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

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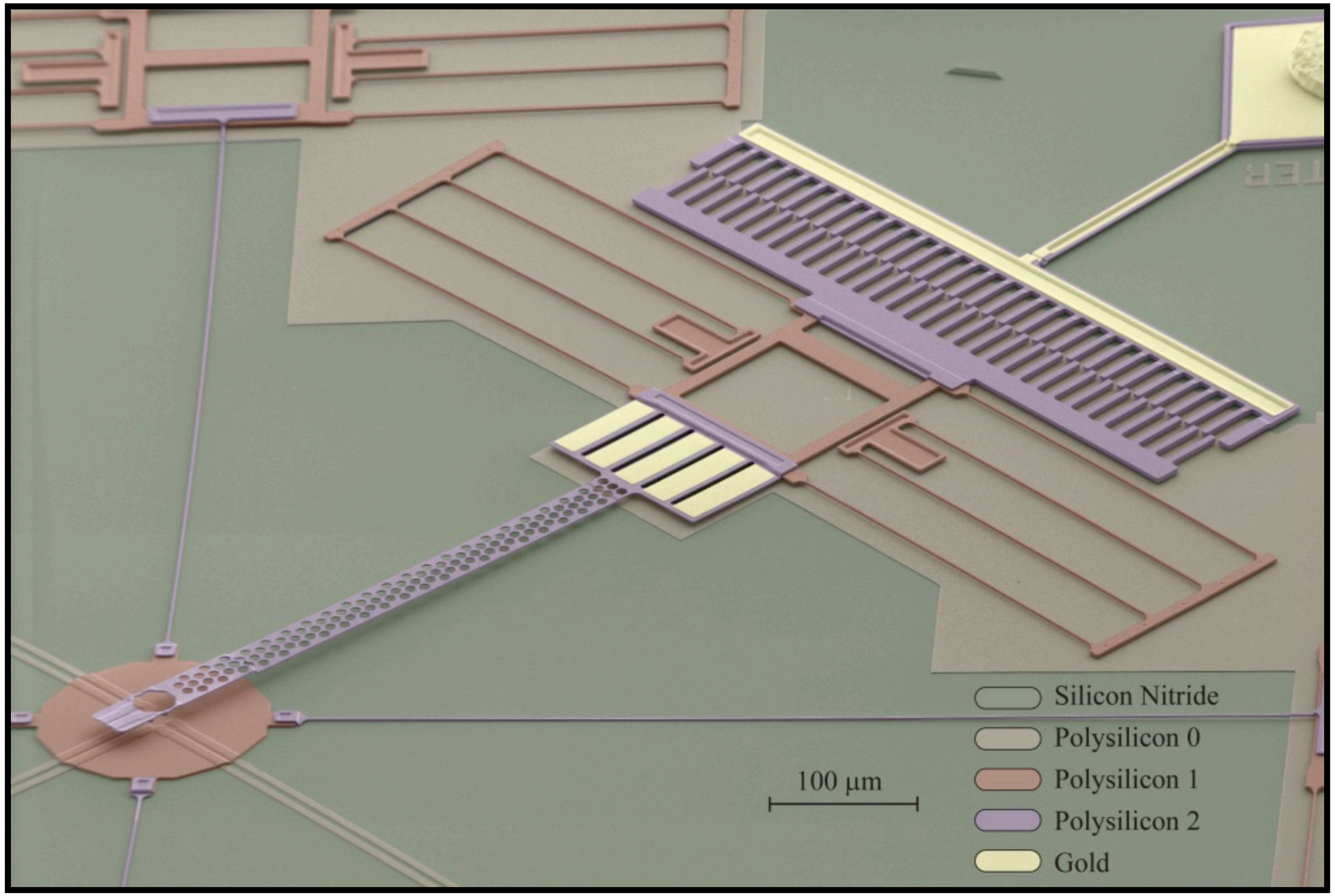

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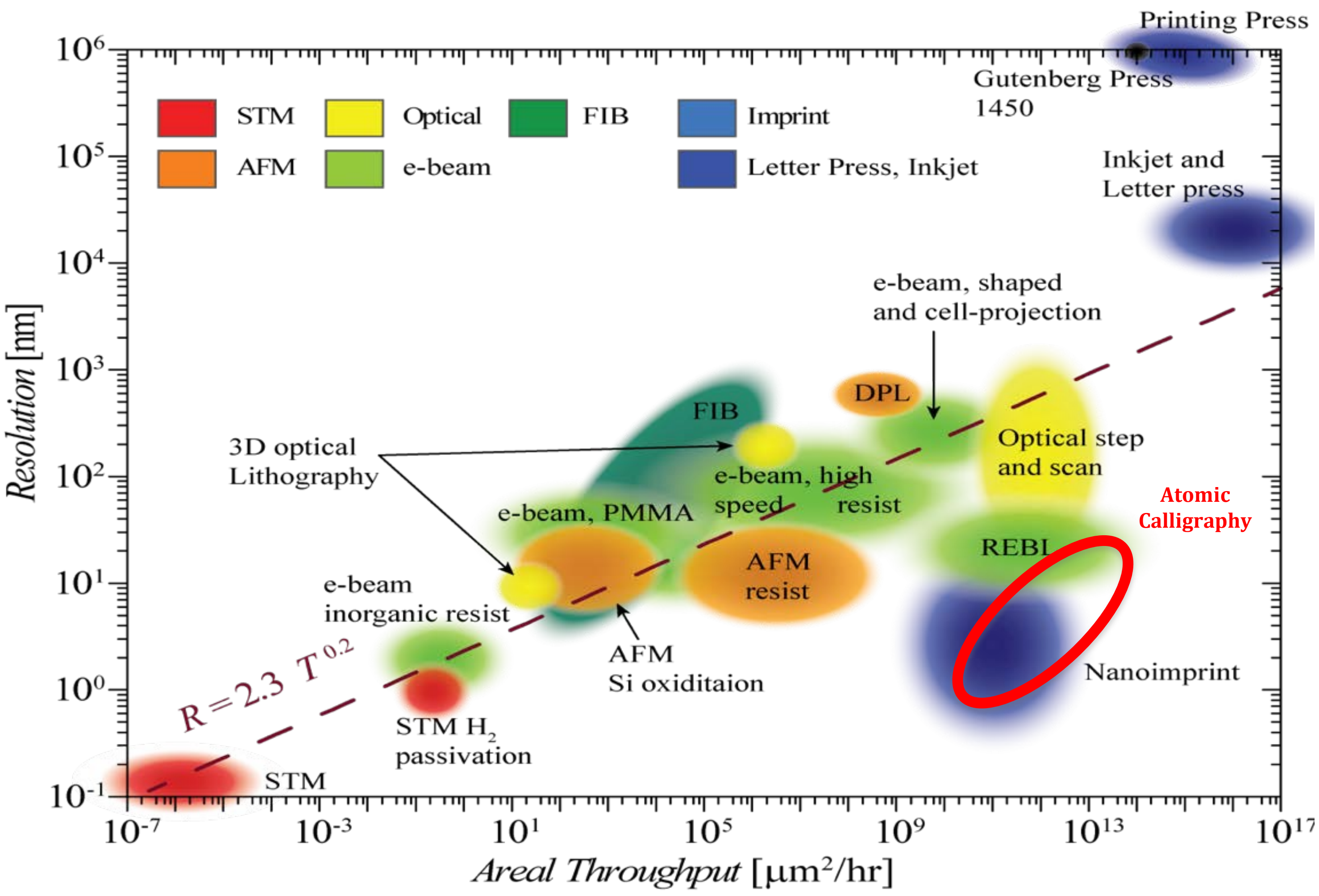
Head, Division of Materials Science and Engineering
Professor of Physics
Professor of Electrical and Computer Engineering
Professor of Materials Science and Engineering
Professor of Mechanical Engineering
Professor of Biomedical Engineering

From Nano-Fabrication to Nanomanufacturing



Tennant's law: Improving resolution results in a large penalty on throughput

Basic Approach

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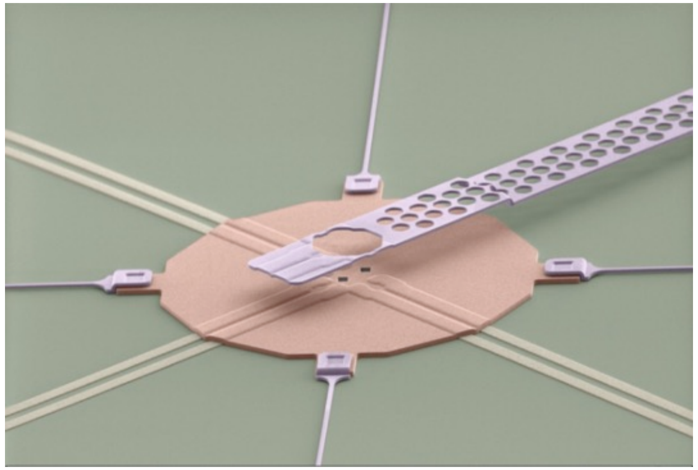
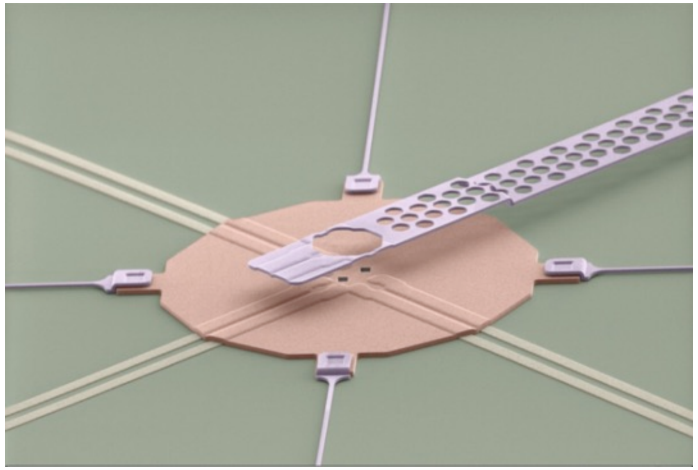
Use Macro Machines to build Micro Machines

→



Then use Micro Machines to build Nano Machines



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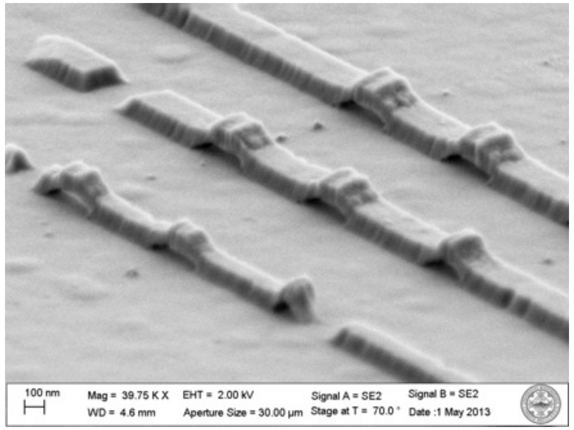

Micro-Electromechanical Systems (MEMS)

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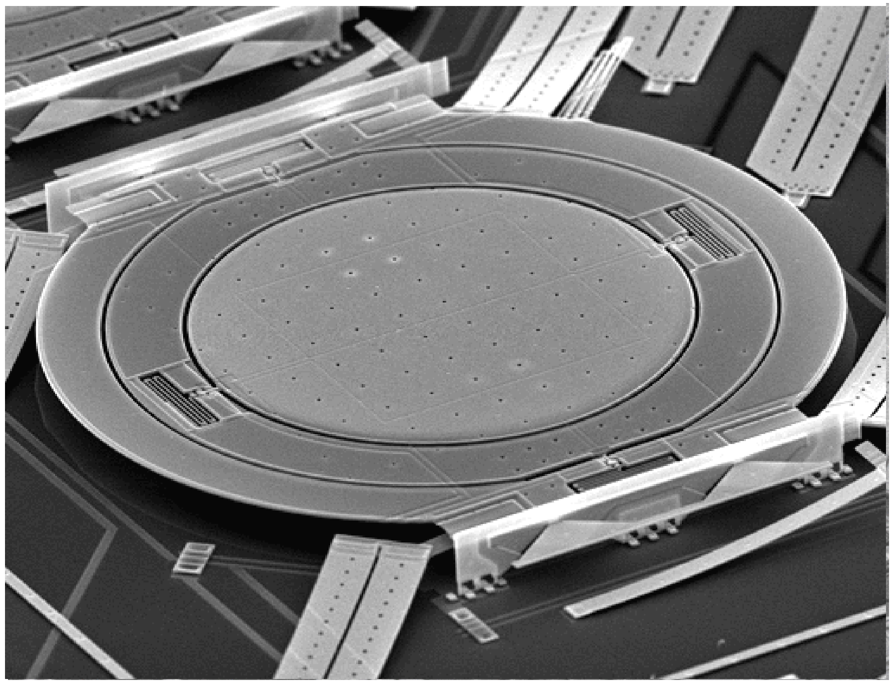
- MEMS are micro-machines that use mechanical degrees of freedom to sense and actuate on the micron scale
- The approach to fabrication uses, as a basis, the materials and processes of microelectronics (IC)

- 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

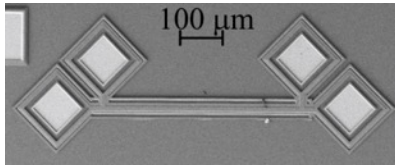


MEMS Based Lithography Tools: Fab on a Chip

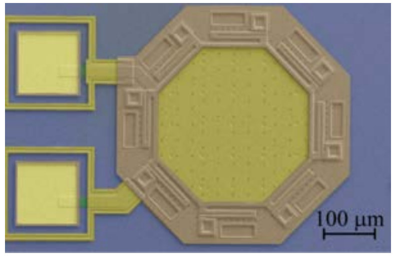
Aim is to fabricate nano-devices using Micro-Machines

- 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

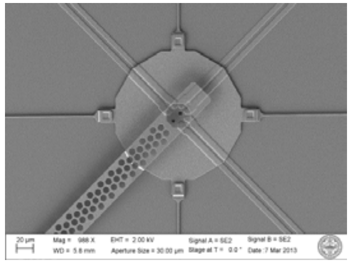
Sensors



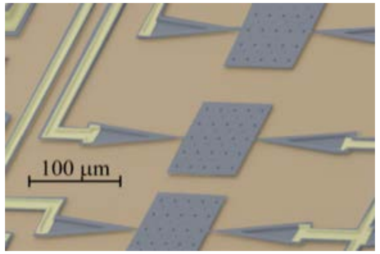
- Thermometers
- Mass sensors



Actuators



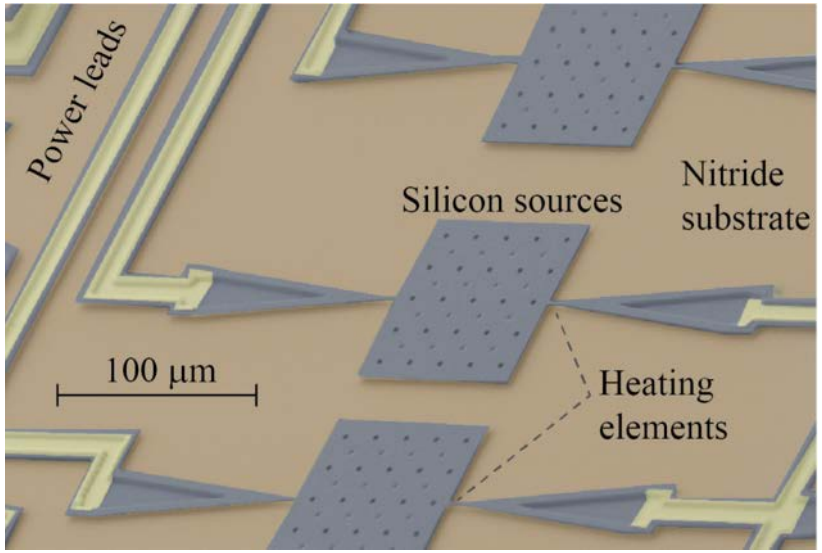
- Dynamic Masks
- Atomic Flux Sources



Fab on a Chip: Fully integrated MEMS counterparts of macroscopic foundry

M. Imboden, H. Han, T. Stark, E. Lowell, J. Chang, F. Pardo, C. Bolle, P.G. del Corro, and D. J. Bishop, "Building a Fab on a Chip", Nanoscale, (2014).

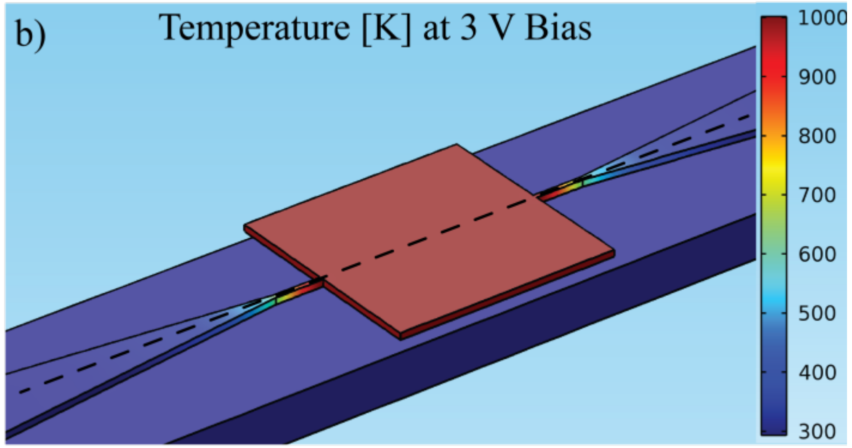
MEMS Micro-Sources

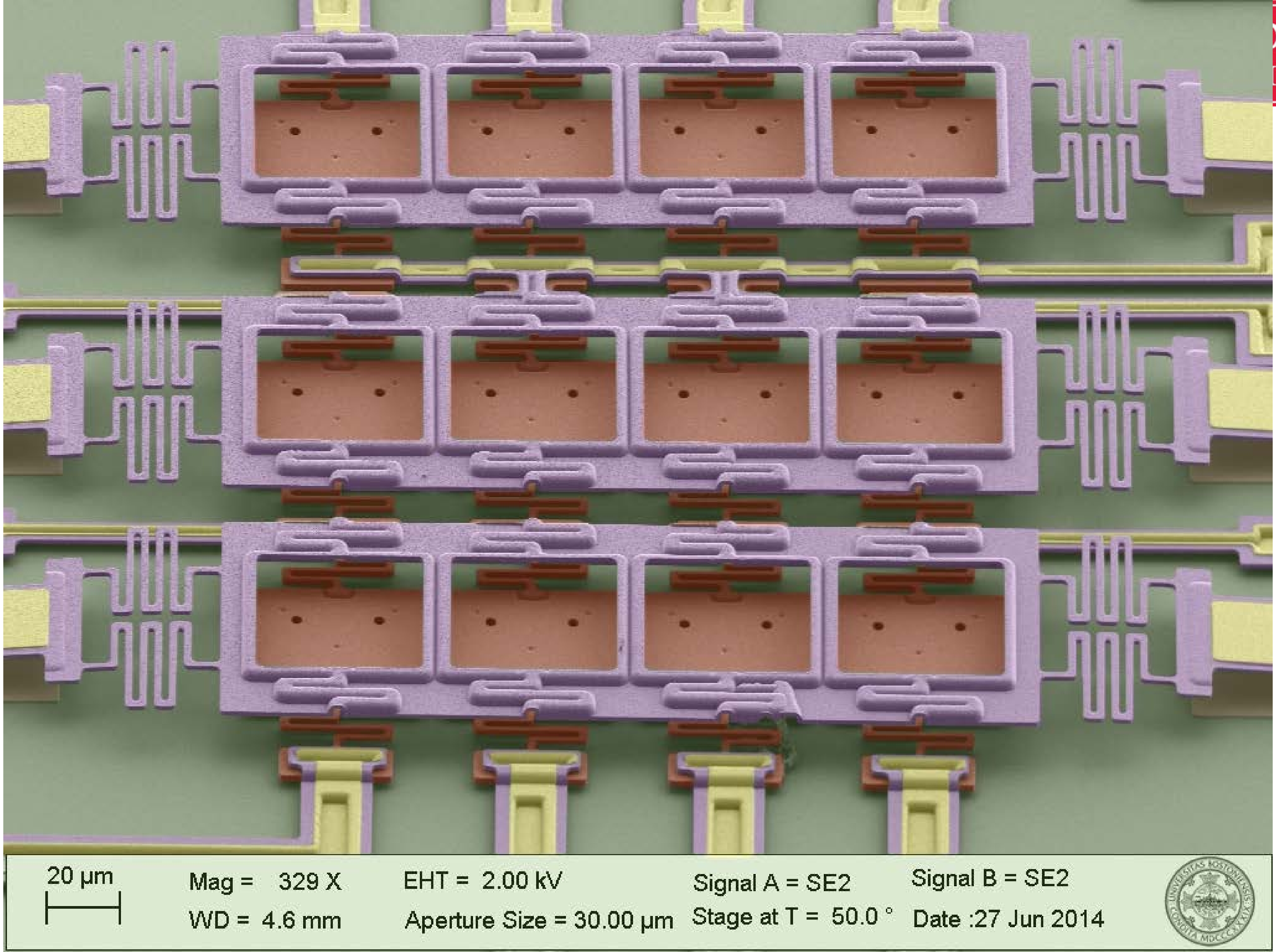


- Suspended Silicon plates ranging from 50x50 μm^2 to 150x150 μm^2
- Constrictions result in heating elements
- Al_2O_3 can electrically isolate and protect the poly-silicon
- Loaded using shadow masks with the desired material

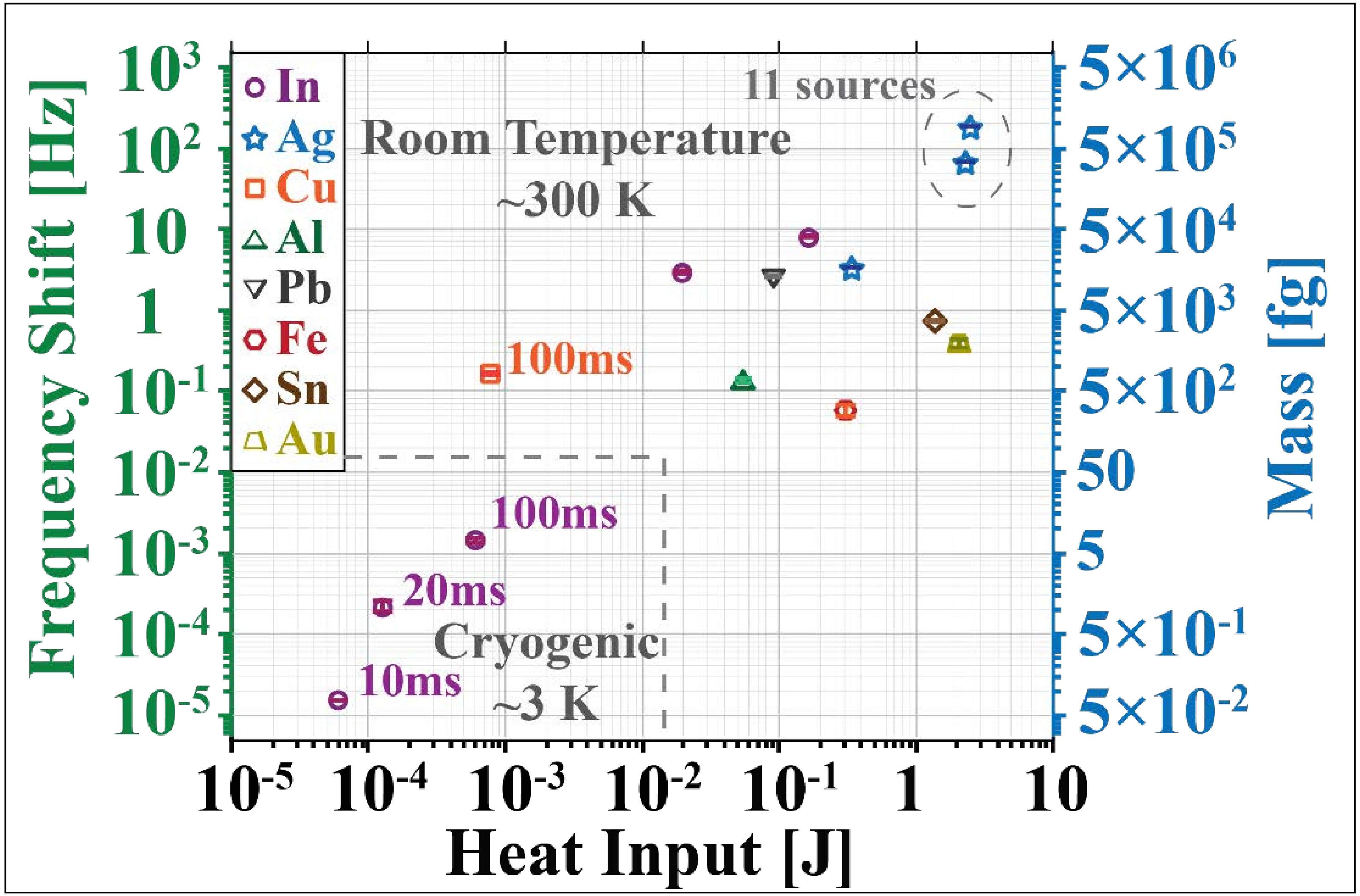
Finite Element Simulation:

- At 1000 K the plate temperature is uniform to within 4 K
- up to ~30 mW before silicon melts (1683 K)

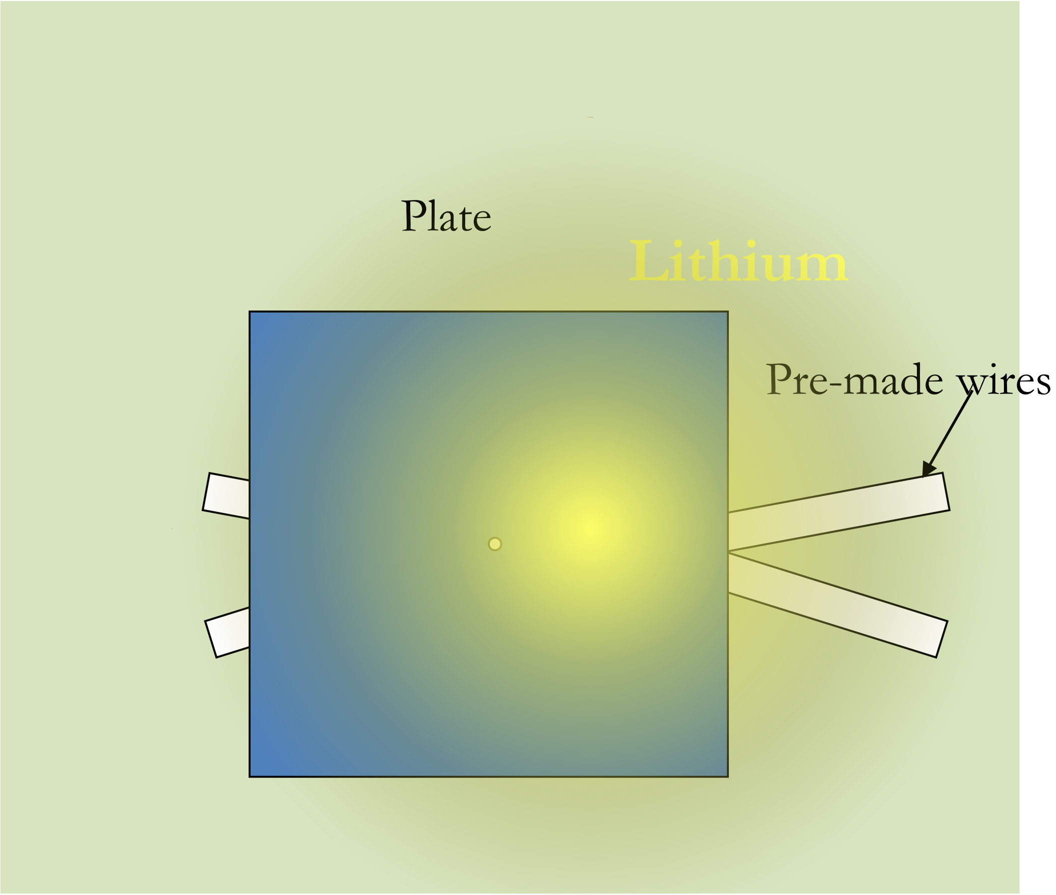



20 µm
Mag = 329 X
WD = 4.6 mm
EHT = 2.00 kV
Aperture Size = 30.00 µm
Signal A = SE2
Stage at T = 50.0 °
Signal B = SE2
Date :27 Jun 2014

Can “puff off” a wide range of materials from attograms to nanograms



Concept



Concept

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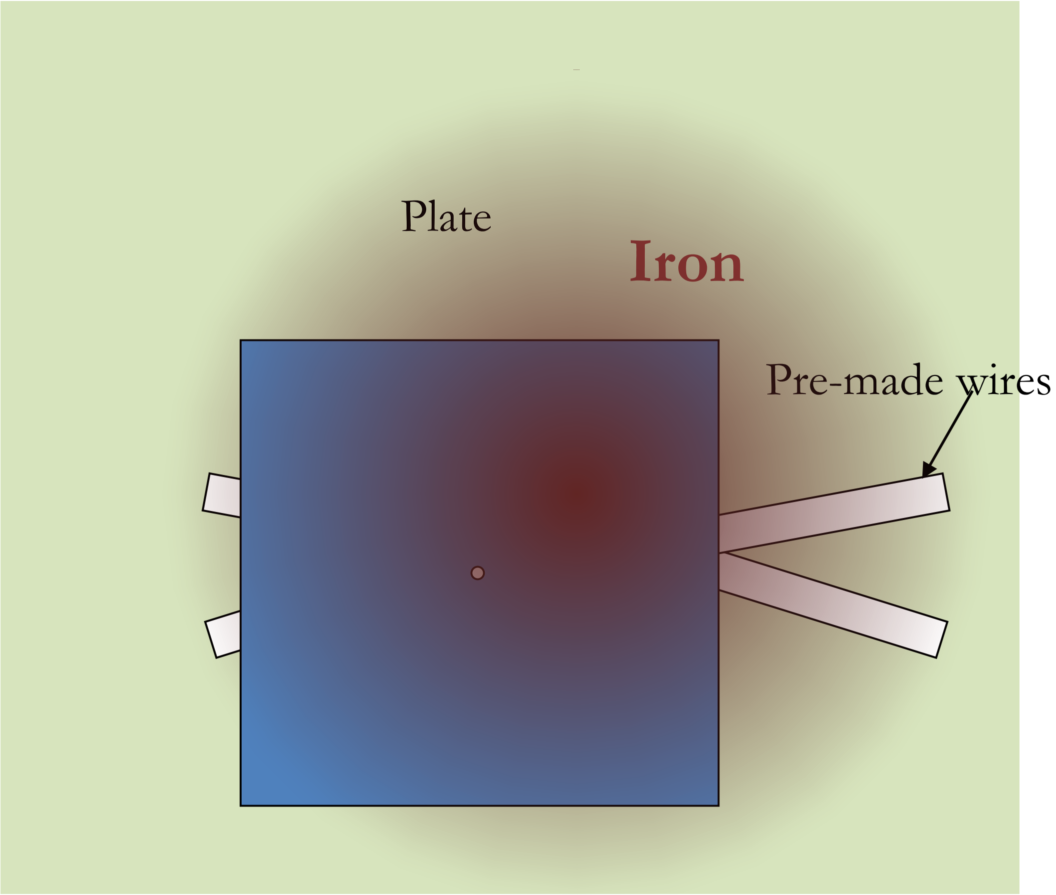
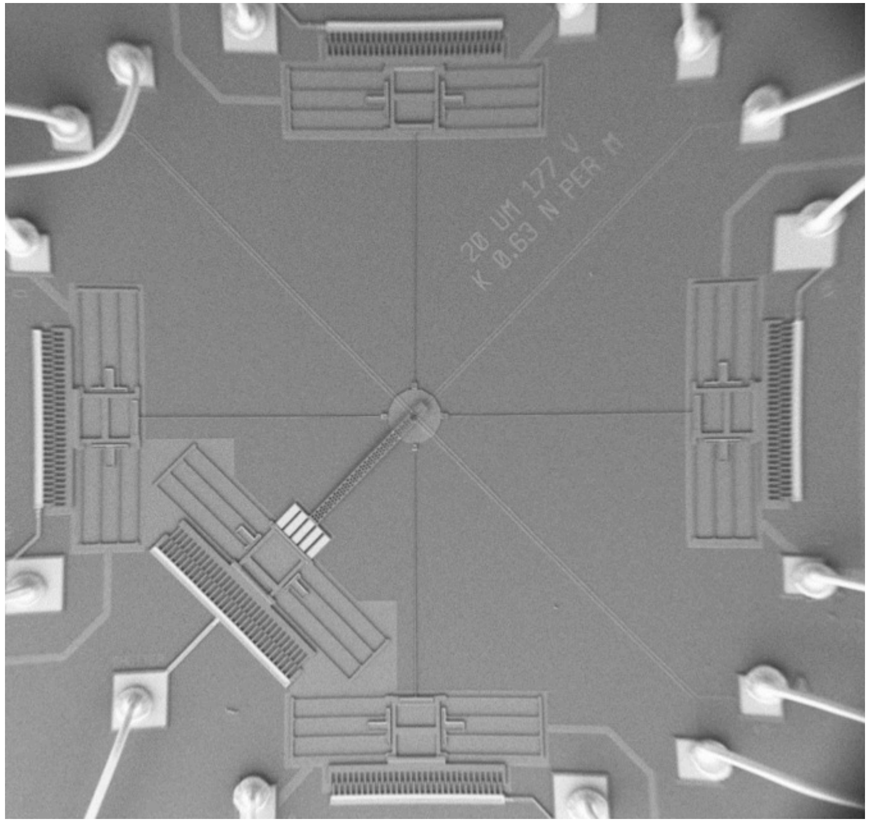
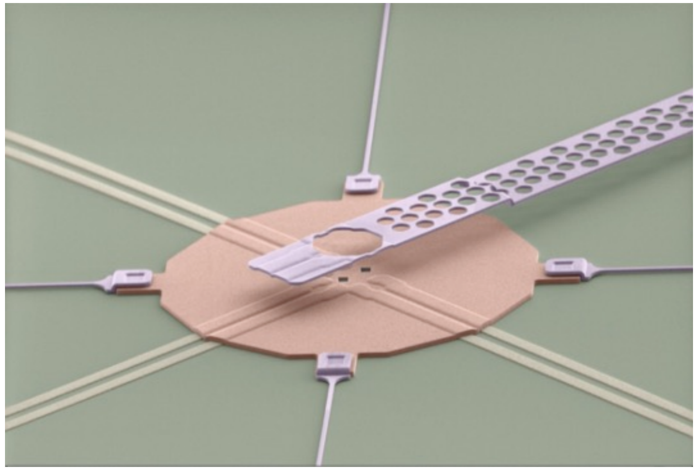


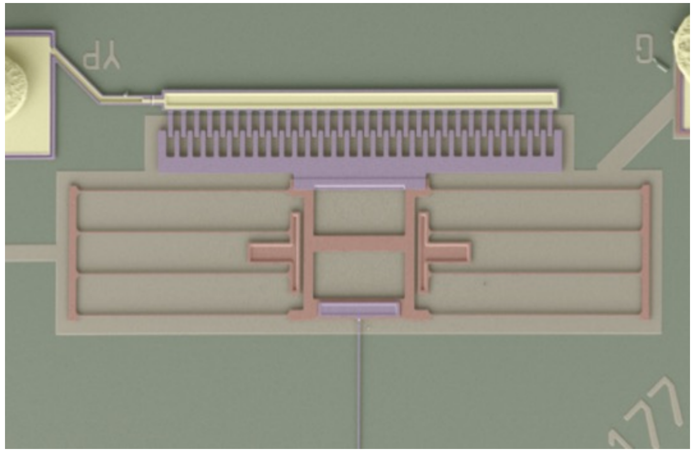
Writers: Placing the Atoms



Shutter, Plate and Apertures



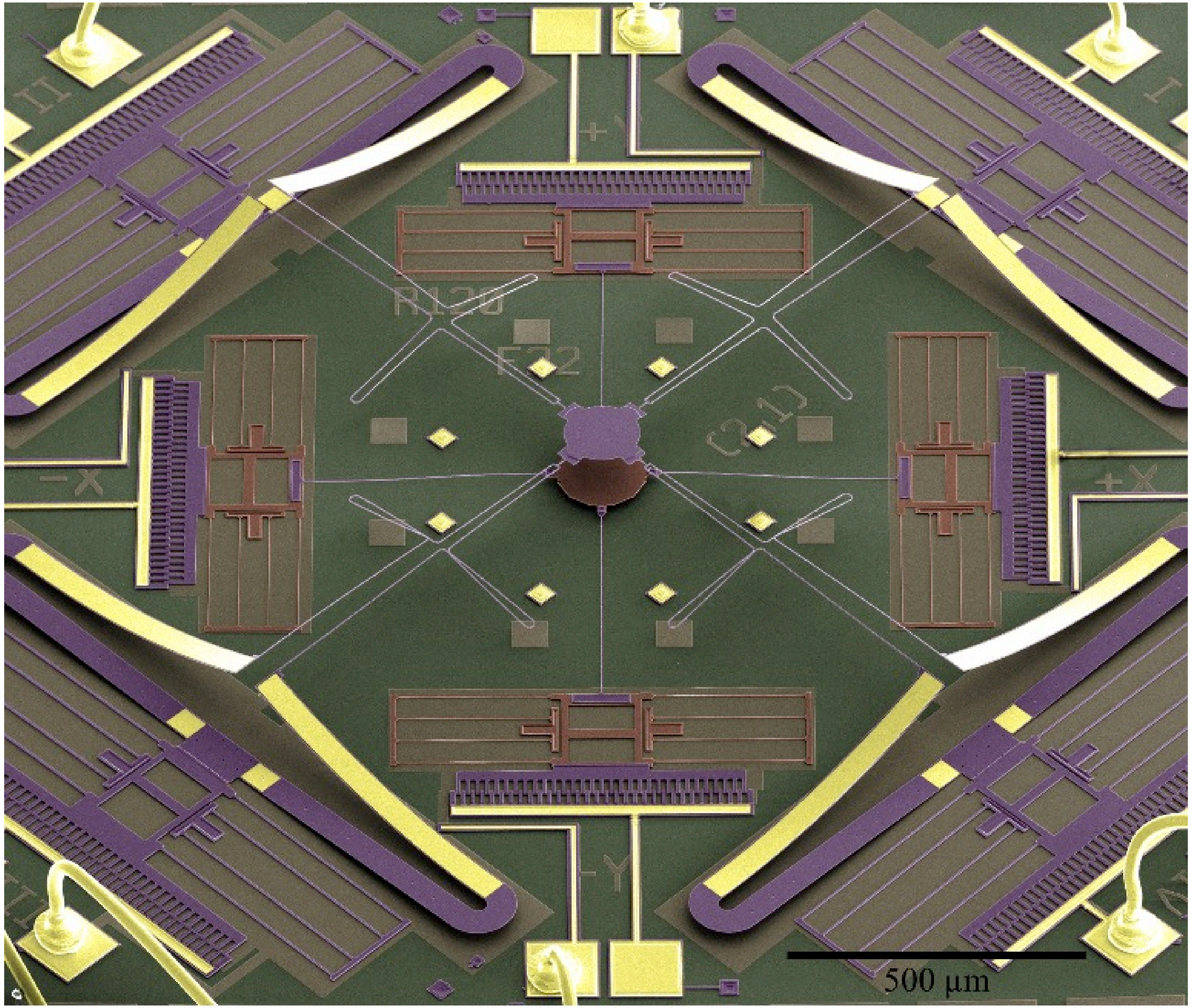
Linear electrostatic motors



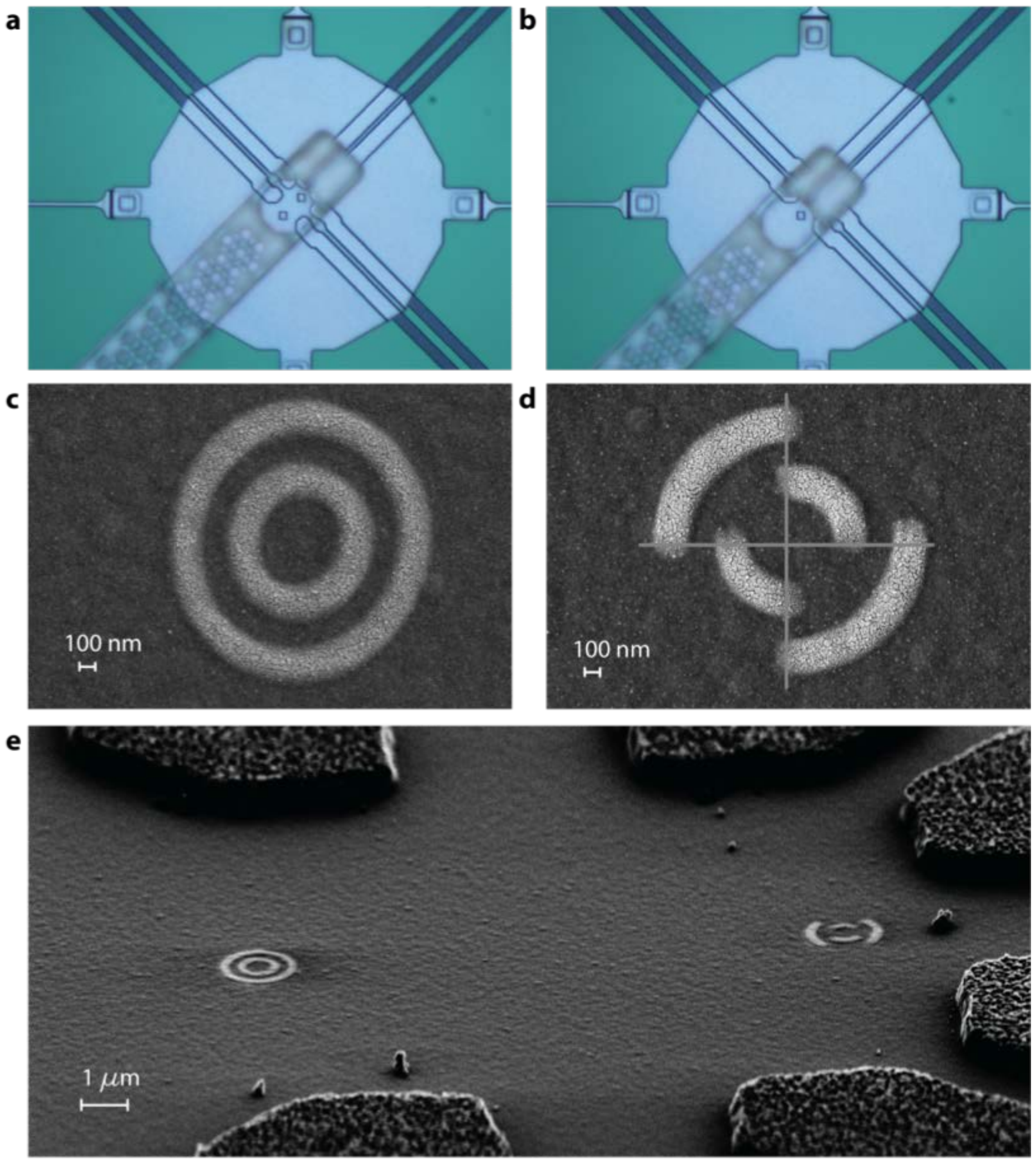
Folded Flexure springs

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

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
   $V_S = 40$ V

b. MEMS Shutter closed over one set of apertures and open over the other
   $V_S = 70$ 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: *Rings*

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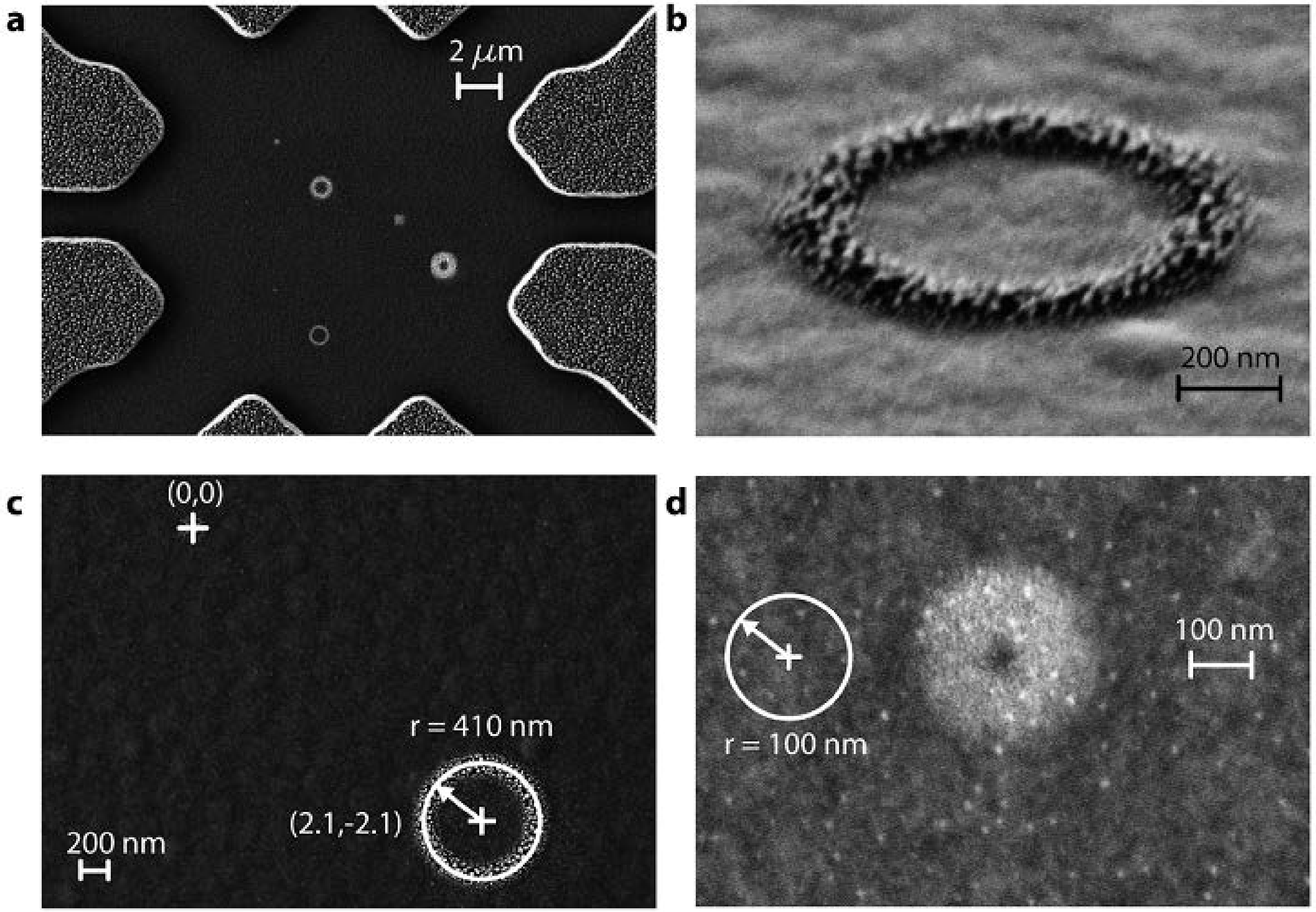
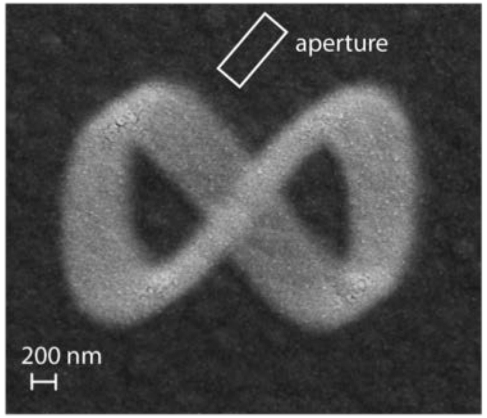
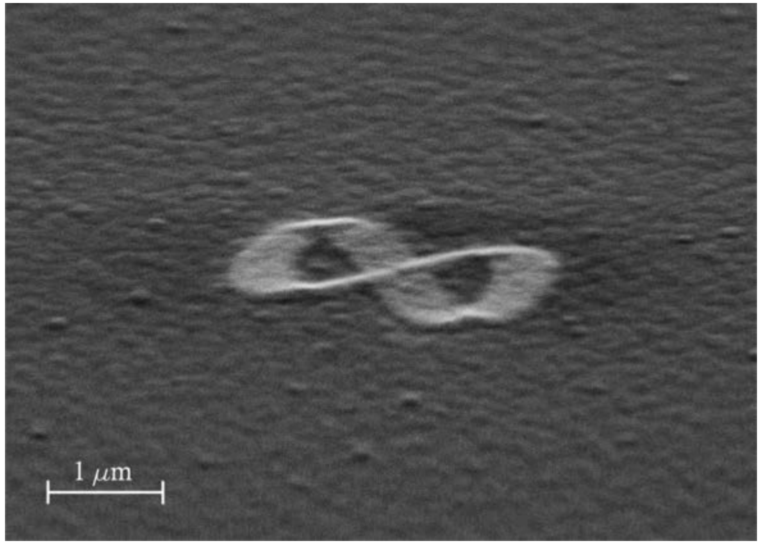
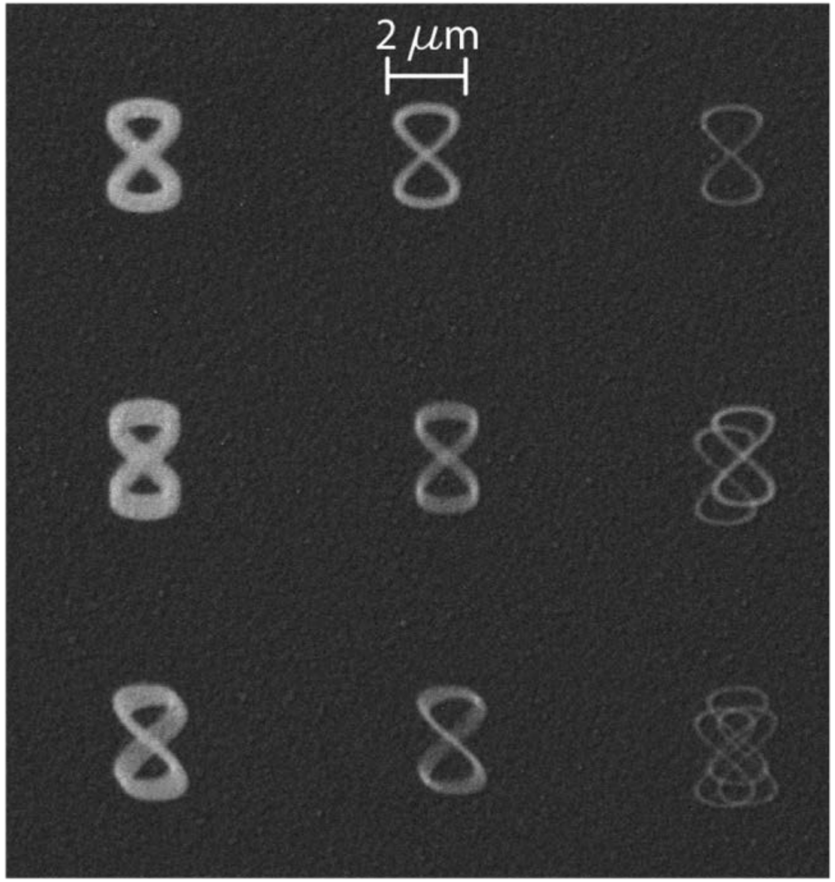


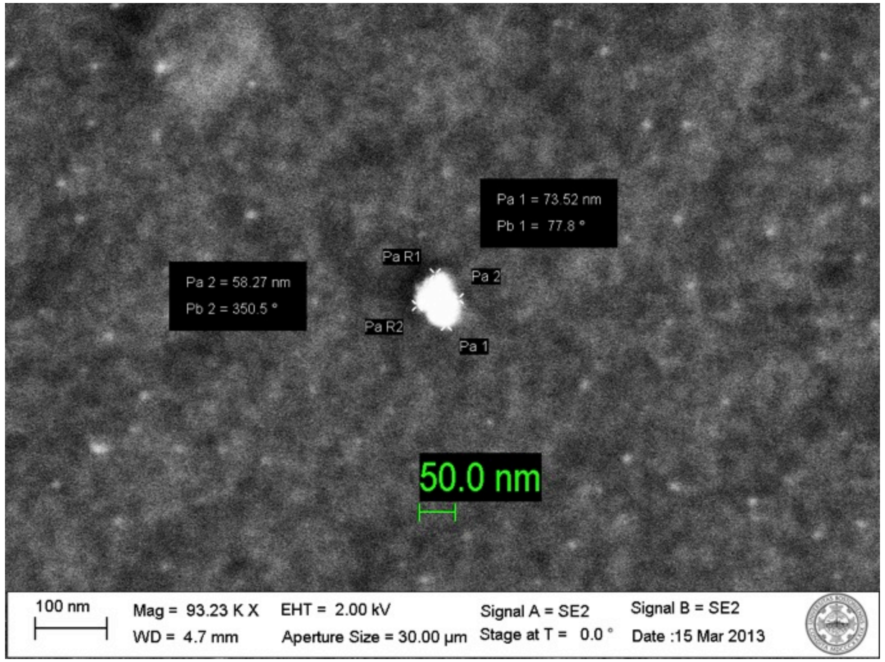
Example Structures: *Lissajous curves*

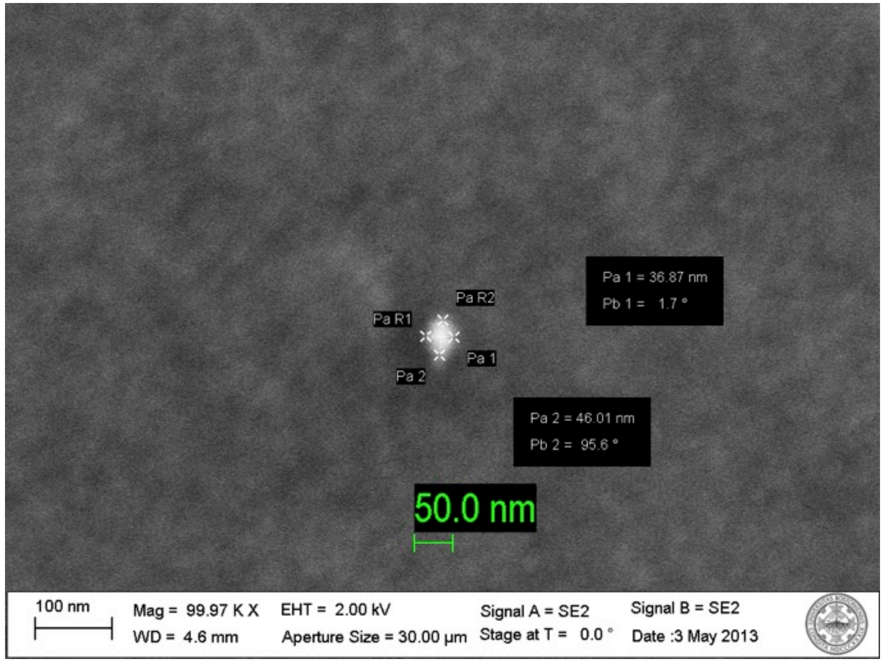






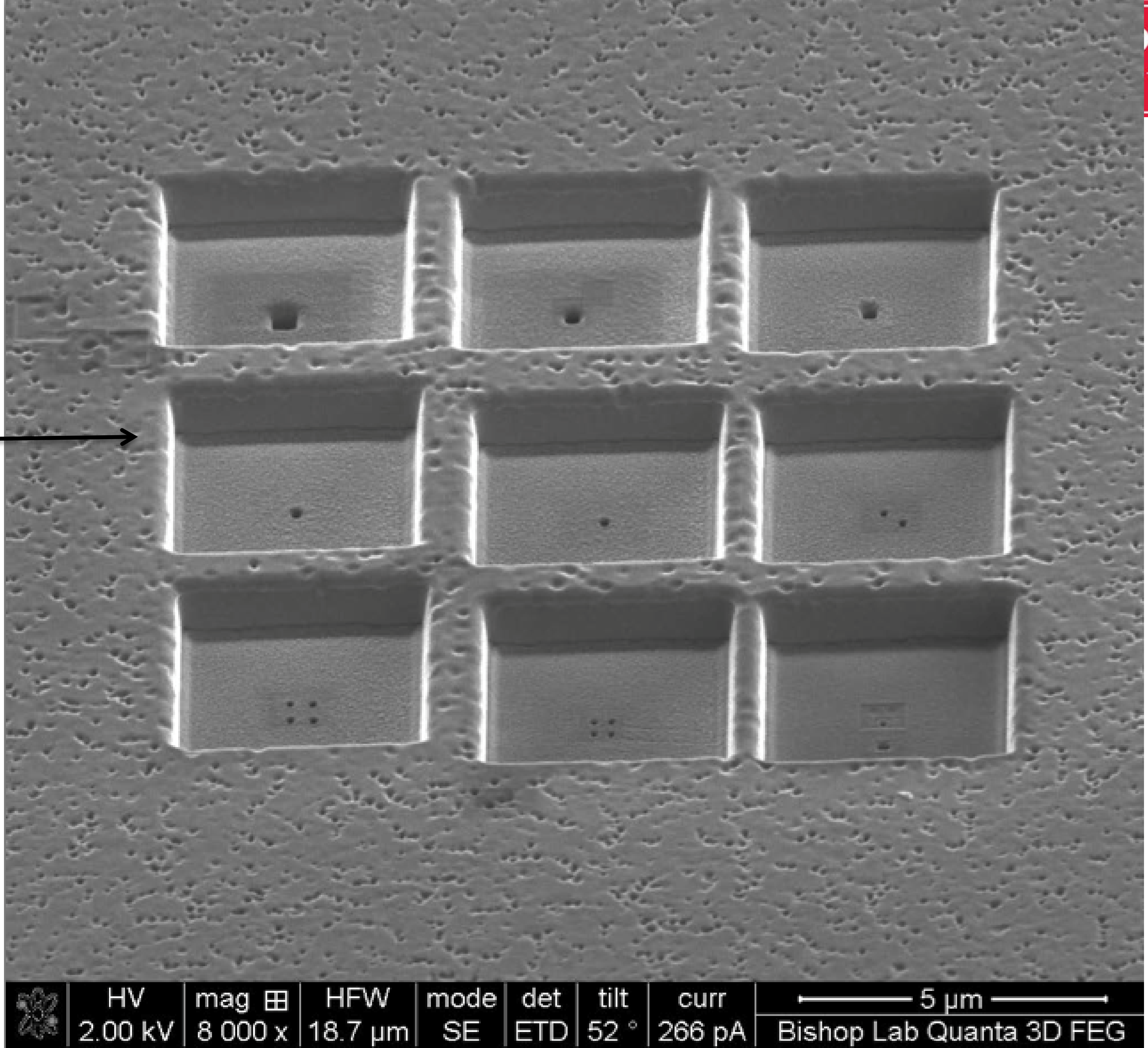
Example Structures: *Chromium nano dots*



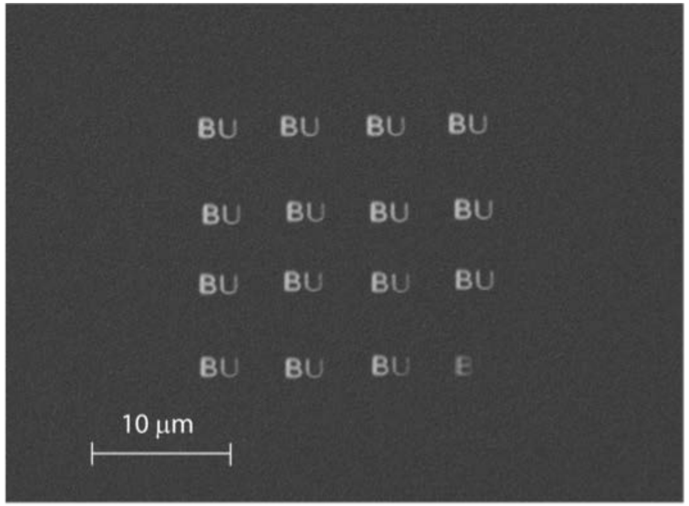


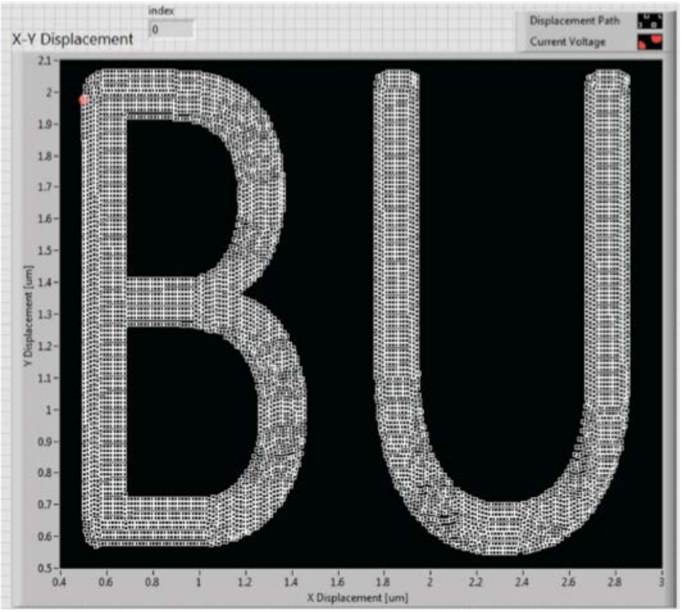
Atoms are placed stochastically within the aperture opening

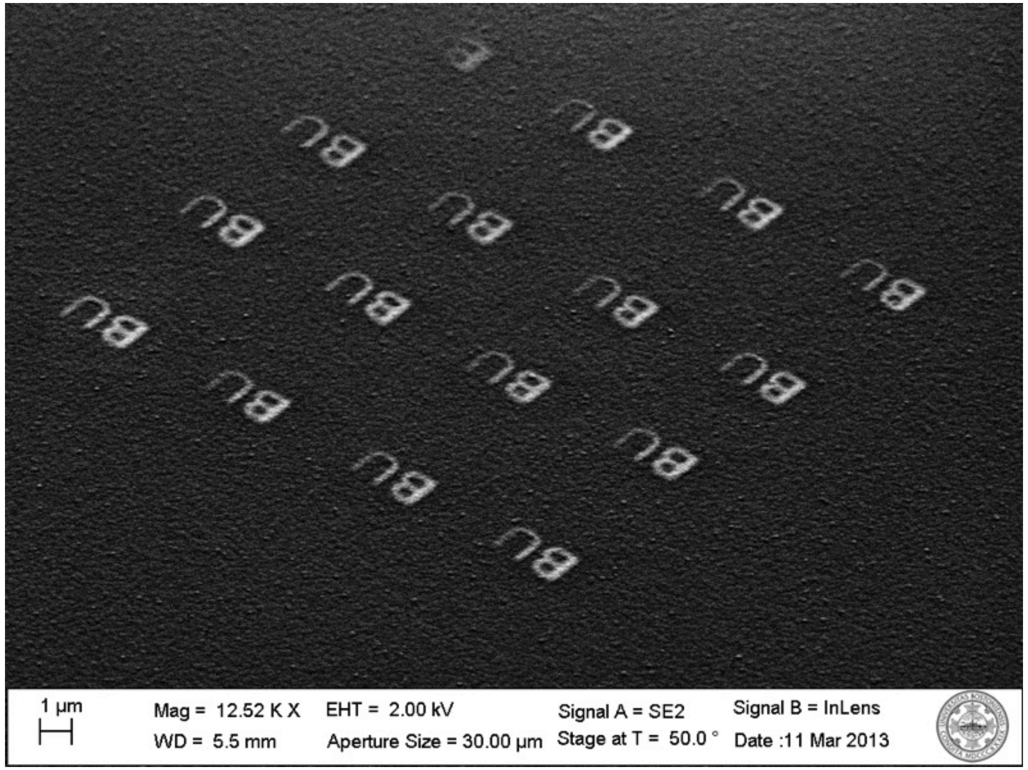
Array of
Apertures



Example Structures: Direct Writing of Arrays



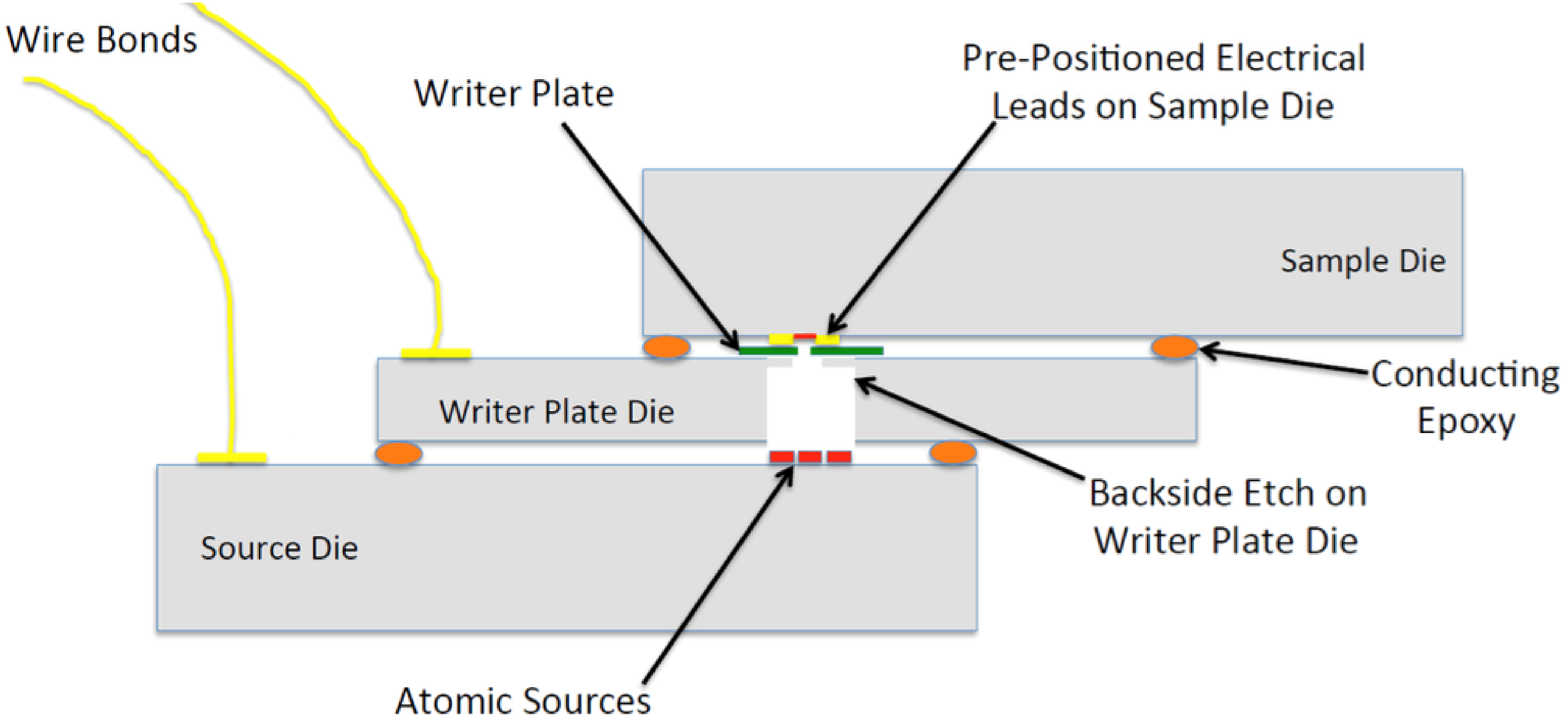




Fully Integrated Fab on a Chip System

Three Stacked MEMS Devices Create a Fab on a Chip

- Source
    - Writer
        - Sample



Fully Integrated Fab-on-a-Chip

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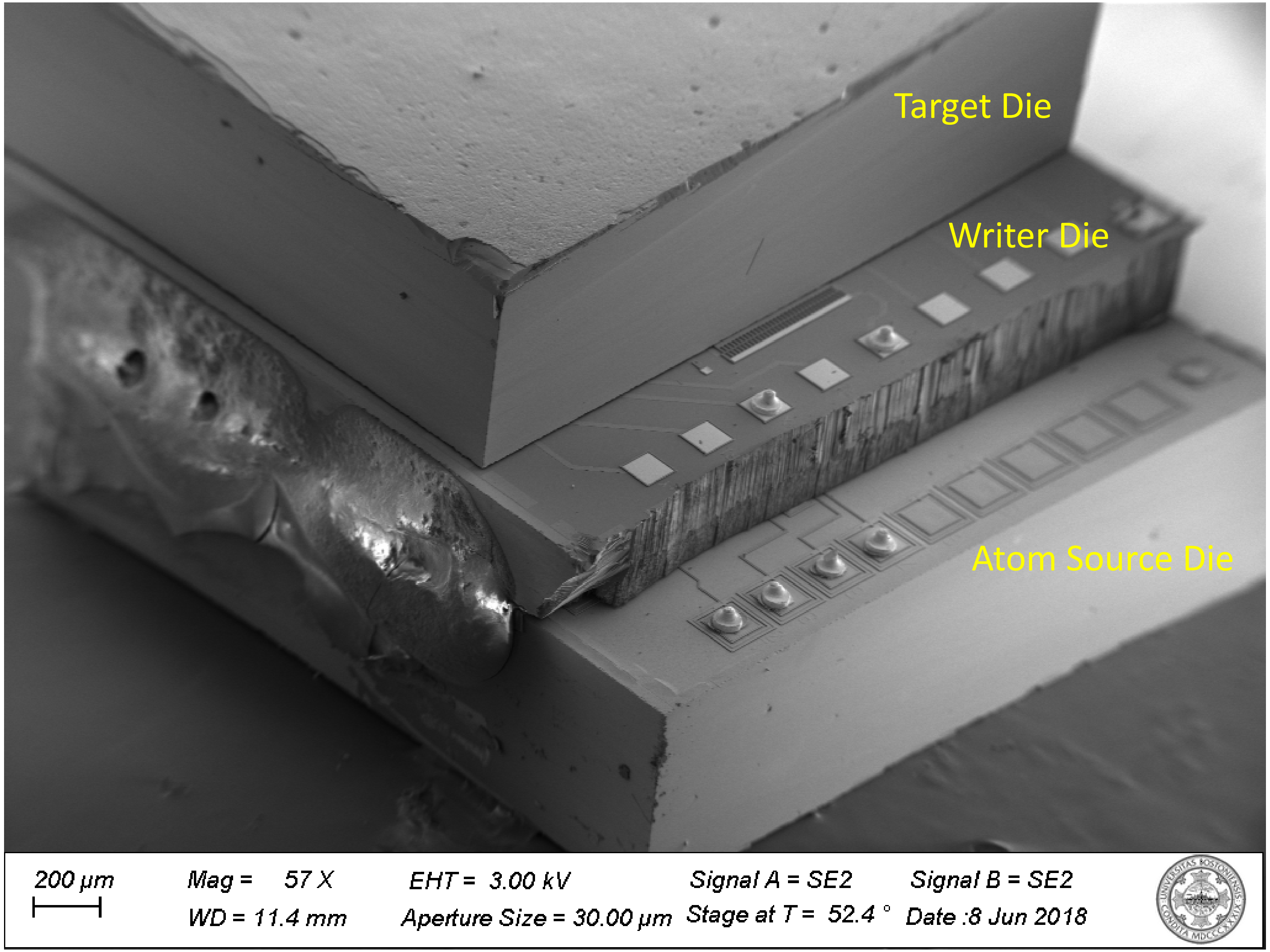
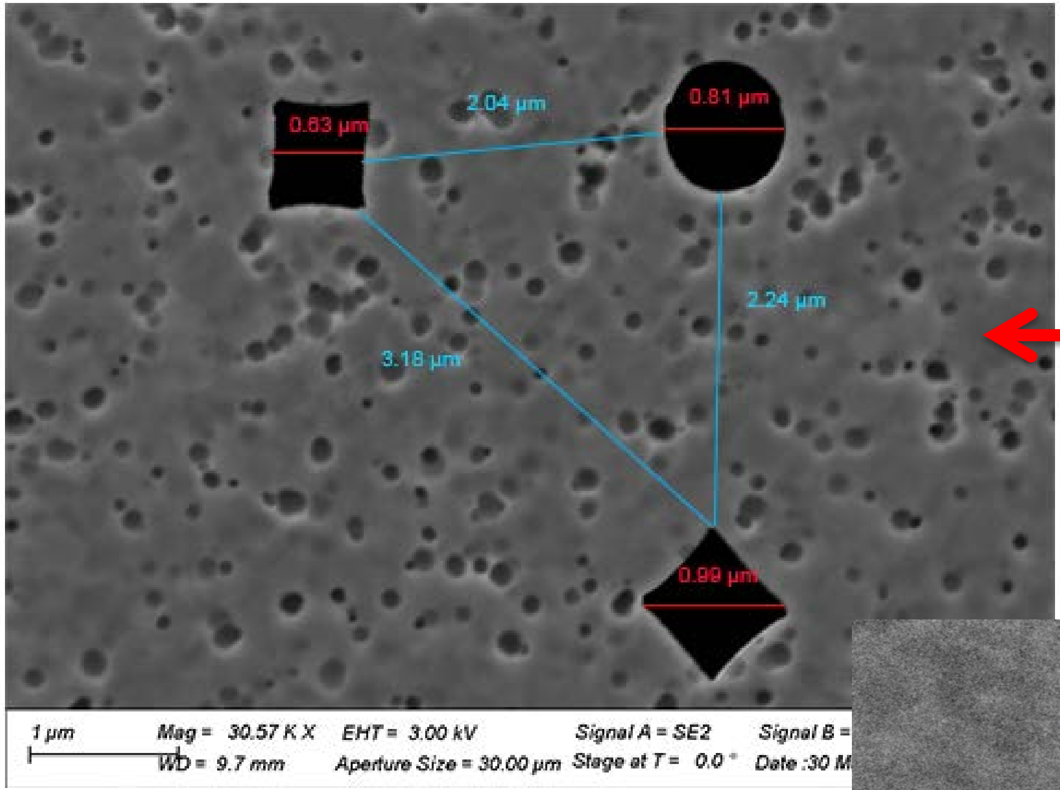
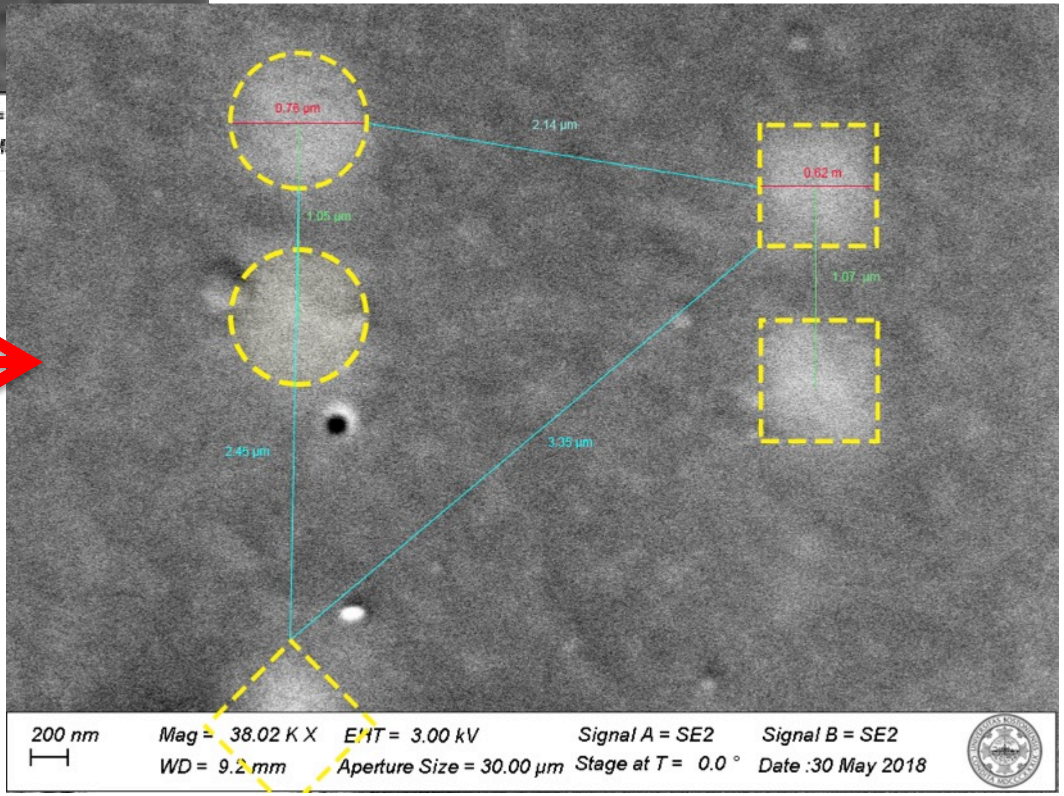
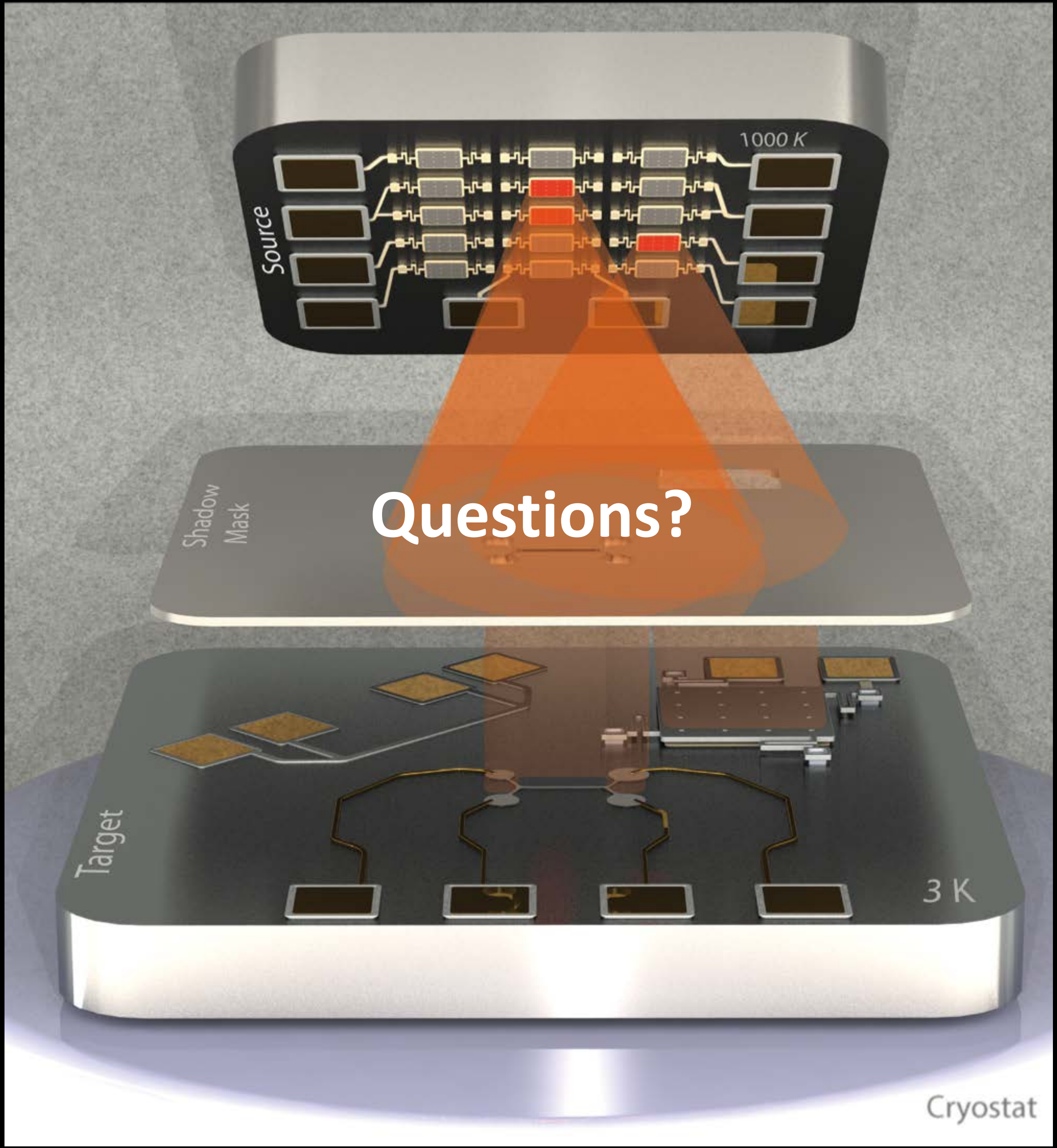




Apertures on Writing Plate

Pattern, written and then writing plate moved and written again





Questions?

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