Fab-on-a-Chip: A Micron Scale Workshop for Nano Fabrication

David Bishop, Ph.D.
Director, CELL-MET NSF ERC
Head, Division of Materials Science and Engineering
Professor of Physics
Professor of Electrical and Computer Engineering
Professor of Materials Science and Engineering
Professor of Mechanical Engineering
Professor of Biomedical Engineering

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From Nano-Fabrication to Nanomanufacturing

Tennant’s law: Improving resolution results in a large penalty on throughput
Basic Approach

Use Macro Machines to build Micro Machines

Then use Micro Machines to build Nano Machines
Micro-Electromechanical Systems (MEMS)

- MEMS are micro-machines that use mechanical degrees of freedom to sense and actuate on the micron scale.
- The approach to fabrication uses, as a basis, the materials and processes of microelectronics (IC).
- The main difference with an IC process is the release step, at which sacrificial materials are removed, allowing the structural materials to be free to move.
- Coupling to the mechanical degree of freedom is typically capacitive, piezoelectric, thermoelectric or optical.
MEMS Based Lithography Tools: Fab on a Chip

Aim is to fabricate nano-devices using Micro-Machines

- We are developing MEMS counterparts of macroscopic tools typically found in a fabrication facility
- MEMS can sense and actuate the nano-world at fast timescales
- High level of tunability and de-coupling from the environment results in high precision and control

MEMS Micro-Sources

- Suspended Silicon plates ranging from 50x50 µm² to 150x150 µm²
- Constrictions result in heating elements
- Al₂O₃ can electrically isolate and protect the poly-silicon
- Loaded using shadow masks with the desired material

Finite Element Simulation:
- At 1000 K the plate temperature is uniform to within 4 K
- up to ~30 mW before silicon melts (1683 K)
Can “puff off” a wide range of materials from attograms to nanograms
Concept

![Diagram of lithium and pre-made wires with a plate]
Pre-made wires

Plate

Iron
Writers: Placing the Atoms

- Aperture shape can be chosen with features well below 50 nm
- Align with Shutter

Shutter, Plate and Apertures

Linear electrostatic motors

Folded Flexure springs
7 DoF MEMS Atomic Writer with 16 Motors and Backside Etch for Thru Wafer Deposition
Selective Opening of Apertures

a. MEMS Shutter open over both sets of apertures
   \( V_s = 40 \text{ V} \)

b. MEMS Shutter closed over one set of apertures and open over the other
   \( V_s = 70 \text{ V} \)

c. Pattern written with continuously open aperture

d. Pattern written with the aperture and shutter opening and closing during deposition showing the control afforded by the shutter

e. Larger area image of both patterns
Example Structures: \textit{Rings}
Example Structures: *Lissajous curves*
Example Structures:  *Chromium nano dots*

Atoms are placed stochastically within the aperture opening.
Array of Apertures
Example Structures: Direct Writing of Arrays
Fully Integrated Fab on a Chip System

Three Stacked MEMS Devices Create a Fab on a Chip
- Source
  - Writer
  - Sample
Fully Integrated Fab-on-a-Chip
Apertures on Writing Plate

Pattern, written and then writing plate moved and written again
Questions?