ME 451: Micromachining

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Microfabrication
MEMS NEMS
Top-down Nanofabrication

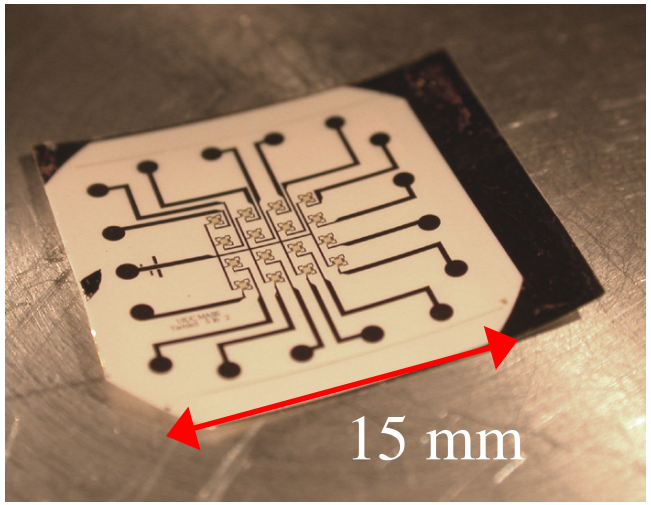
Outline of Class

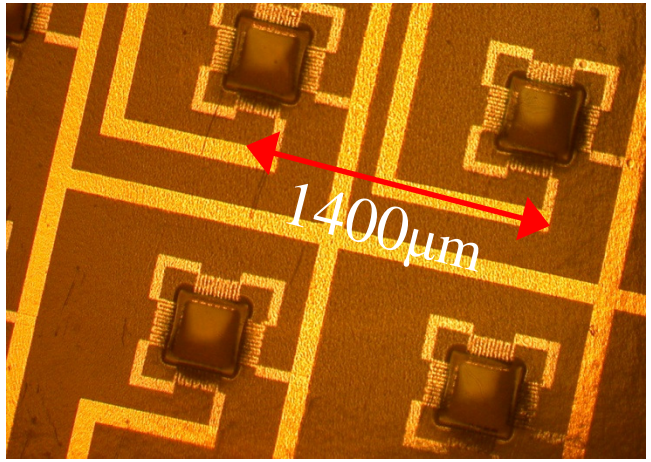
- Framework of microfab and basic steps (metal deposition)
- Basics of microfab: lithography
- Basics of microfab: oxidation
- Basics of microfab: chemical vapor deposition
- Basics of microfab: plasma etching, reactive ion etching, deep reactive ion etching
- Packaging, integration
- Mask making and layout; teaming
- Device museum
- Lab tour and Mini lab
- Introduction to MEMS
- Basics of MEMS devices: sensors
- Basics of MEMS devices: actuators
- Surface micromachining and sacrificial etching (2)
- Bulk micromachining (process compatibility table)

Get Scale Straight

- 1 μm = 1/1000 mm
- 1 nm = 1/1000 μm = 1/1,000,000 mm

- Characteristic length scale of MEMS
  - 1 micrometer to 1 mm
  - Special case: large distributed array.

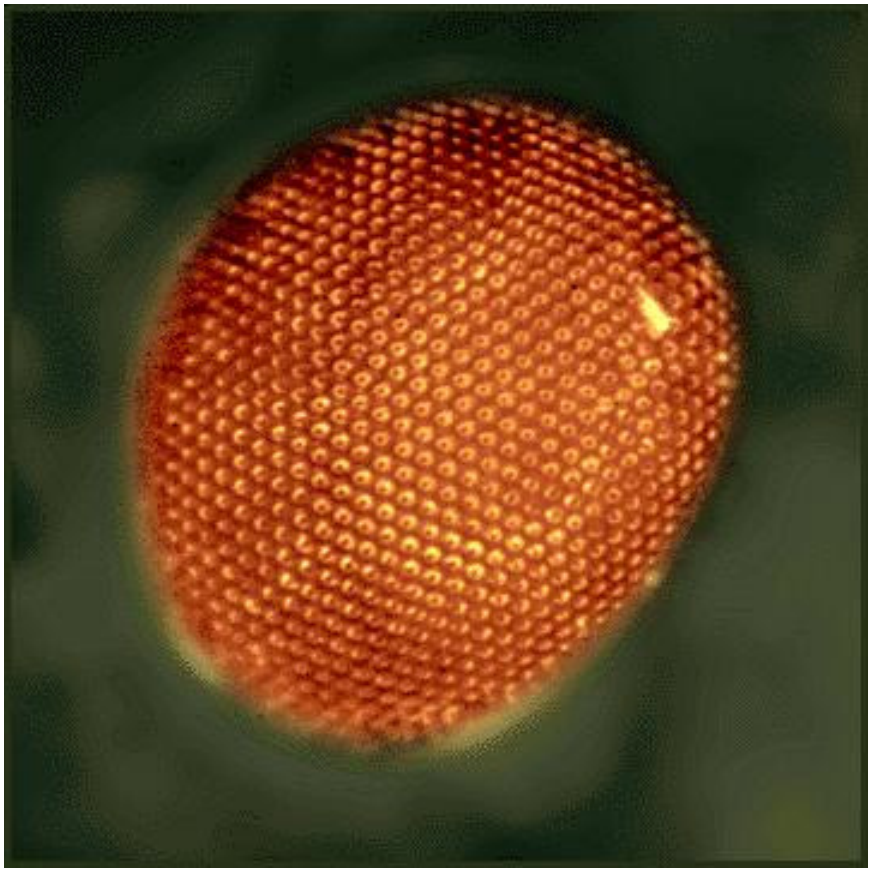




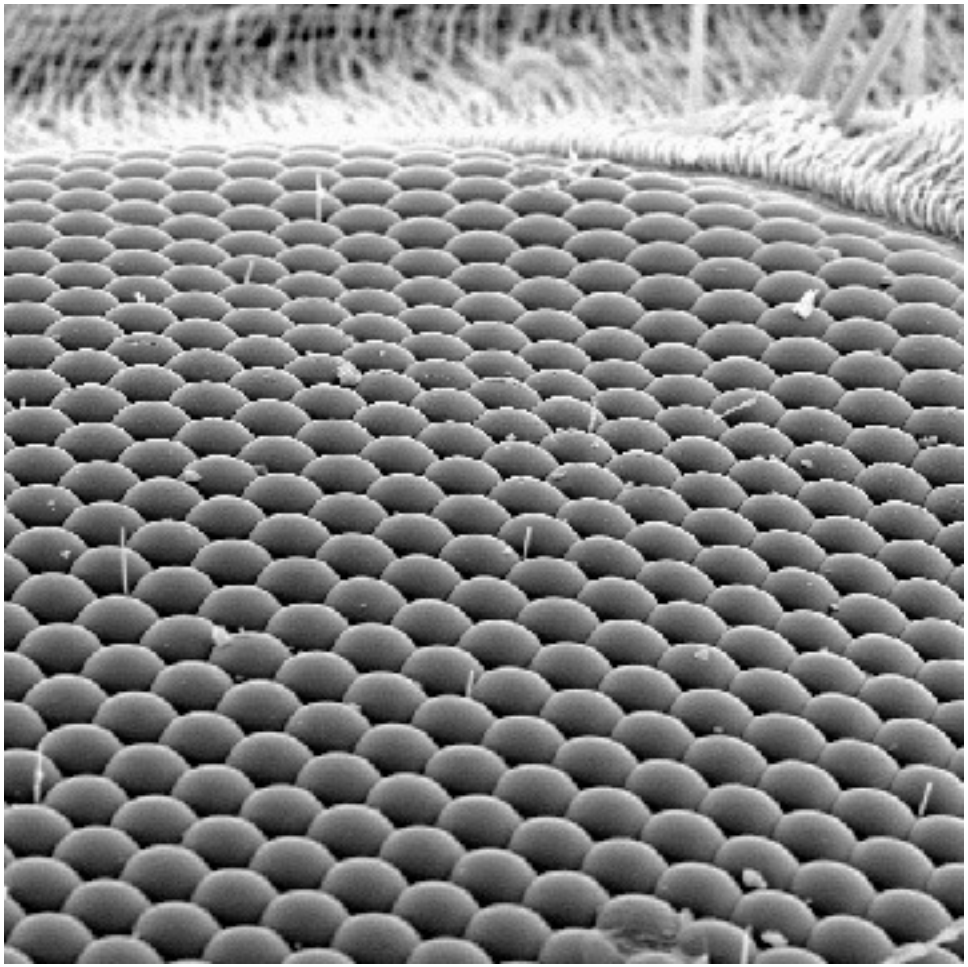
Large array ⟶ Small nodes

0.01 meter, or 10 mm

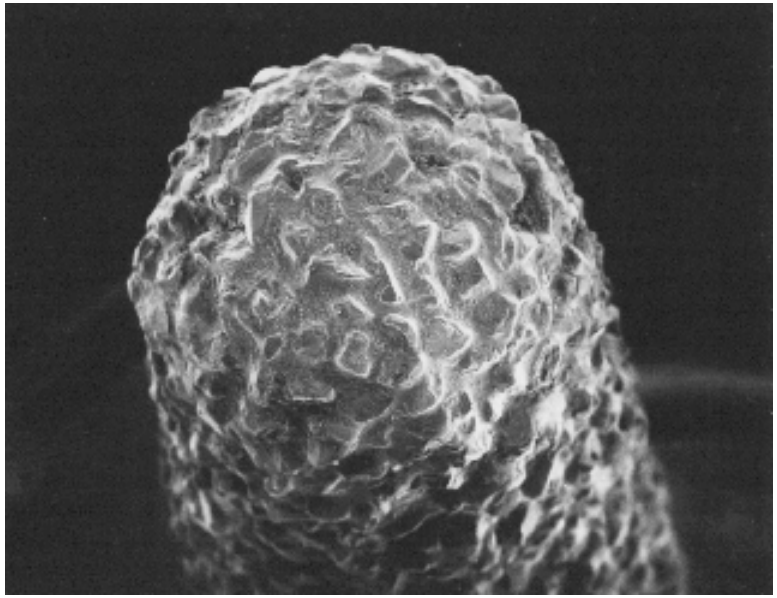
0.001 meter, or 1 mm



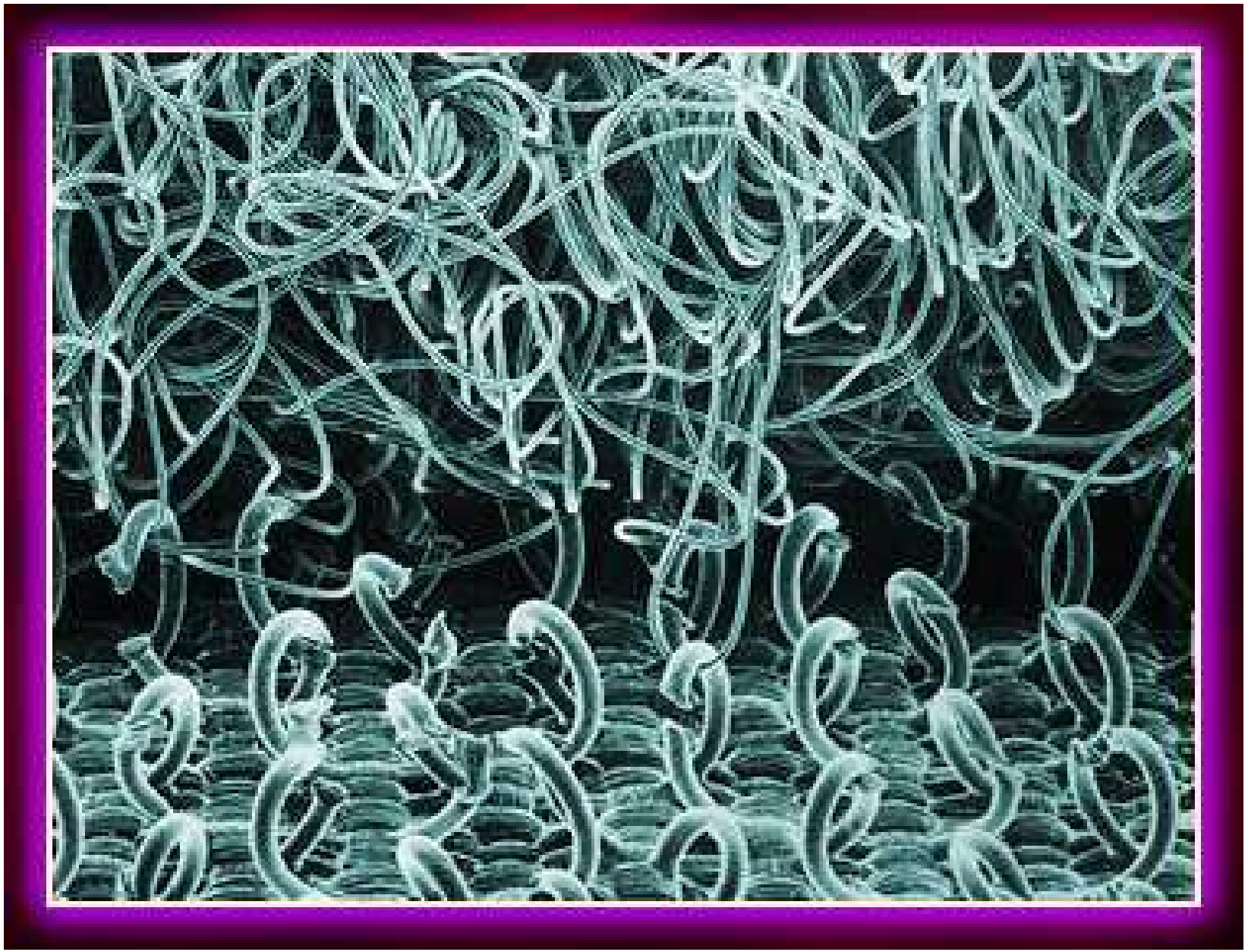
0.1 mm, or 100 micrometer



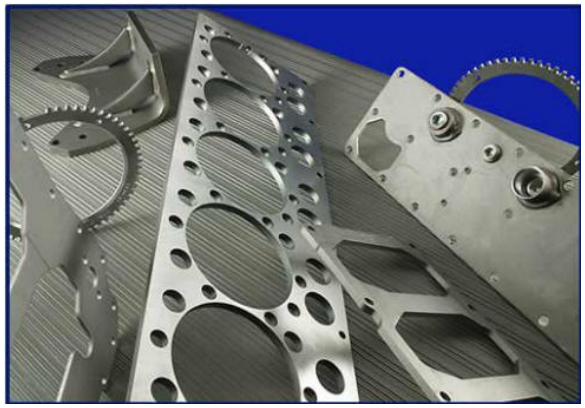
Dentist’s drill (1 mm)

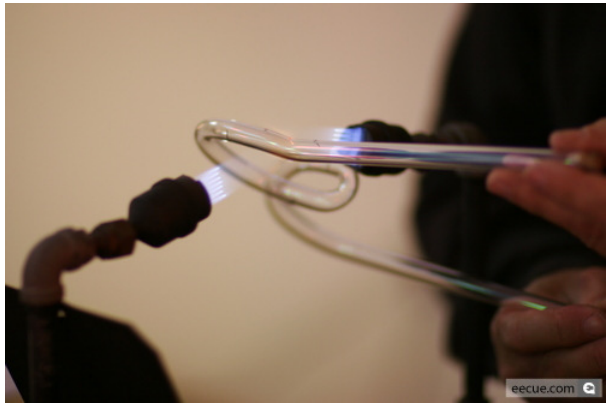


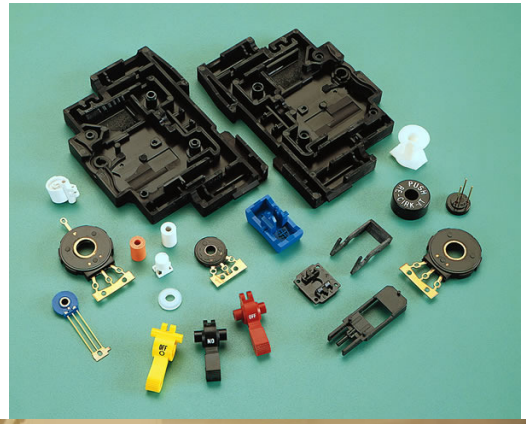
Velcro (1 mm)

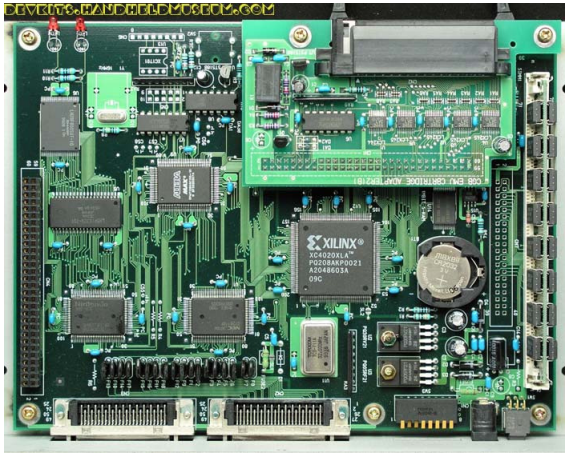


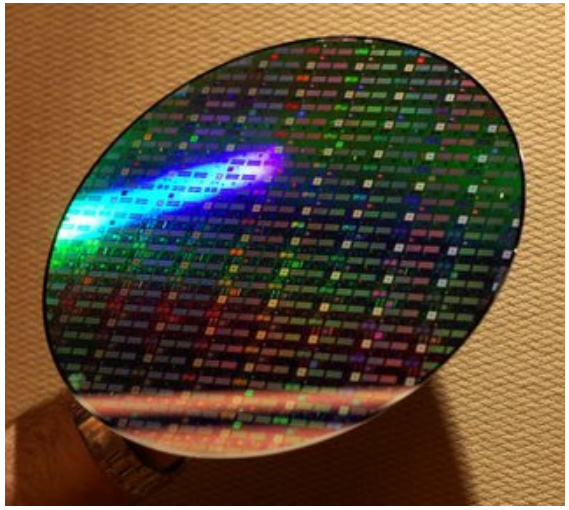
Manufacturing Realm

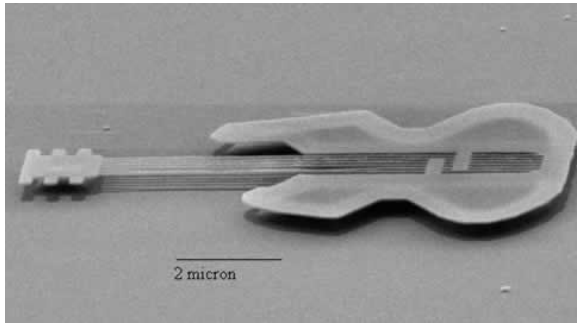


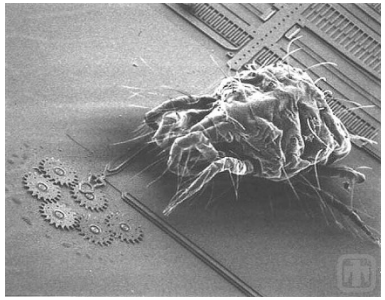


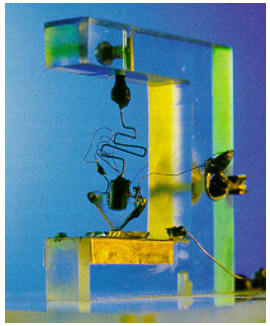




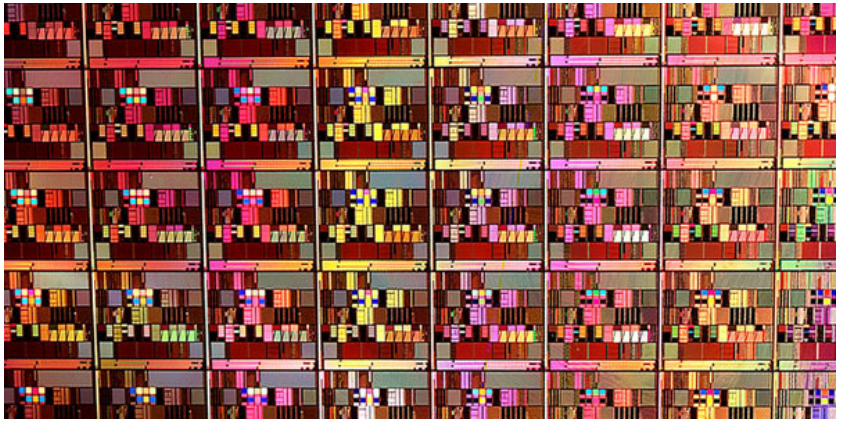








Microelectronics – The IT Backbone



- Microelectronics and optoelectronics
  - Infrastructure of today's information technology – communication, computation, control
  - Model, design, fabrication technology, and device implementation for tomorrow's micro processors and communications chips

Fiber for fast internet

IBM 1 GB Microdrive (model for illustration only)

IBM GB hard drive

Low lost, photo-Quality Ink Jet

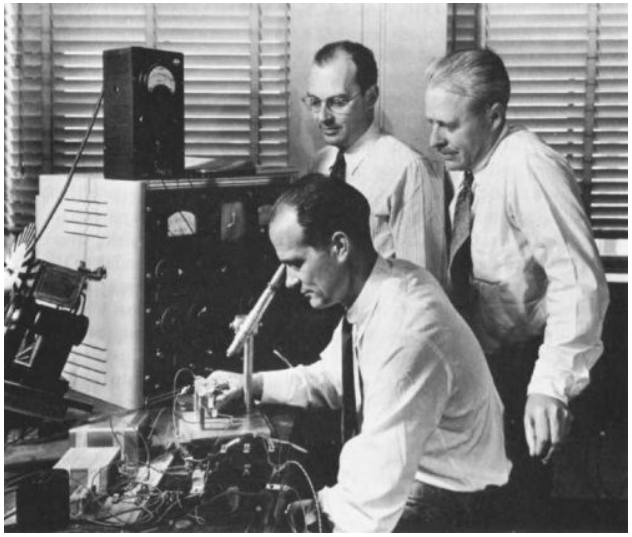
Personal communication

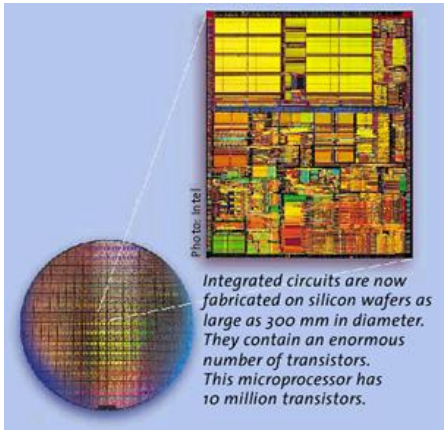
Digital photography

History

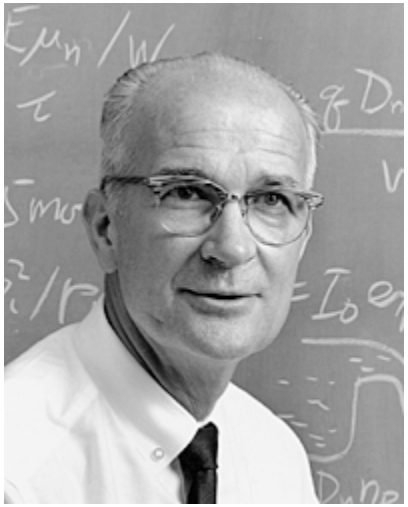
Kilby's first integrated circuit in germanium.

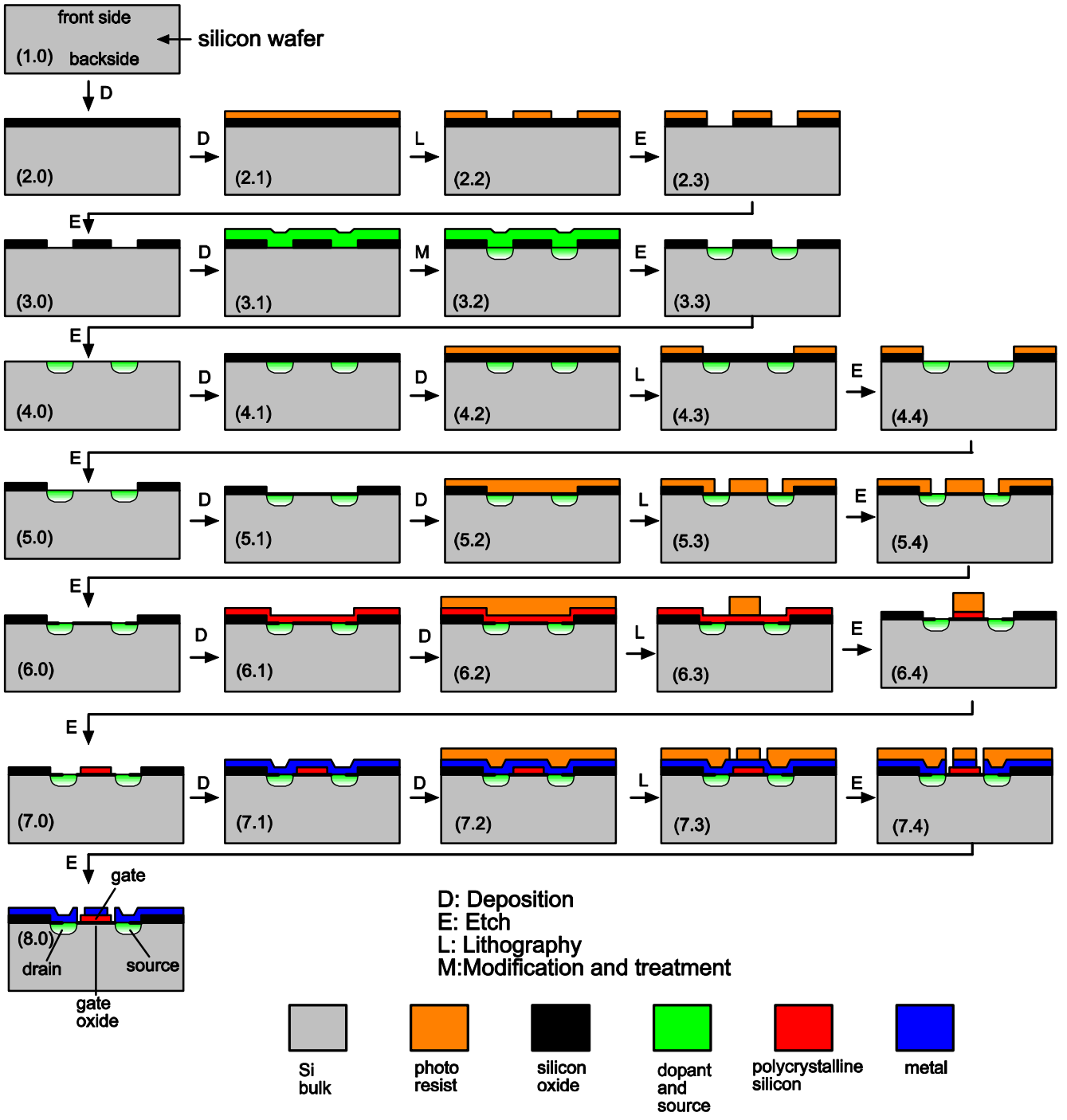
Bardeen and co-workers invented the semiconductor transistor



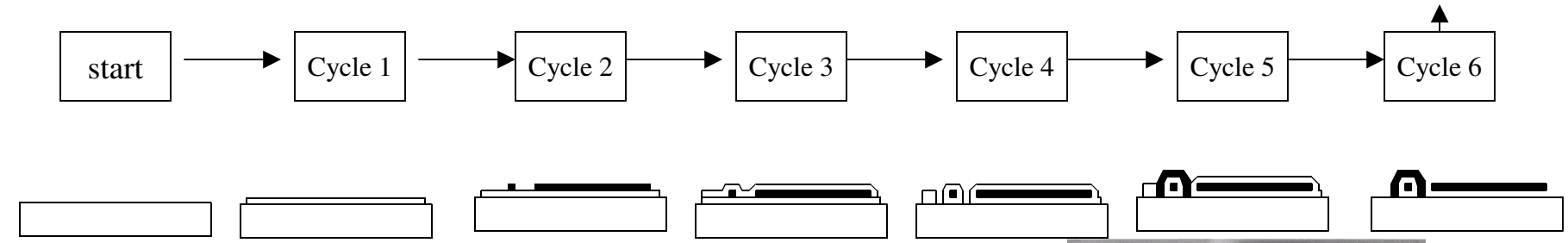


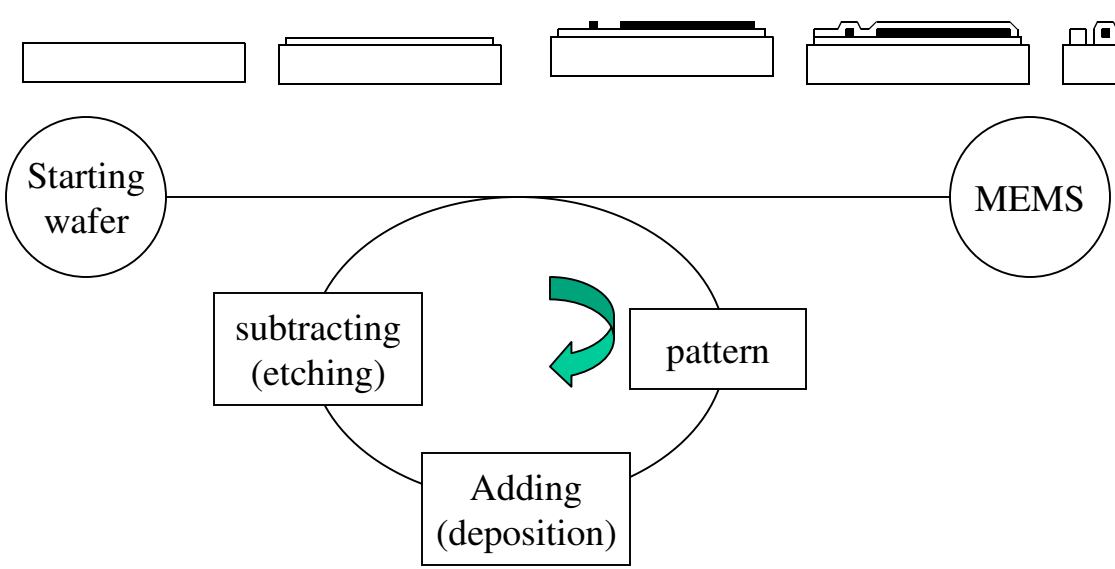
Integrated circuits are now fabricated on silicon wafers as large as 300 mm in diameter. They contain an enormous number of transistors. This microprocessor has 10 million transistors.

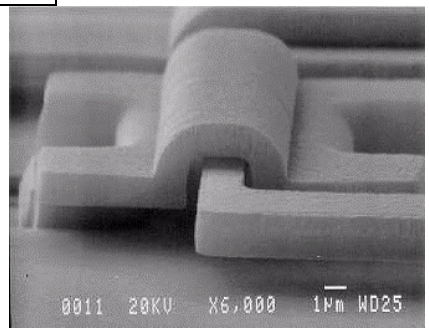


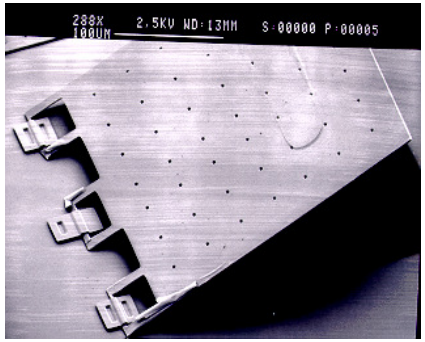

front side
(1.0) backside
silicon wafer
D
(2.0)
D
(2.1)
L
(2.2)
E
(2.3)
E
(3.0)
D
(3.1)
M
(3.2)
E
(3.3)
E
(4.0)
D
(4.1)
D
(4.2)
L
(4.3)
E
(4.4)
E
(5.0)
D
(5.1)
D
(5.2)
L
(5.3)
E
(5.4)
E
(6.0)
D
(6.1)
D
(6.2)
L
(6.3)
E
(6.4)
E
(7.0)
D
(7.1)
D
(7.2)
L
(7.3)
E
(7.4)
E
gate
(8.0)
drain
source
gate oxide
D: Deposition
E: Etch
L: Lithography
M:Modification and treatment
Si bulk
photo resist
silicon oxide
dopant and source
polycrystalline silicon
metal

Micro Fabrication Technology

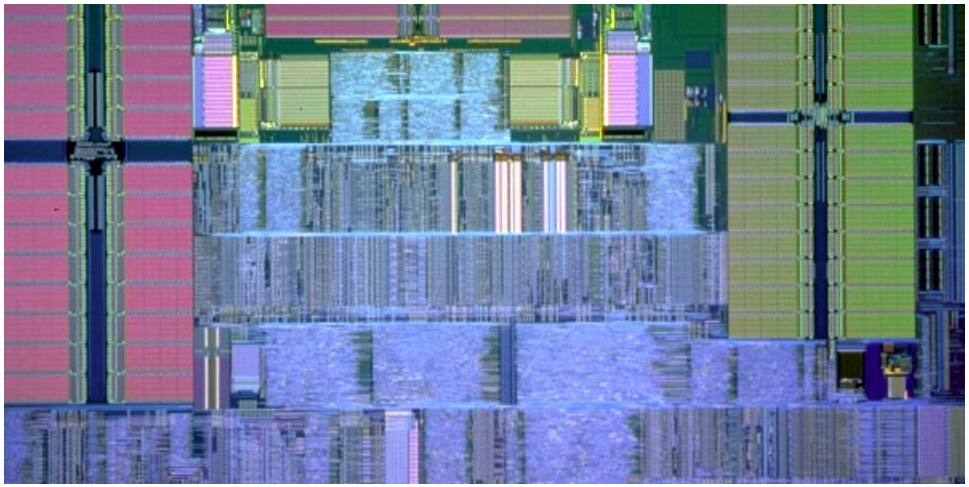


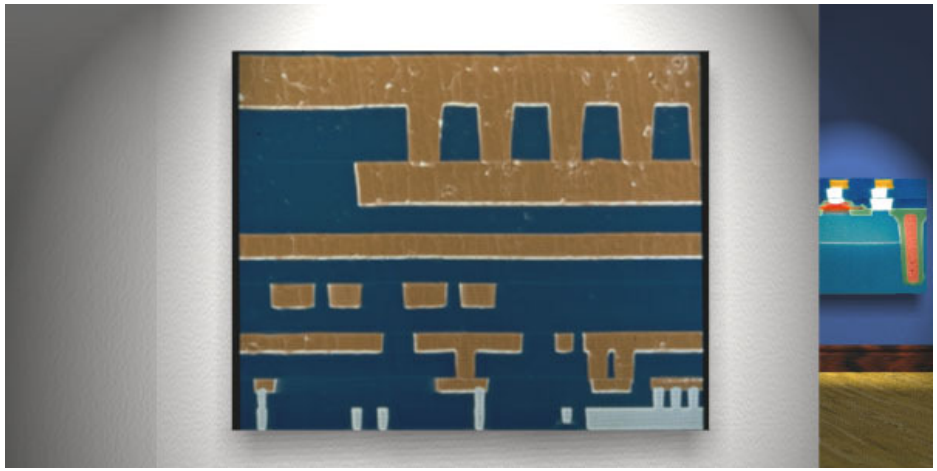


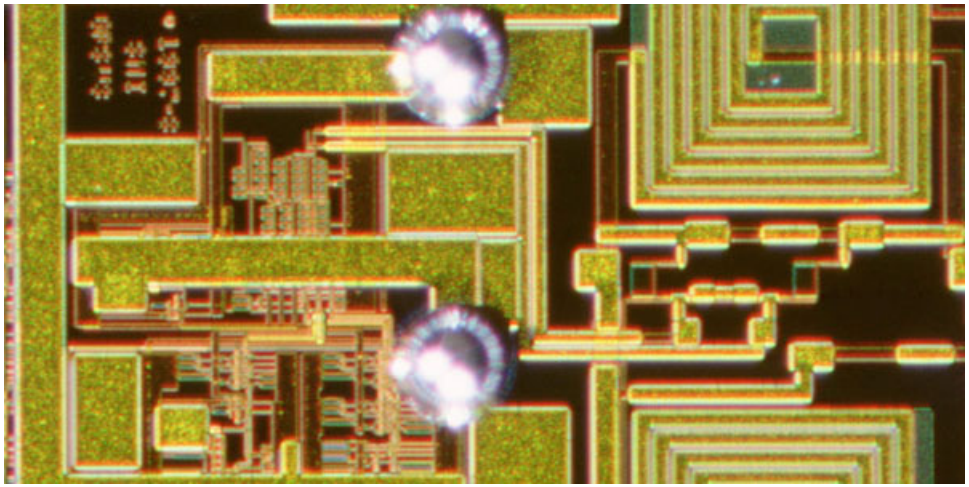


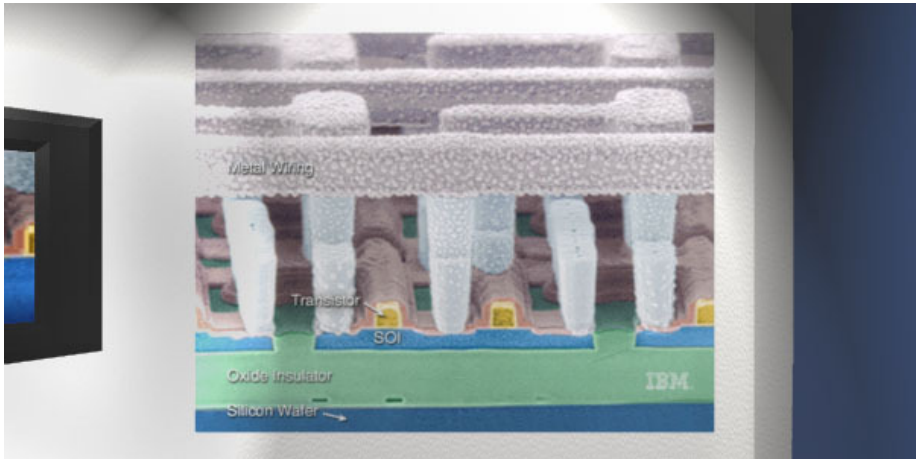


SEM of modern transistor circuitry

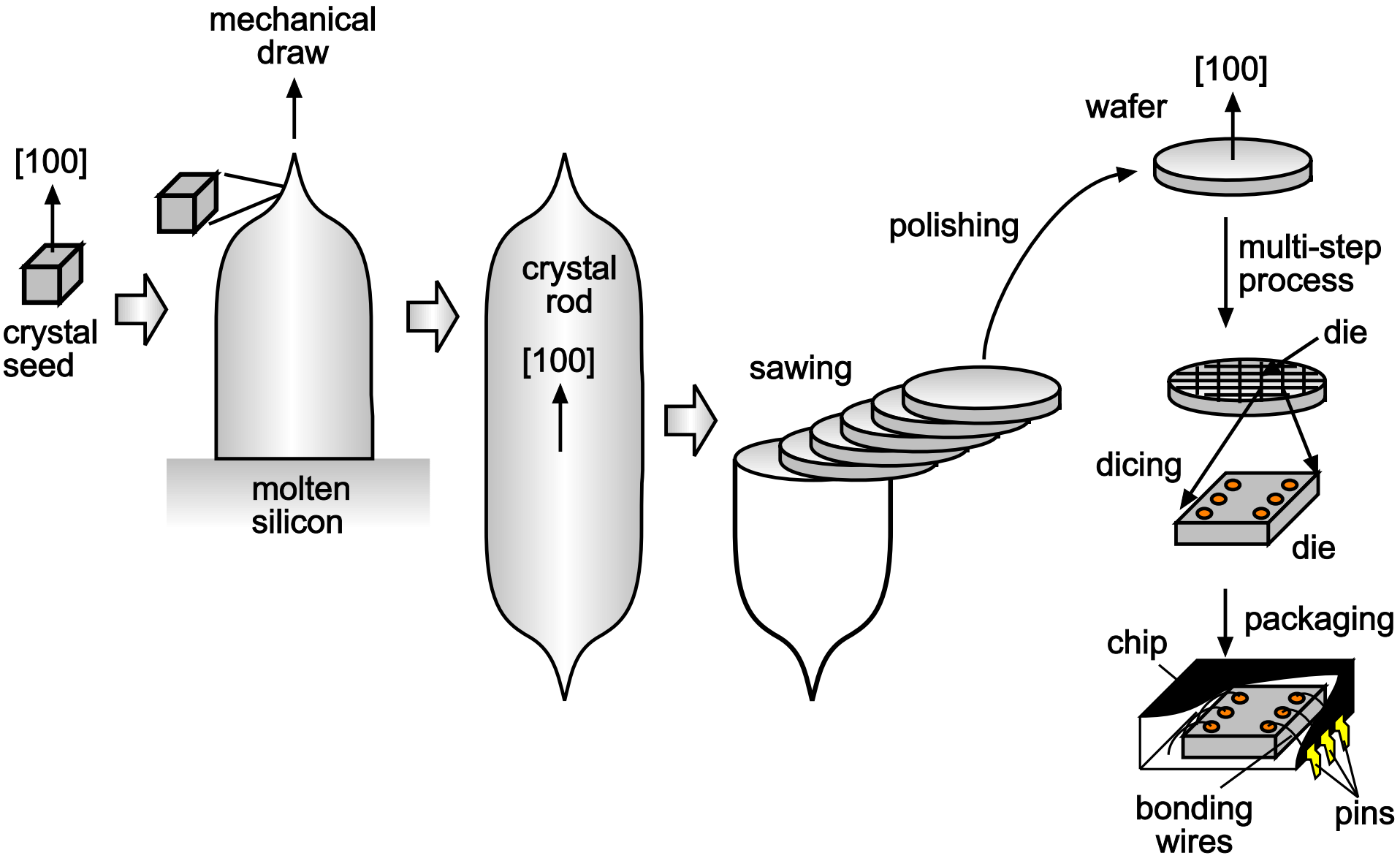




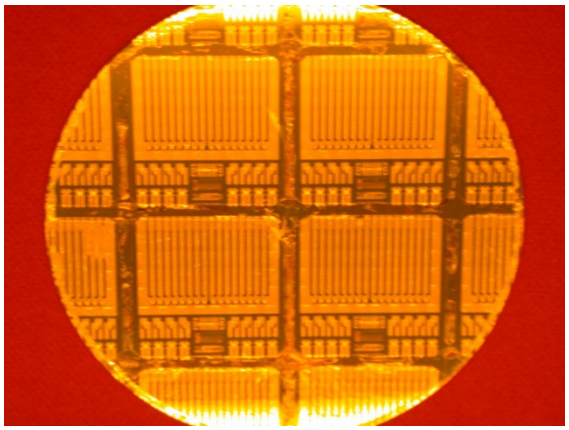


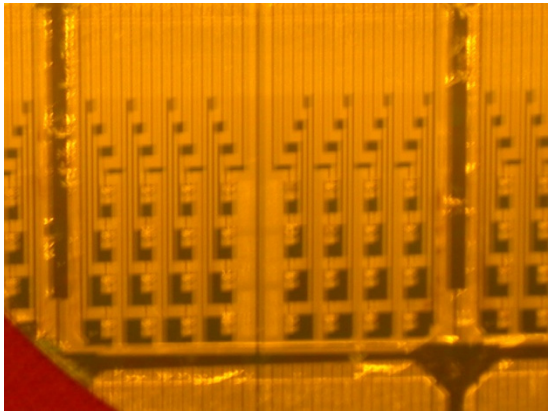


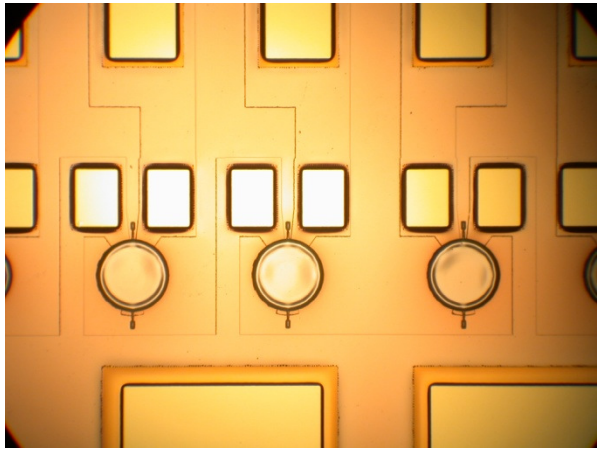
3D Features

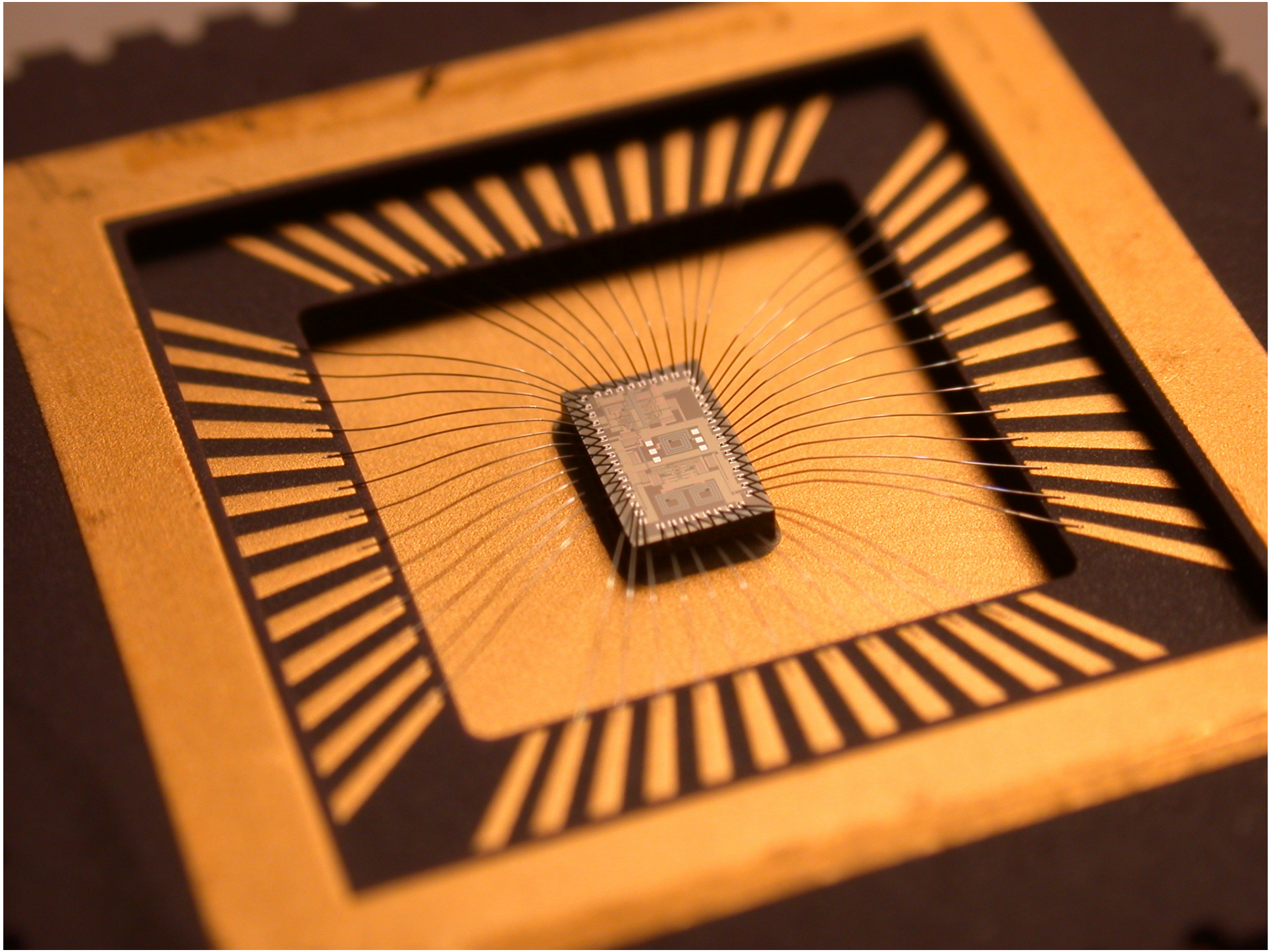

mechanical
draw
[100]
crystal
seed
molten
silicon
crystal
rod
[100]
sawing
polishing
wafer
[100]
multi-step
process
die
dicing
die
packaging
chip
bonding
wires
pins

From wafer to device









Processing Equipments

A tour of lab is arranged in the middle of semester

Wafer aligner
and exposure tool

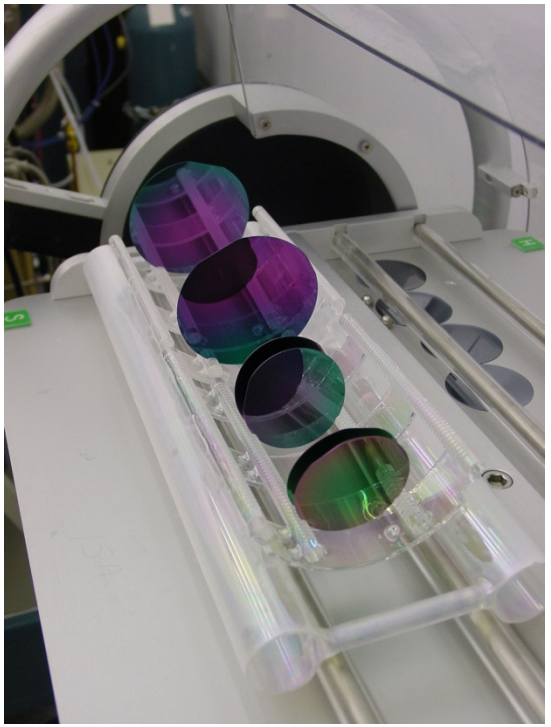
Metal Evaporator

Plasma etcher

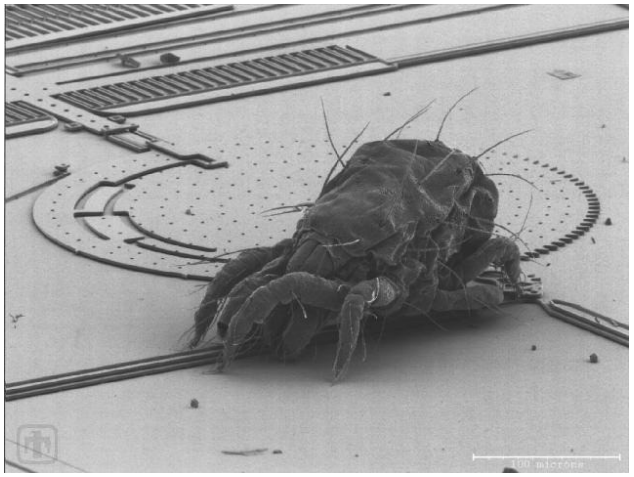
The Silicon Material Family

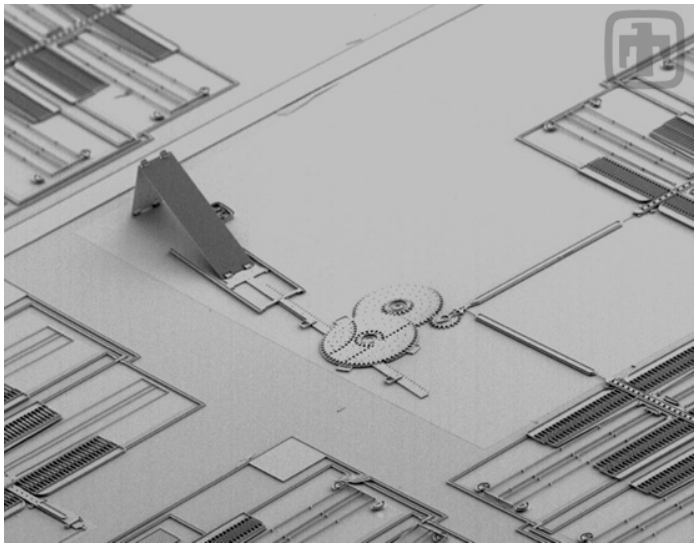
- Single crystalline silicon:
  - Bulk silicon by melt/crystallization
  - Thin film silicon by epitaxy
- Polycrystalline silicon: CVD
- Amorphous silicon: CVD

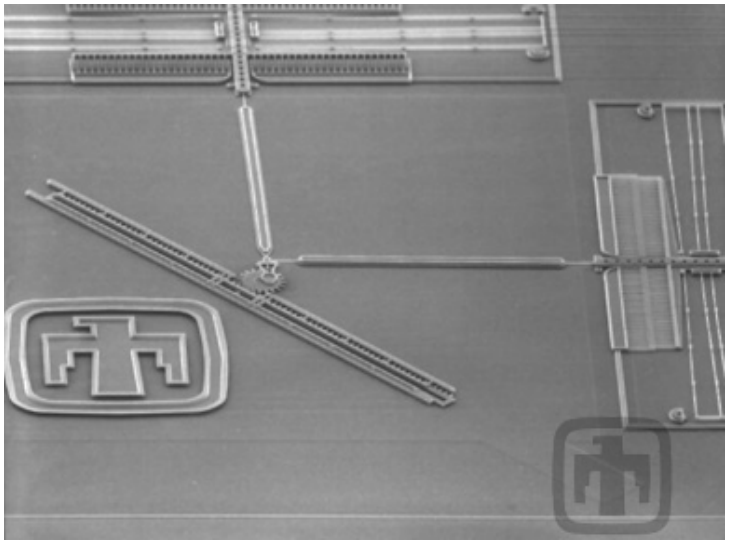
- Silicon nitride
- Silicon dioxide

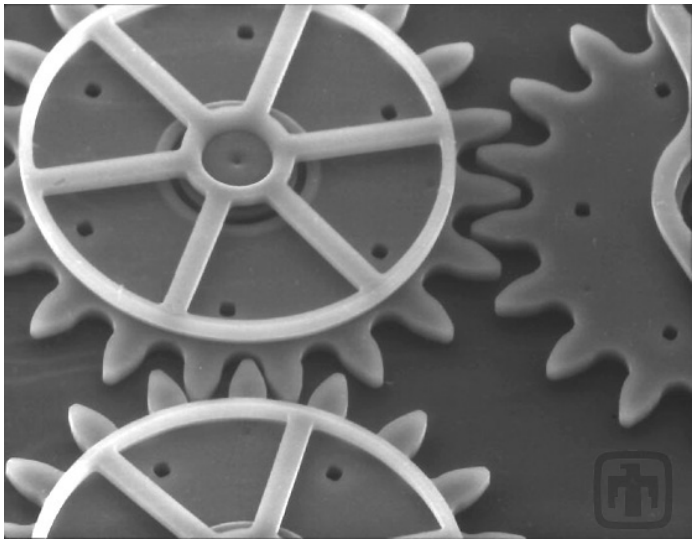


Weapon Safeguarding – Sandia National Lab.

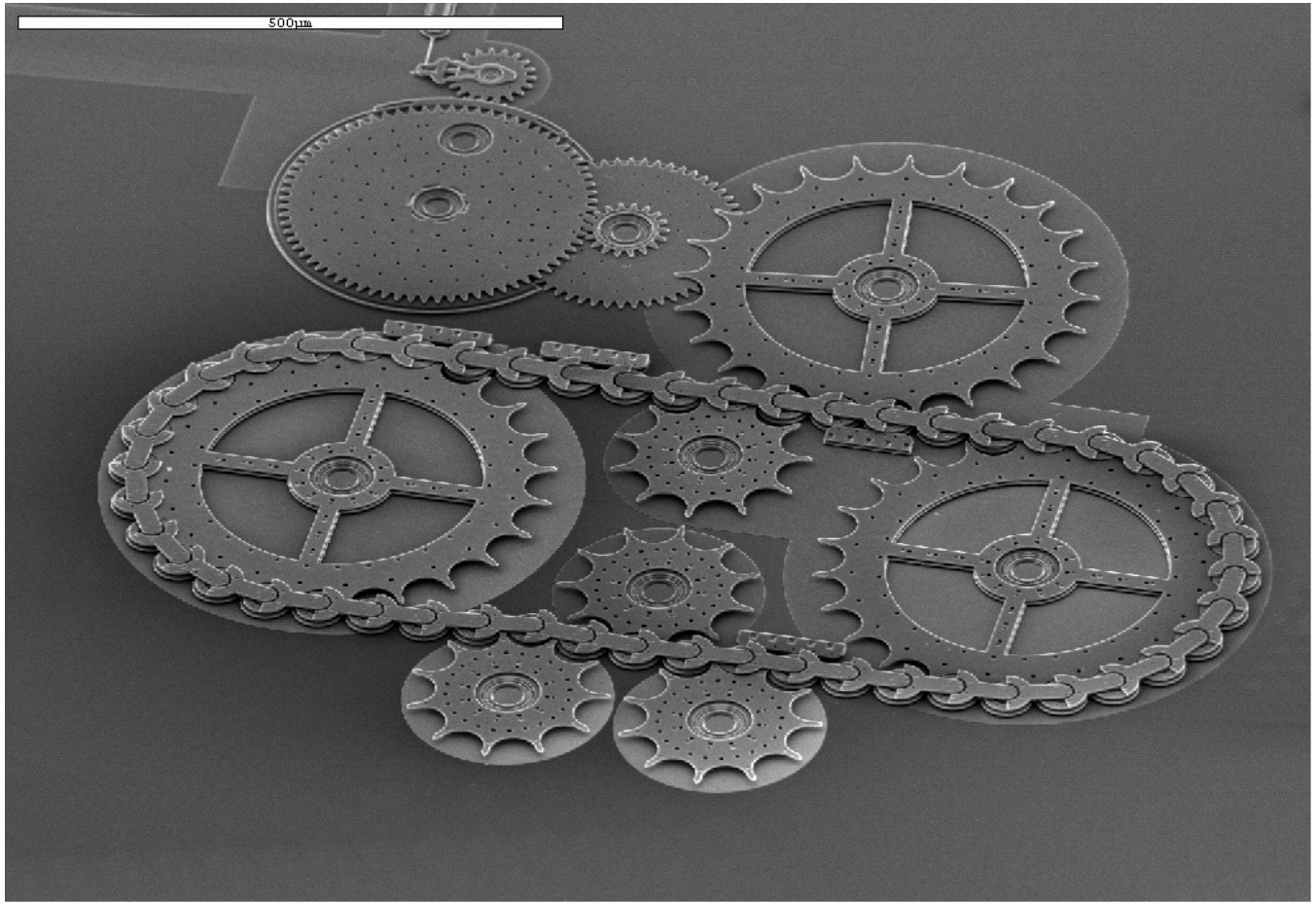








Surface Micromachined Gear Chains



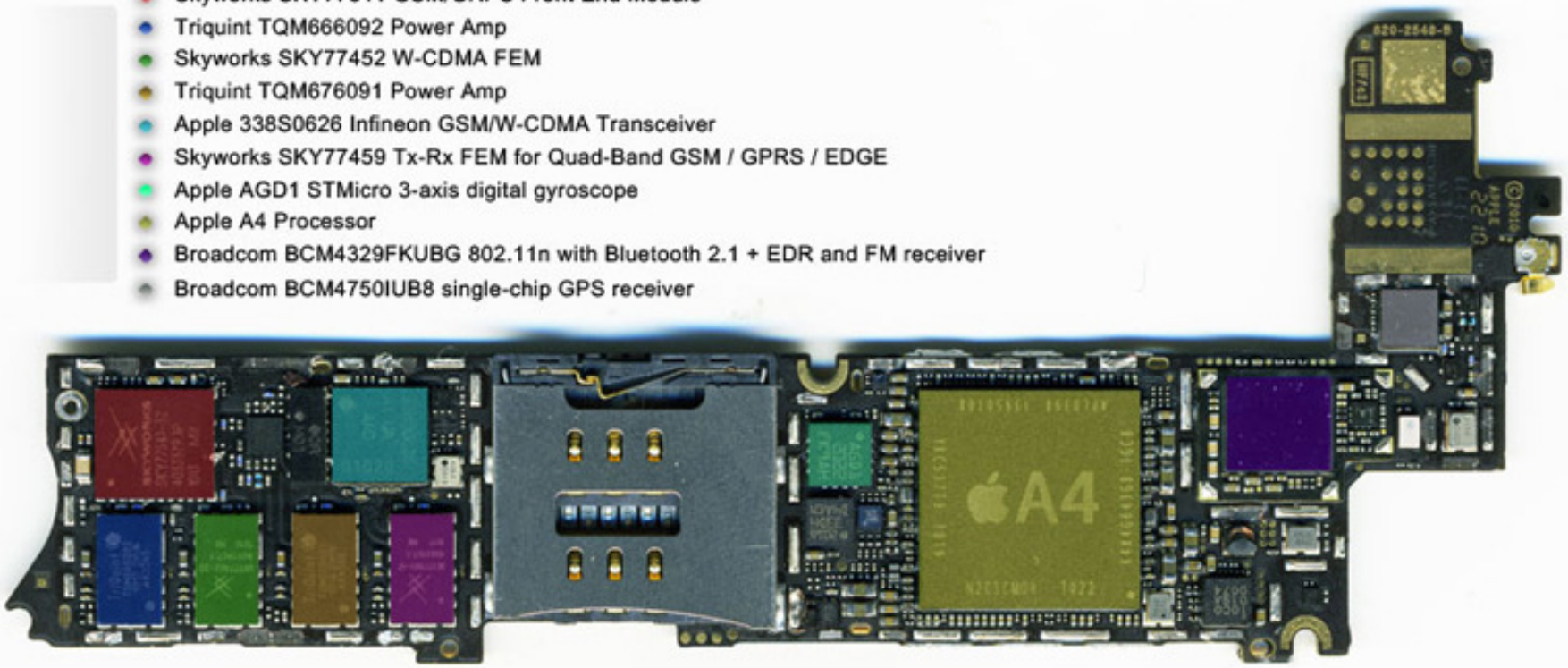
Apple's iPad

Apple iPhone 4 - Back

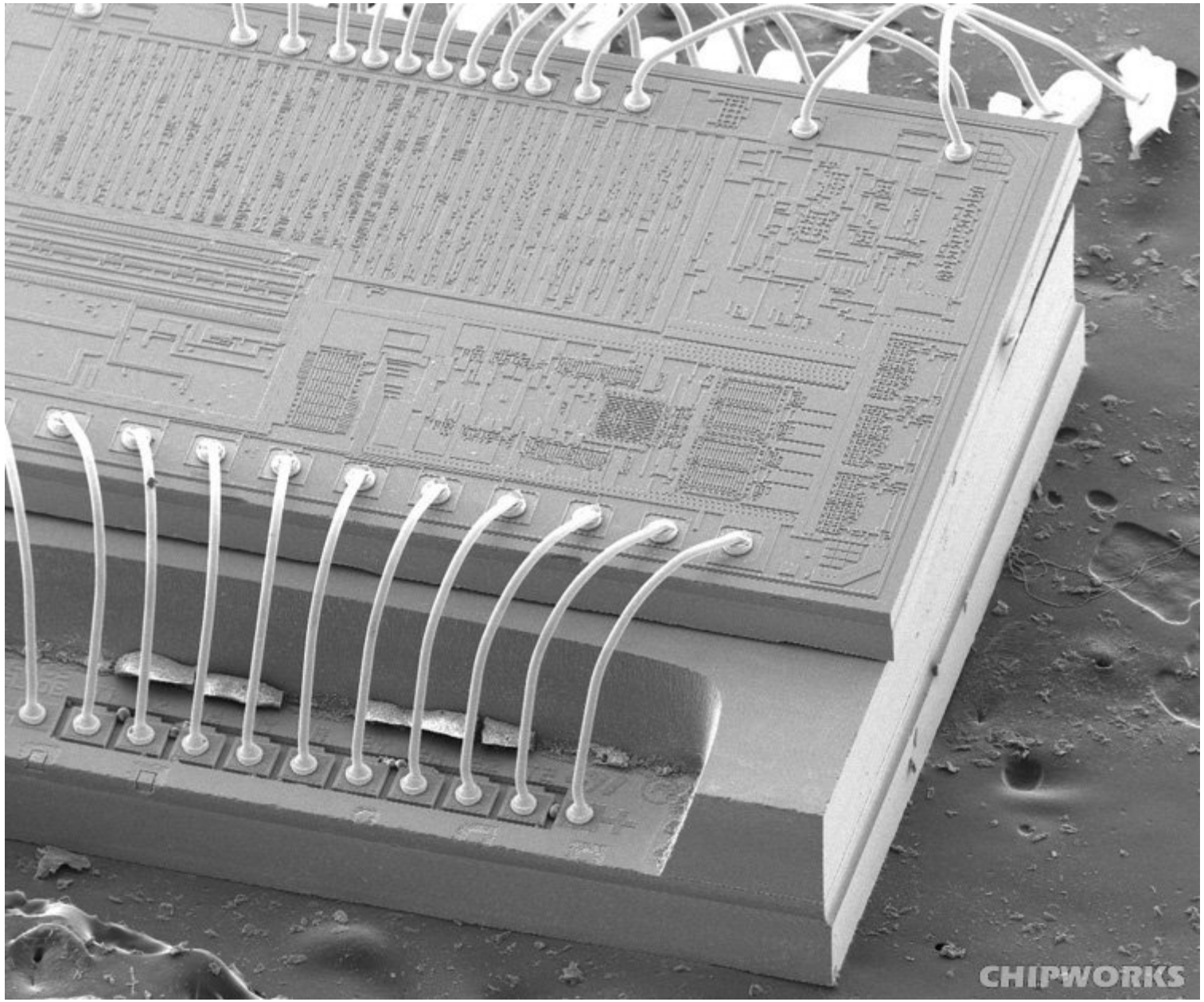
- Apple 343S0499 – Texas Instruments Touchscreen controller
- The Cirrus Logic 338S0589 audio codec
- Samsung K9PFG08U5M 256G bit, x8 FLASH MEMORY
- 338S0867 Dialog (Die marks D1815A 'Ashley') Power Management Unit
- 3383 Infineon X-GOLD 61x Baseband Processor
- Intel 36My1EF - ELPIDA 128 Mbits Mobile DDR SDRAM & 28F128FM Intel/Numonyx NOR

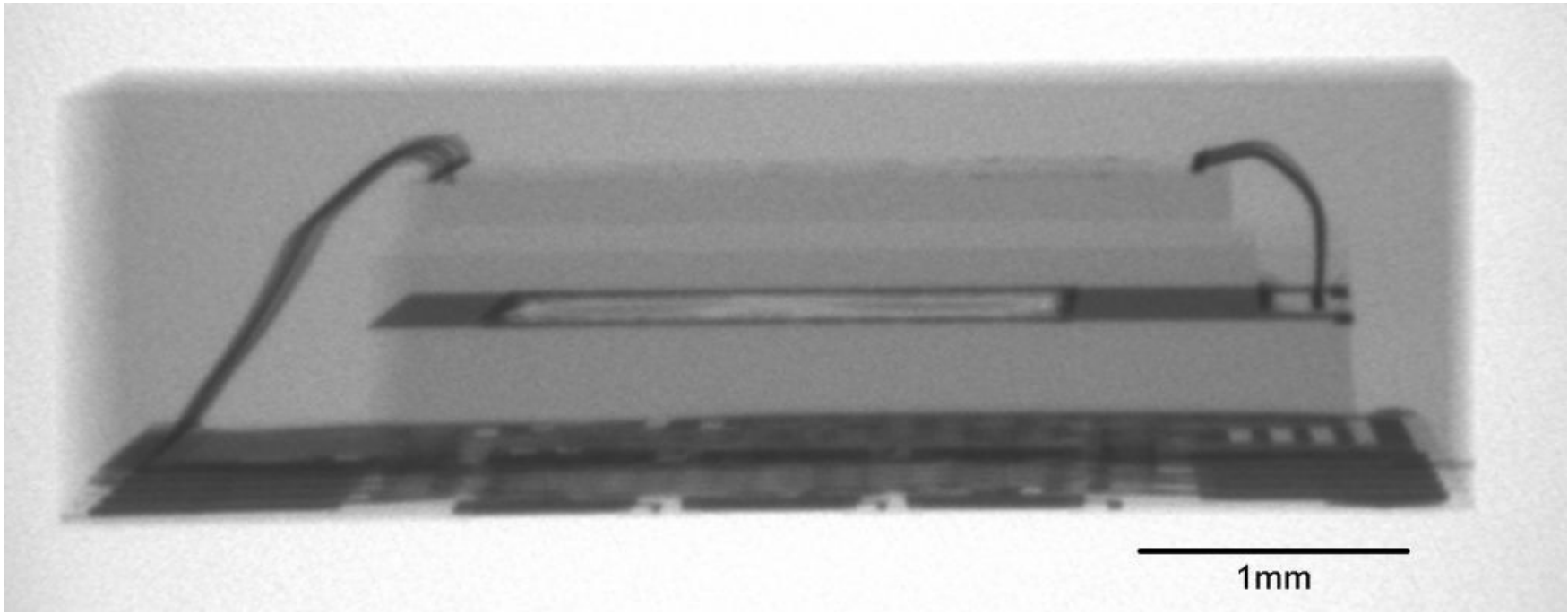
Apple iPhone 4 - Front

- Skyworks SKY77541 GSM/GRPS Front End Module
- Triquint TQM666092 Power Amp
- Skyworks SKY77452 W-CDMA FEM
- Triquint TQM676091 Power Amp
- Apple 338S0626 Infineon GSM/W-CDMA Transceiver
- Skyworks SKY77459 Tx-Rx FEM for Quad-Band GSM / GPRS / EDGE
- Apple AGD1 STMicro 3-axis digital gyroscope
- Apple A4 Processor
- Broadcom BCM4329FKUBG 802.11n with Bluetooth 2.1 + EDR and FM receiver
- Broadcom BCM4750IUB8 single-chip GPS receiver



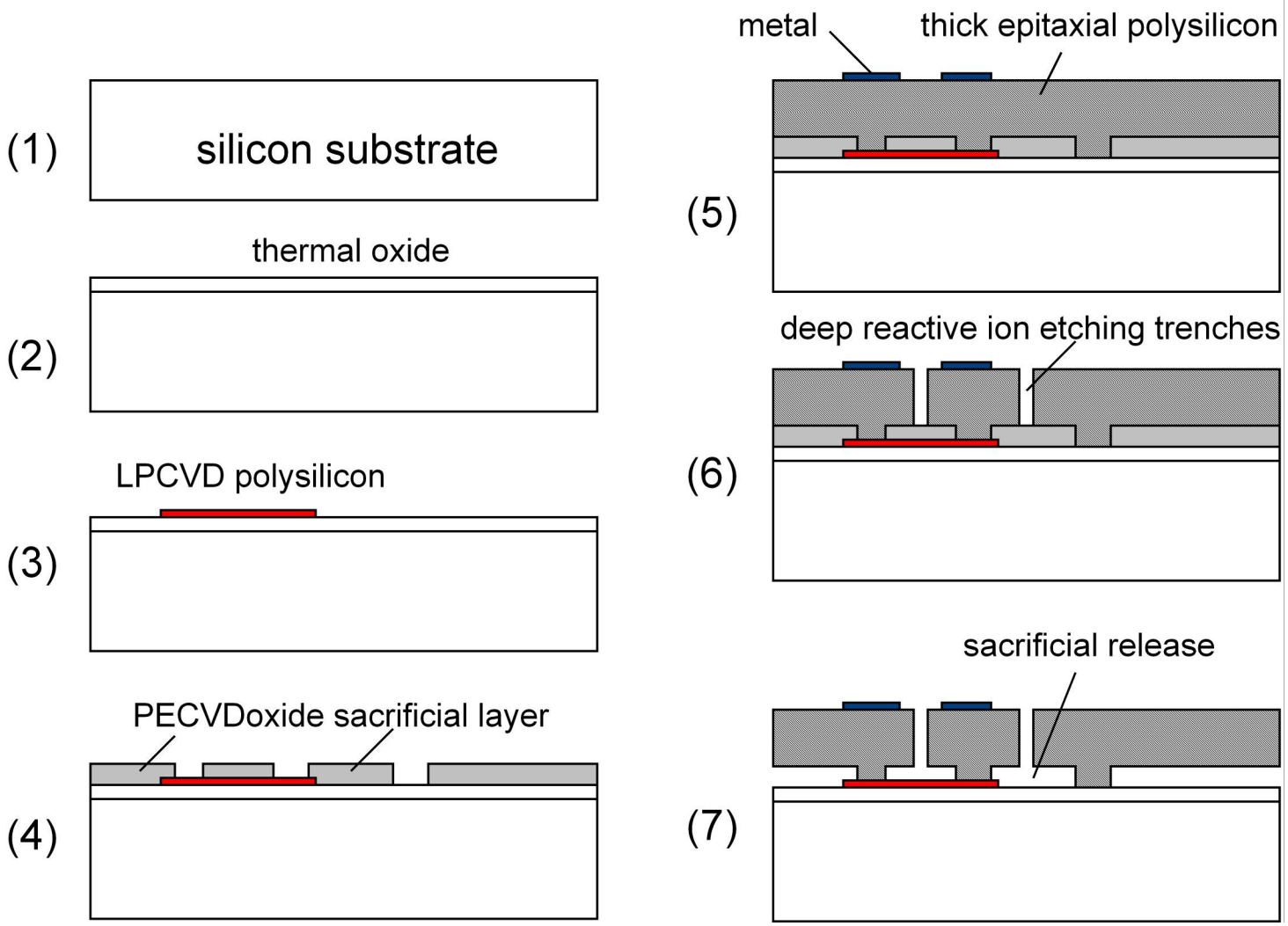
TECHINSIGHTS

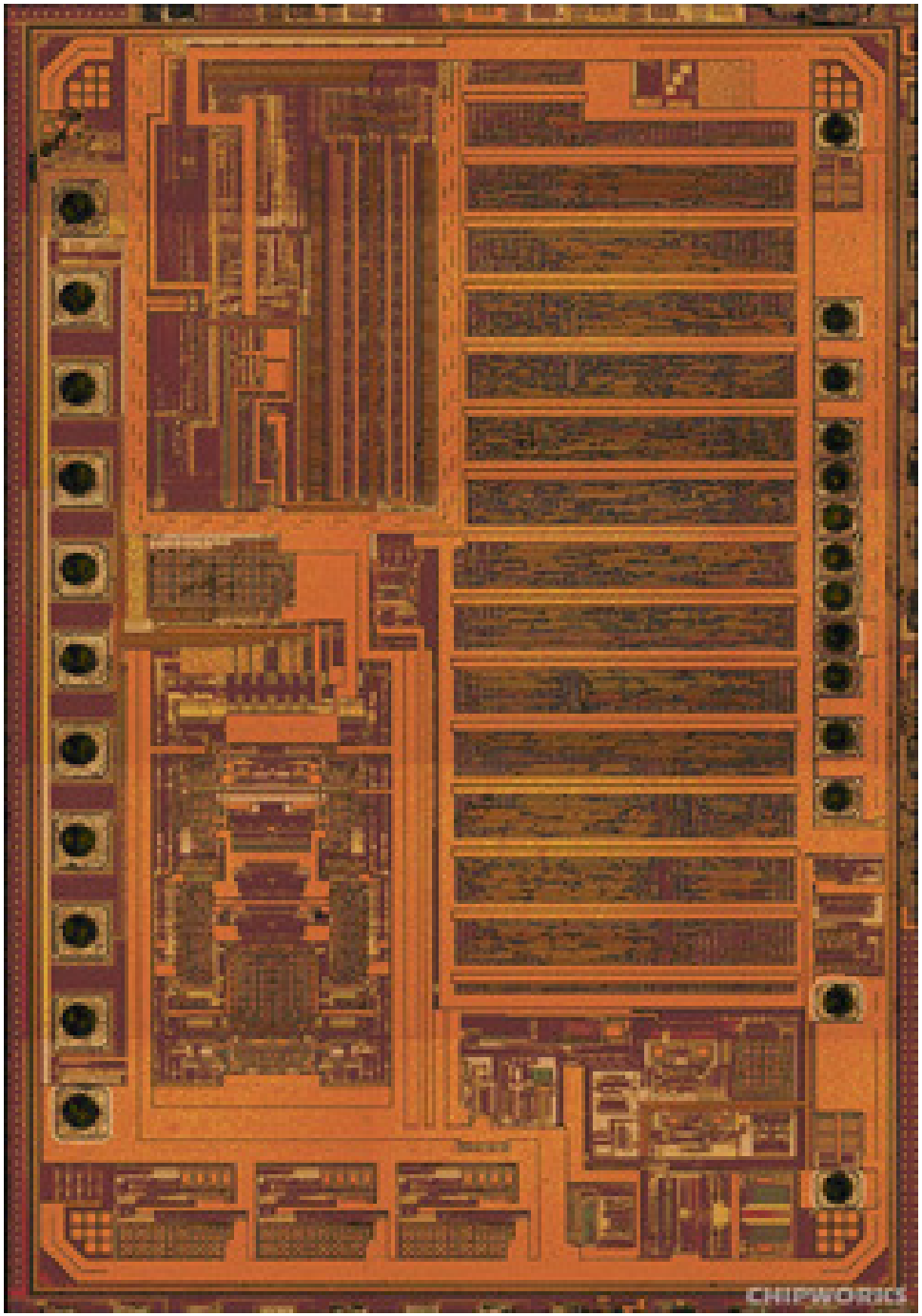

CHIPWORKS

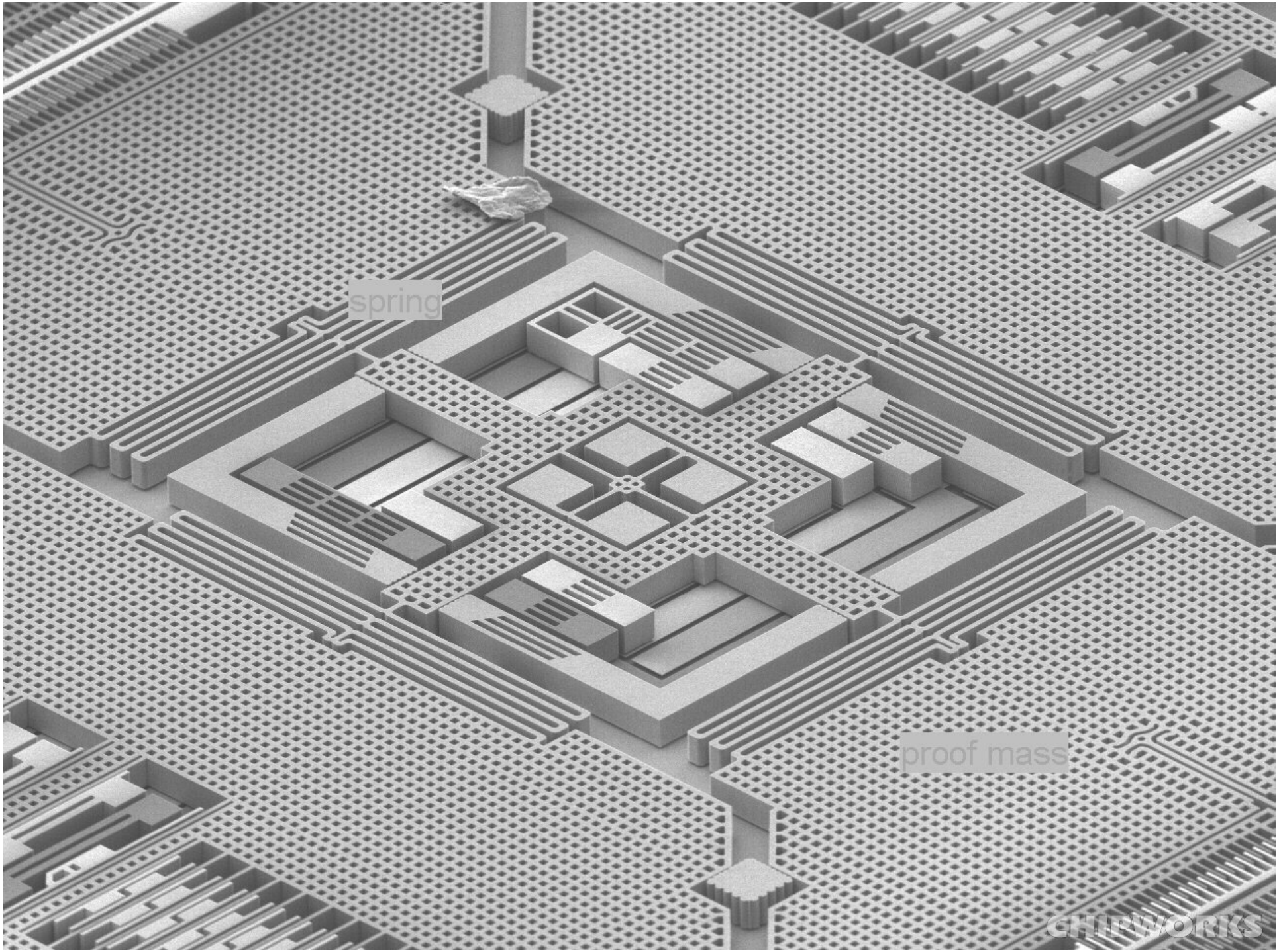

1mm

*ST*Microelectronics THELMA Process

Thick Epi-Poly Layer for Micro-actuators and Accelerometers

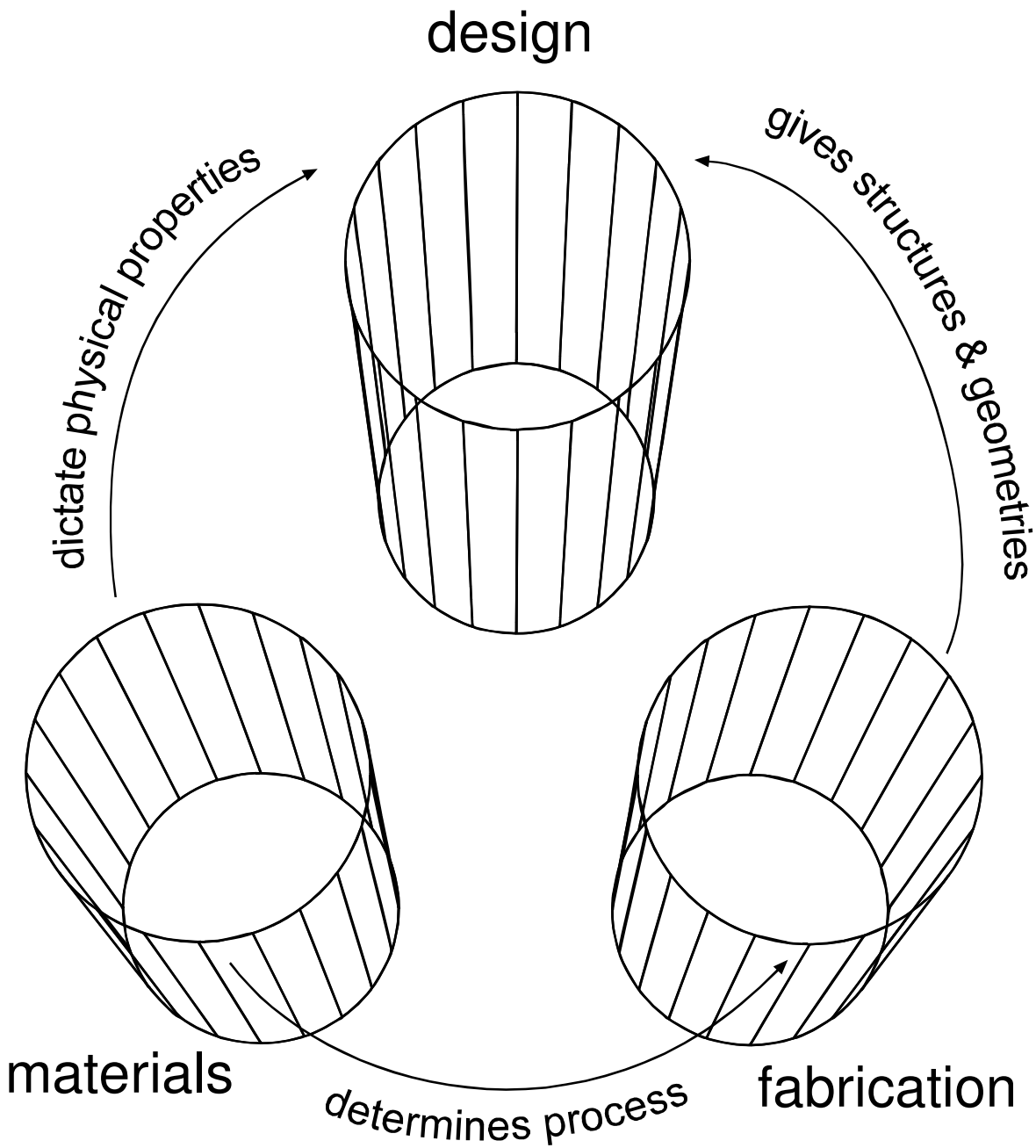



CHIPWORKS


spring
proof mass
CHIPWORKS

Small is Powerful

- MEMS is a class of device …
- As well as a means of fabrication and manufacturing.


design
dictate physical properties
gives structures & geometries
materials
determines process
fabrication

More Exciting Elements

Low cost mass manufacturing; Application domain knowledge
Intellectual property

Logistics

- Textbooks
- Teaming
- Computer
- Grading
-