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SACNAS

Sandia's MESA Facility: Integrating Micro and Nano to Create Innovative Microsystem Devices and Technologies.

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Director

Microsystems Science, Technology & Components Center

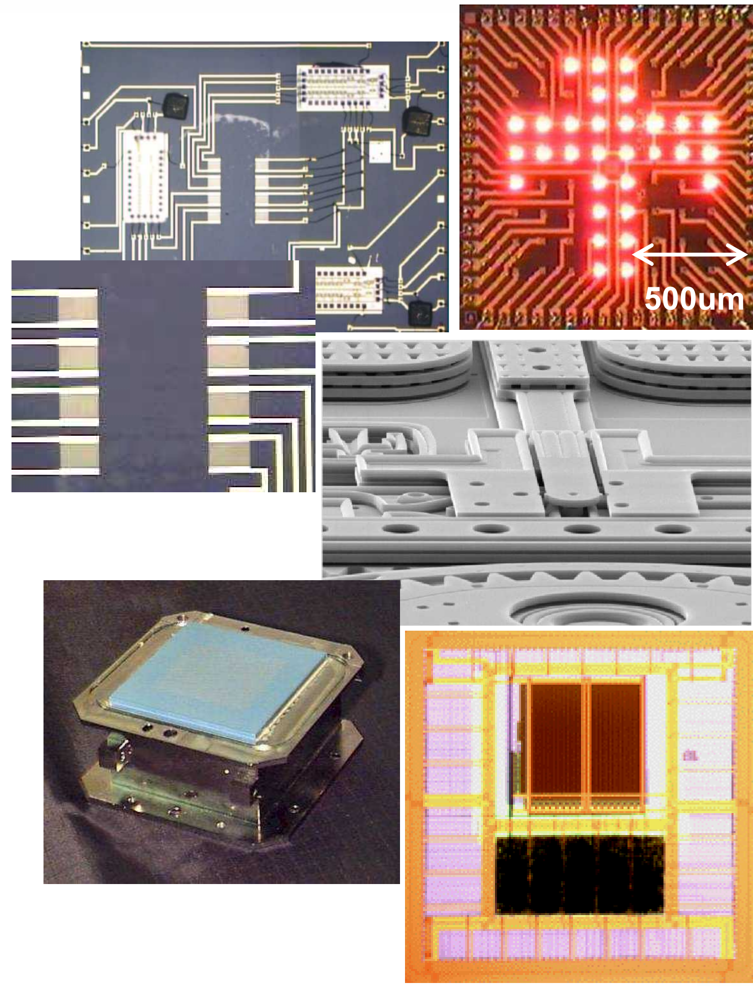
Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

NNSA National Nuclear Security Administration

Sandia National Laboratories

Exploiting smaller length scales: from discrete components to integrated products.

- **Microsystems components such as pressure sensors, accelerometers, inkjet print heads, etc. are incorporated into larger assemblies to enable unique products.**
- **Emerging applications integrate electrical, optical, mechanical, and fluidic microsystems with advanced packaging to produce truly integrated microsystems.**
- **Microsystems enable diagnosis and understanding of nanotechnology. This will enable the use of nanoscale phenomena in future integrated systems.**



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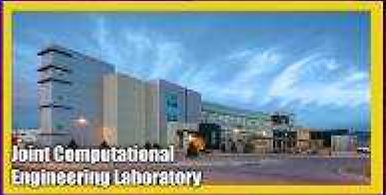
MESA Provides Top Facilities and Equipment For Microsystems Design, Fabrication and Test

Key element in the Center for Integrated Nanotechnologies (CINT)

- Trusted Digital, Analog, Mixed Signal & RF Integrated Circuits Design & Fabrication
- Micromachining
- RAD Effects and Assurance
- Failure Analysis,
- Reliability Physics
- Test & Validation
- 3-D Integration

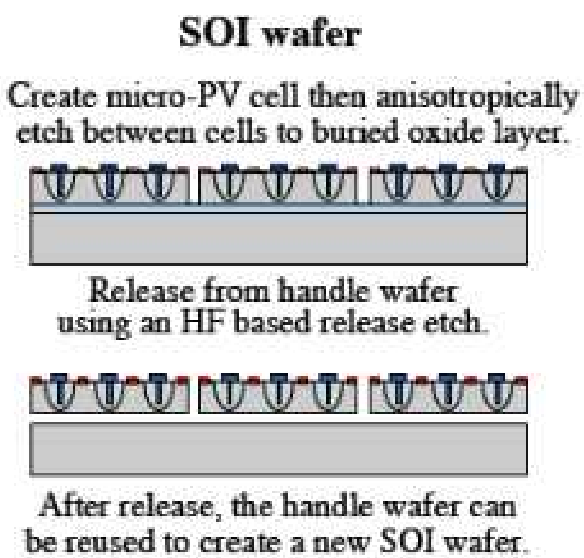
- Compound Semiconductor Epitaxial Growth
- Photonics, Optoelectronics
- MEMS, VCSELs
- Specialized Sensors
- Materials Science
- Nanotechnology, Chem/Bio
- Mixed-Technology Integration & Processing



- Advanced Computation
- Modeling & Simulation
- COTS Qualification
- Custom Electronic Components
- Advanced Packaging
- System Design & Test

National Laboratories

Novel microscale devices: Low-cost lift-off silicon solar cells



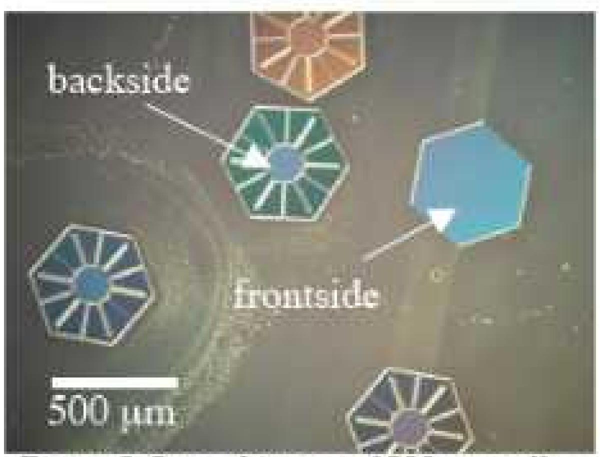
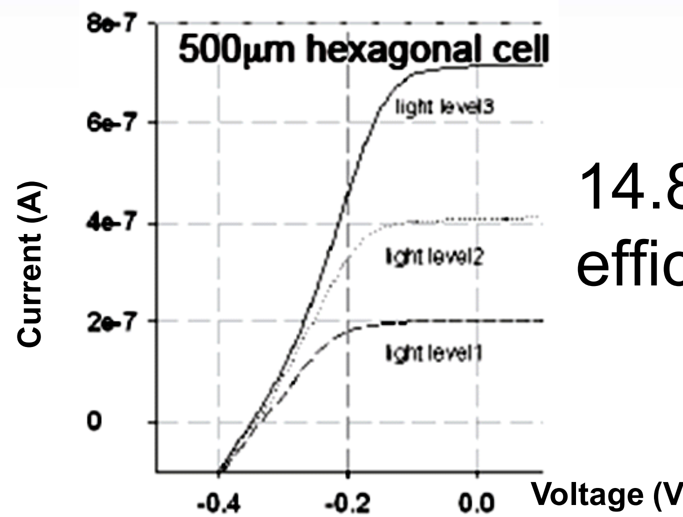


Figure 2 Optical image of 500 µm cells.



14.8% efficient

- **Silicon material accounts for 50% of module cost of single-crystalline silicon solar cells.**
- **Most of the solar spectrum absorbed in first 10-20µm of silicon.**
- **SOI release technology allows of factor of 10 savings in silicon material by re-use of silicon substrates.**

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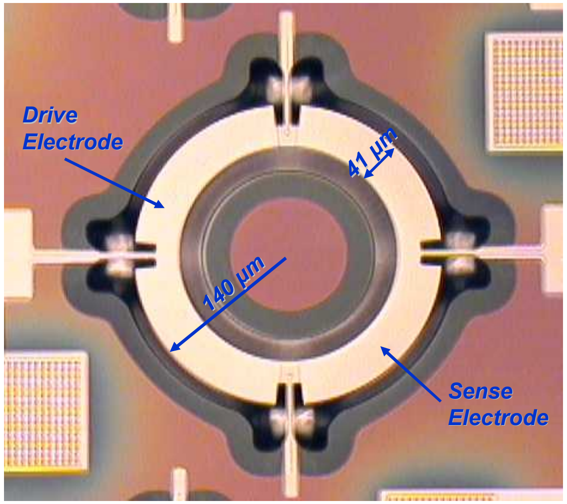
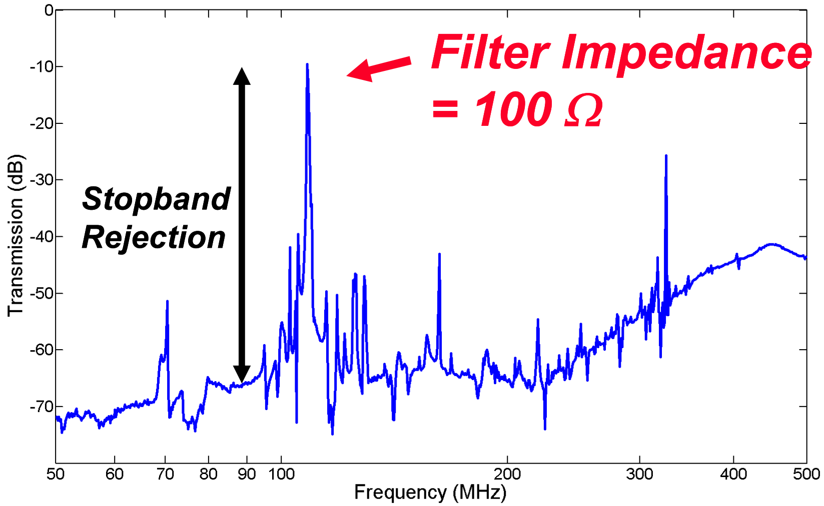
Toward Microsystem Integration: Monolithic RF MEMS Resonator Technologies enable new architectures.

- **Properties**
  - Lithographically Defined Mechanical Resonance from ***1 MHz – 3 GHz***
  - Resonator Impedance ***10 – 500 Ω*** can be matched to standard impedances
  - Quality Factors: ***1500 – 5000***
  - Integrates filters, oscillators and sensors directly on foundry CMOS
  - Reduces size, cost, compared to SAW devices, crystal resonators and filters.
  - Eliminated hundreds of wire bonds in alternative approaches.
- **Motivation**
  - Microresonators enable new architectures for small superheterodyne radios (miniature + high performance)
  - Microresonators enable small multi-channel radios for commercial and defense applications



Dual mode AlN filter



Wideband transmission of dual mode filter

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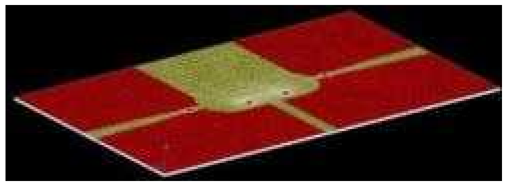
Sandia's broad capabilities enable a systems approach to Quantum Computing.

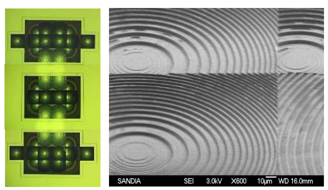
Sandia researches ion traps, silicon quantum dots, neutral atoms, topological and Josephson Junctions.

Computational Science Research Institute

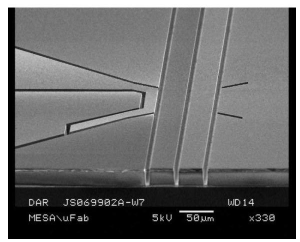


Device Modeling Using HPC

Center for Integrated Nanotechnologies (CINT)

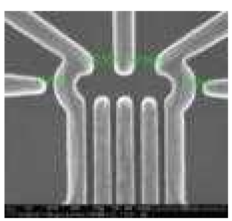


UV Diffractive Optics



Microfabricated Silicon Ion Traps

MESA Fabrication Facility

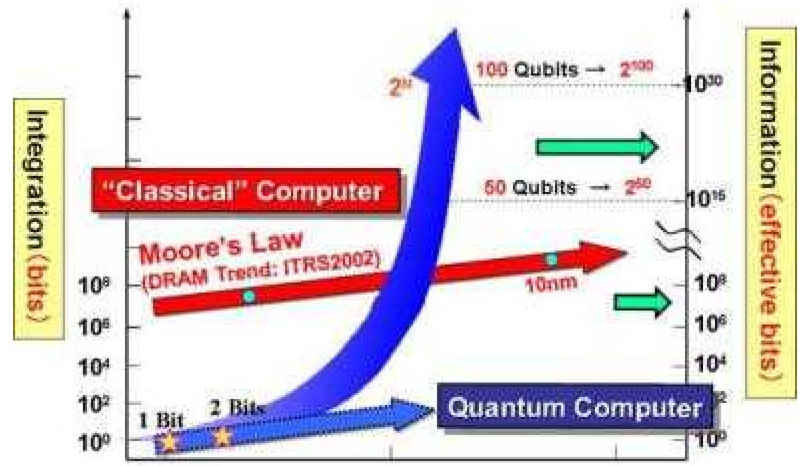


Silicon Quantum Dot Qubits

Cryogenic CMOS

Multidisciplinary S&T activity to understand quantum engineering

- Atomic and electron physics
- Microfabrication and integration
- Computer architecture
- Technology applications



- Quadratic speedup in sorting
- Simulation of quantum systems
- Cyber-Ops
- Secure Communication
- Logistics (Traveling Salesman)
- Image analysis
- Understanding of quantum effects for classical computing (i.e. Beyond Moore's Law)

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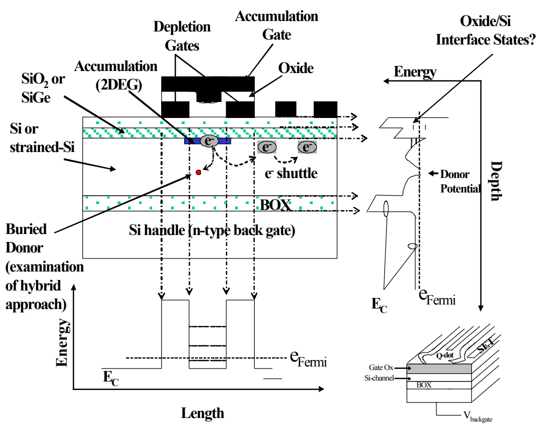
Vision of an integrated microsystem: from Silicon Qubit to Error Corrected Logical Quantum Circuit.

Silicon Qubit Hardware



Qubit Gates & Lay-out

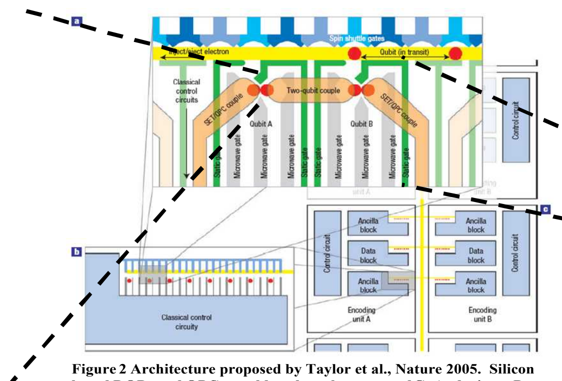
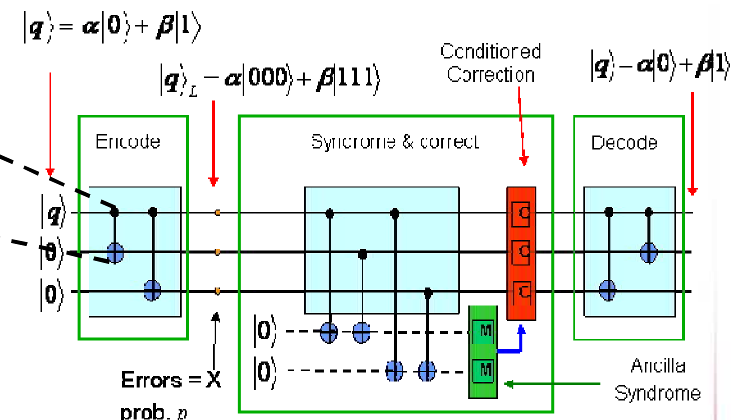


Figure 2 Architecture proposed by Taylor et al., Nature 2005. Silicon based DQDs and QPCs would replace the proposed GaAs devices. Donors are proposed as a supplement to enhance the architecture in this work.

Error Corrected Logical Qubit



- *<u>Primary goal:</u> demonstrate feasibility of silicon qubits at silicon/insulator interface*
  - GaAs has demonstrated that qubits may be formed in semiconductors
  - Silicon-based double quantum dot is appealing because of promise of long T_2
  - The dominating doubt about Si QC is the qubit existence proof
- *<u>Technical hurdle</u> => develop silicon qubit hardware and plans to extend physical qubits to a logical qubit*

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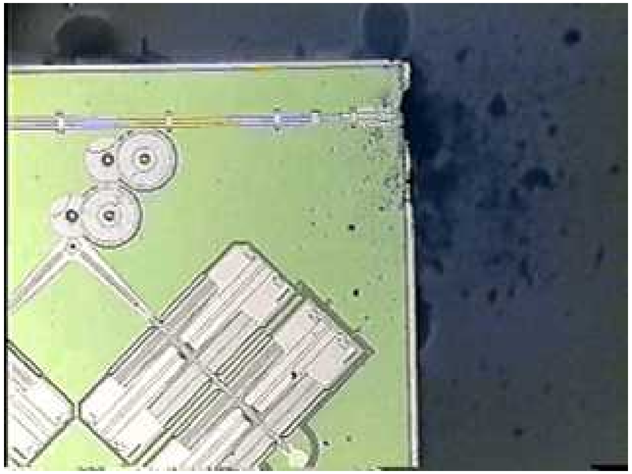
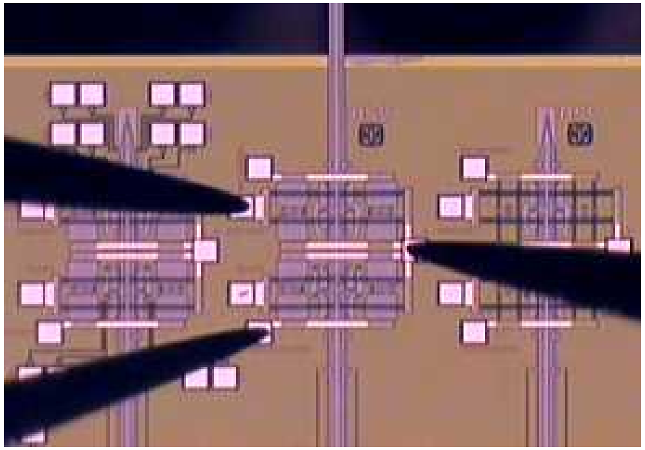
Micromachined Neural Probes

- First off-chip coupling to the external world (4mm extension)
- Testing under way at Arizona State University
- New designs have higher force, longer throw and better functionality with ratcheting thermal actuators

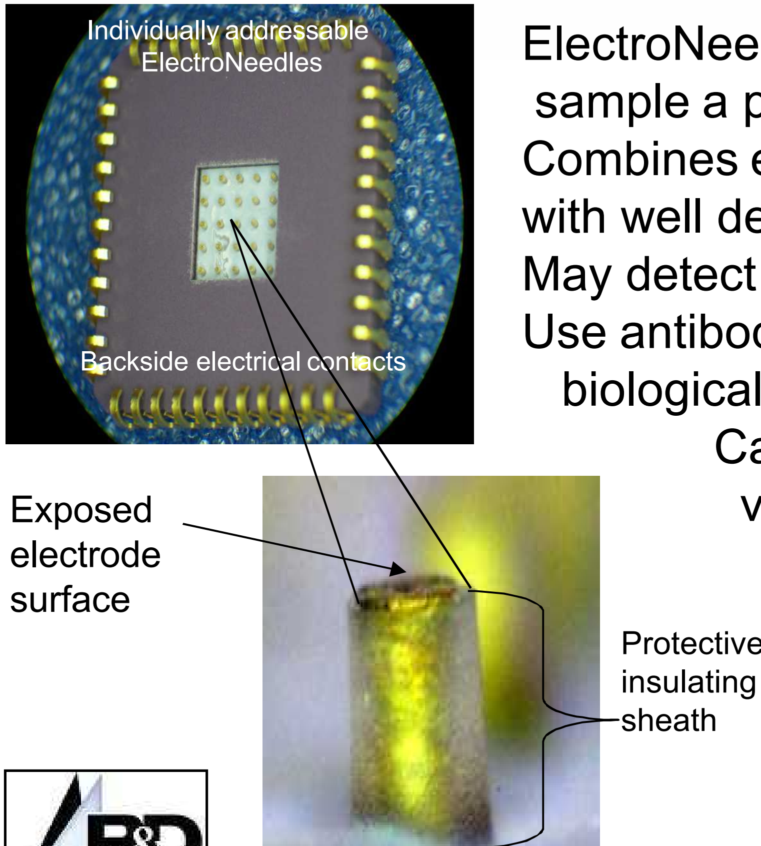


First probe design using electrostatic actuation



Current design using thermal actuation

Sandia-Developed ElectroNeedle array



ElectroNeedles are micron-scale electrodes that ***painlessly*** sample a patient interstitial fluid or blood

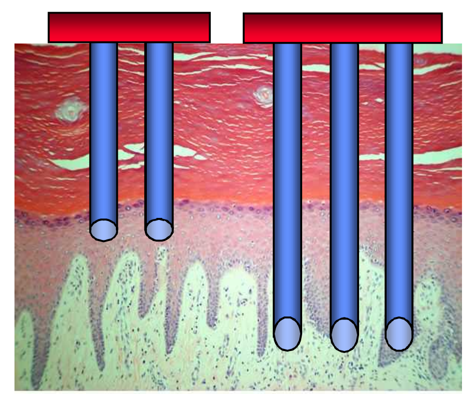
Combines electrochemical measurement techniques with well defined immunoassay chemistry

May detect up to 50 targeted analytes in minutes

Use antibodies, enzymes, and cellular receptors to detect biological components, including...

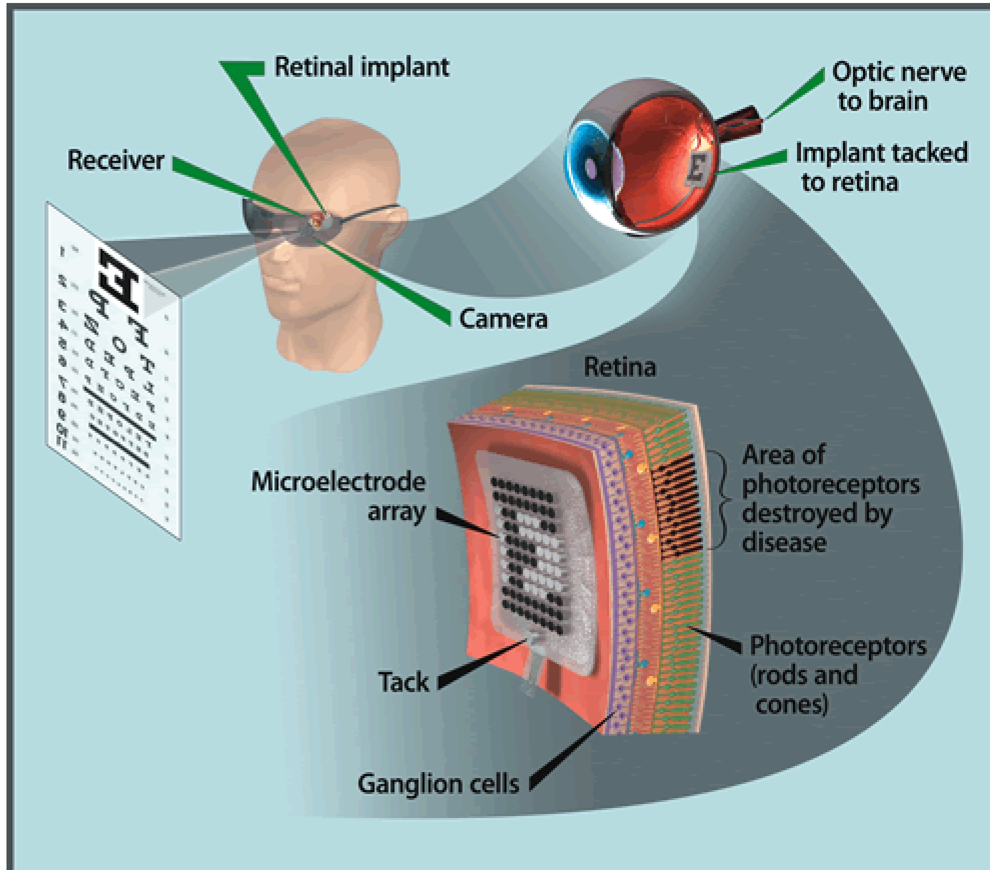
Carbohydrates, lipids, enzymes, toxins, proteins, viruses, and bacteria

Tailor ElectroNeedle height to access various analytes



Cross section of skin

Artificial Retina Project



Collaborators;
Doheny Eye Institute at the University of Southern California; Second Sight™ Medical Products, Inc.; Argonne National Laboratory; Brookhaven National Laboratory; Lawrence Livermore National Laboratory, Los Alamos National Laboratory, North Carolina State University, Oak Ridge National Laboratory, Sandia National Laboratories, University of California, Santa Cruz, California Institute of Technology.

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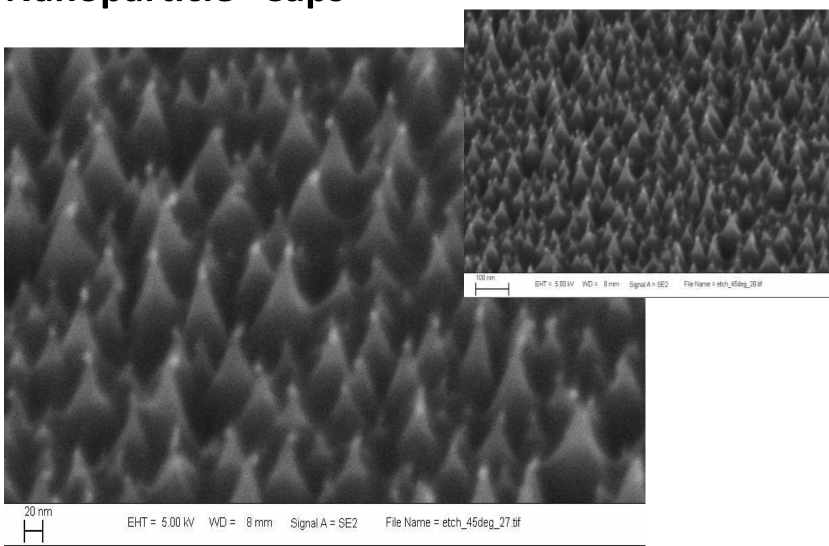
Microscale support for Nanoparticle-based Biosensing without reagents

Step 1: Expose prefabricated nanoparticle array to suspect solution

Reactive Ion Etching of Gold Nanoparticle PPF* Results in Pyramidal Carbon Pillars with Gold Nanoparticle "Caps"

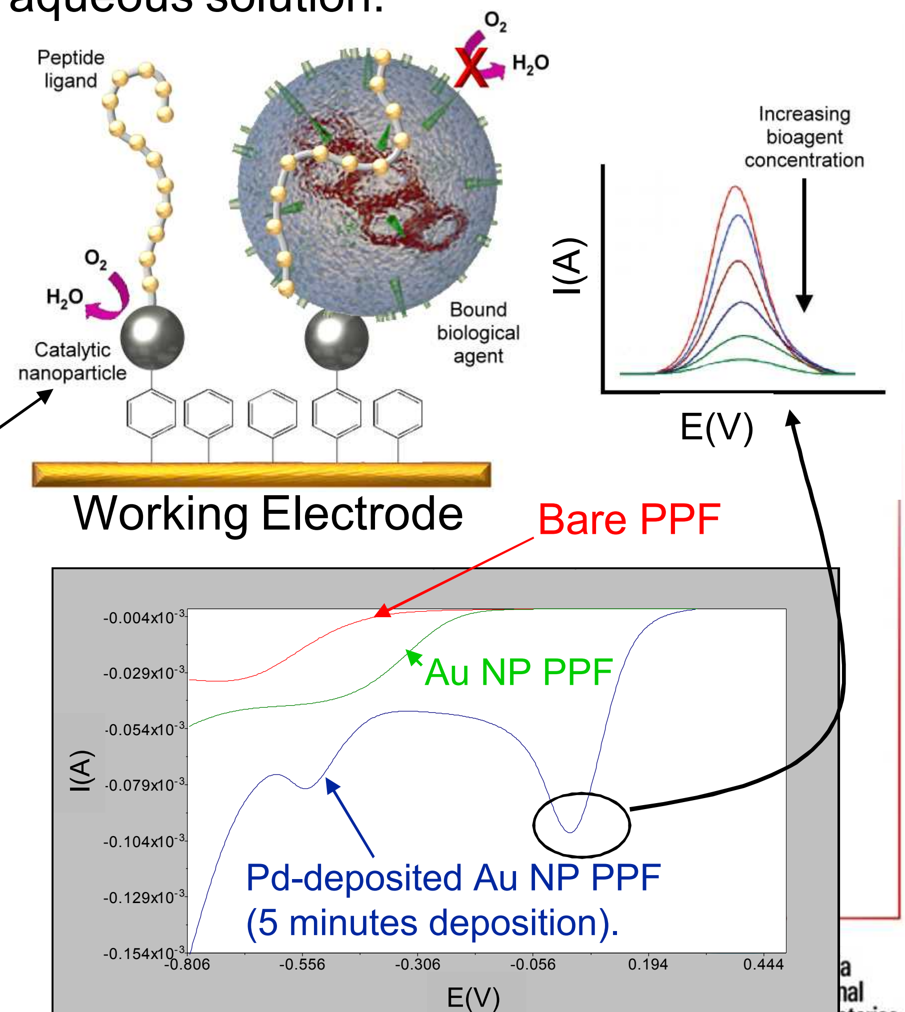


O2 Plasma Etch Conditions: 80 Watt, 40 mtorr, 20 sccm O2, 10 min

Polsky et al., *Small,* **2009,** *in press,* DOI:10.1002/smll.200901007

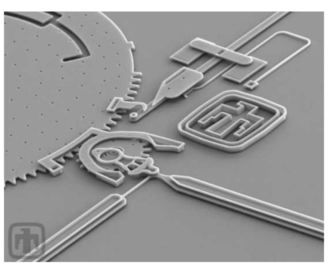
*PPF-Pyrolyzed Photoresist Film

Step 2: Electrochemical analysis in aqueous solution.

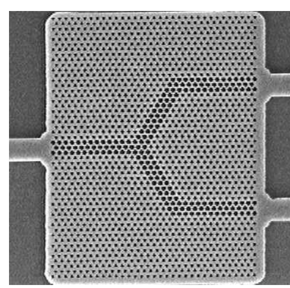


Bridging Micro to Nano:
Center for Integrated Nanotechnologies (CINT)

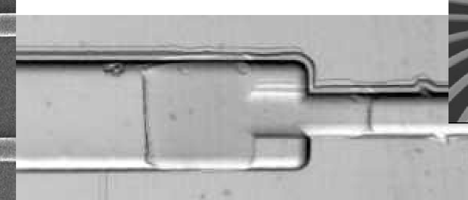
- **New Tools: CINT Discovery Platforms™**
  - Standardized modular, micro-laboratories—designed and batch fabricated for:
    - Integrating nano and micro length scales
    - Studying the physical/chemical properties of nanoscale materials and devices
  - Integrates the spectrum of microsystem technologies



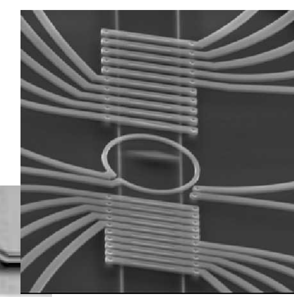
Mechanics



Optics



Fluidics



Electronics

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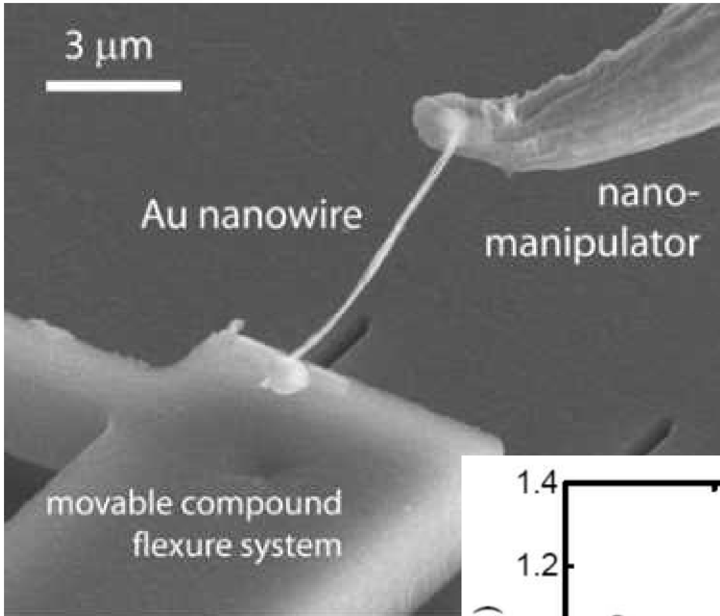
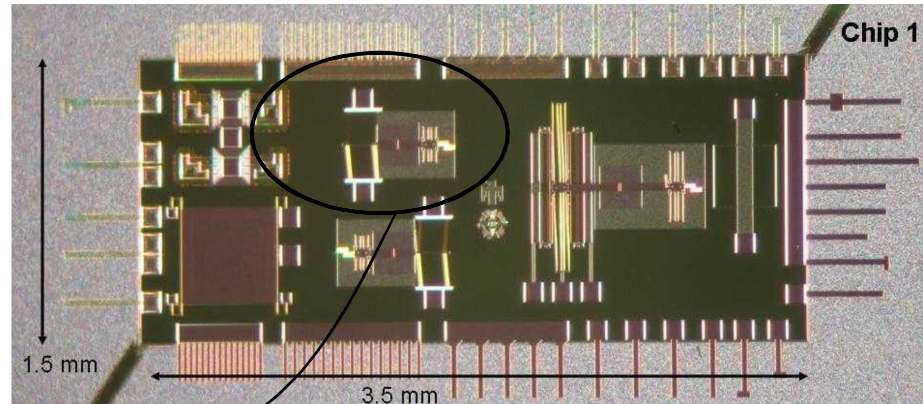
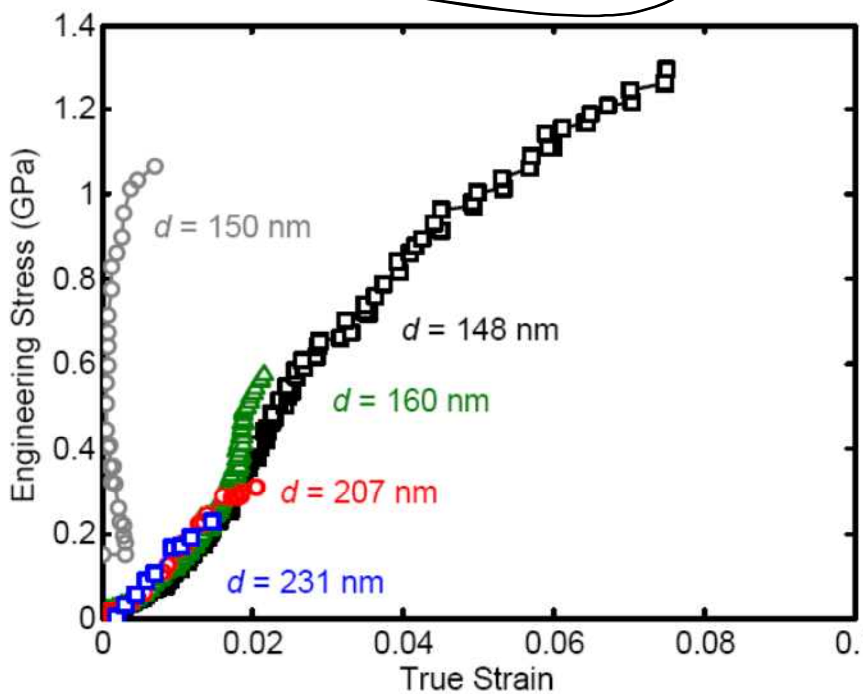
Discovery Platforms™ enable measurement of mechanical properties at nanoscale.







- **Au nanowires with <110> orientation**
- **Comparison: Tensile strength of bulk annealed gold is about 0.1 GPa**

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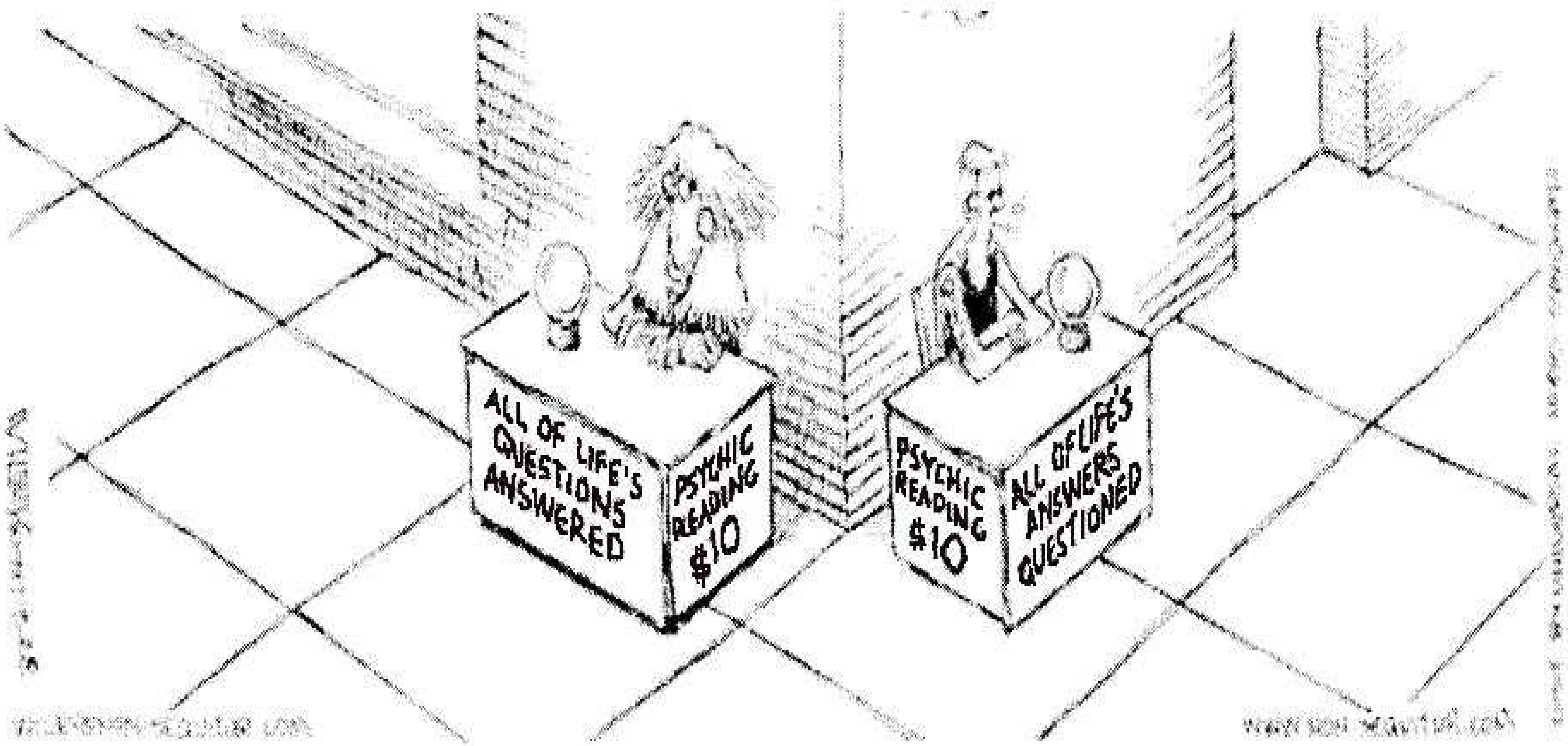
Questions?


ALL OF LIFE'S QUESTIONS ANSWERED
PSYCHIC READING $10
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