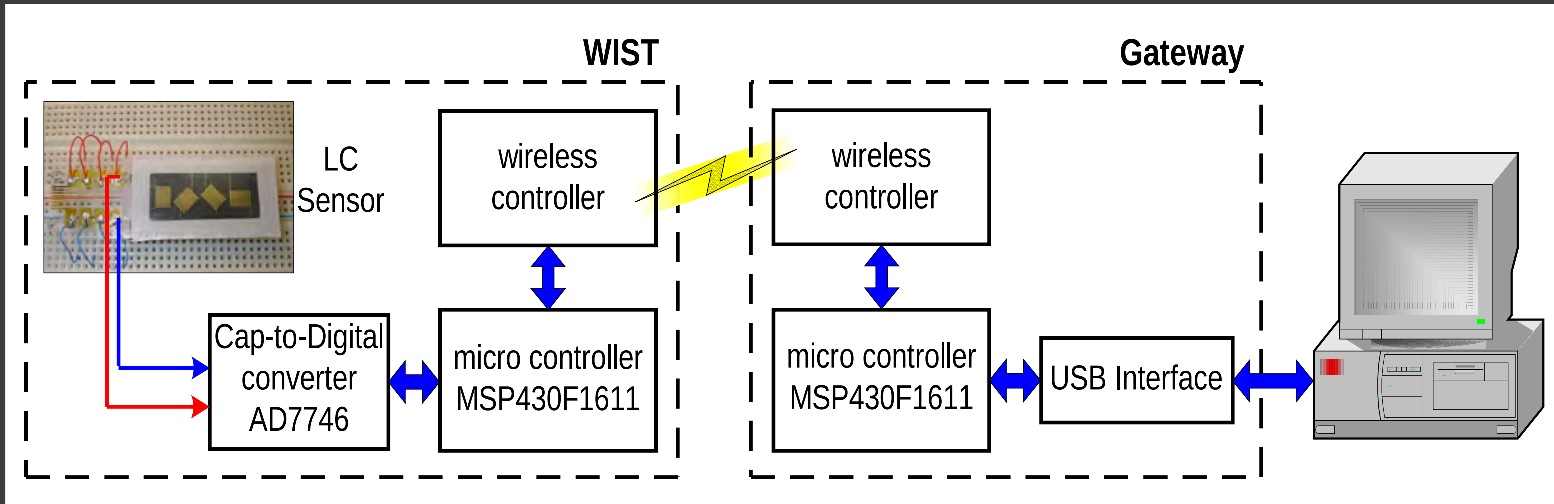


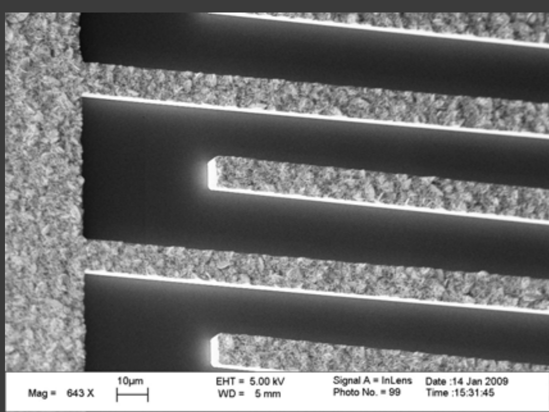
125 nm nanofluidic channel in glass



Yongbin Lin and Frank Berisford, UAHuntsville ECE Department

Portable Wireless Sensor Platform





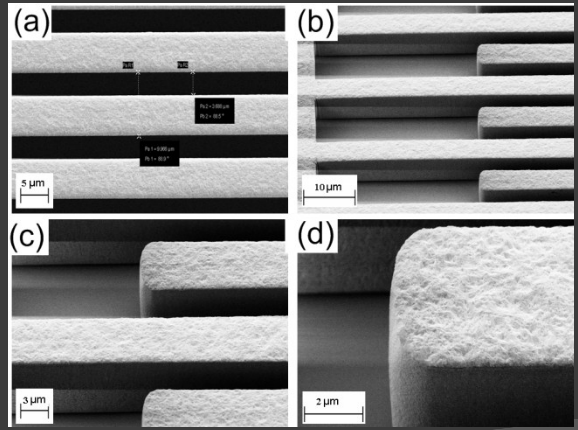
Wireless Sensor Transducer (WIST)
- **Capacitance to Digital Converter Analog AD7746**
- **Ultra Low Power microcontroller Motorola MSP430F1611**
- **2.4 GHz wireless controller, Nordic 24L01 (medium range, 50m)**

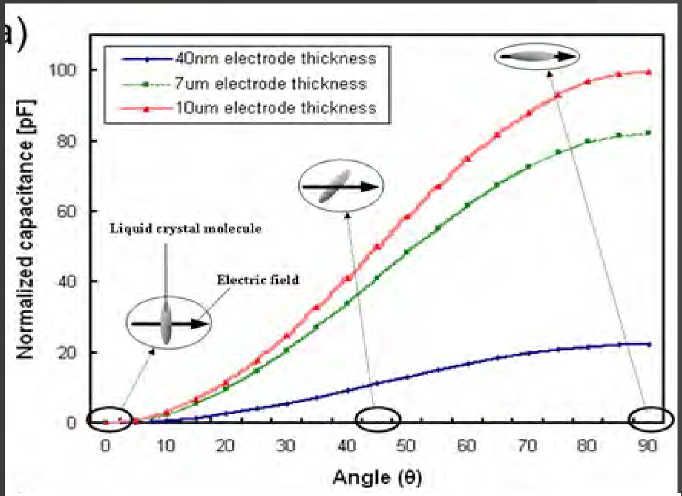
Platform can network 256 sensor

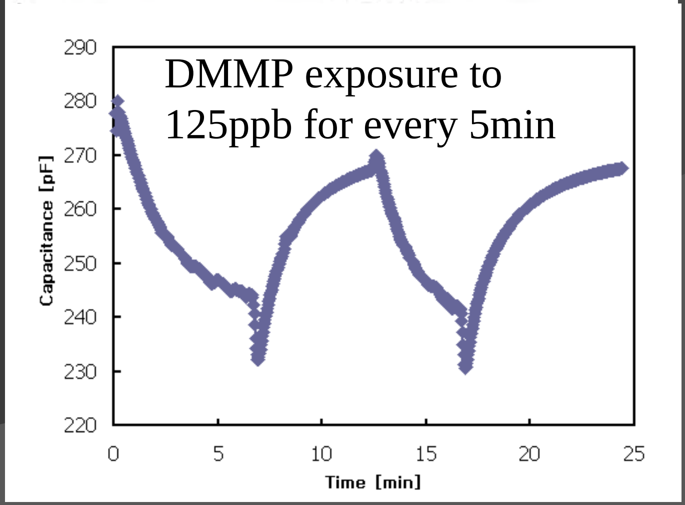
Can store several weeks of data

Improved Nematic Liquid Crystal Sensor using Electroplated Capacitors

- Standard LC sensor technologies are developed using thin film capacitors
- By plating thick film devices, we confined the electric field between two parallel structures
- This increases the sensitivity of the sensor by nearly five times
- The use of gold electrodes improves device sensitivity to biological analytes.







J. Namkung, Y. Zou, R. Kamali, **J D. Williams**, R. G. Lindquist, "Improvement of sensing characteristics by using microelectroplating technique for nematic liquid crystals based chemical and biological sensors," CLEO, San Diego, CA, (May 2010).

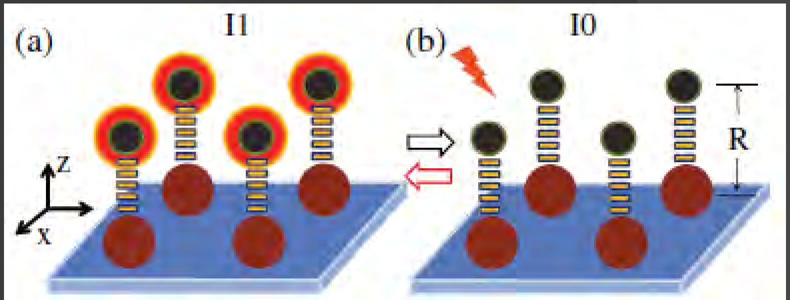
Meta-molecules for Tunable Nanoswitches

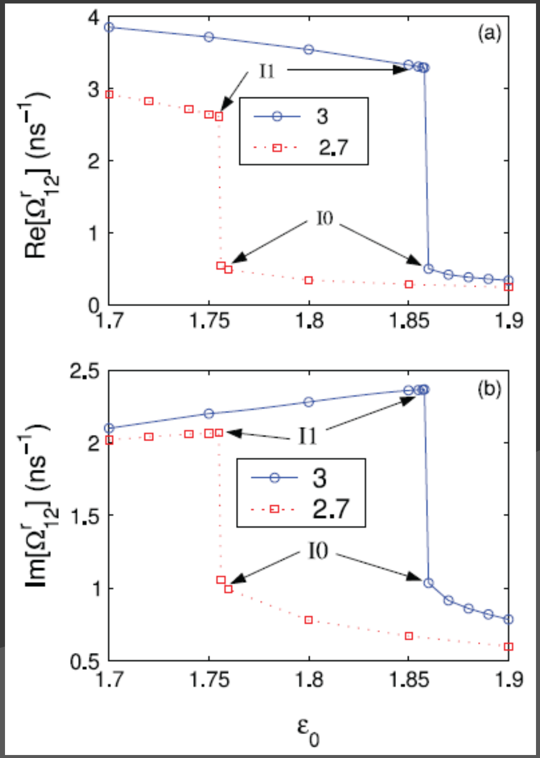
Control of energy transfer between nanoparticles

- •plasmons to turn off or on the flow of energy from one nanoparticle to another?
- •manipulate transfer of energy from a quantum dot to a metallic nanoparticle

2-Control of plasmonic fields of metallic nanoparticles using quantum dots.

- • quantum dot to remove the near fields of metallic nanoparticle or enhance them.
- • 3-Enhancement and suppression of quantum dot emission using plasmons
- •emission of the quantum dot changes via plasmonic effects.

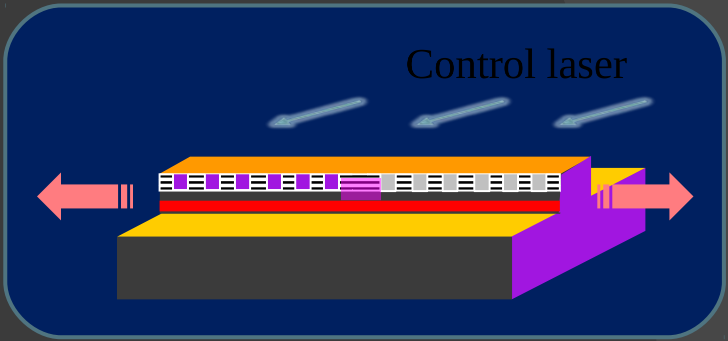


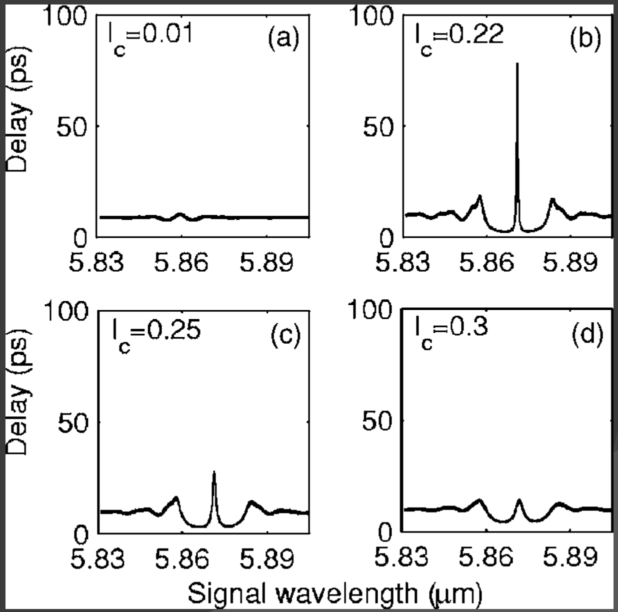


S. M. Sadeghi, ‘Tunable nanoswitches based on nanoparticle meta-molecules,” Nanotechnology 21 (2010) 355501.

Photonic Lasers:

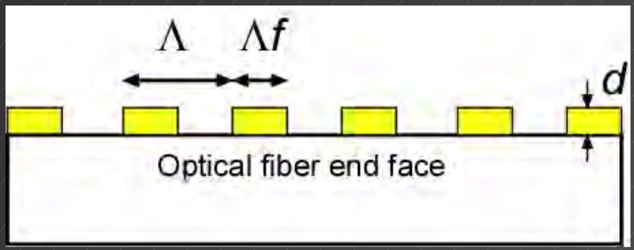
1. Development of novel lasers systems
   - Tunable mid-infrared lasers
   - Intrinsically single lasers
1. Development of time delay lines based on nonlinear optical processes in semiconductors
   - We design waveguide structures that allow us to use a laser to slow down the speed of propagation of the signal light passing through a waveguide in a controlled way.
1. Active photonic band gaps:
   - We develop photonic structures that can become photonic gap structure when activated with a laser beam in a reversible wavy



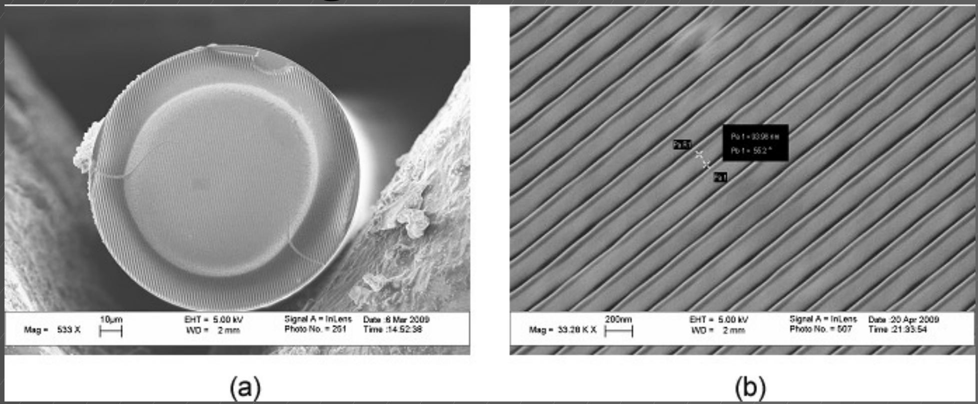


Ultra-wideband optical fiber inline polarizer

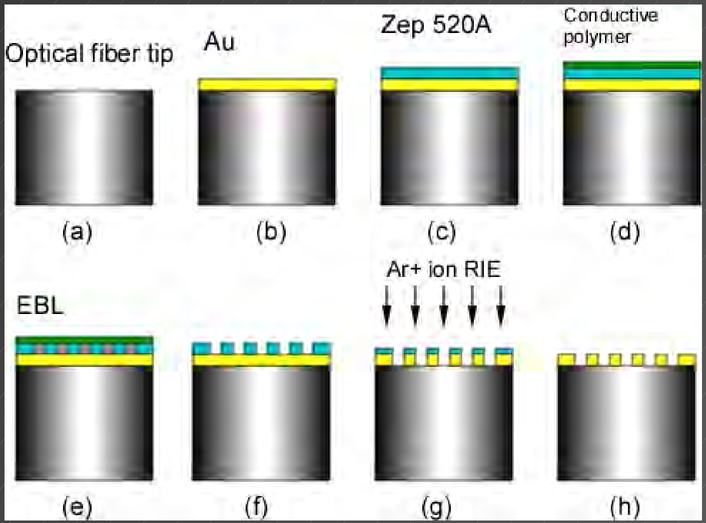
Λ =200nm, f=0.5
D=100nm



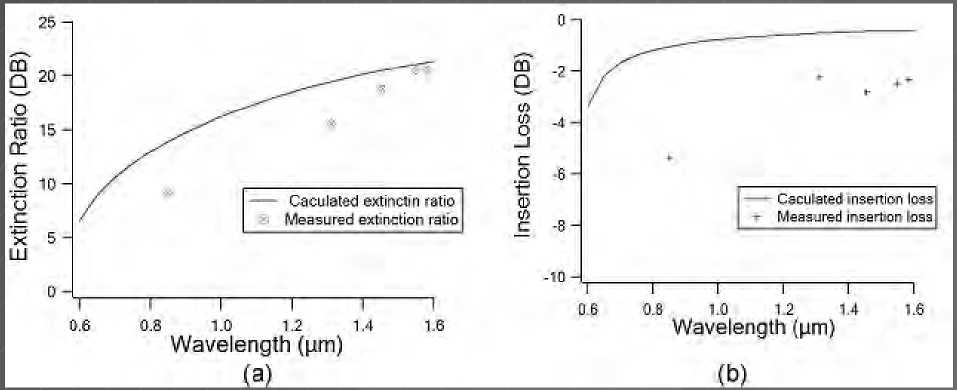
SEM image:



Fabrication Process:



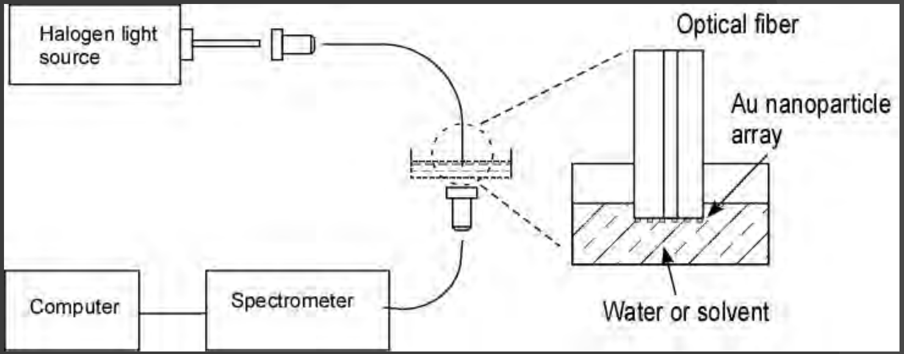
Device Characterization:

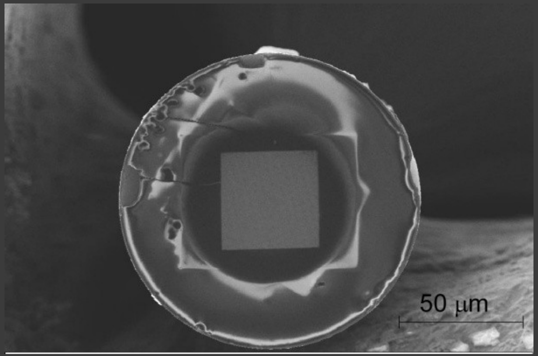


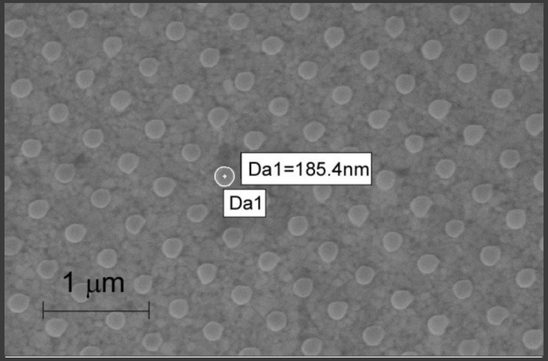
Yongbin Lin, Junpeng Guo, and Robert G. Lindquist, "Demonstration of an ultra-wideband optical fiber inline polarizer with metal nano-grid on the fiber tip," Opt. Express 17, 17849-17854 (2009).

E-Beam Patterned Gold Nanodots Arrays on Optical Fiber Tips

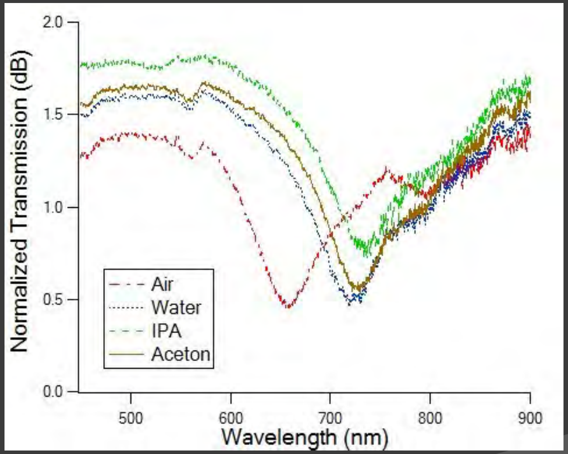
Optical setup for sensor charactrizations:

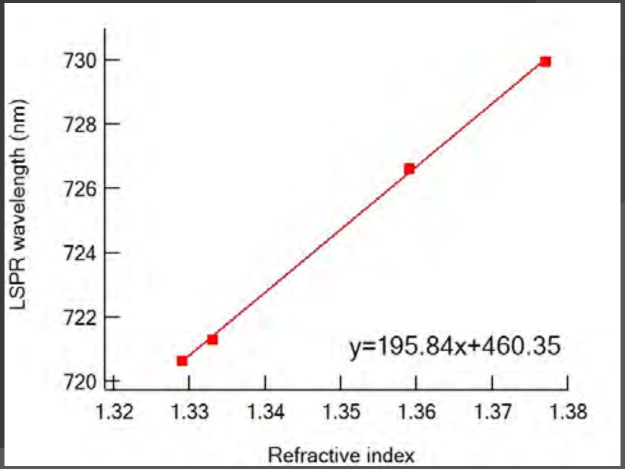






Measured transmission spectra for the fiber sensor in various solvents, and dependence of the LSPR peak wavelength on the index of refraction of the solvents.

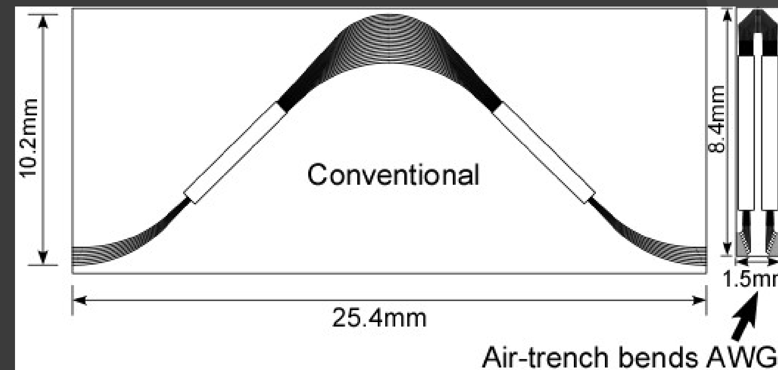


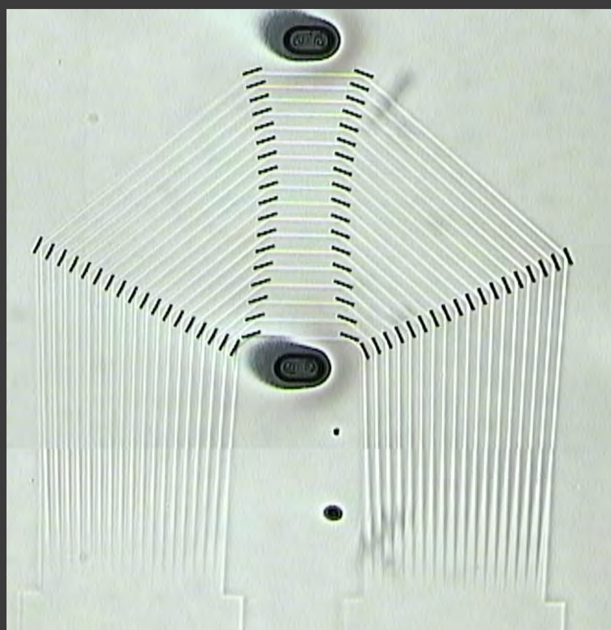


Yongbin Lin, Yang Zou, Yuanyao Mo, Junpeng Guo, and Robert G. Lindquist, "E-Beam Patterned Gold Nanodots Arrays on Optical Fiber Tips for Localized Surface Plasmon Resonance Biochemical Sensing," Submitted to Sensors journal.

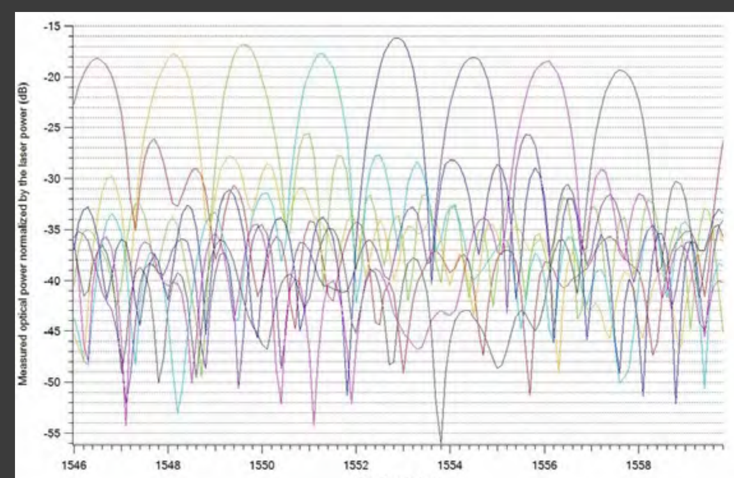
Photonic Design and Analysis

20x reduction in AWG





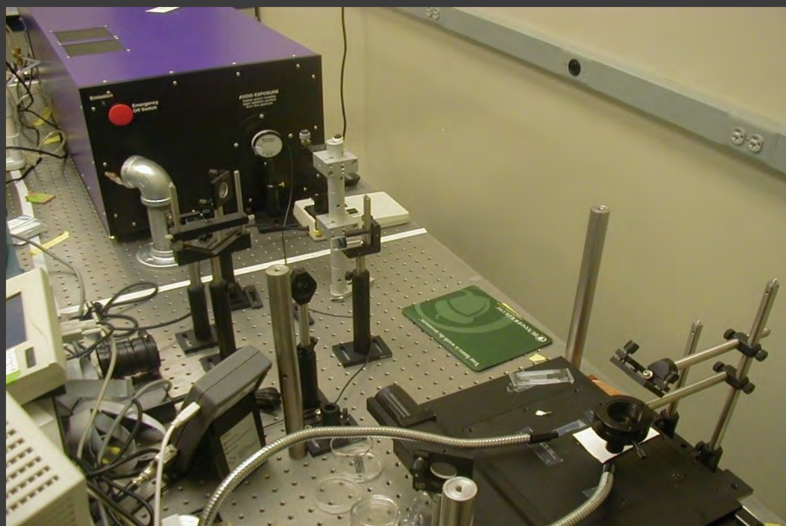
Fabricated Air Trench Design

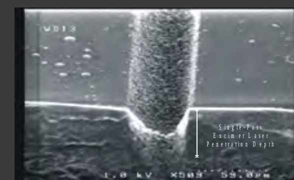


Promising Results

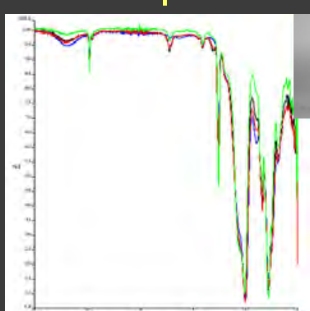
ytical Chemistry is the science of determining what and how much of a chemical is presen
Analytical Chemists are interested in doing things cheaper, faster, and with less waste.

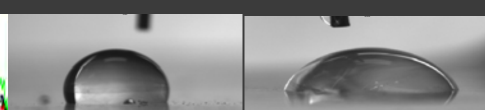
rofluidics involves moving nanoliters (10^{-9}L) of fluid through micron(10^{-6}m) sized channels.
Channels are fabricated with a high powered laser using a technique called laser ablati

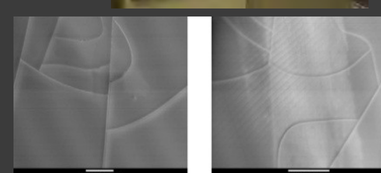


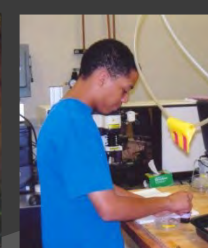


Students perform measurements that allow us to understand chemical changes.



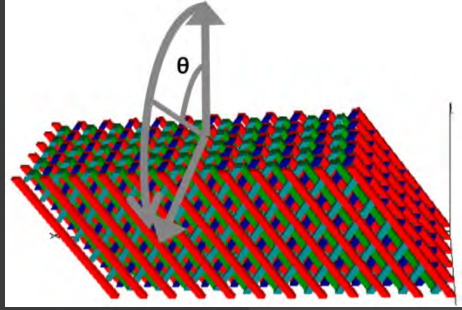




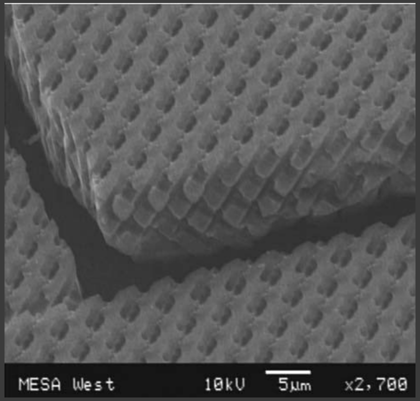


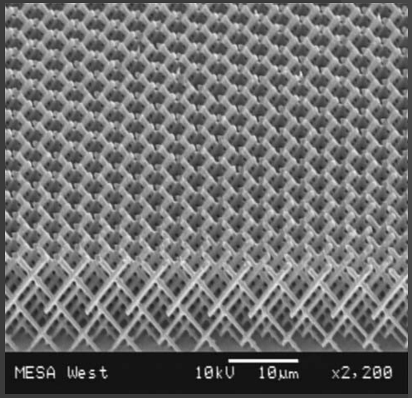
Dr. Emanuel Waddell, chemistry.uah.edu/faculty/waddell

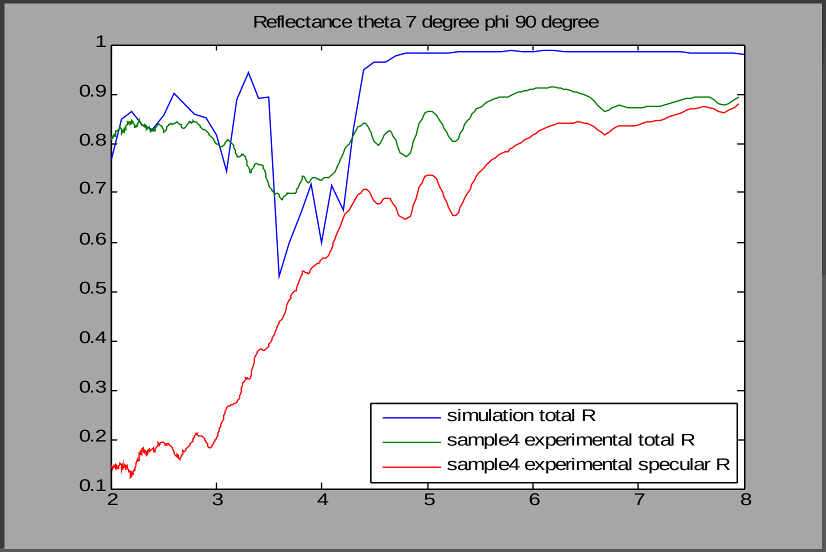
3-D Photonic Crystals



- 3-D metallic photonic crystals patterned over a few square inches
- Crystals are 3 unit cells tall and patterned in a single lithography process
- Current band edge is 4 μm
- Next generation devices will have a 2um band edge to be used with thermal photovoltaics
- A second research effort is underway to produce diffractive transmission patterns through the crystal
- Based on fabrication work developed by Dr. Williams at Sandia National Laboratories



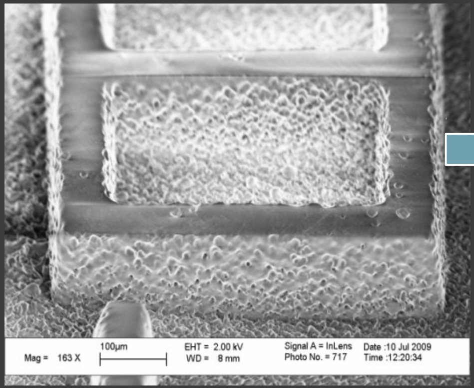


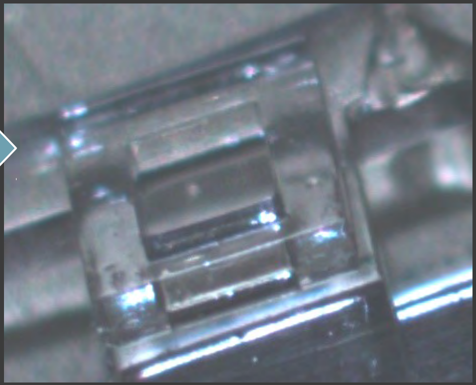


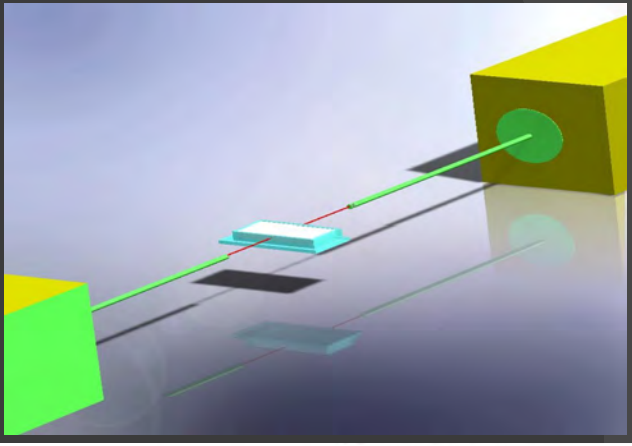
J. D. Williams, W. C. Sweatt, A. R. Ellis, "Woodpile photonic crystals using the LIGA technique," Journal of Micro/Nanolithography, MEMS, and MOEMS 9(02), 023011 (2010).

Lithographic Processing of APEX Glass

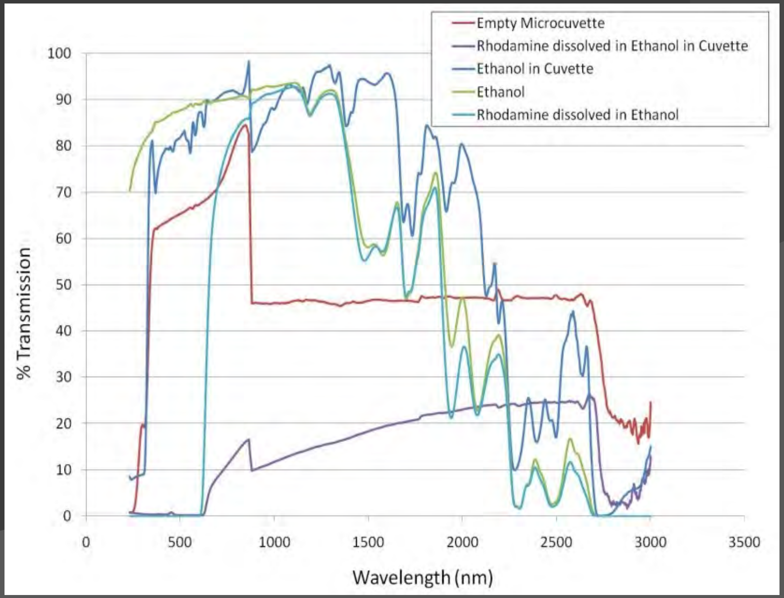
king optically smooth glass sidewalls from Photodefined gla







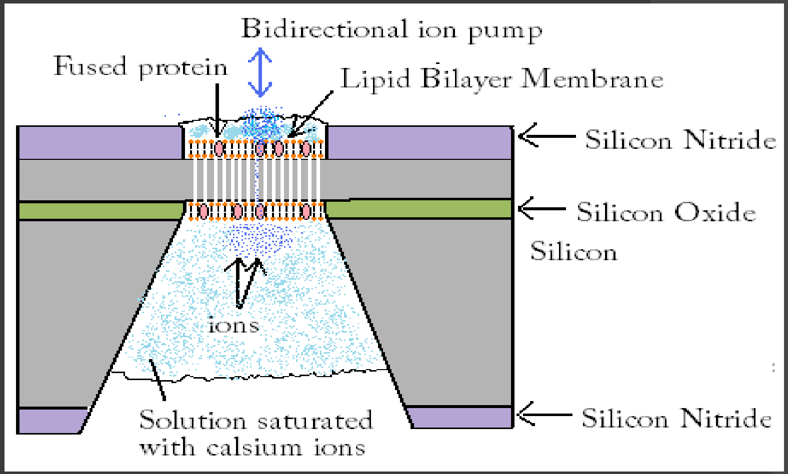
- Glass is biocompatible, chemically stable to 400°C and can be sealed hermetically
- Our Post etch anneal yields a 20 nm surface roughness
- Allows one to perform visible and IR spectroscopy in the plane of the microfluidic channel

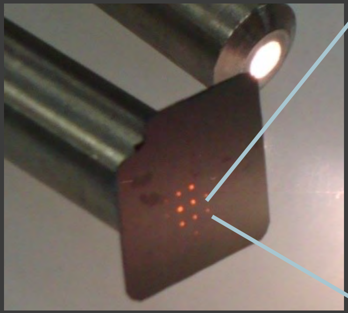


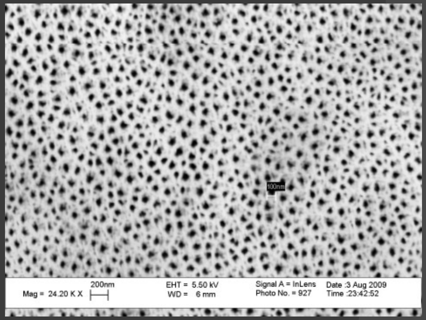
K. H. M. Tantawi, J. Oates, J. D. Williams, "Processing of lithographically defined Apex glass structures with smooth and transparent sidewalls," 6th International Conference and Exhibition on Device Packaging, Scottsdale, AZ, (2010).

Silicon Biomembrane Technology

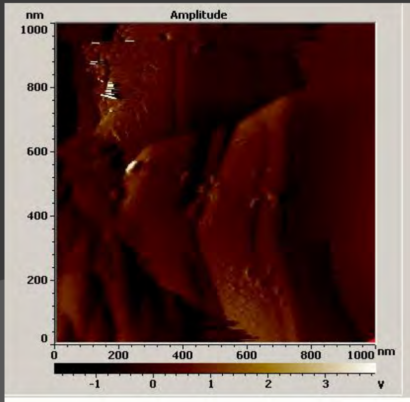
- Anodic HF etching of 3 µm silicon membranes with 50 nm pores
- Lipid Bilayers are deposited and fused with proteins with the help of Dr. Cerro of Chemical Eng. at UAH and Dr. Berdiev of the UAB Biophysics Department
- AFM scans of Lipid coated porous silicon were taken with the aid of Dr. Patel in the Math Department of Oakwood College
- Future work:
  - deposition of lipid bilayers with fused proteins onto porous membranes
  - Test for changes in electrochemical impedance.
  - Drive ions across the membrane and measure differential impedance
  - Provide AFM and NSOM scans of surface tested







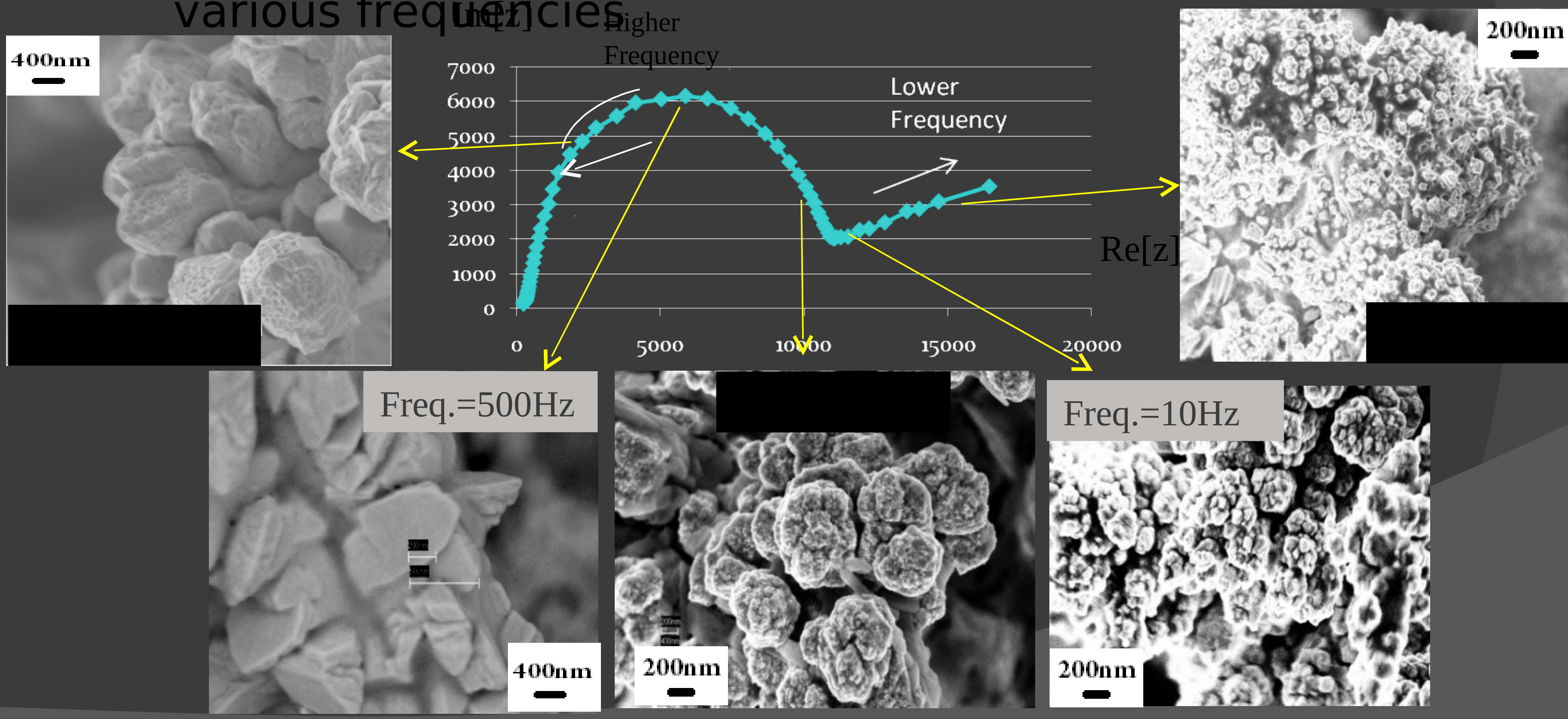
50 nm pores in Silicon



AFM of Lipid Bilayer with fused protein (?) on porous silicon

Modifying Grain Size in Electroplated Gold

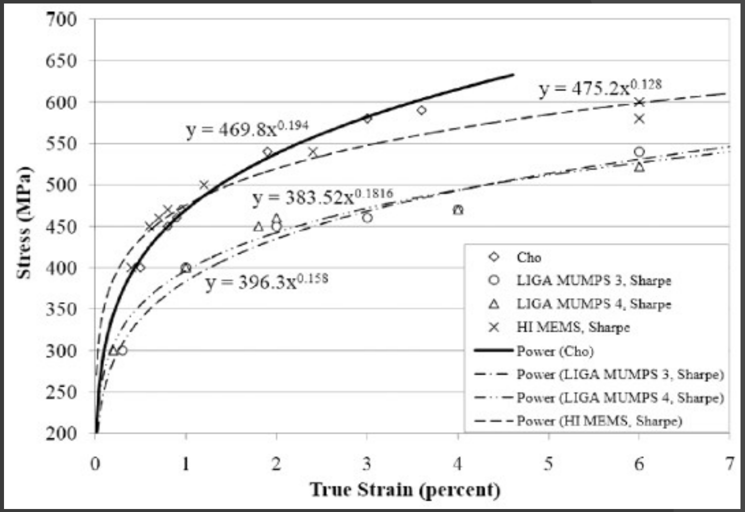
- UAHuntsville Engineers have developed the means to control the grain size of electroplated gold from grain sizes of 40 nm to 2 µm by controlling deposition bath a various frequencies

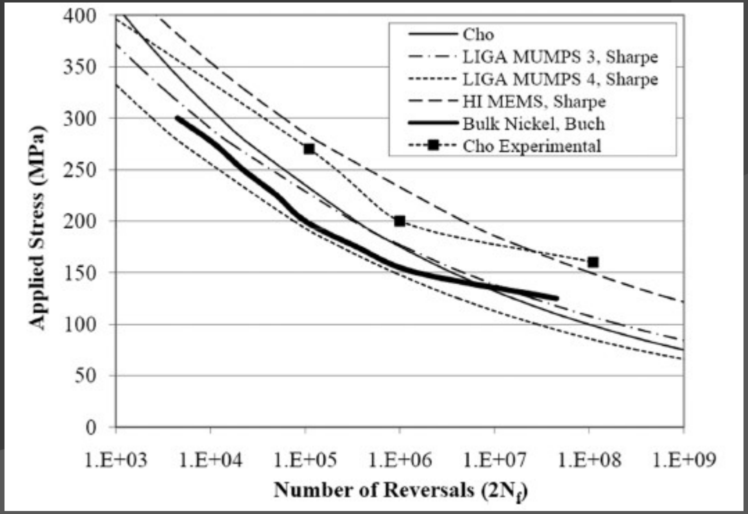


R. Kamali S., J. D. Williams, " Frequency dependant control of grain size in electroplating gold for nanoscale applications," Electrochemical and Solid State Letters 13(6), D37 - D39 (2010).

Fracture Mechanics of Electroplated Ni and NiFe Alloys

- Theoretical model using known fatigue data on electroplated nickel microstructures from various groups
- Curve fitting allowed for the prediction of failure mechanics
- The model predicts brittle fracture on the nanoscale with crack lengths equivalent to the grain size of the metal microstructure
- The use of this crack propagation constant allowed us to fit experimental fatigue data across multiple research efforts for the first time
- This effort can be extended to a number of different metallic micro-structural materials to provide a viable standard for the prediction of mechanicalfailure in MEMS components

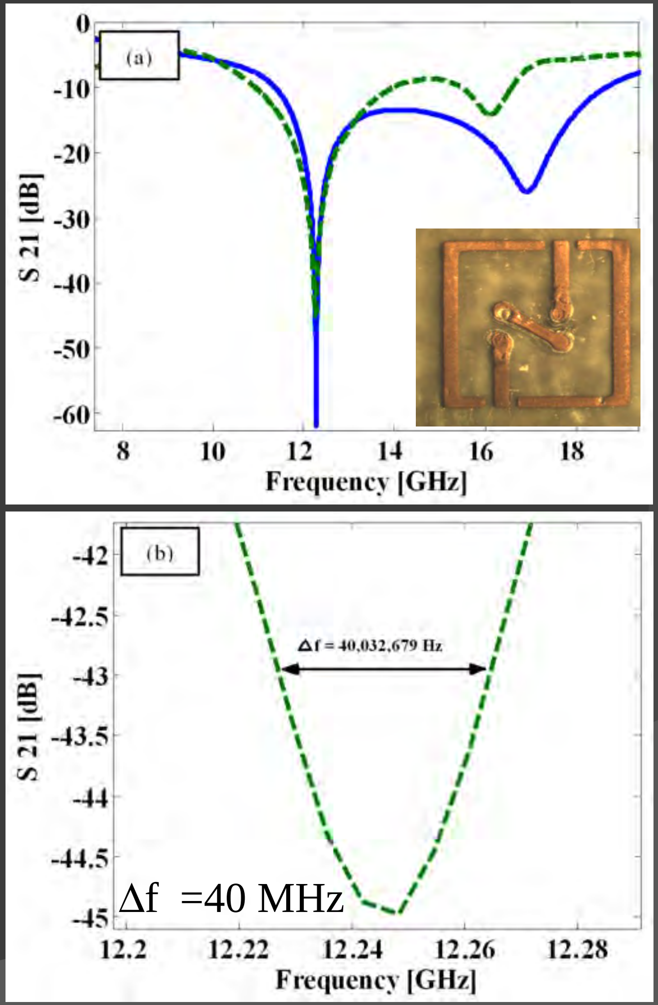




J. D. Williams, "Fatigue and Fracture Mechanics of LIGA Fabricated Nickel and Ni-20%Fe Microstructures," International Journal of Theoretical and Applied Multiscale Mechanics 1(3), 266 - 279 (2010).

GHz Filter Technologies

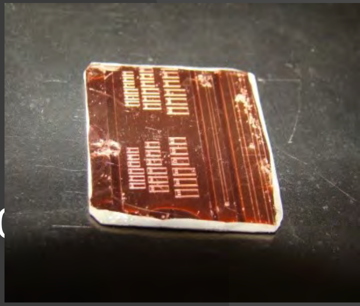
- Resonator for filtering front end GHz networks
- Bandwidth of 1-15 GHz by design
- Application window includes WiMax, Radar, GPS, WiFi, FSM, LTE, and Satellite communications
- Product size is 3x3x6 mm^3
- 300 Q filter at 12 GHz with a 3 db bandwidth of 50 MHz
- Demonstrated linear phase shift matches simulation data
- Currently being licensed for commercial development

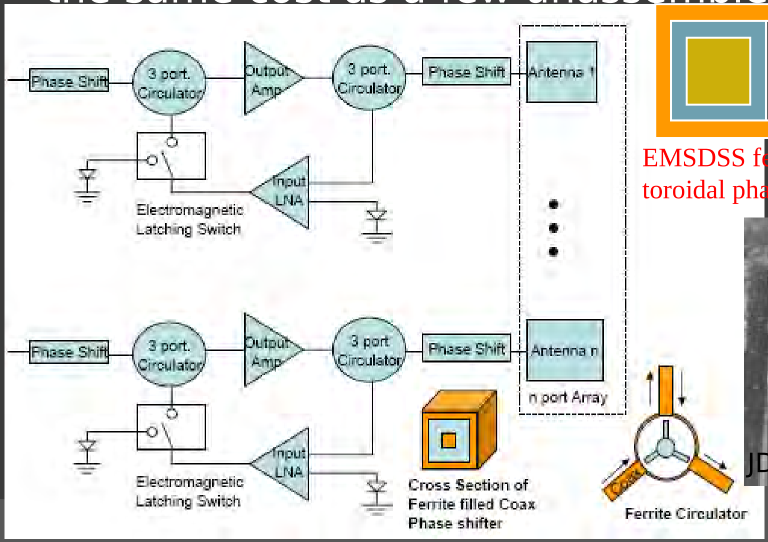


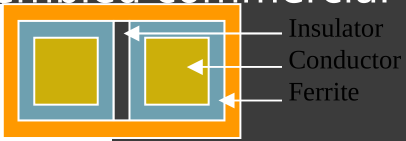
R. Kamali S., **J. D. Williams**, "Fabrication of High Quality Factor RF-Resonator Using Embedded Inductor and Via Capacitor," Conference of the IEEE Industrial Electronic Society (IECON) Phoenix, AZ. (Nov. 2010).

Upcoming Project: Microfabricated Monolithic RF Transceivers

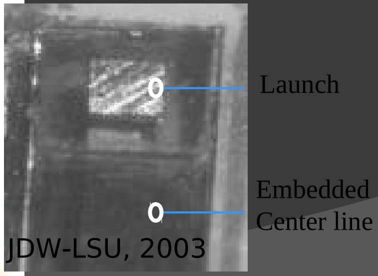
- wafer level RF transceiver technology for Ka band GHz frequency applications
- high aspect ratio lithographic patterning to combine MEMS coaxial technology with ferrite filled isolators, circulators, and phase shifters
- Decreases the size of synthetic aperture radar (SAR) systems by 10(times with 10 times less loss
- SARS can then be mounted on small unmanned air vehicle (UAV) platforms for regions where manned recognizance is either unsafe or cost prohibitive
- The envisioned system can be mass manufactured for approximately the same cost as a few unassembled commercial off the shelf (COTS)







EMSDSS ferrite loaded toroidal phase shifter [20]



SU-8 Filled μ-Coax

Waveguide (Cu conductor)	Power (W)	Band-width (GHz)	Loss (db/m) @ 30GHz
Microstrip (air)		0 - 100	66
Rectangular (air)	140	20 - 200	4
Coax (air)	10	0 - 100	4.5
Coax (ferrite)	8	0 - 40	0.05
Rectangular (ferrite)	80	15 - 40	0.03
Ferrite COTS isolator	5 -10	15 - 40	0.75

Technical Issues:
- Lithographic patterning of Cu, NiFe, NdFeB, and Ferrite on the same substrate
- Magnetic field uniformity of laser machined ferrites
- Final tests depend on customer driven application

What’s Next at NMDC?

- Study of the morphology and orientation
- Deposition of periodic grain size structures
- Ultra high surface area catalysts