

All About MEMS Pressure Sensors for Medical Devices

Medical Electronics Symposium, Portland OR

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& ASSOCIATES



Outline

- **About us**
- **MEMS pressure sensors in medical devices**
- **Basic principles**
- **How MEMS sensors are made and packaged**
- **Typical challenges with integrating MEMS**

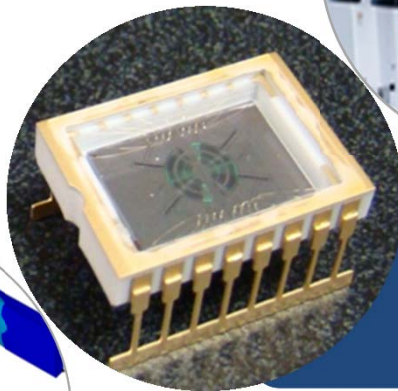
AMFitzgerald: Your Partner in MEMS Product Development



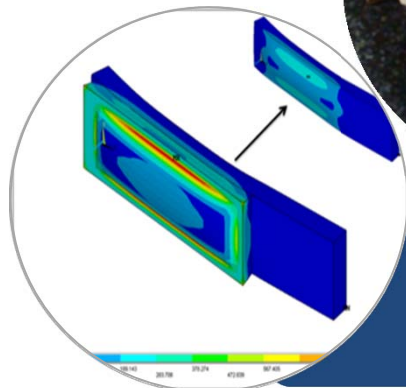
MEMS Product



Manufacturing

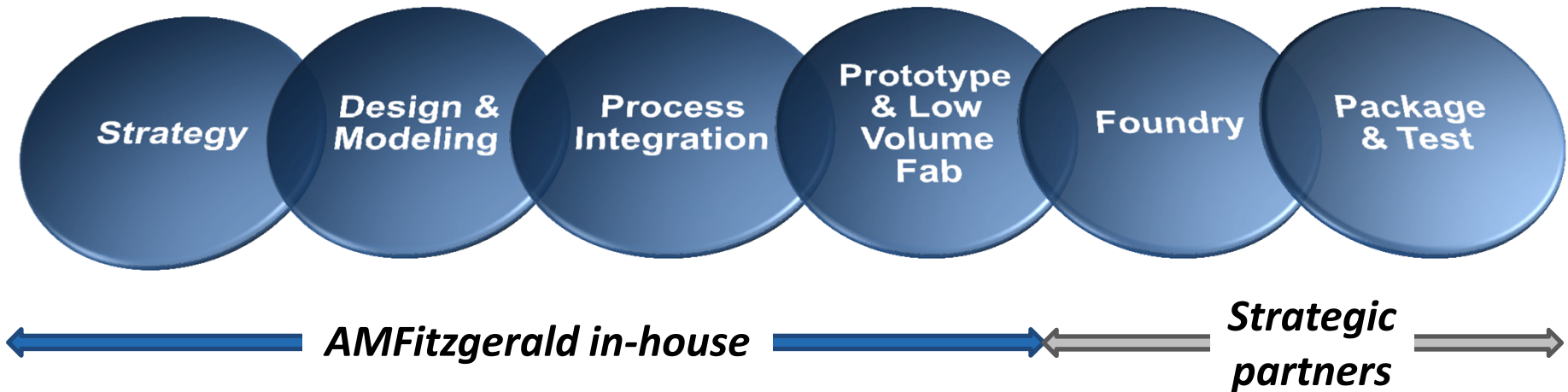


Prototype



Design

Complete services from concept to production

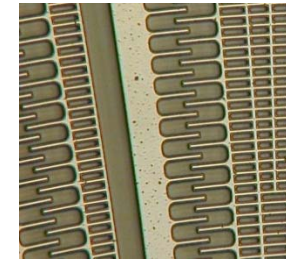


- **Multi-disciplinary, expert engineering team**
- **Custom MEMS development from start to finish**
- **Design and process integration for volume production**
- **In-house prototype fabrication, easy transition to production**

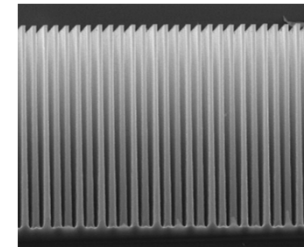
MEMS Pressure Sensors in Medical Devices

Micro Electro Mechanical Systems

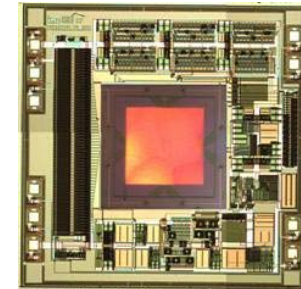
- Micro
 - Feature sizes range 0.5 μm to 1 mm
- Electrical sensing/actuation
 - Capacitive
 - Piezoelectric
 - Piezoresistive
- Mechanical devices with a third dimension
- Systems
 - Multiple functions on one piece of silicon



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IMD

Birth of MEMS

- Evolved from semiconductor processes
- 1970's: using silicon processing to make mechanical devices, not transistors
 - Accelerometers
 - Pressure sensors
 - Inkjet nozzles
- 1982: Petersen's "Silicon as a Mechanical Material"

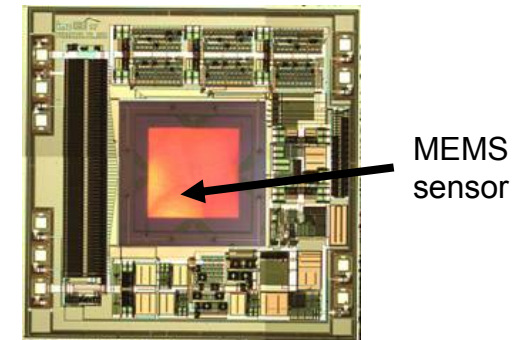


Popular Science, June 1984

Why MEMS are exciting for medical applications

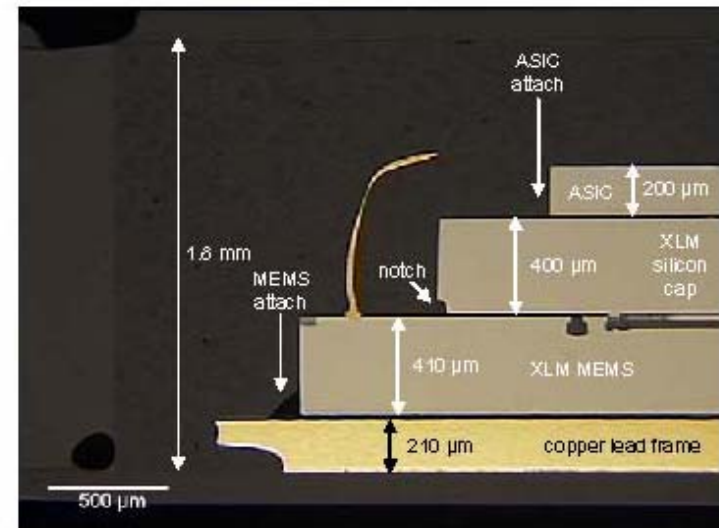
- **Ease of electronics integration enables sophisticated capabilities in small form factor:**
 - Signal processing and analysis
 - Wireless capability
 - Battery-less operation (power/read)
 - Telemetry for medical sensor network (with cell phone)

Integrated Pressure Sensor



Source: IMD

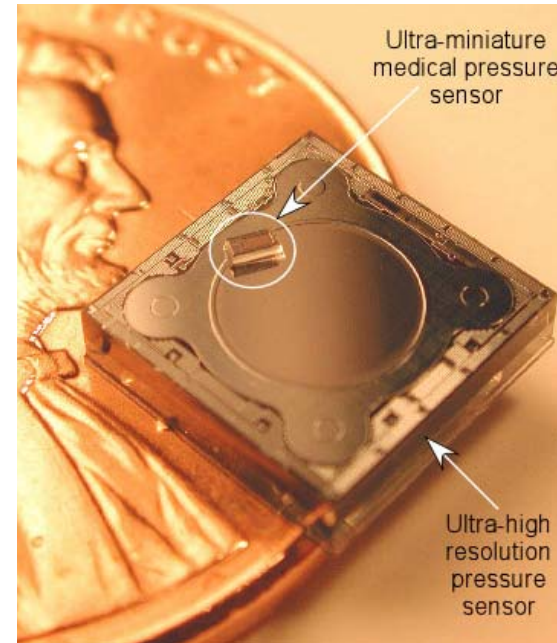
**Stacked
MEMS and
ASIC chips,
wirebonded**



Source: Chipworks/Kionix

MEMS Pressure Sensors

- **Used in non-invasive medical equipment since 1980's**
 - Respiratory equipment
 - Blood pressure cuffs
- **Invasive uses increasing**
 - Guidewire, catheter tip sensors
- **Many manufacturers:**
 - GE Sensors
 - Measurement Specialties
 - Silicon Microstructures
 - ISSYS
 - Tronics



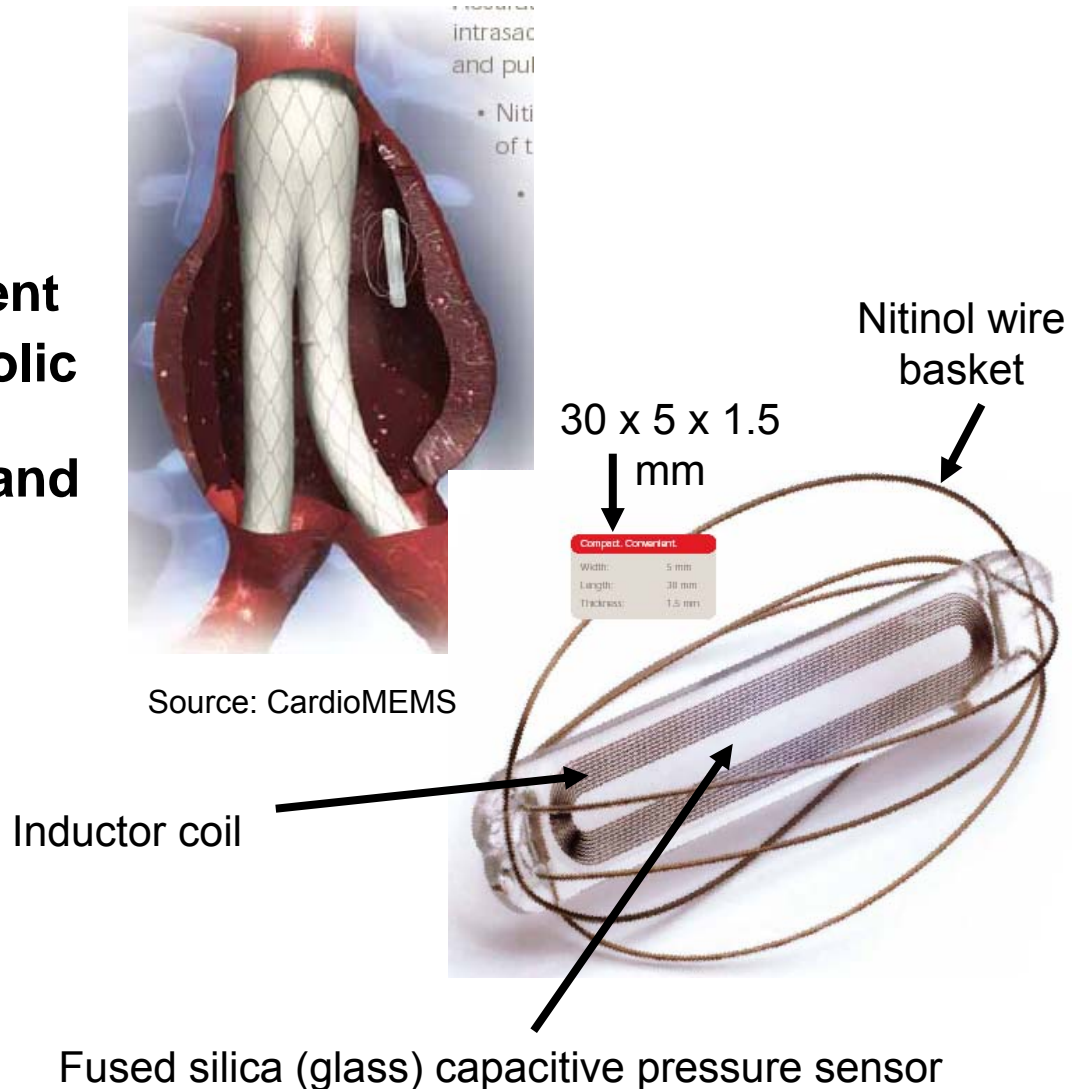
Source: ISSYS



Source: GE

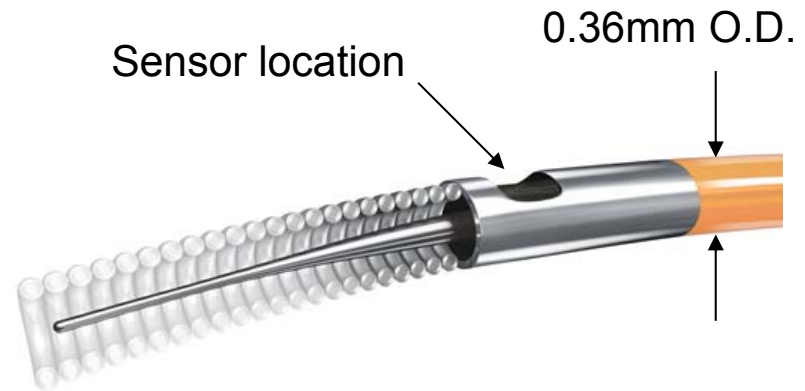
St. Jude Medical: CardioMEMS Pressure Sensor

- **FDA-approved**
 - Aorta stent graft monitoring
 - Pulmonary artery pressure measurement
 - Mean pressure, systolic pressure, diastolic pressure, heart rate and cardiac output
- **Capacitive pressure sensor with wireless readout, catheter deployed**
- **Readout at doctor's office**

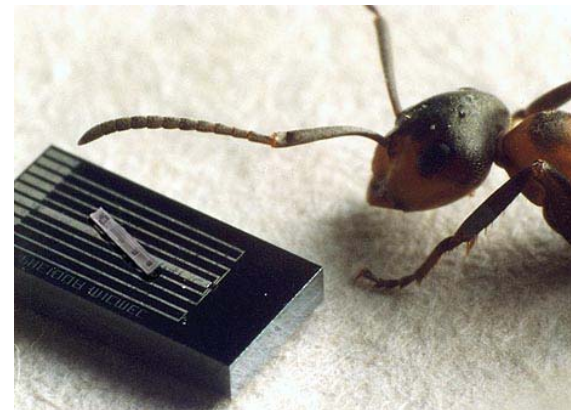


St. Jude Medical: Guidewires

- **PressureWire Aeris**
 - Fractional flow reserve measurements (pressure drop across coronary artery stenosis)
 - Also temperature, flow
 - Stent or balloon treatment
- **Piezoresistive pressure sensor**



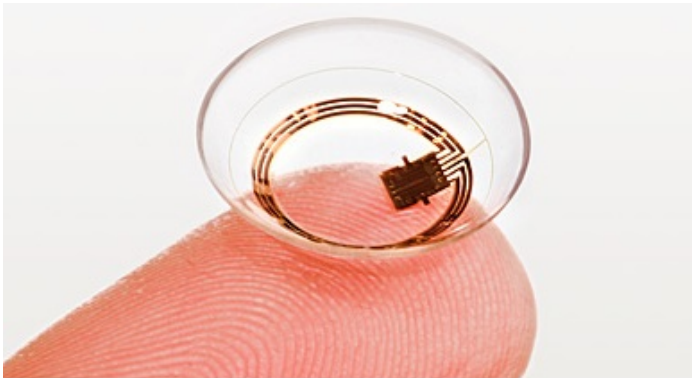
St.Jude Medical PressureWire with AgileTip



Source: KTH, Sweden

Sensimed Triggerfish IOP monitor

- Continuous intraocular pressure (IOP) measurement for glaucoma diagnosis
 - Size: 2.2mm x 2.5mm x 50microns
- Disposable lens
- Strain gage with wireless telemetry
- Under evaluation in Europe

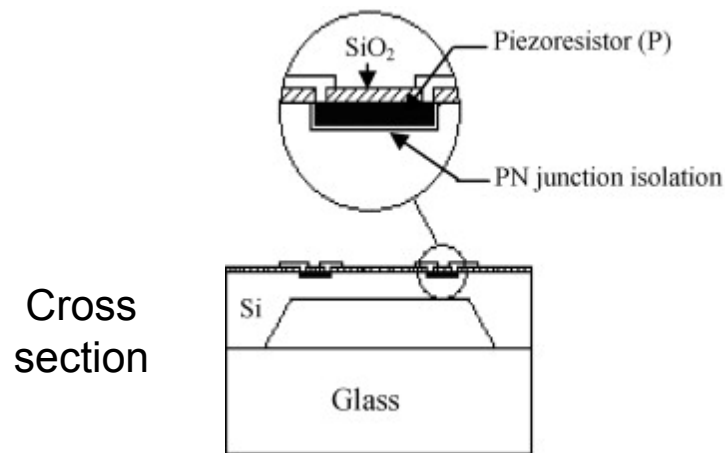


Recorder syncs with doctor's computer via Bluetooth

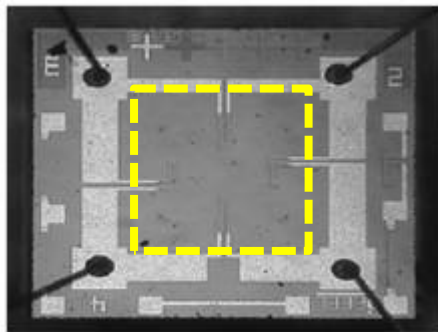


Basic principles: MEMS pressure sensors

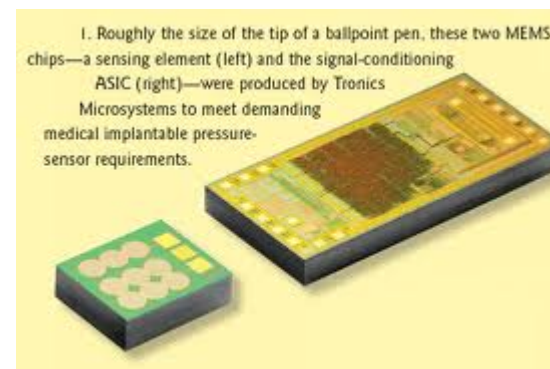
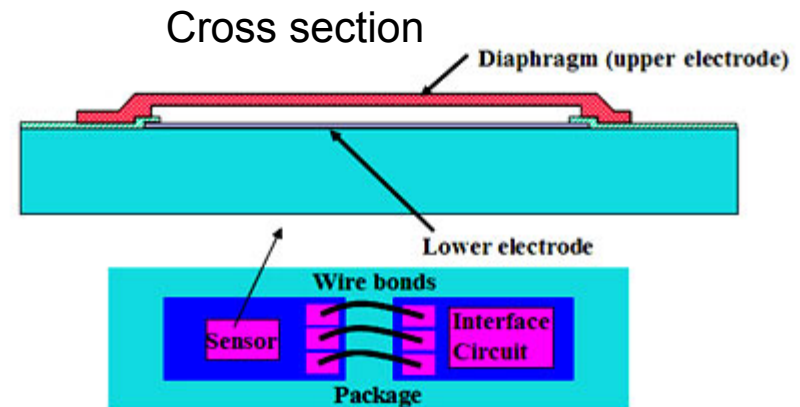
- Piezoresistive



Plan view



- Capacitive



Source: Tronics

Common embodiment: passive LC resonant sensors

- **Battery-free**
- **Power limited by inductor coil size**
- **Large, external reader with power source**

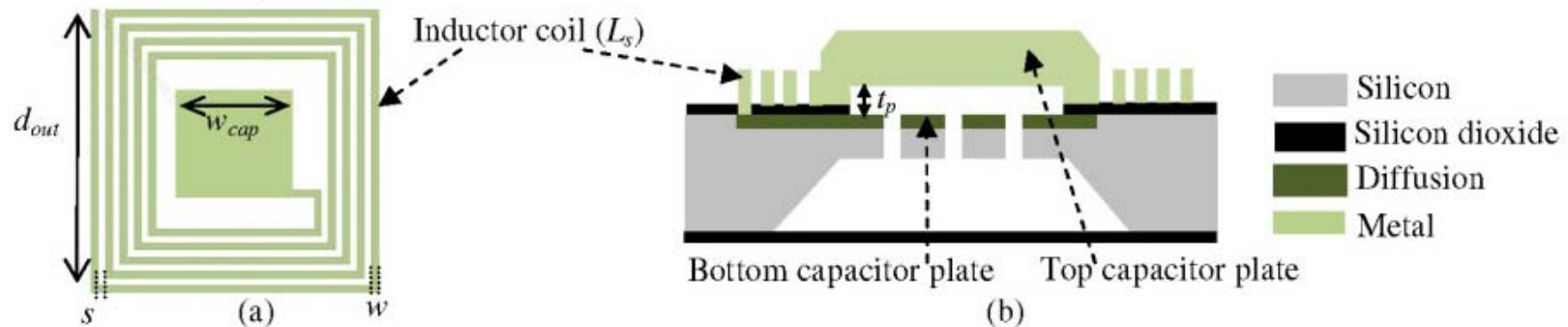
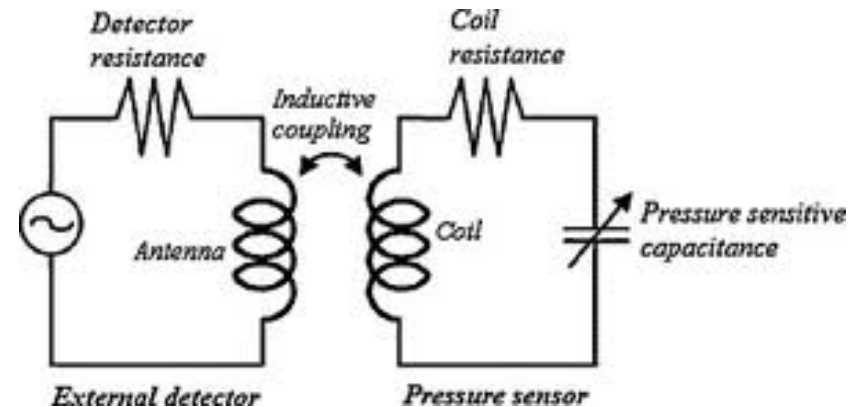


Fig 2. MEMS pressure sensor (a) top view (b) cross section

From: Yvanoff and Venkataraman, "Implantable LC Sensors for Biotelemetry"

MEMS pressure sensors: typical specs

	Piezoresistive	Capacitive
Value	Resistor change, m Ω	Capacitor change, pF
Readout	Wheatstone bridge	ASIC, digital
Type	Absolute or gage	Absolute or gage
Pressure range (mmHg)	30 – 300	30 – 300
Edge length (mm)	0.5 - 2.0	0.5 – 2.0
Thickness (mm)	0.15 – 0.65	0.15 – 0.65
Wireless readout	Not typical	Yes

MEMS pressure sensors available today

Vendor	Acuity	GE	Murata
Model	AC3030	P161	SCB10H
Type	Piezoresistive	Piezoresistive	Capacitive
Pressure Range (mmHg)	0 to 375	-50 to 300	0 to 900
Die Size (mm)	1.6 x 1.6 x 0.4	1.2 x 0.7 x 0.17	1.4 x 1.4 x 0.85

Many more available...

How MEMS are made

Silicon – the purest material refined by humans

Start



Silicon dioxide

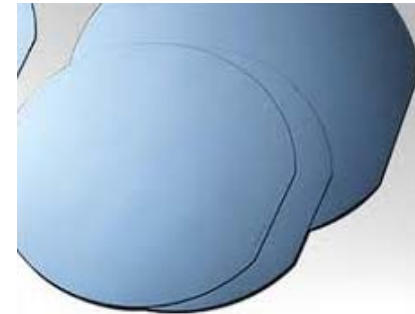


“Pulling” crystals

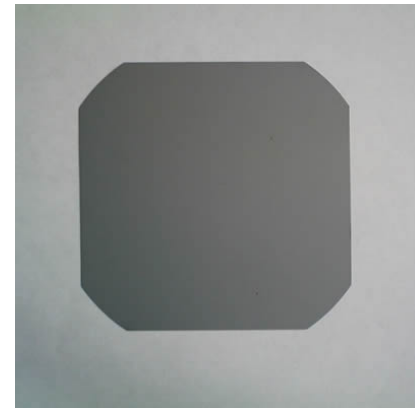


Ingot

Finish



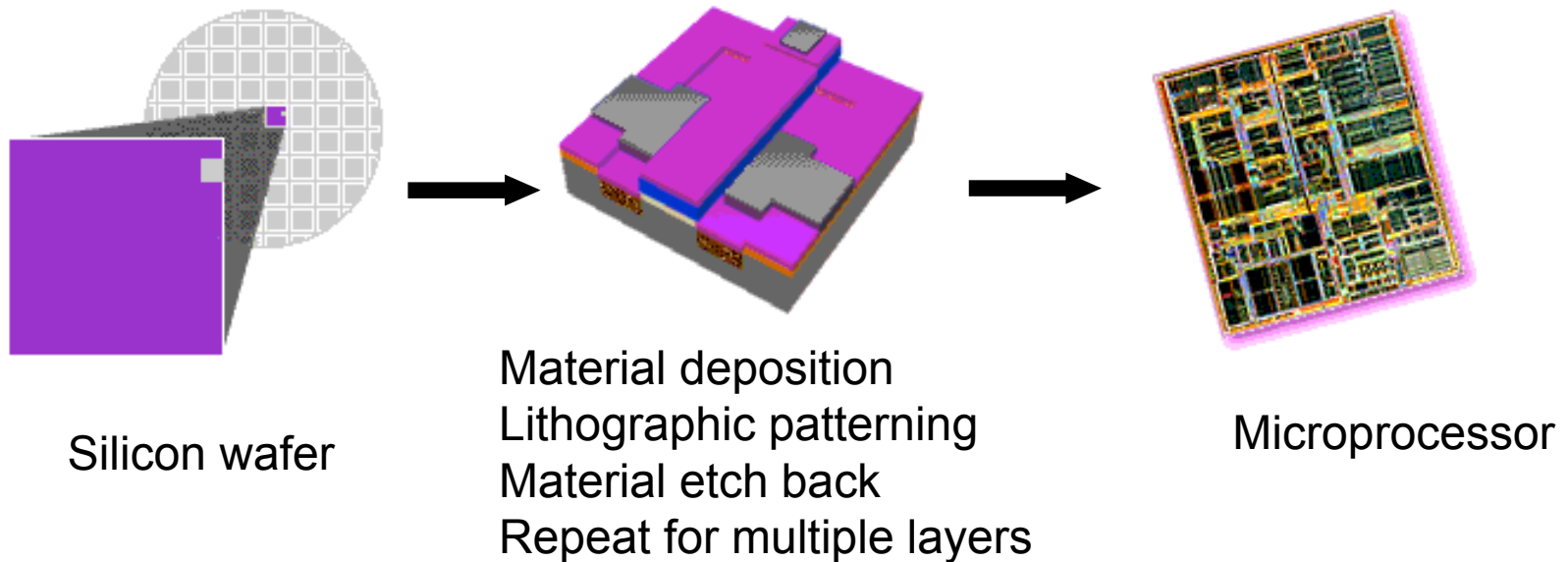
Semiconductor wafer



Solar cell wafer

Silicon process technology

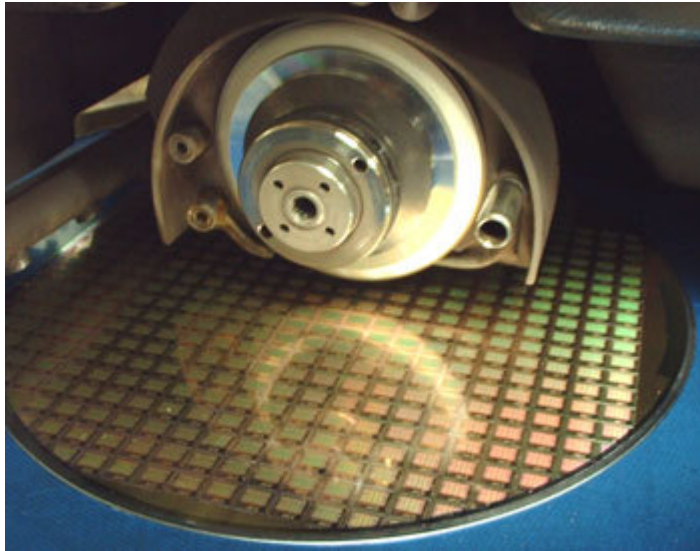
- **Developed to make transistors and integrated circuits**



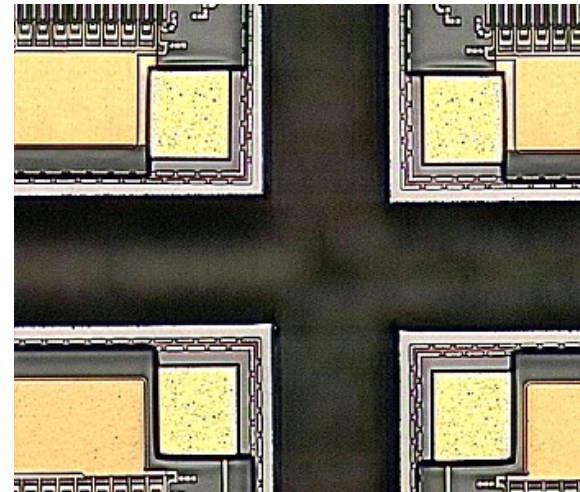
Images from: <http://www.intel.com/education/chips/index.htm>

Wafer dicing

- **Similar to cutting tile**



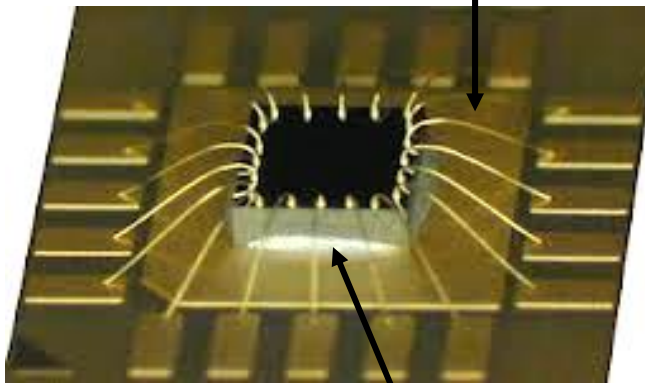
A pressure sensor wafer
may have 50,000+ die!



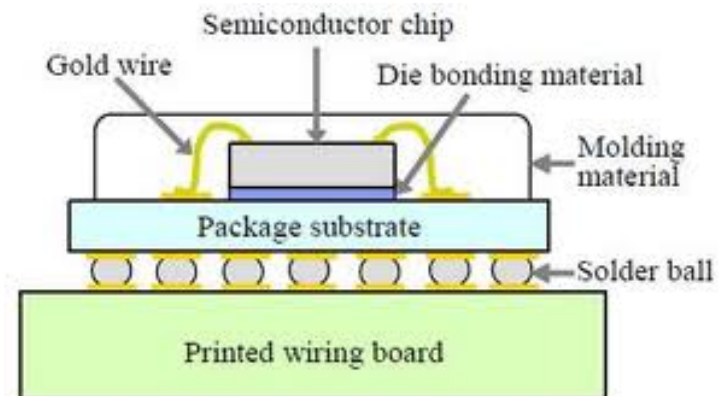
Dicing leaves sharp corners
and edges

Die attach and wire-bonding

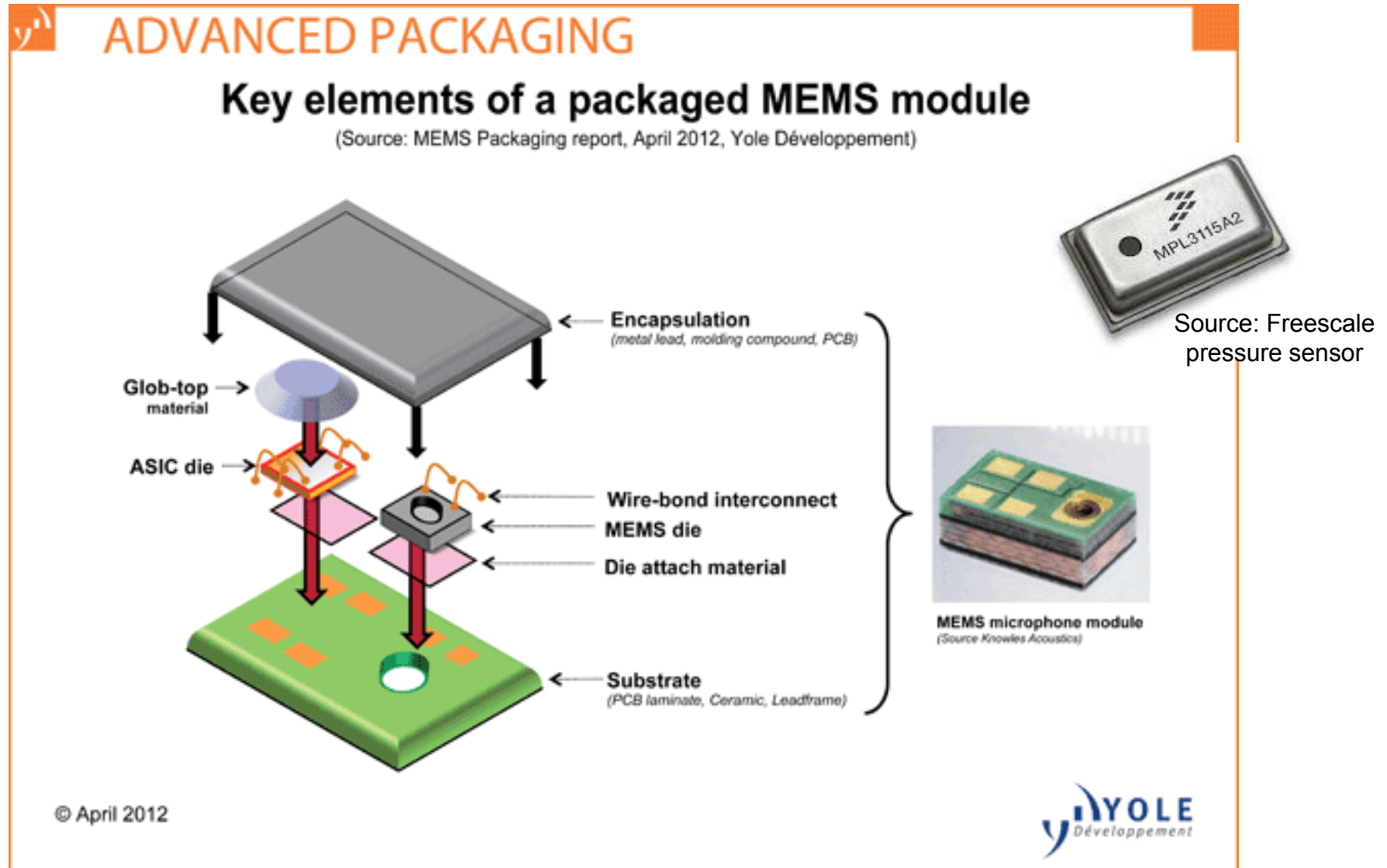
25 micron (1 mil) gold wire



Die attach epoxy

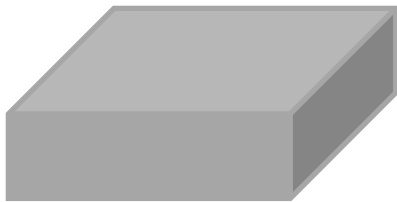


Typical package architecture – pressure, microphones

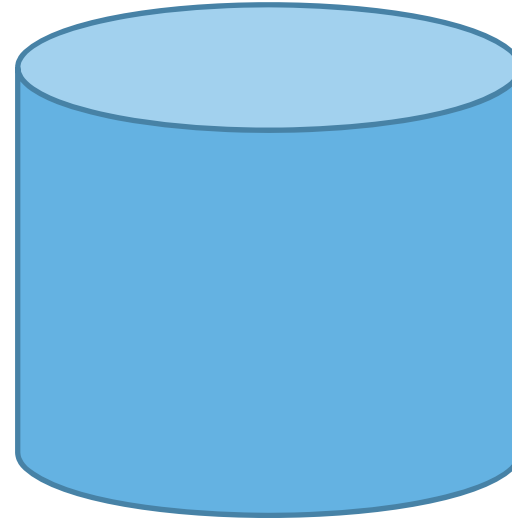


Challenge of packaging MEMS sensors for medical

Rigid, brittle rectangle



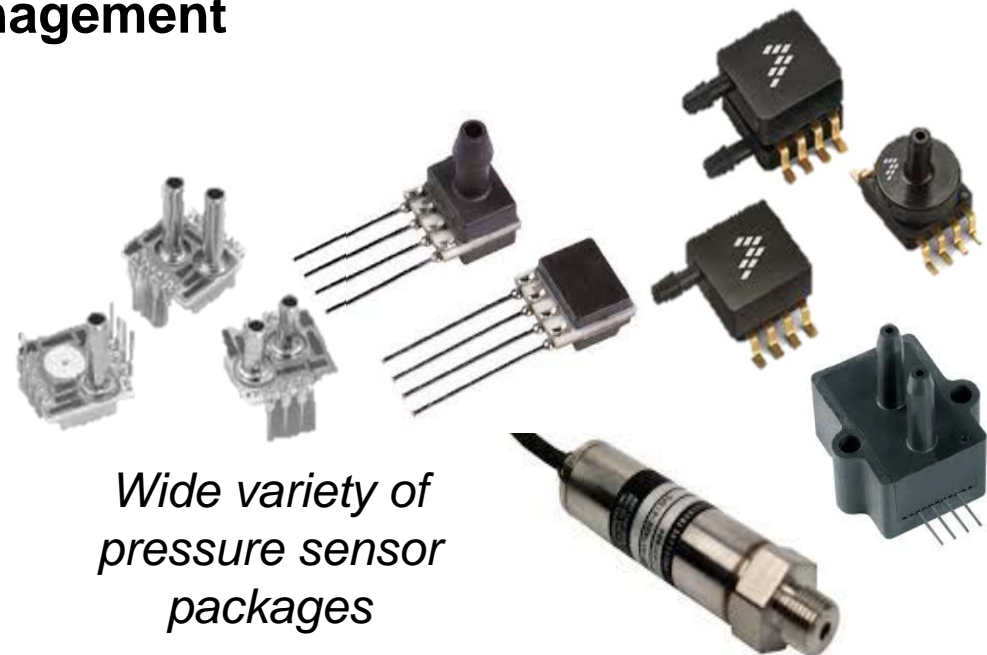
Flexible, round tube



- **MEMS/IC packaging techniques and materials were originally developed to place chips on rigid printed circuit boards**

Packaging challenges

- Packaging is ~70% of unit cost of a MEMS sensor
- Where MEMS companies spend the most time and effort during development
- Invasive or implant use of MEMS further complicates packaging/assembly
 - Mechanical stress management
 - Hermeticity
 - Fracture protection
 - Electrical interconnect



*Wide variety of
pressure sensor
packages*

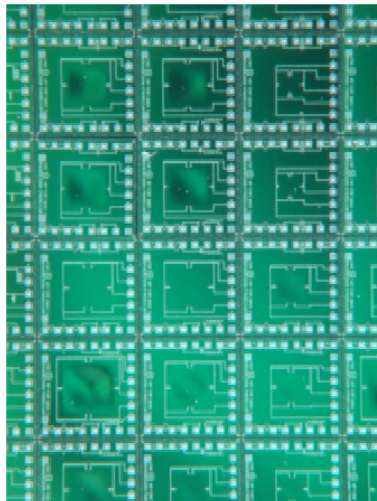
Environmental challenges

- **Medical environment**
 - **Moisture**
 - **Radiation**
 - **Magnetic fields**
 - **Sterilization**
- **Biocompatibility**
 - **Sharp edges on chip are thrombogenic**
 - **Silicon's biocompatibility not yet established**
 - **Chips will need some level of encapsulation**
 - **Silicones, parylenes**

Buy vs. Make

- **Many MEMS pressure sensors available off the shelf**
 - Low prices (\$0.10 - \$2.00 per sensor)
 - Reliability data available
 - Many IDMs restrict use in invasive medical applications
 - Generally sized/spec'd for consumer electronics apps
- **Customization attractive, but:**
 - Low volume MEMS have high unit costs (> \$5 per sensor)
 - Environmental and reliability qualification testing is expensive
 - Custom development is long (> 3 years) and expensive (> \$1M
 - simple sensor, > \$5M complex sensor with ASIC)

AMFitzgerald's RocketMEMS®: Semi-custom sensors



Variety of RocketMEMS
Pressure Sensors

- Customizable pressure sensors for OEMs and system integrators
 - Based on AMFitzgerald reference designs
 - Low cost, fast turn time (~6 months)
- 1. Customer provides desired sensor specification
- 2. AMFitzgerald tailors sensor design to meet customer's spec
- 3. ISO-certified foundry manufactures wafers
- 4. AMFitzgerald tests and delivers sensors to customer

Summary

- **MEMS pressure sensors present a huge opportunity for medical devices, particularly for invasive and implantable uses**
 - **Sophisticated sensor functions**
 - **Electronics system integration**
 - **Clinically-relevant data**
- **Integration challenges are primarily in packaging and assembly**
 - **Solutions will be specific to usage and form factor**
- **We can help you find the right solution for your product**

Contact

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- **650 347 MEMS x101**



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