

The LIGA Process

What is LIGA?

German	English
<u>L</u> ithographie	Lithography
<u>G</u> alvanoformung	Electroforming / Electroplating
<u>A</u> bformung	Moulding

Definition of LIGA

- LIGA is a German acronym that stands for Lithographie, Galvanoformung and Abformung.
- When translated it means lithography, electroplating and molding.

LIGA: Background



- LIGA is a three stage micromachining technology used to manufacture high aspect ratio microstructures.
- Originally LIGA technology was researched in Germany in order to be used for the separation of uranium isotopes.
- Henry Guckel of the University of Wisconsin brought LIGA technology to the USA.
- Two main types of LIGA Technology: X-ray LIGA and Extreme Ultraviolet (EUV) LIGA.
- X-ray LIGA can fabricate with great precision high aspect ratio microstructures.
- EUV LIGA can fabricate lower quality microstructures.

LIGA Process



- LIGA is a hybrid fabrication technique
- The LIGA Process
 - Lithography
 - ✦ Electron beam lithography
 - ✦ Focused ion beam lithography
 - ✦ Optical and excimer laser lithography
 - ✦ Deep X-ray lithography using synchrotron radiation
 - Electroplating
 - ✦ metalized layer (seed layer)
 - Molding
 - ✦ Machining process to remove overplated metal region

Function of LIGA

- To produce high aspect ratio
- To manufacture 3-D microstructures from a wide variety of materials

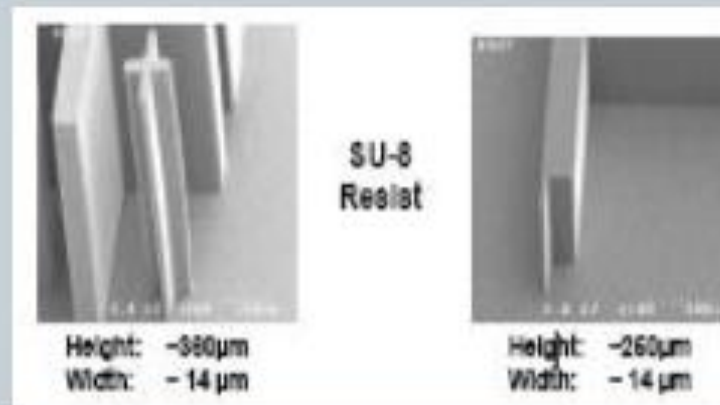


Figure1: 3-D microstructure

LIGA Process

- Deep X-ray lithography
 - Historically chosen as a source for LIGA process
 - superior to optical lithography
 - ✦ Utilize short wavelength
 - ✦ very large depth of focus
 - ✦ Synchrotron Light Source maintains energy anywhere from 10^6 to 10^9 eV

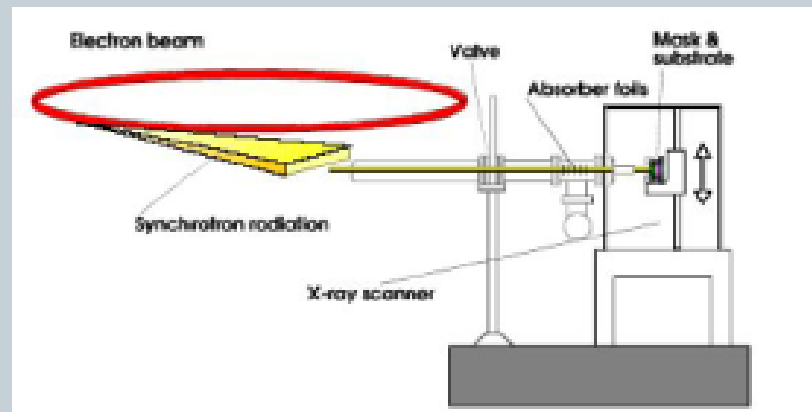
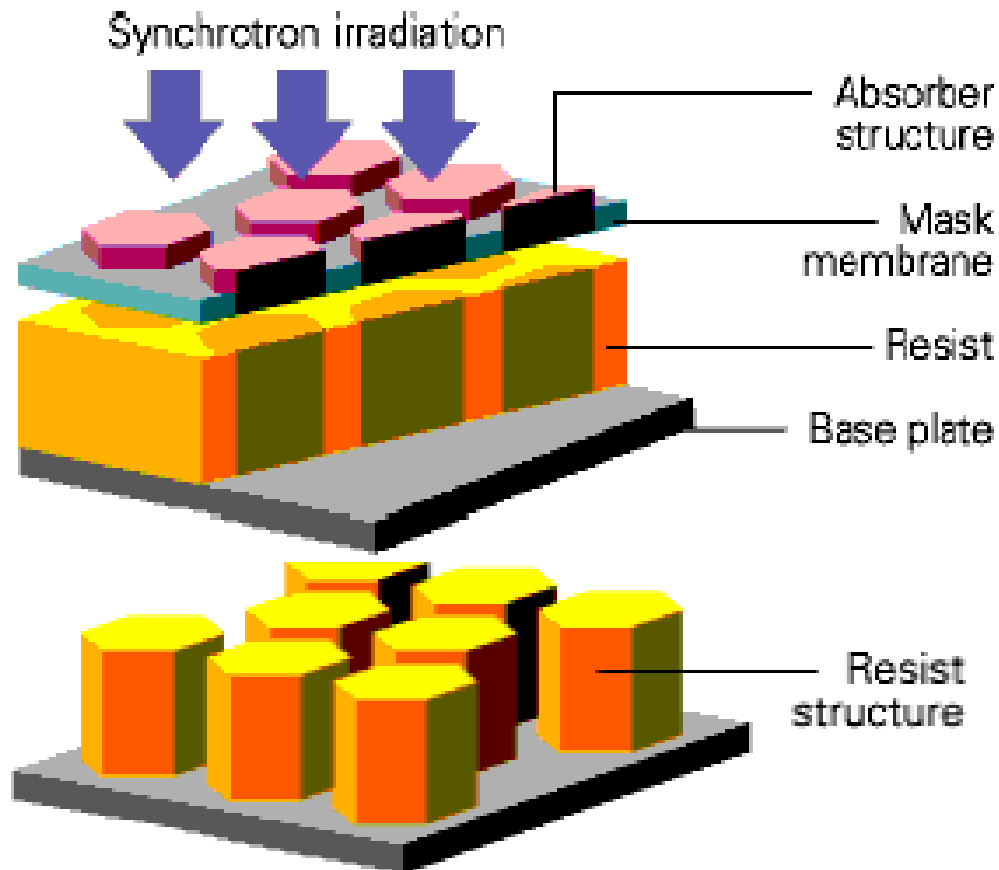


Figure2: Synchrotron Light Source setup

X-ray Lithography

Shadow Printing Using X-rays

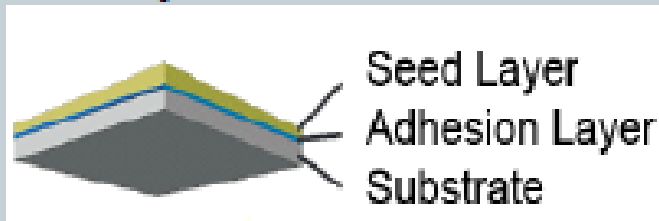


- X-ray mask
- Resist
- Substrate
- Development

Deep X-ray Lithography Techniques

- Step 1:

- Deposition of Adhesion
- Seed layer



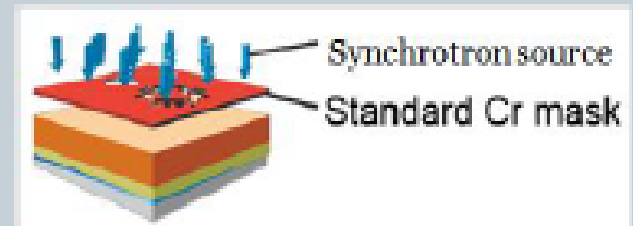
- Step 2:

- resist coating



- Step 3:

- expose the PMMA resist



- Step 4:

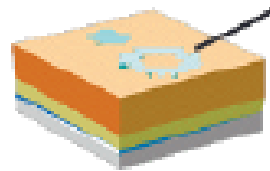
- development of the exposed resist



Deep X-ray Lithography Techniques

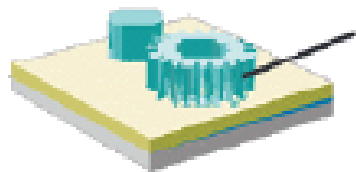
Electroplating and Micro-Molding Techniques

- Electroplating is a process to fill in the voids between the polymeric features.
- Step 5:
-metal plating



Microstructure filled with metal

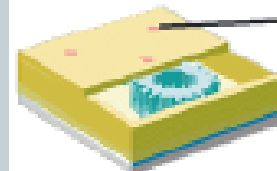
- Step 6:
-removal of the remaining resist



Microstructure (metal)

Molding is process of machining the overplated region filling the microstructure

- Step 7:



Gate System (feeder);
Mold insert



Advantages and Disadvantages

- Large structural height and sidewall properties.
- Thickness ranging from 100-1000 μm .
- Spatial resolution.
- High aspect ratios.
- EUV LIGA is a cheaper alternative.

- X-ray LIGA is expensive due to the equipment required.
- Slow process.
- Complicated process.
- Difficulty transitioning from research to production.

Applications



- MEMS Components
- Sensors
- Actuators
- Trajectory Sensing Devices
- Mass Spectrometers
- Microoptical Components

Hot Embossing

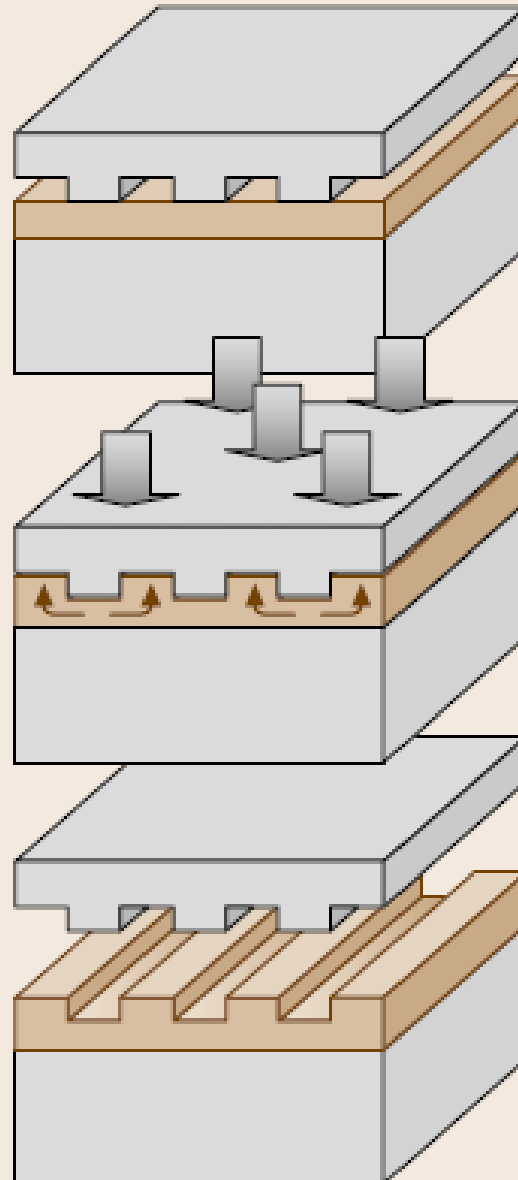
Hard stamp

Solid polymer

Substrate

Viscous polymer

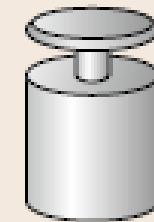
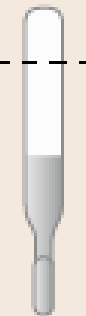
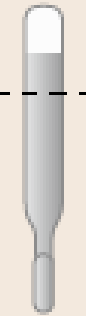
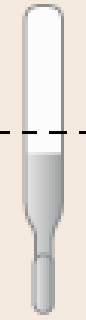
Solid polymer



T_g

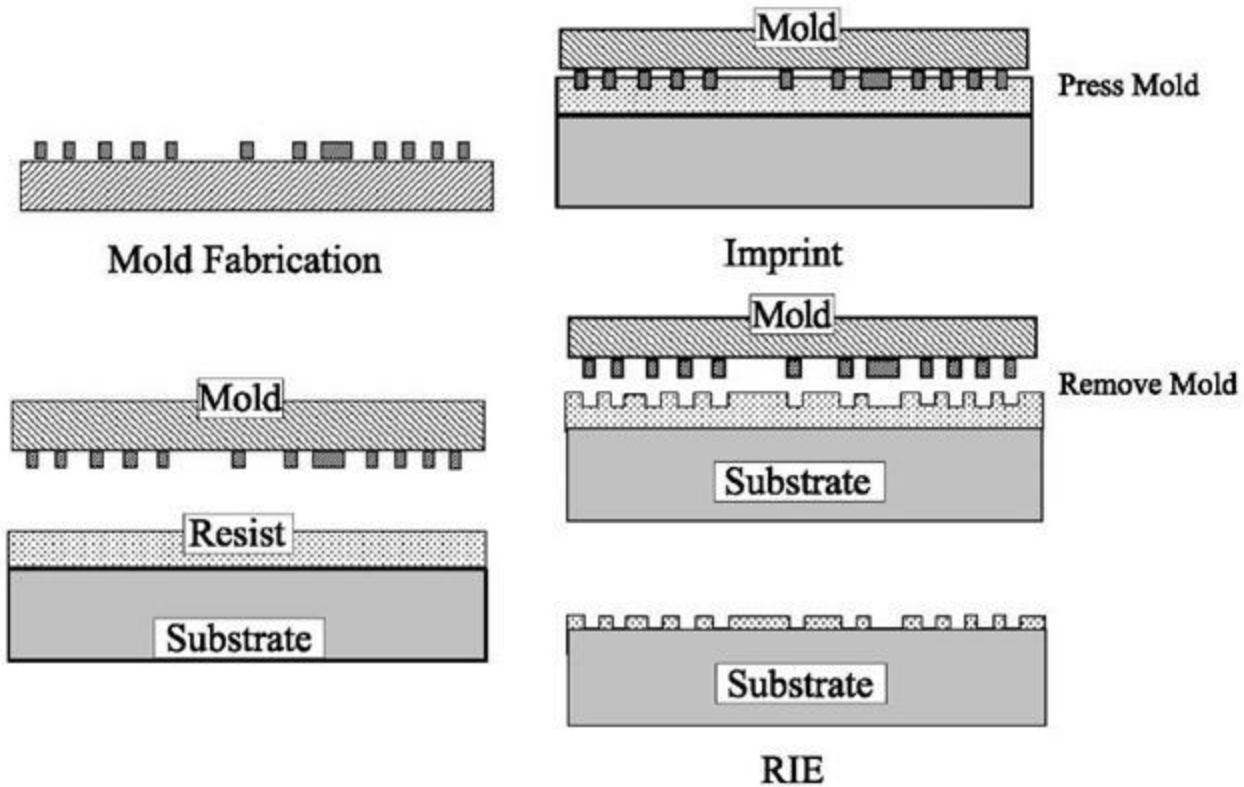
T_g

T_g

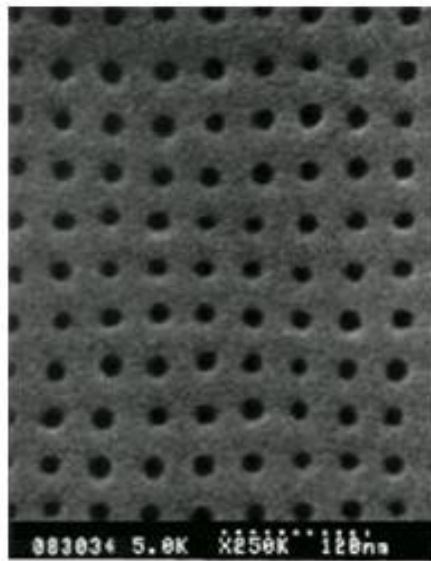
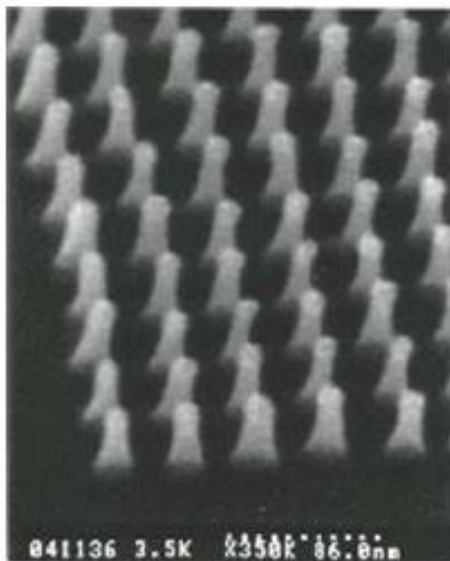
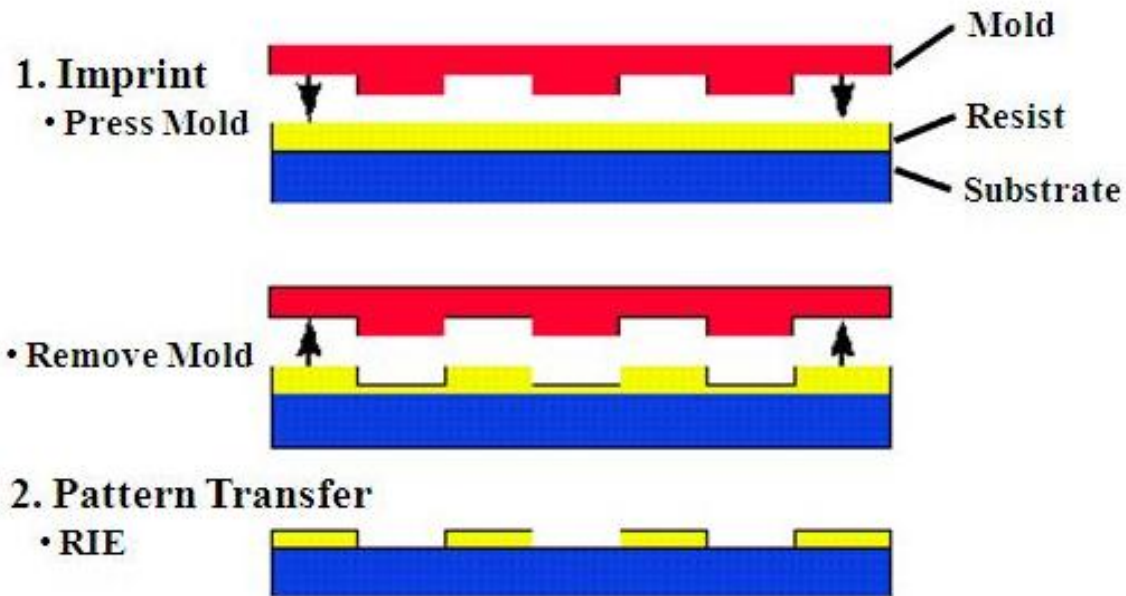


80 bar

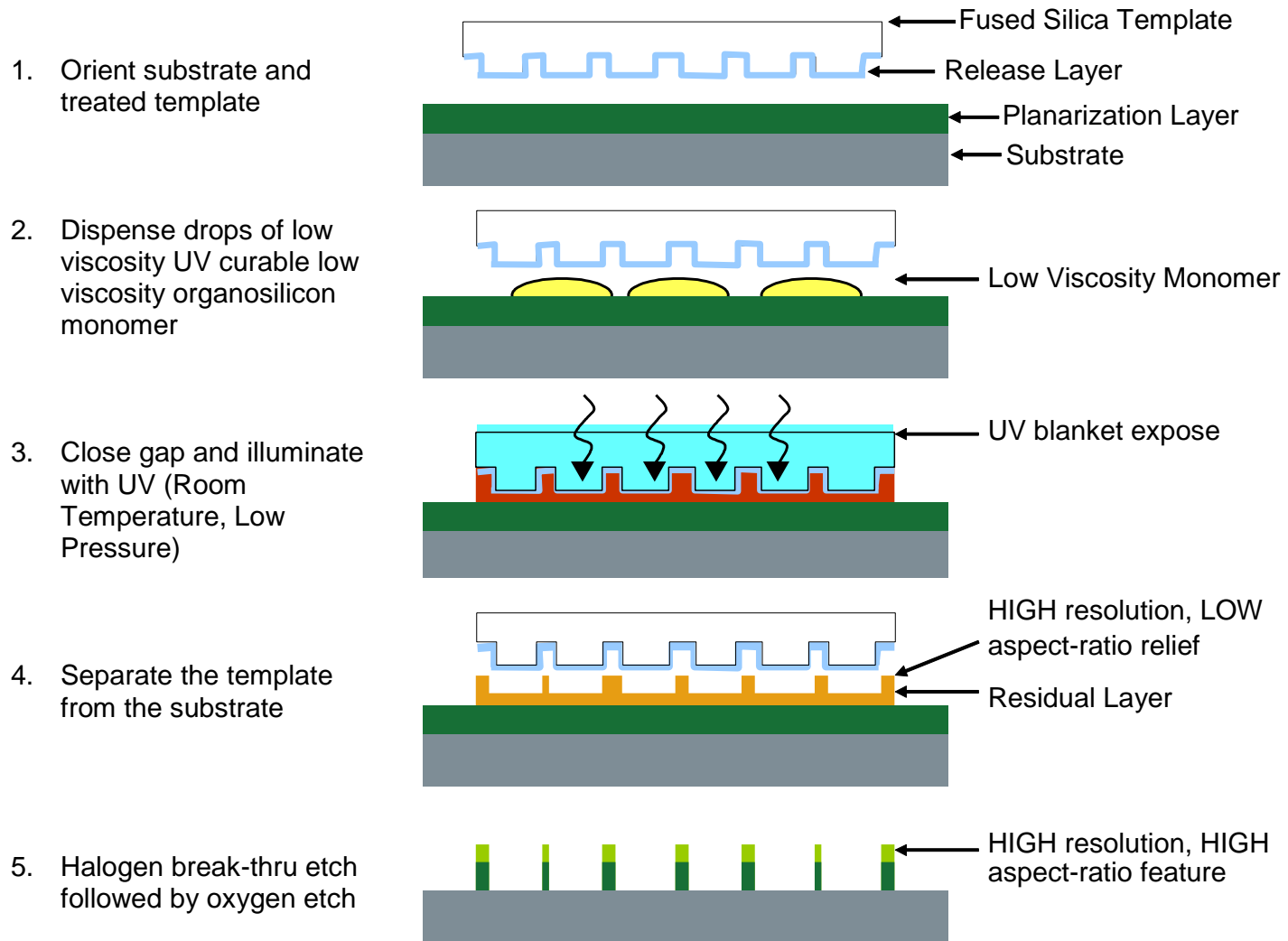
Hot Embossing



Nanoimprint Lithography



Nano-imprinting Lithography:



Step and Flash Imprinting Lithography (S-FIL™)

Thermal Modeling of UV Nanoimprint Lithography



Template

Monomer on substrate



Imprint and
UV-cure

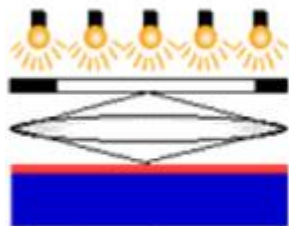


Remove template

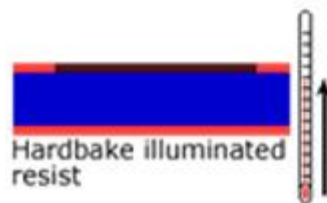


Pattern transfer

Optical Lithography



Condenser lens projects image from mask, patterning resist

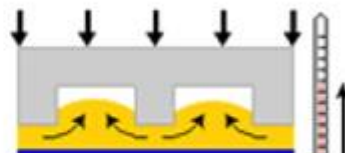


Hardbake illuminated resist

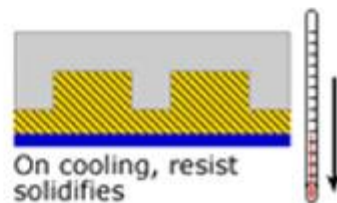


Resist clean to remove patterned resist

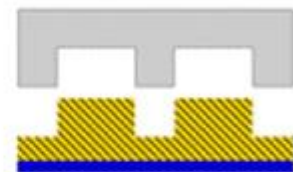
Thermal Nanoimprint Lithography



Heat thermoplastic polymer to decrease viscosity, then imprint malleable resist



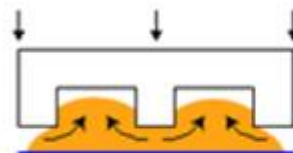
On cooling, resist solidifies



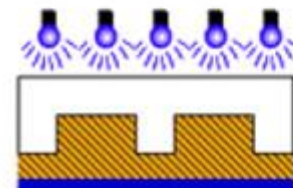
De-embossing leaves negative imprint



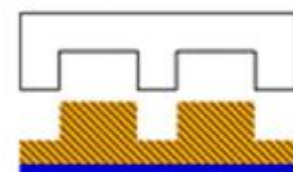
UV Nanoimprint Lithography



Imprint liquid resist, conforms easily to stamp



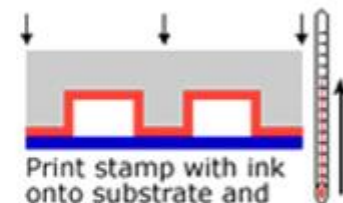
Transparent stamp allows UV light to polymerize resist, causing solidification



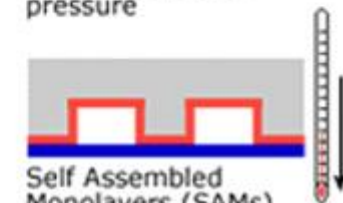
UV polymerization, resist solidifies



Micro Contact Printing



Print stamp with ink onto substrate and increase the temperature and pressure



Self Assembled Monolayers (SAMs) attach to substrate



Stamp removal leaves printed pattern

To create islands of material i.e. for etching a substrate, a Reactive Ion Etch is needed to remove the residual layer

MEMS Fabrication Techniques

There are three basic building blocks in MEMS technology

- **Deposition (Additive Method) :**
 - Thin Film Deposition

- **Etching (Subtractive Method) :**
 - Wet Etching
 - Dry Etching

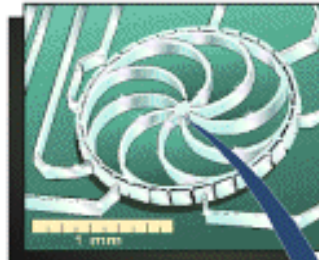
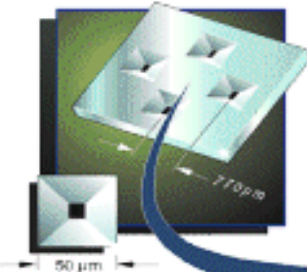
- **Patterning (Pattern Transfer Method) :**
 - Photo Lithography
 - E-beam Lithography
 - Nano-imprinting Lithography
 - LIGA

MEMS Applications in the Car

Courtesy of D. Thomas,
Perkin-Elmer Applied
Biosystems

Inertial Navigation Sensors
• Acceleration
• Yaw Rate

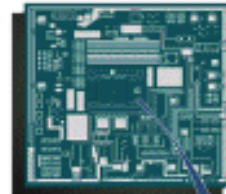
**Silicon Nozzles
for Fuel Injection**



Fuel
Pressure
Sensor

Micromachined Transducer

Applications for Automotive
Operation & Safety



**Micromachined
Accelerometer
for Airbag**

Microphones
for Noise
Cancellation

Airbag
Side Impact
Sensor

Fuel Sensors
• Level
• Vapor Pressure

Air-Conditioning
Compressor
Sensor

Manifold
Air
Pressure
Sensor

Mass
Air Flow
Sensor

Force Sensors
• Brakes
• Throttle Pedals

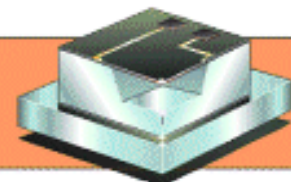
Accelerometer
for Suspension
Control

Pressure and Inertial
Sensors for
Braking Control

**Tire
Pressure
Sensors**

Crash
Sensor

Exhaust
Gas
Sensor



MEMS Applications

• Micro-engines	✓ Micro-Reactors
	✓ Vibrating Wheel
• Inertial Sensors	✓ Virtual Reality Systems
• Accelerometers	✓ Airbag
	✓ Accelerometer
• Pressure Sensors	✓ Air Pressure Sensors
• Optical MEMS	✓ Pill Camera
• Fluidic MEMS	✓ Cartridges for Printers
• Bio-MEMS	✓ Blood Pressure Sensors
• MEMS Memory Units	✓ Flash Memory

Definitions

- **Measurand (Physical quantities):**
 - Position, displacement
 - Temperature
 - Force
 - Pressure,...
 - Concentrations, chemicals,....
- **Sensor:**
 - is a device that detects a change in a physical stimulus and turns it into a signal which can be measured or recorded
- **Signal conditioning:**
 - Amplifying, wave- shaping, filtering, rectifying,...
- **Transducer**
 - is a device that transfers power from one system to another in the same or in a different form.

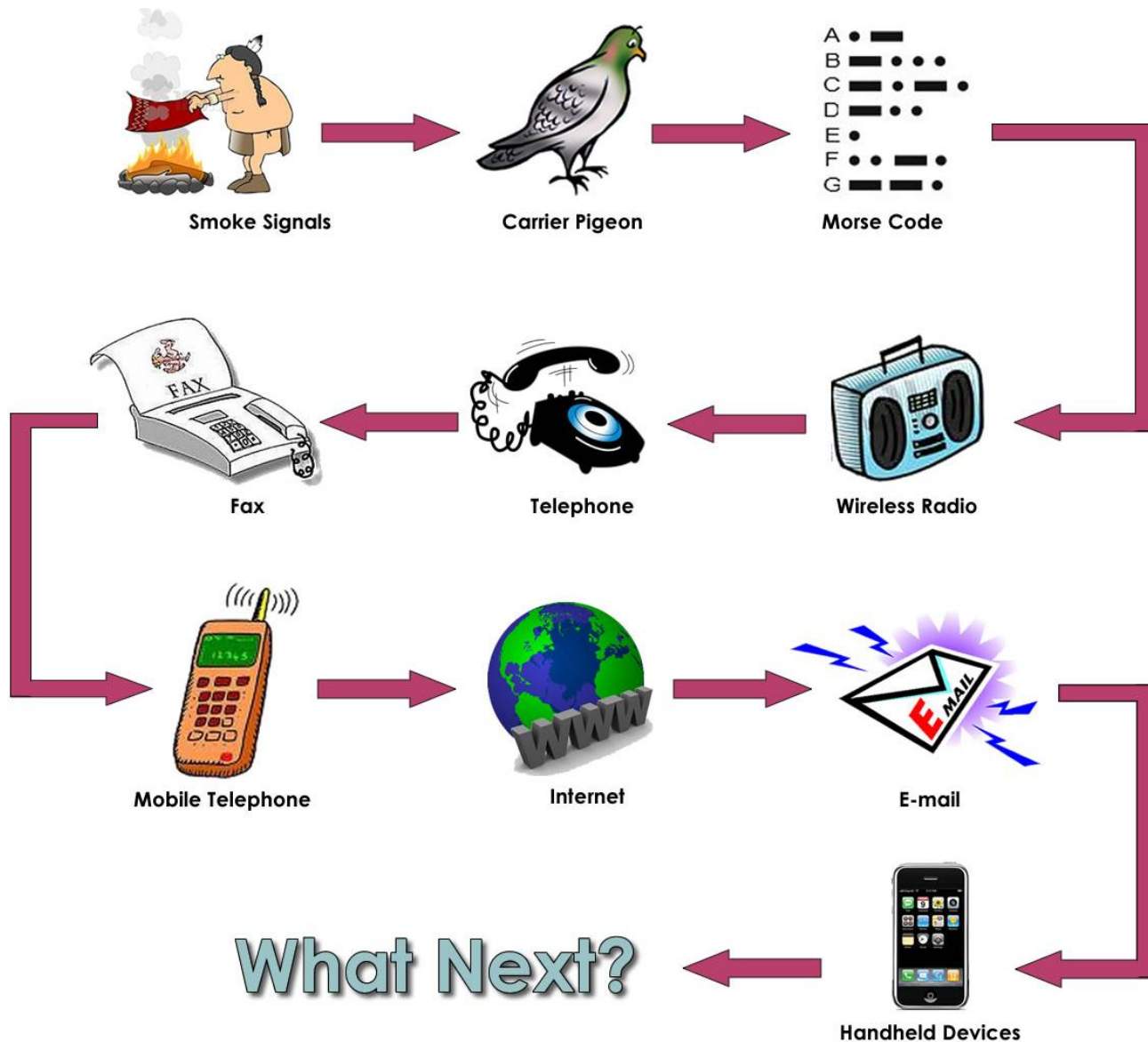
Smart Phone Tough: Techno Sensitivity

- The two key elements of a MEMS are:
 - MEMS sensor, the silicon mechanical element which senses the motion;
 - Interface chip, the IC which converts the motion measured by the sensor into an analog or digital signal.



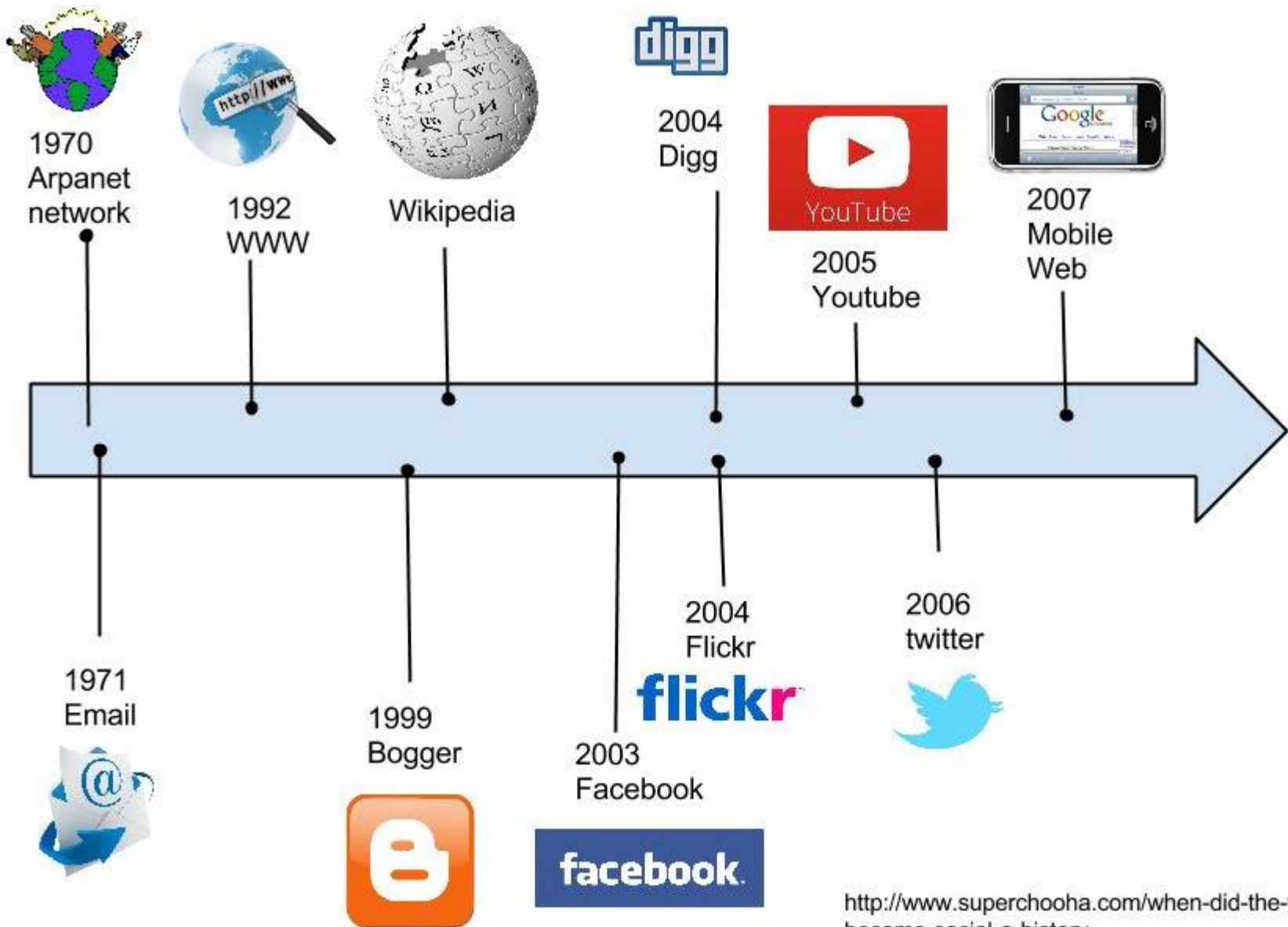
Integrated circuit (IC)

Communication Timeline



What Next?

The History of Internet



The evolution of the cellphone



1982
Mobira Senator
Finnish company Mobira Oy, a precursor to Nokia, introduced its first car phone, the Mobira Senator NMT-450. It weighed about 22 pounds.



1984
Motorola DynaTac 8000x
The first cellphone to be offered commercially hit the market priced at \$3,995 (\$9,237 in 2012 dollars) and weighed just under 2 pounds.



1987
Mobira Cityman
One of the world's first handheld phones, the Cityman weighed 28 ounces with the battery.



1989
Motorola MicroTac
Initially manufactured as an analog cellphone, the MicroTac was an early example of a flip phone, in which the mouthpiece folded over the keypad.



1992
Nokia 1011
The first digital handheld phone, the Nokia 1011 would become the company's best-selling phone ever.



1993
BellSouth/IBM Simon Personal Communicator
First phone with a touch screen and smartphone features (pager, calculator, address book, send/receive faxes, games and email). Cost about \$900.



2000
Ericsson R380
The first device marketed as a smartphone.



2002
BlackBerry 5810
Made by Research In Motion, the 5810 was a cellphone with organizer functions and a keyboard for thumbs; a wired headset was mandatory.



2004
Motorola RAZR
Was part phone, part fashion accessory. In the Razr's first four years, Motorola sold more than 110 million units.

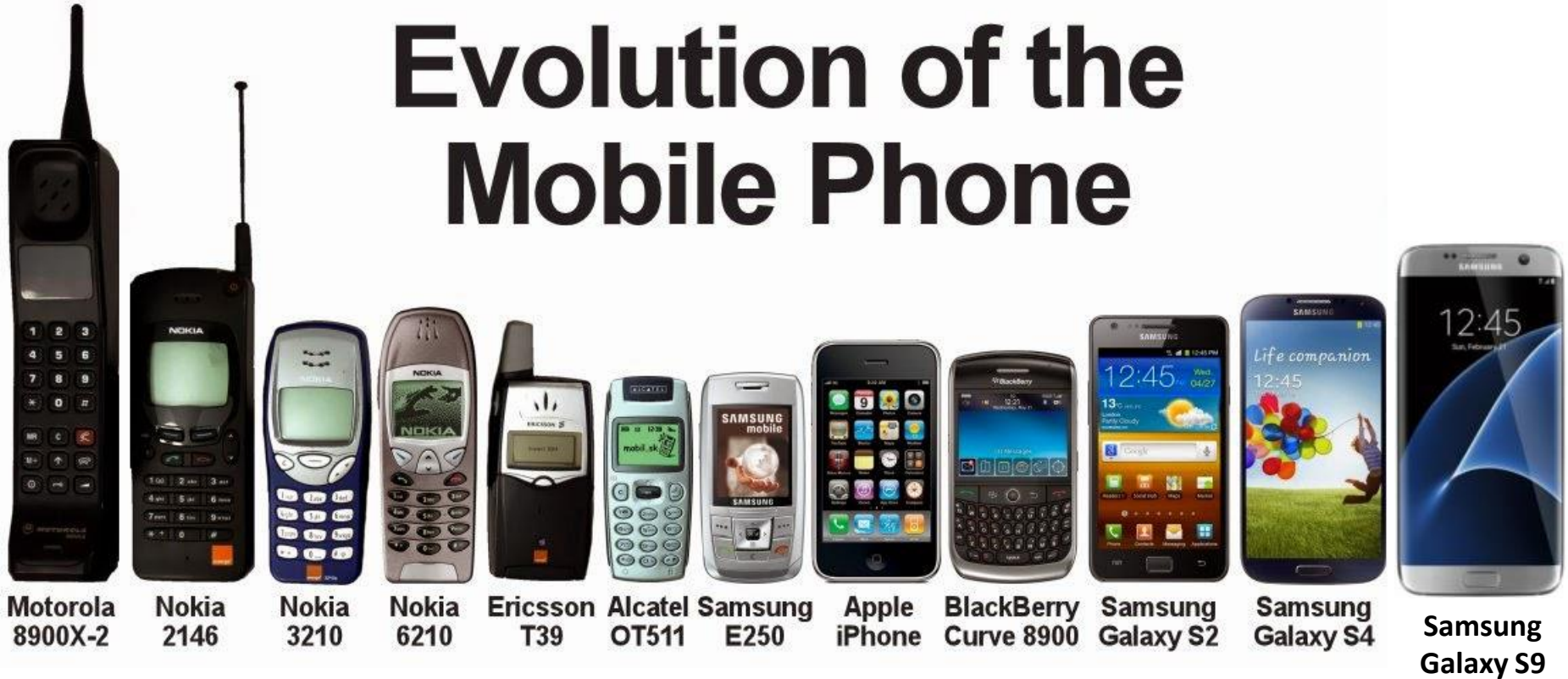


2007
Apple iPhone
Hundreds of people lined up outside Apple stores to buy the first iPhone, priced at \$499 (4GB) and \$599 (8GB).

Source: WSJ research; Photos: Nokia (3), Motorola (3), BlackBerry, Ericsson, Associated Press

The Wall Street Journal

Evolution of the Mobile Phone



Motorola 8900X-2

Nokia 2146

Nokia 3210

Nokia 6210

Ericsson T39

Alcatel OT511

Samsung E250

Apple iPhone

BlackBerry Curve 8900

Samsung Galaxy S2

Samsung Galaxy S4

Samsung Galaxy S9

Mobile Technology

Mobile 1G
AMPS, NMT, TACS



Mobile 2G
D-AMPS, GSM/GPRS,
cdmaOne



Mobile 3G
CDMA2000/EV-DQ,
WCDMA/HSPA+, TD-SCDMA



Mobile 4GLTE
LTE, LTE Advanced



N/A

Analog Voice



<0.5 Mbps¹

Digital Voice + Simple Data



63+ Mbps²

Mobile Broadband



300+ Mbps³

Faster and Better



Comparison between 4G vs. 5G

The following basis differences between 4G and 5G are:

	4G (2000-10)	5G (2010-20)
Switching	Circuit/Packet	Circuit/Packet
Data Rate	Upto 20 Mbps	Upto 1 Gbps
Technology	Combination of broadband LAN/WAN/PAN	Combination of broadband LAN/WAN/PAN

Technology Generation

2014

2017

2020?

45nm
2007

32nm
2009

22nm
2011

14nm
2013

10nm
2015

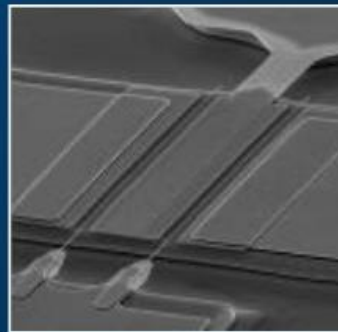
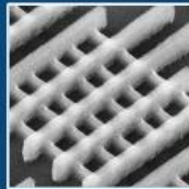
7nm
2017

Beyond
2020

MANUFACTURING

DEVELOPMENT

RESEARCH



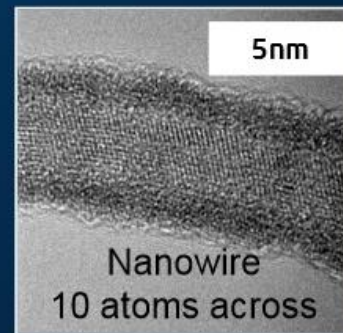
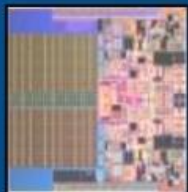
Carbon Nanotube
~1nm diameter



Graphene
1 atom thick



QW III-V Device

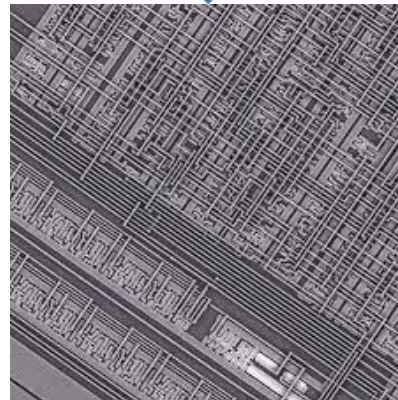
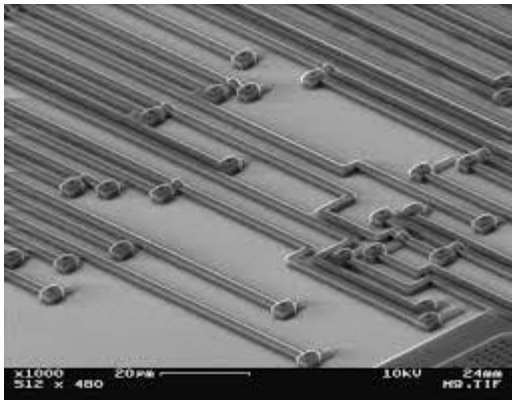
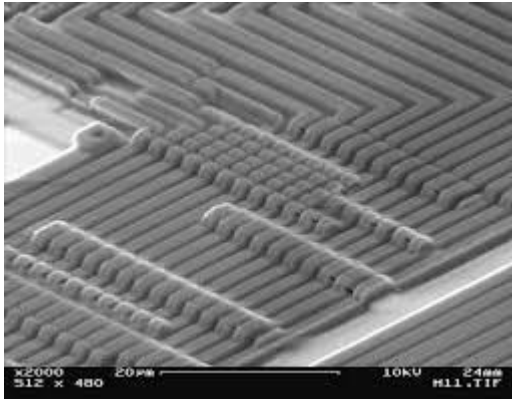
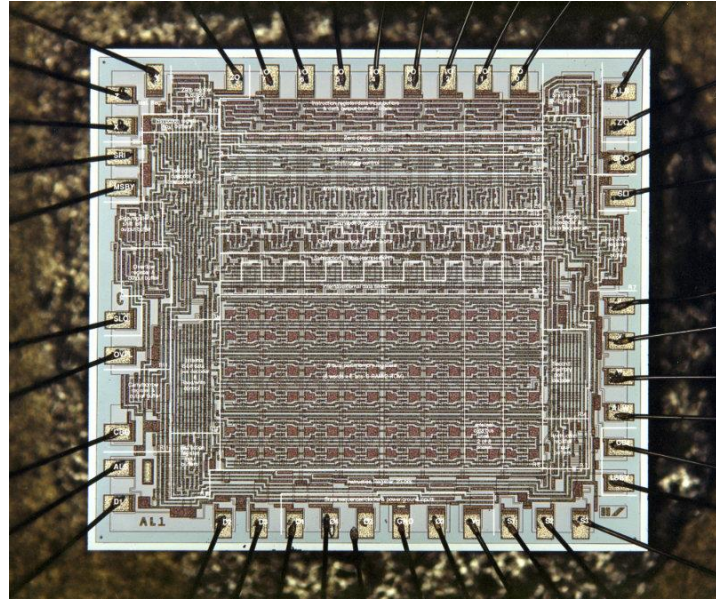
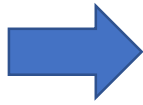


Not to scale

- Silicon lattice is ~ 0.5nm, hard to imagine good devices smaller than 10 lattices across - reached in 2020

Metric Prefixes

Symbol	Name	Multiplication
p	pico	1×10^{-12}
n	nano	1×10^{-9}
μ	micro	1×10^{-6}
mm	milli	1×10^{-3}
m	meter	1
k	kilo	1×10^3
M	Mega	1×10^6
G	Giga	1×10^9
T	Tera	1×10^{12}
PETA	Peta	1×10^{15}
EXA	Exa	1×10^{18}



Conclusion

- The medical, wireless technology, biotechnology, computer, automotive and aerospace industries are only a few that will benefit greatly from MEMS.
- This enabling technology promises to create entirely new categories of products
- MEMS will be the indispensable factor for advancing technology in the 21st century

