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Electronic Packaging Technologies for Advanced Medical Device Applications

IMAPS ATW on Microelectronics, Systems & Packaging for Medical Applications

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Electronic Packaging Technologies for Advanced Medical Device Applications

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Presentation given by: Susan Bagen, PE

Medical Device

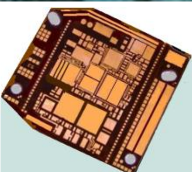
A medical device is a product used for medical purposes in patients, in diagnosis, therapy or surgery.

- What does this definition tell us?
  - Almost nothing!
- Probably the most nebulous, diverse market.
  - Unlike other electronics markets (computers, cellphones, entertainment, and even A&D), there is often little or no commonality in technology used even within similar product segments.

Medical Electronics/Devices

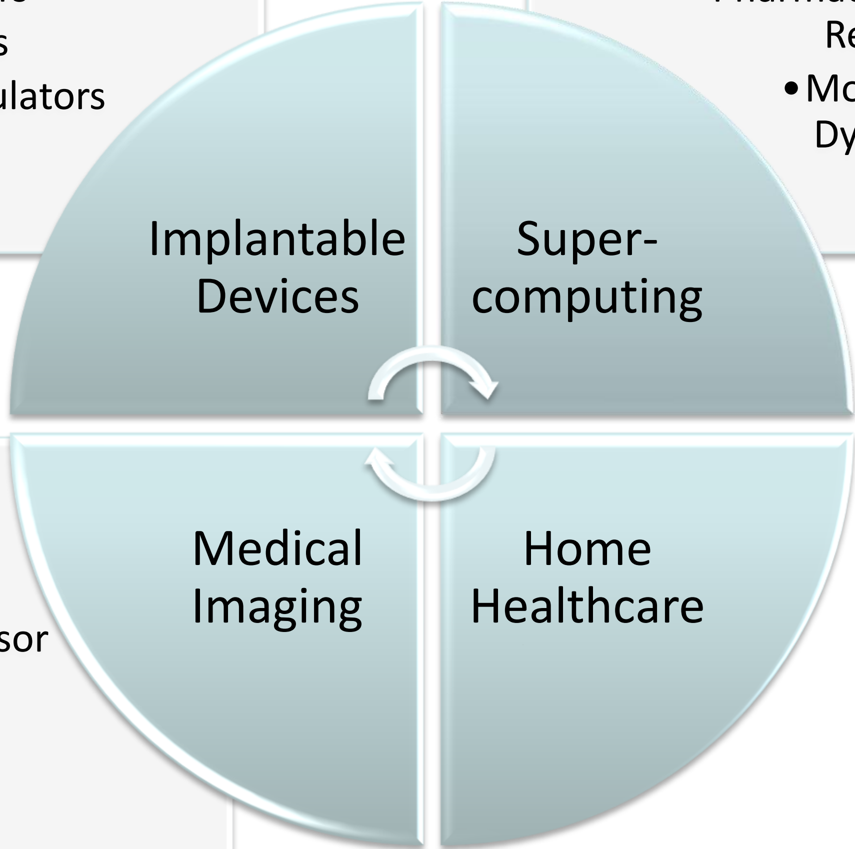
- Medical Electronics
  - Medical Equipment
    - Imaging
      - X-Ray
      - CT Scan
      - PET
      - MRI
      - Ultrasound
    - Patient Monitoting
      - Multiparameter
      - Ambulatory Telemetry
      - Remote Monitoring
      - Point of Care Equipment
    - Diagnostic Equipment
      - Laboratory Diagnostic Equipment
      - Self Test Equipment
  - Therapeutic Medical Devices
    - Implantable Devices
      - Cochlear Implants
      - Neuro Stimulators
      - Infusion Pumps
      - Pace Makers
      - Defibrillators
      - Retinal Implants
    - Surgical Devices
      - Sensors
      - Optical
    - Non-Implantable
      - Portable Defibrillators
      - Hearing Aids
  - Medical IT

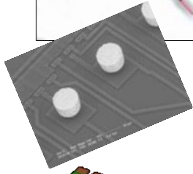
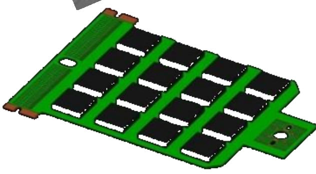
Medical Opportunities



- Defibrillators
- Pacemakers
- Neurostimulators

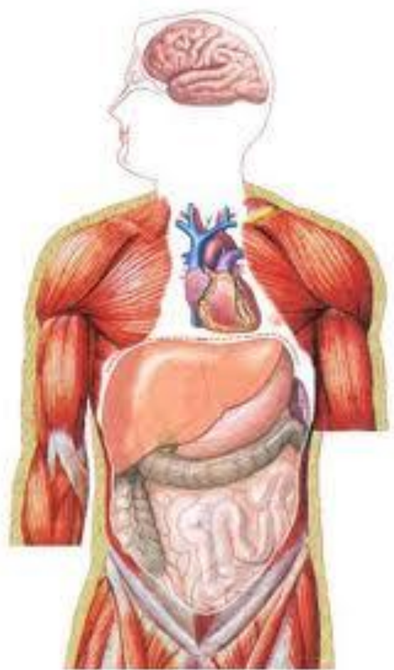
- Pharmaceutical Research
- Molecular Dynamics

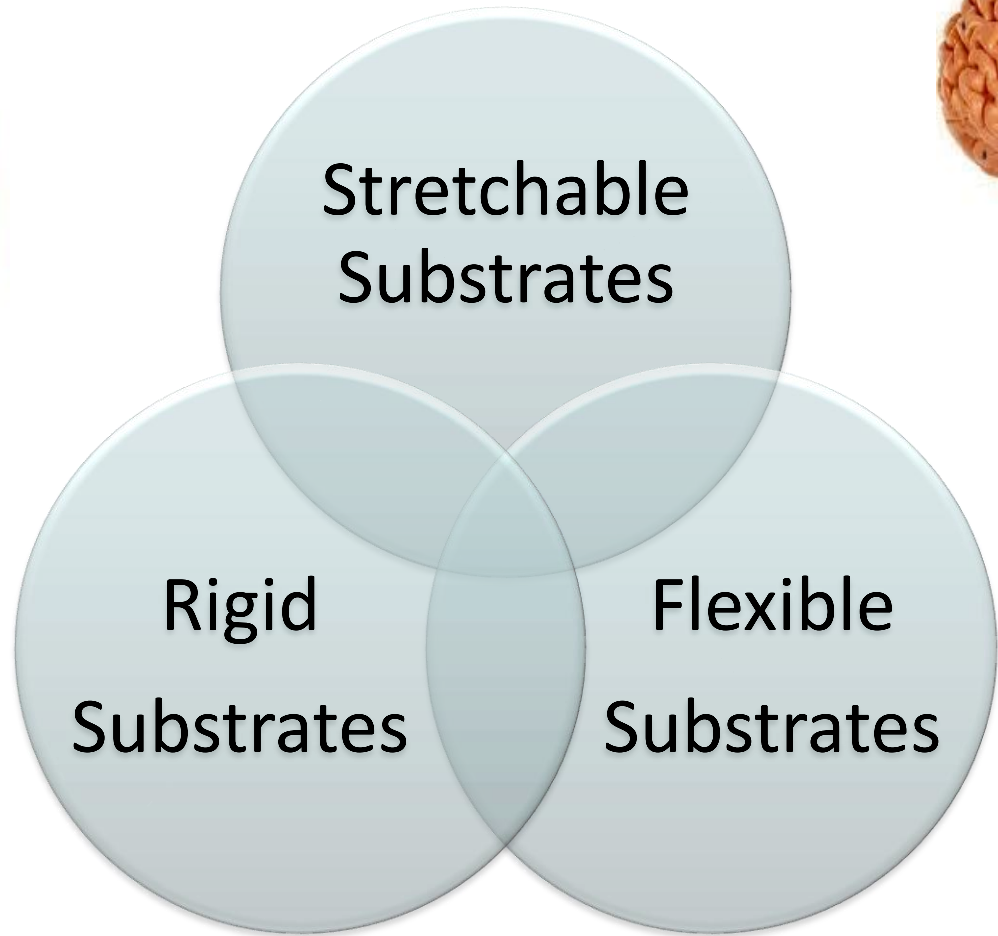


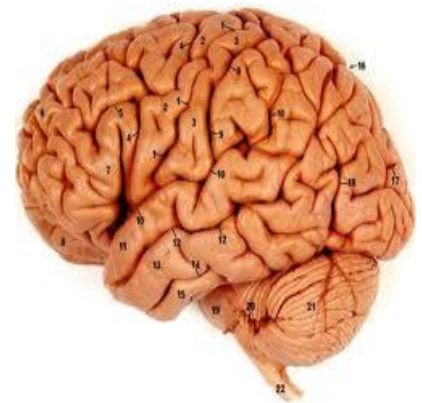



- Intravascular Ultrasound Catheter Sensor Package
- Ultrasound
- X-ray CT
- Digital Radiography
- Mammography

Implantable Electronics: Substrate Technology







Objectives

- Develop miniaturized rigid substrate for *SWaP (size, power and weight) advantage.*
- Develop flexible substrates to satisfy space requirements for medical imaging and health monitoring devices.
- Develop bio-compatible and or bio-stable shapeless substrates for Conformal Electronics.

Implantable Electronics

Law	Requirements	Approaches	Check Points
FDA CE Mark	Bio-compatible & Bio-stable: •Body fluid solution stability •Cytotoxicity Testing •Cell growth •Other….	•Substrate •Coating •Over mold •Housing	• Material purity •Product Quality •Product Traceability •Product Reliability

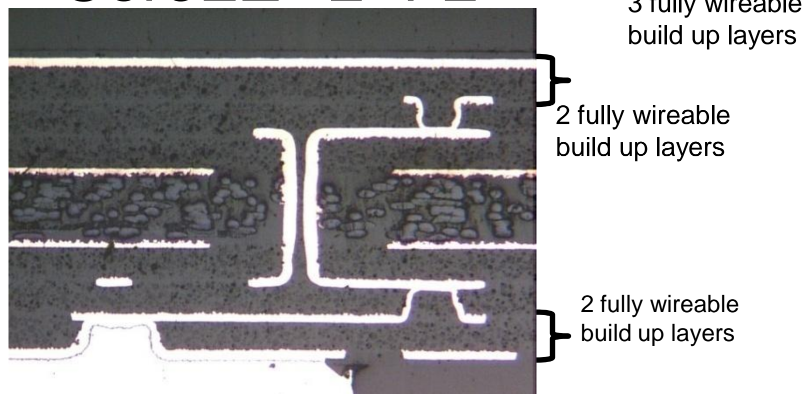
Rigid Substrates

Electronics Miniaturization via System-in-Package (SiP)

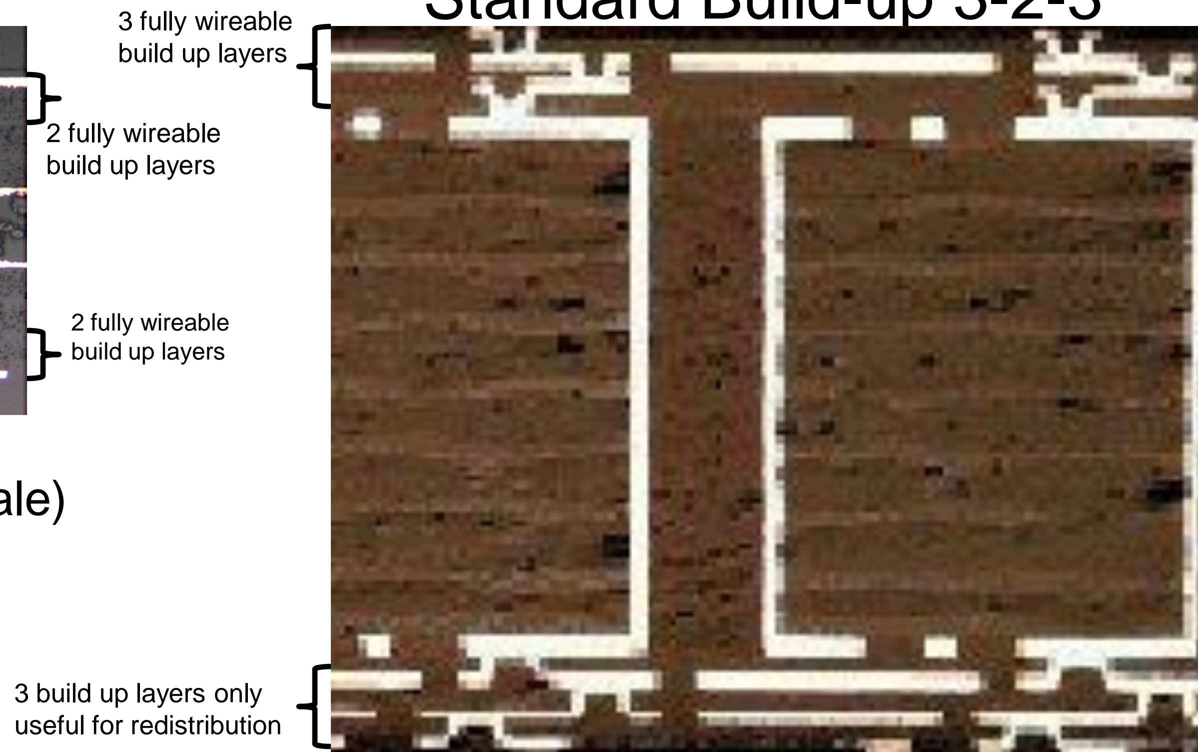
Building Blocks

SiP Fabrication & Assembly Technology – HDI Substrates

CoreEZ® 2-4-2



Standard Build-up 3-2-3



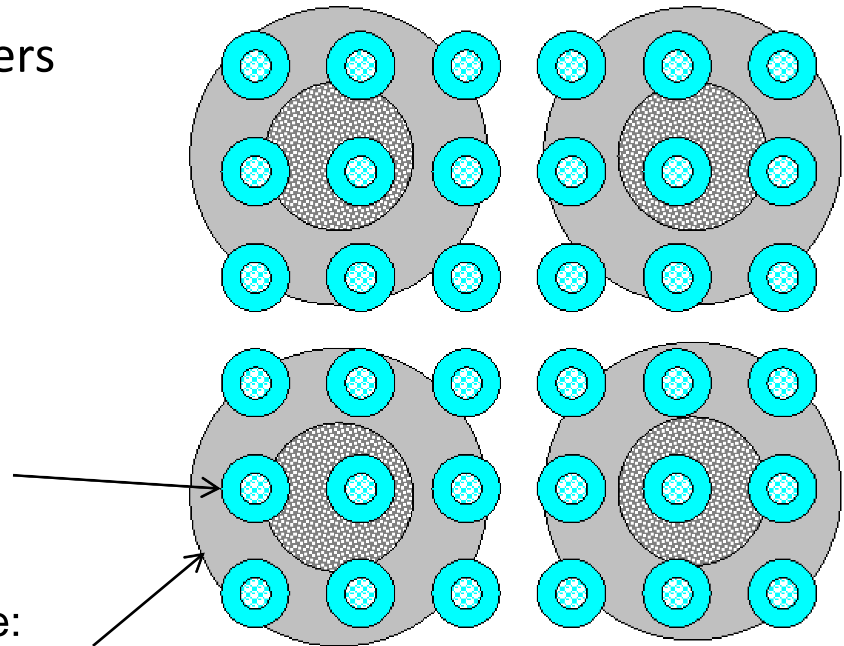
(photos are to scale)

- Thin core vias are 4x smaller
- Thin core requires fewer costly build up layers for the same wiring capacity
- Thinner core reduces electrical parasitics

Building Blocks

Rigid HDI Substrate With High Core Via Density

- Very Dense Package Interconnect
  - Ultra Dense Core Via Pitch can eliminate additional build up layers
- Dual Side Component Mounting
- Fine Line Width and Spacing
  - 18 – 25 µm

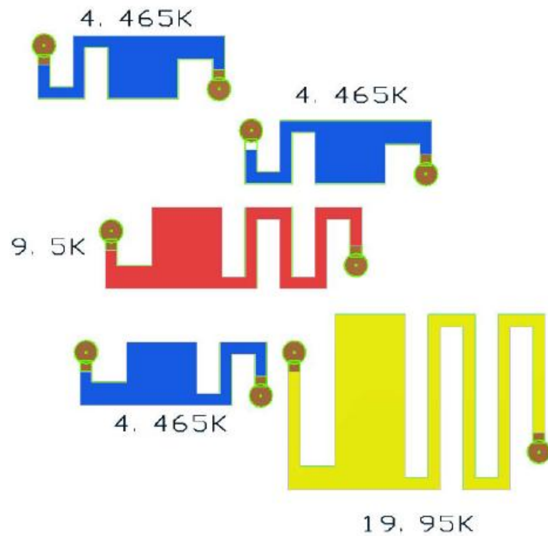


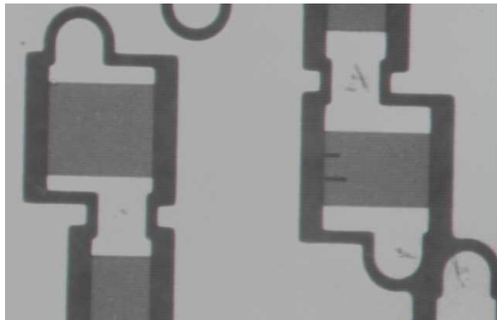
UV Laser Drilled CoreEZ® Thin Core:
100 um diameter pad (50 um via)

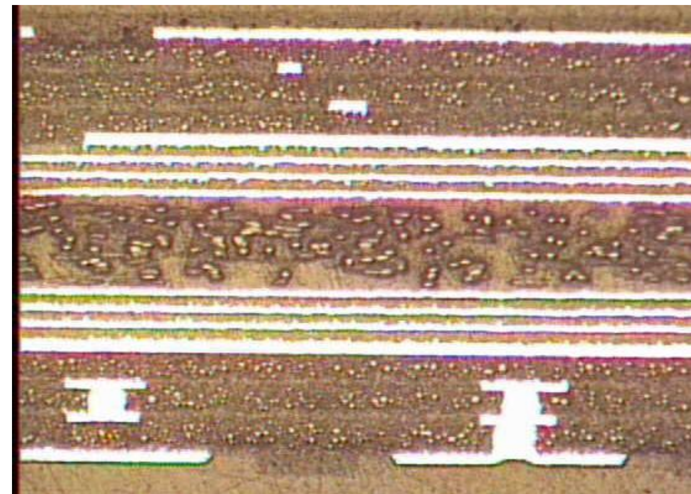
Standard Build-Up Mechanically drilled core:
400 micron diameter pad, 200 um diameter via

HDI Substrate has 9X Core Via Density over conventional build up PWB

- Embedding Resistors and Capacitors (R&C)
  - Remove discrete passive devices and incorporate into the substrate to reduce required surface area





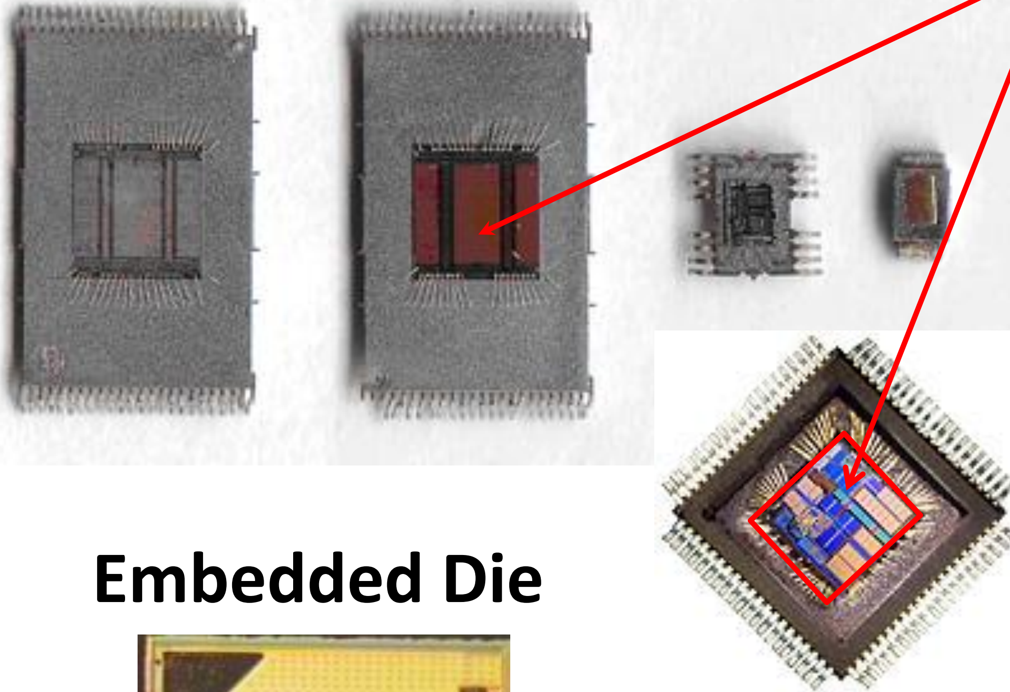


CoreEZ® 3-8-3
with Embedded R&C

Building Blocks

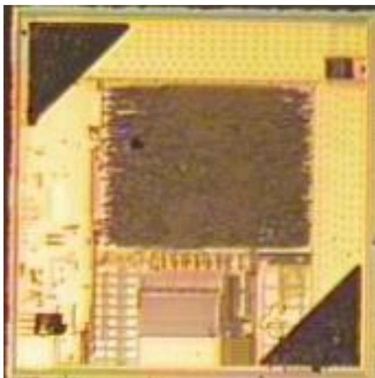
SiP Fabrication & Assembly Technology – Bare Die

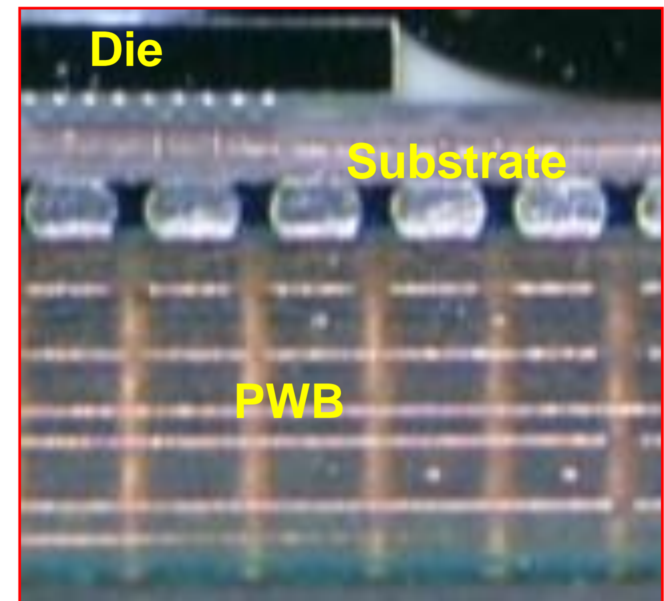
- **Bare Semiconductor Die**



- Unpackaged die has significantly smaller footprint.
- Flipchip attach results in smallest configuration.

Embedded Die

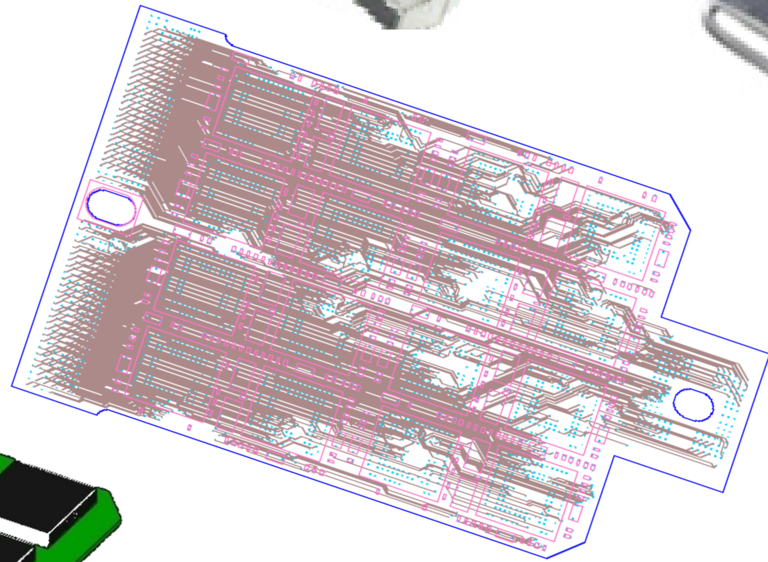


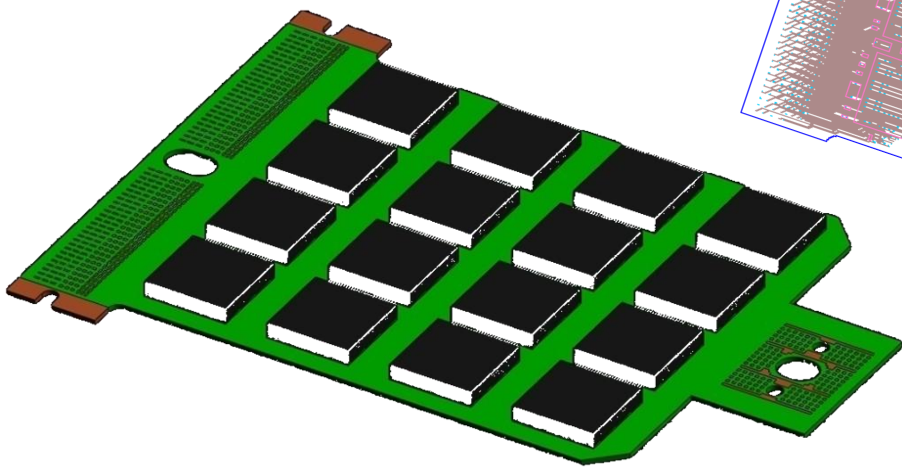


Ultrasound Application

Si Package – Medical Imaging

- CoreEZ® 2-4-2 substrate
- SiP assembly (FCA)





Miniaturized Rigid Substrate

Shrink Device

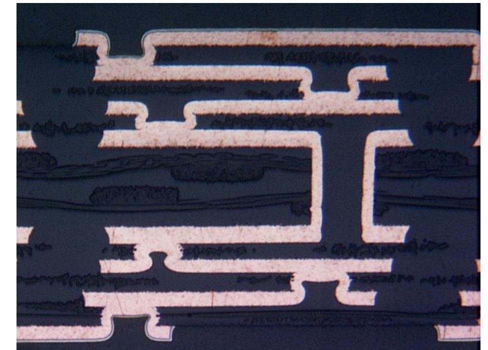
SWaP Reductions

Increased Functionality

- Defibrillators
- Pacemakers
- Pulse generators

ICD (Implantable Cardioverter Defibrillator) and Pacemaker

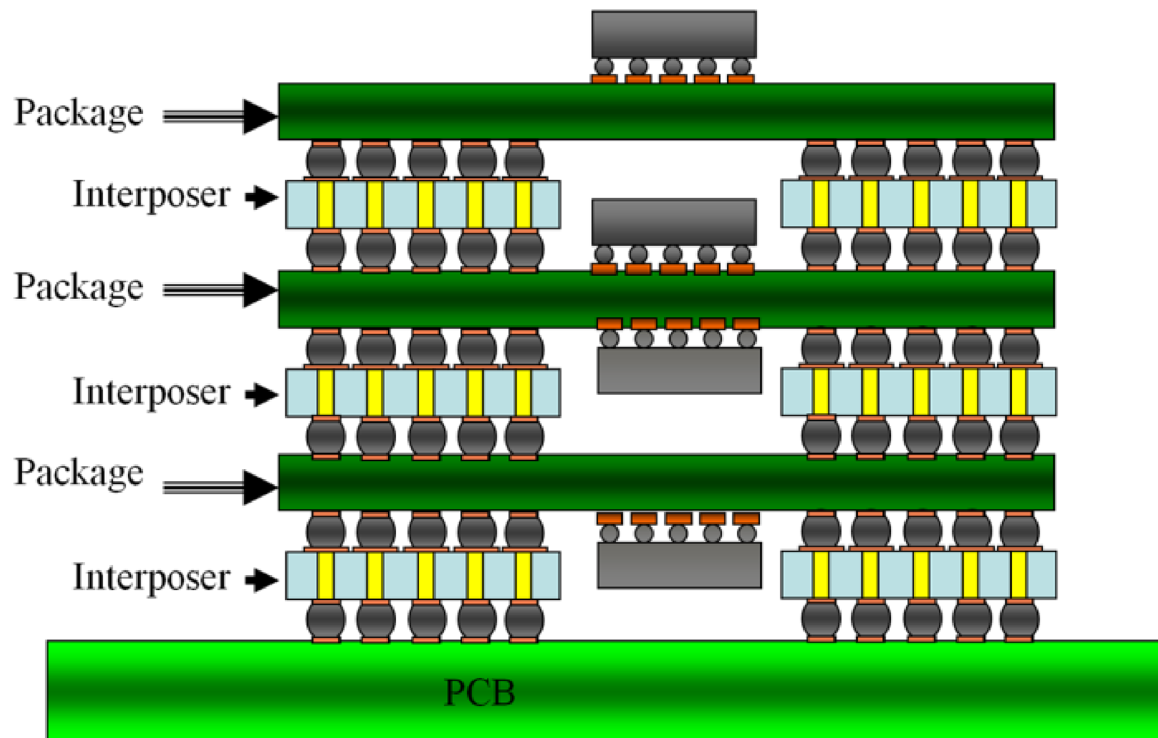
- Smaller, less intrusive applications for implantable devices
- High density interconnect substrate
  - 8 layers
  - 30.5x 12.8 mm & 43.8 x 40.6 mm
- October 2008 marked 1st human implant with EI substrate.



3D Packaging

Package-Interposer-Package (PIP) Technology

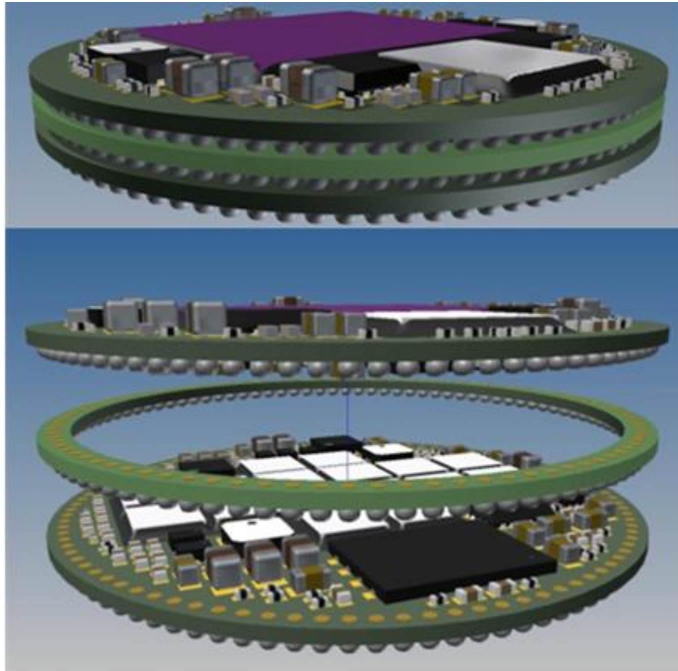
A new 3D "Package Interposer Package" (PIP) solution is suitable for combining multiple memory, ASICs, stacked die, stacked packaged die, etc., into a single package.



Schematic of Package-Interposer-Package (PIP) construction with 4 packages and 3 interposers

3D Packaging

Package-Interposer-Package (PIP) Technology

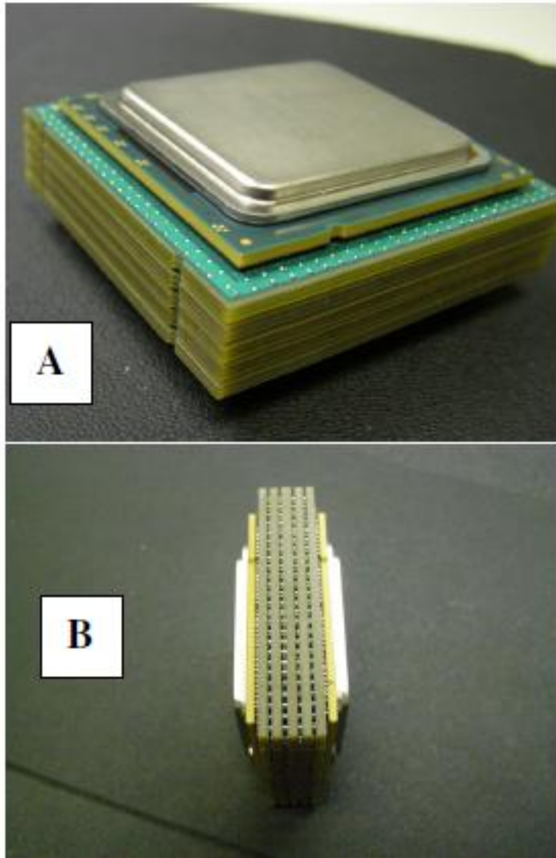


Benefits of Package-Interposer-Package

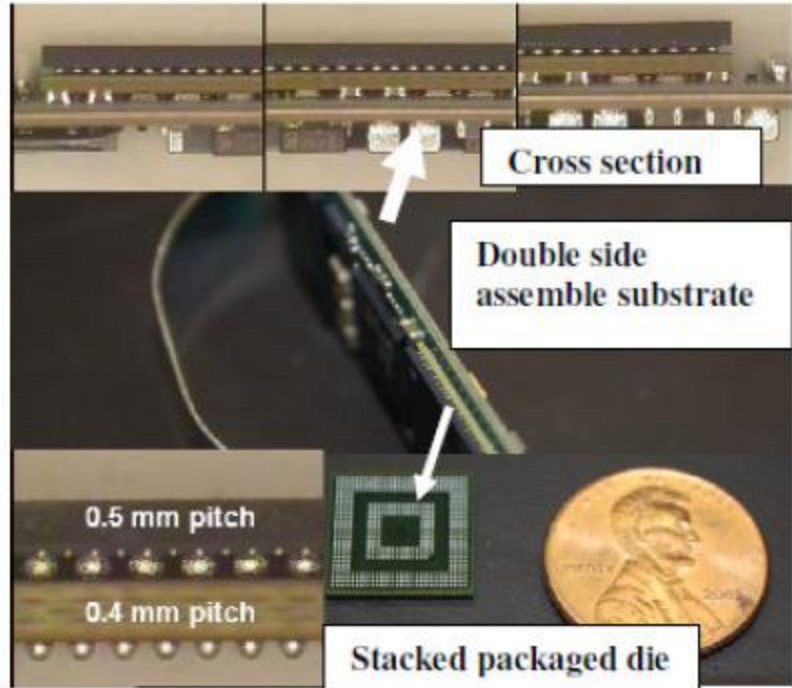
- High density, small pitch
- Re-workable and replaceable
- Polymer or ceramic interposer provides additional support for improving stability and reliability
- PIP will experience less warpage and thermal stress
- Mitigates problems with coplanarity between packages

3D Packaging

Package-Interposer-Package (PIP) Technology



Package-Interposer Package (PiP) construction with multiple substrates
A – Top View   B- Cross-section



Double side assembled substrate with stacked packaged die (memory attached to processor)

Flexible Substrates

Extreme Electronics Miniaturization via Microflex Assemblies

Microflex Device Packaging

Transducers & Die

- PZT, PLZT, PMN-PT,
- ASIC Die

Substrate Fabrication

- 25 µm laser drilled vias (minimum)
- 12/12µm line width & space (minimum)

IC Assembly

- Flip chip pitch down to 70 µm (minimum)
- Piezoelectric Crystal assembly

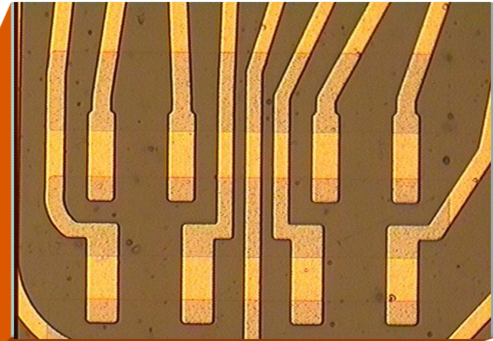
Module Tester

- Full functional module test

Ultra Thin Polyimide Flex Manufacturing

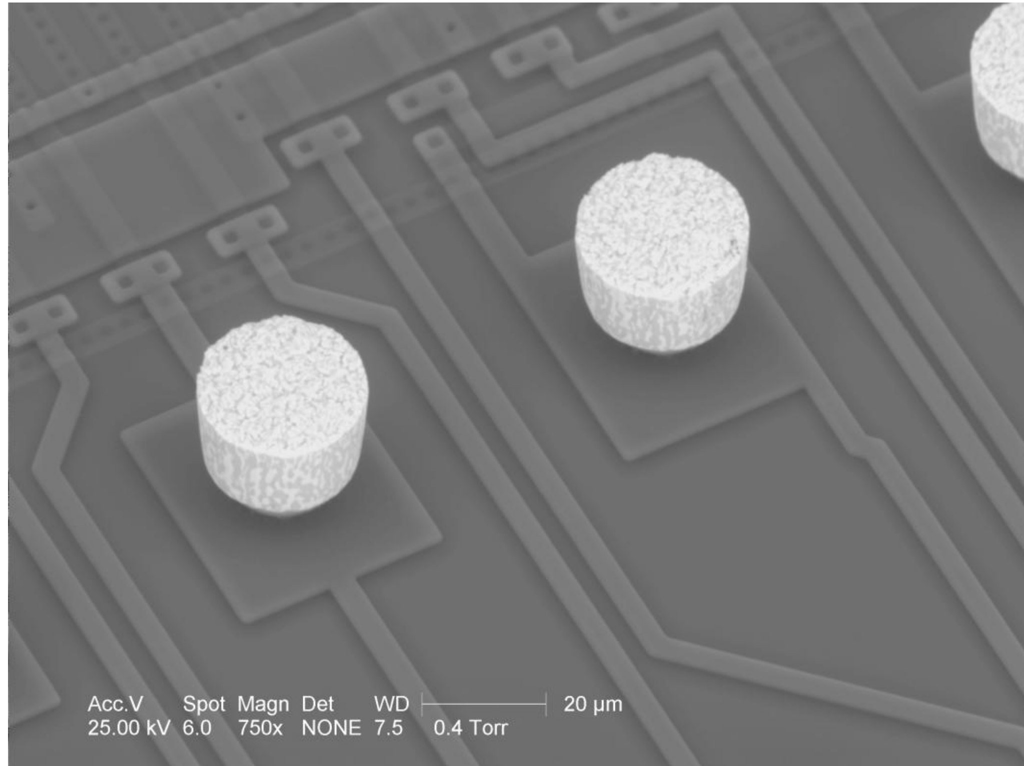
Support of 12.5 µm polyimide film during substrate fabrication: use of rigid frame

152.4 mm (6 in)



14 µm line and space

Micro Pillar Technology for Finer Pitch Applications

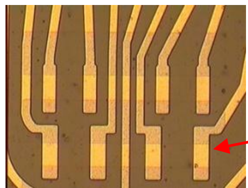


ASIC die with 70 µm bonding pad pitch

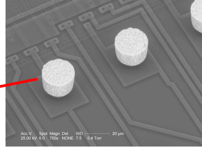
Microflex Assembly Package

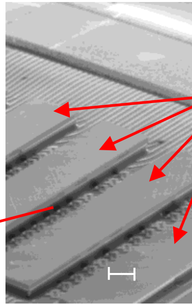
Extreme Miniaturization

Single layer HDI Flex

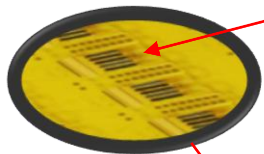


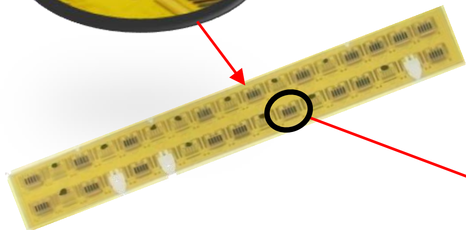
Flip Chip Bumps

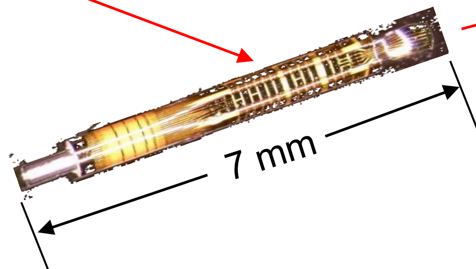




ASIC Die





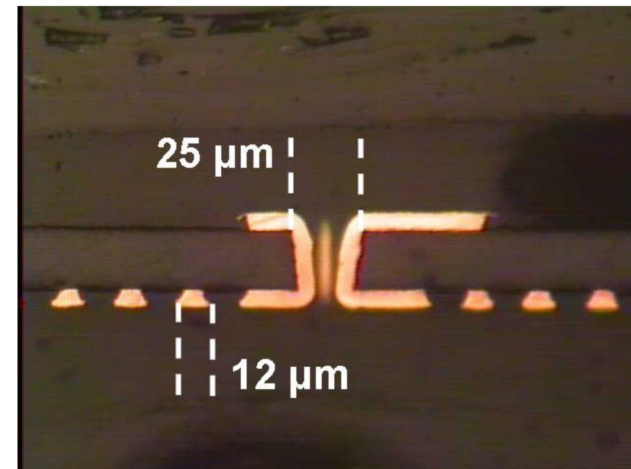


- **Sensor assembly rolled to 1.175mm diameter**
- 5 Flip Chip ASIC,.1mm thick, 31 I/O each, 2.5mm x 0.5mm
  - 22 micron flip chip bumps on 70 micron die pad pitch
- 12.5mm by 6.5 mm single layer flex circuit
  - 14 micron wide lines and space copper circuitry
  - 12.5 micron thick polyimide dielectric
- Prototype to production
  - Over 1.5M shipped

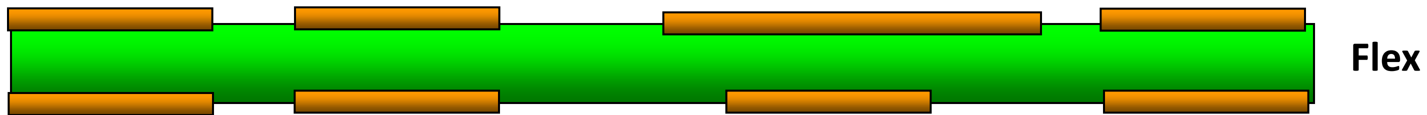
High Density Double-Sided Flex

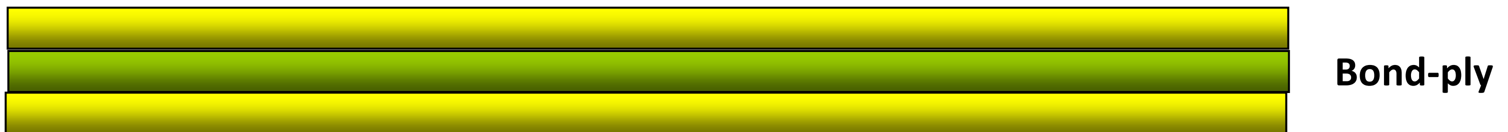
Ultrasound Medical Application

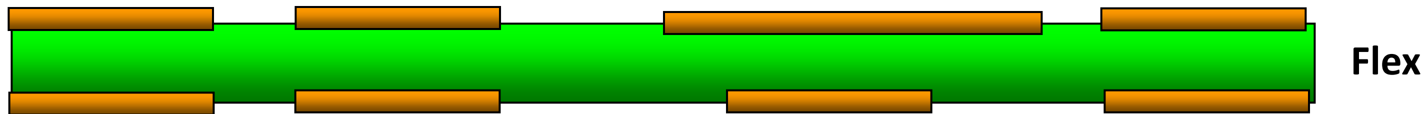
- 11 µm lines / spaces
- 25 µm vias
- 6 µm thick metallurgy
- 12.5 µm polyimide
- Flexible soldermask
- FC ASIC Die & SMT passives

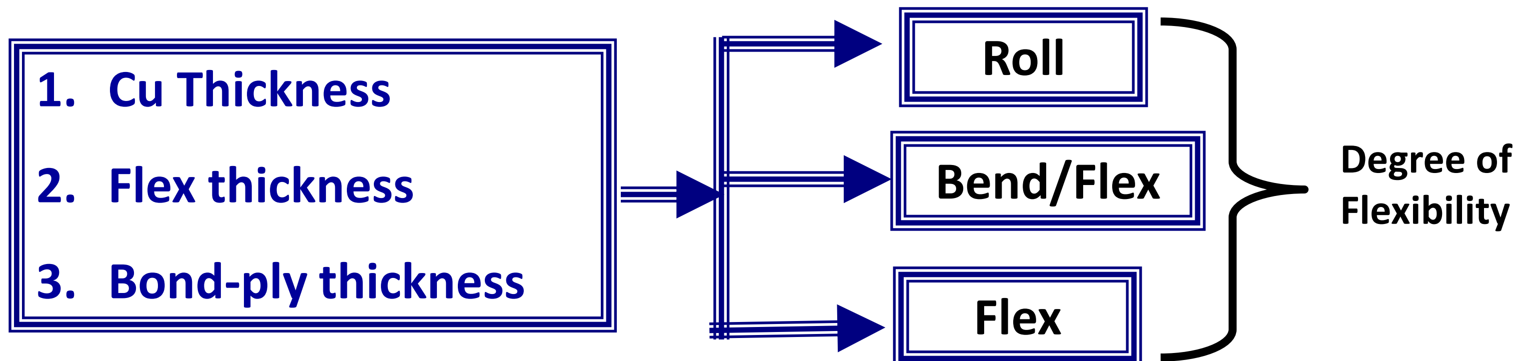


Multilayer Flex – Study to Define Design Rules









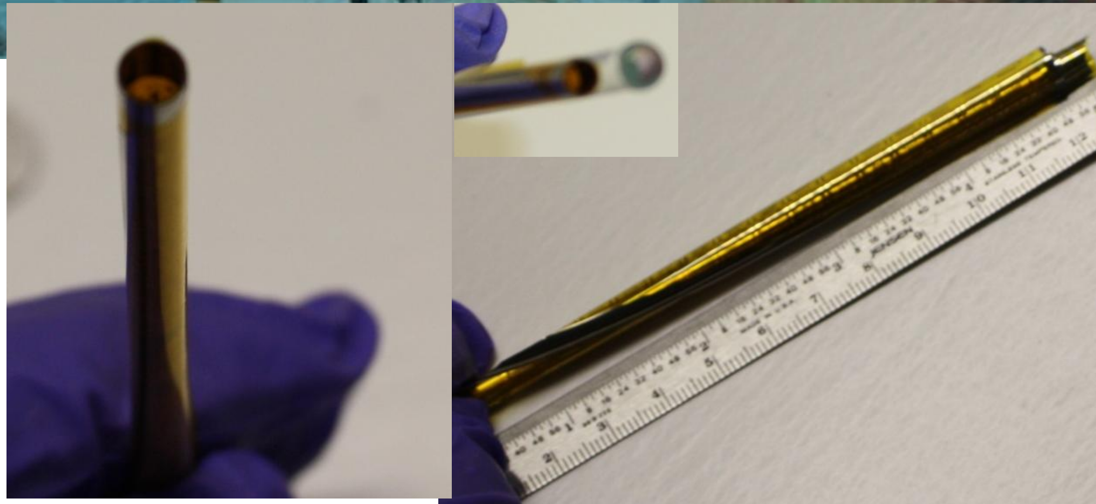
Multilayer Flex

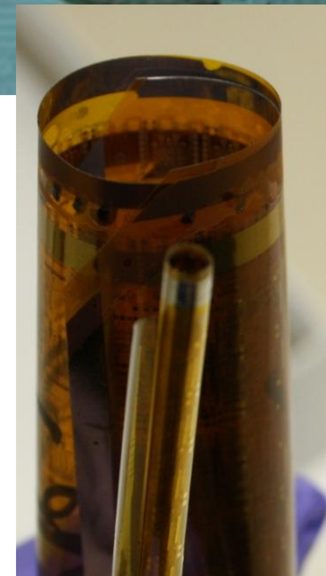
12 metal layers, 325 – 330 µm thick, bend radius 25 mm or higher

Multilayer Flex

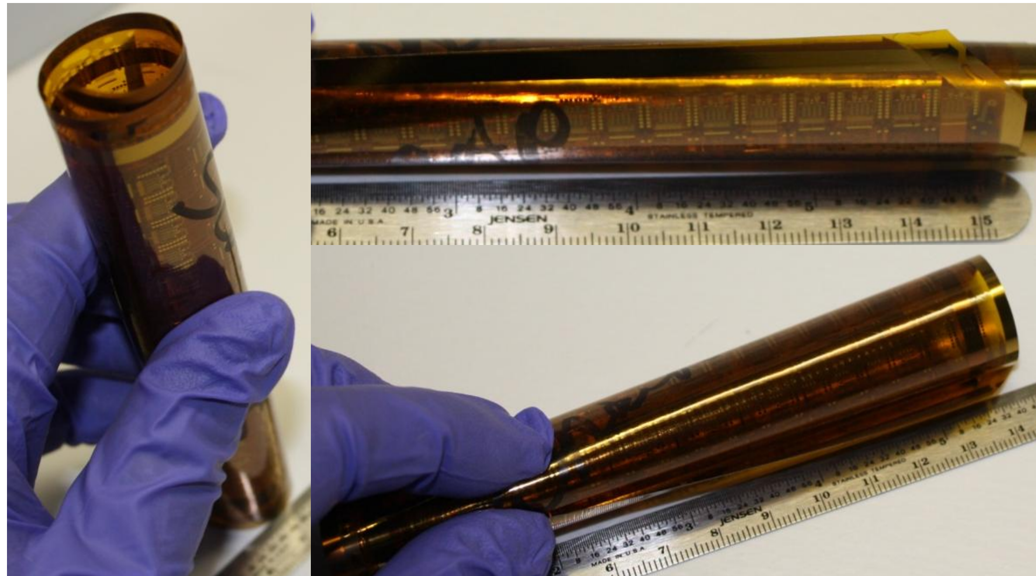
12 metal layers, 190 µm thick, bend radius 25 mm or less

Multilayer Flex



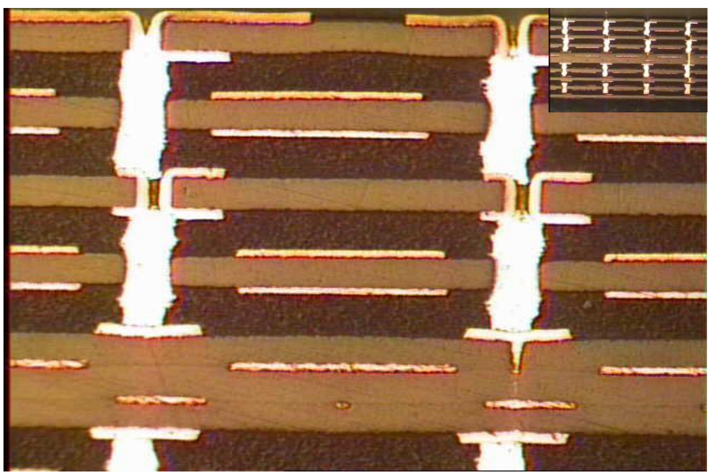


2 metal layers, ~25 µm thick, Roll diameter: 4.6 mm



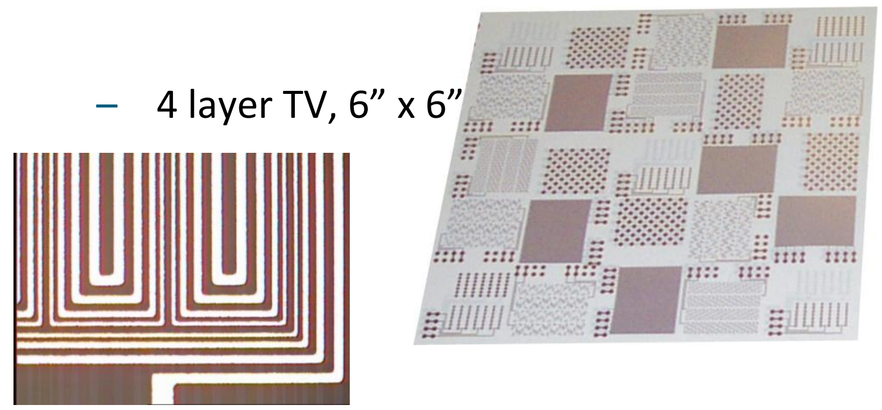
6 metal layers, ~125 µm thick

Liquid Crystal Polymer (LCP)

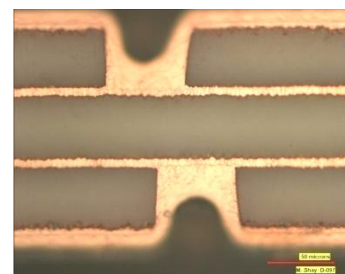


LCP based Z-interconnect substrate

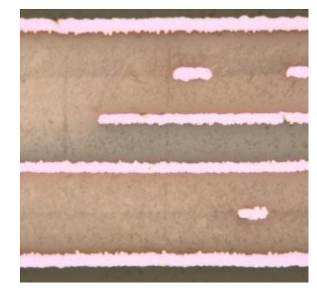
- 4 layer TV, 6” x 6”



- 1, 1.5, 2, 2.5 mil lines & spaces
- 2 & 4 mil thru vias
- 1, 2, 3 mil blind vias



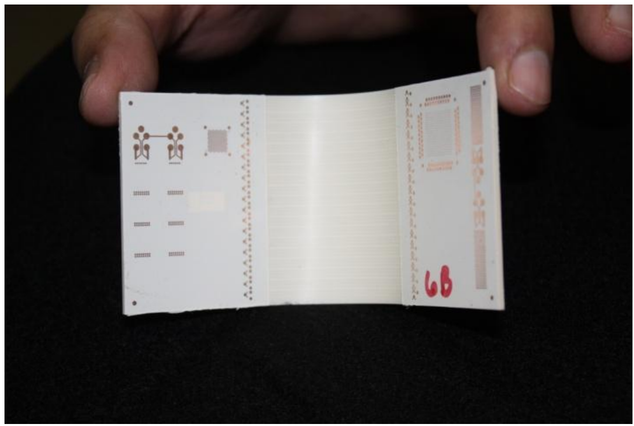
2 mil uvia

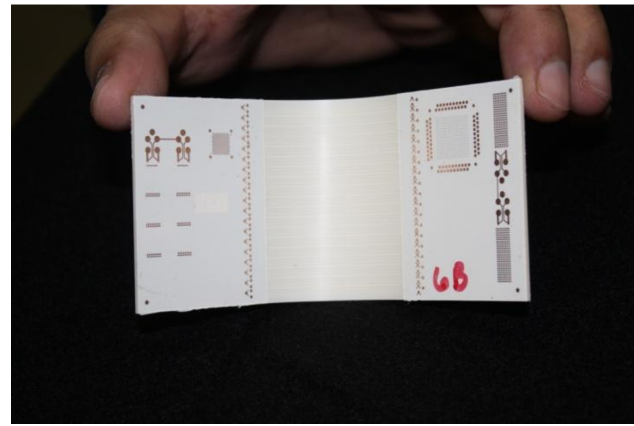


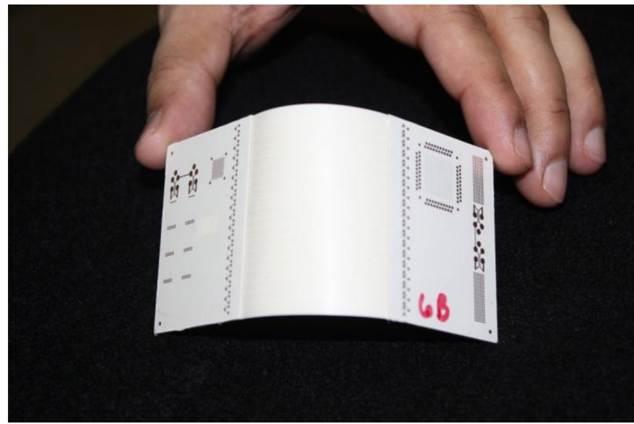
6 Layer

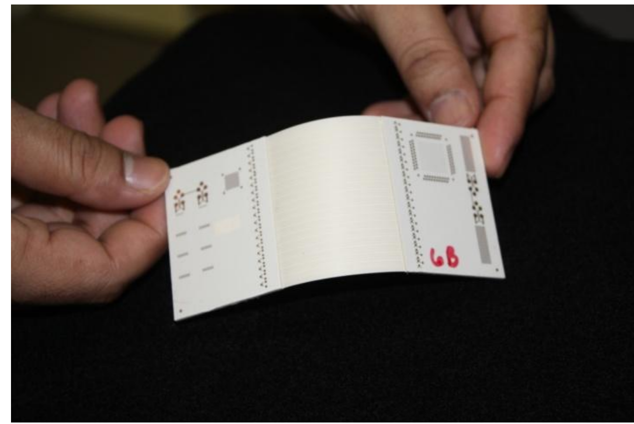
- Understand uVia Reliability

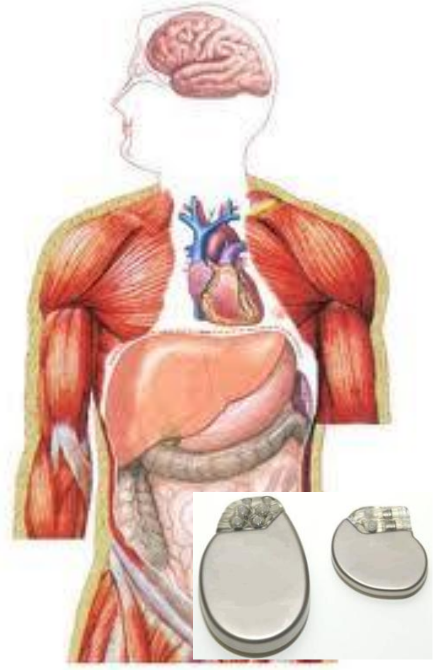
LCP based Rigid-Flex







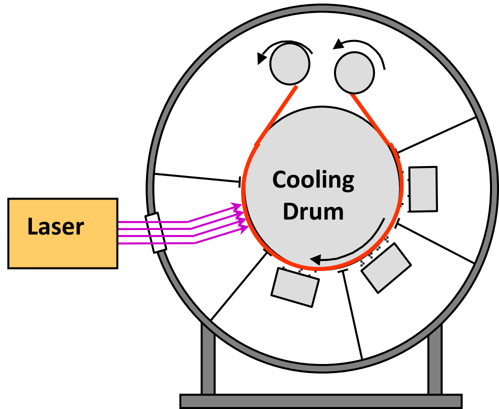


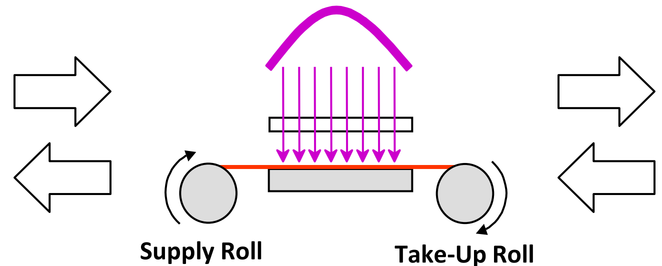


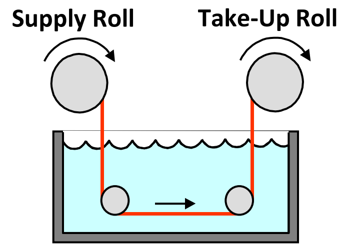
- Rigid-flex can stay inside a semi-conformal metal shell

Rigid Flex gives the ability to design circuitry to fit the device, rather than building the device to fit the circuitry.

Roll-to-Roll Manufacturing

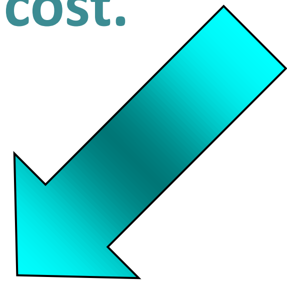






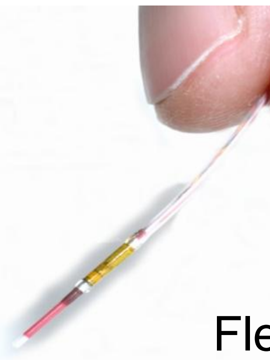
R2R can lead to reductions in cost.

- A fully integrated facility
- Lower capital & labor cost



Rigid

Rigid-Flex



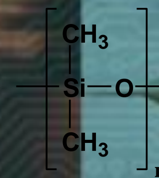
Flex

Stretchable Substrates

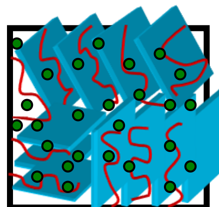
Conformable Electronics

Silicones

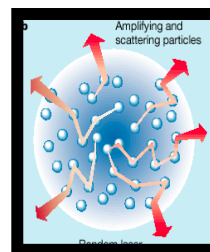
Polydimethylsiloxane (PDMS)



Medicals

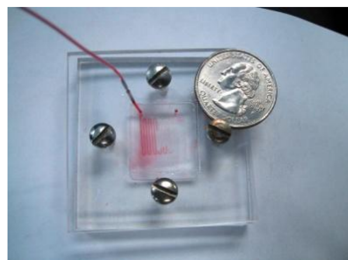


Nano composites



Random lasers

Electromechanical actuators

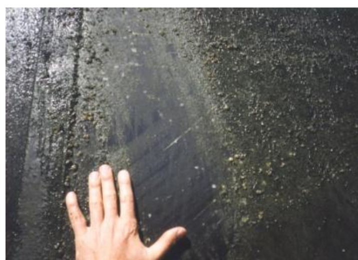


Microfluidics

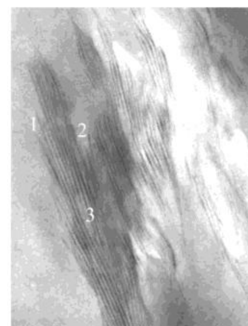
Silicones

Microbe-resistant household products

Thermal interface materials



Marine coatings

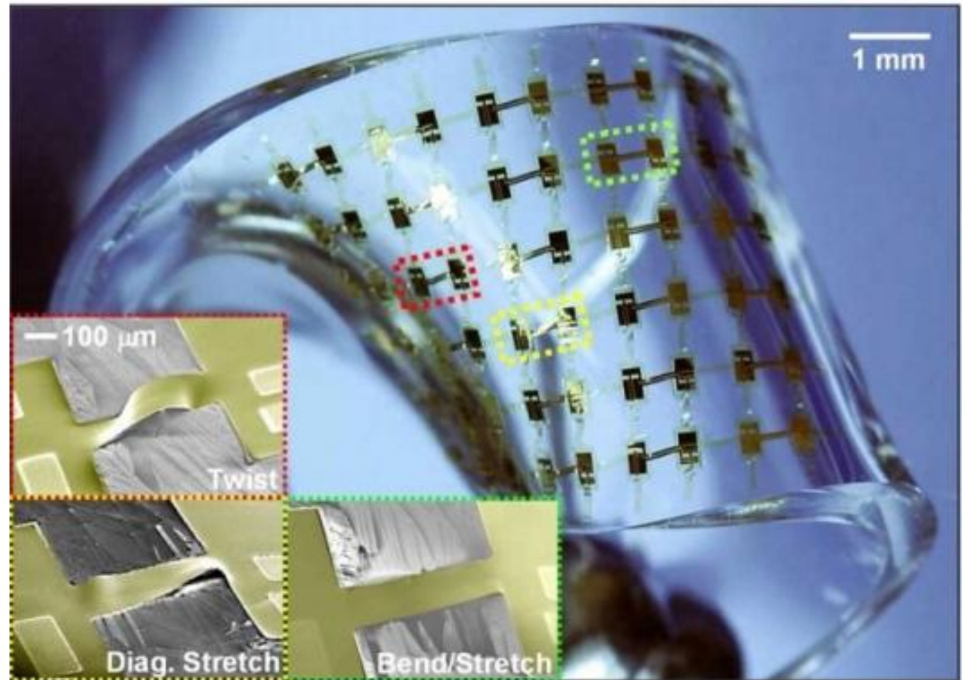


Magnetic

Stretchable Electronics

Conductive wires made from a new carbon nanotube-polymer composite.

Professor Takao Someya of the University of Tokyo

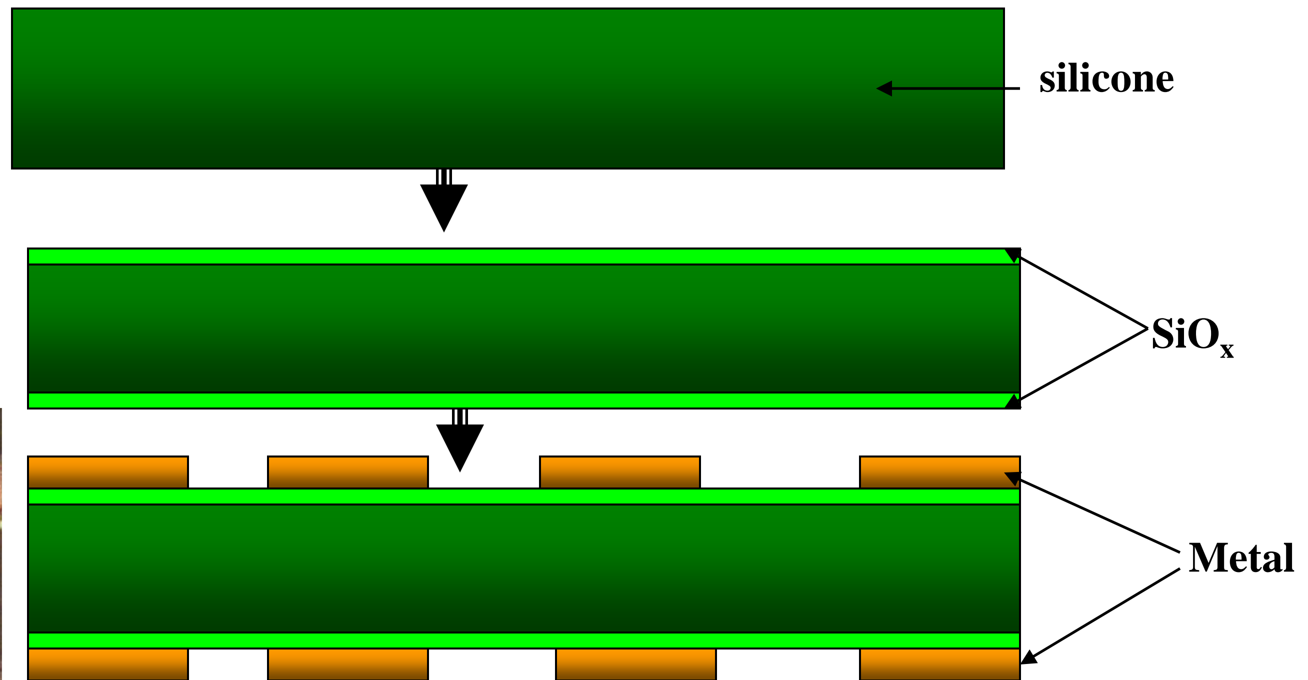


Stretchable Electronics with a Twist: Prof. John A. Rogers, University of Illinois at Urbana-Champaign)

Stretchable Electronics

Process Development for Metal Adhesion

- Bio-compatible
- Bio-stable
- Fine lines



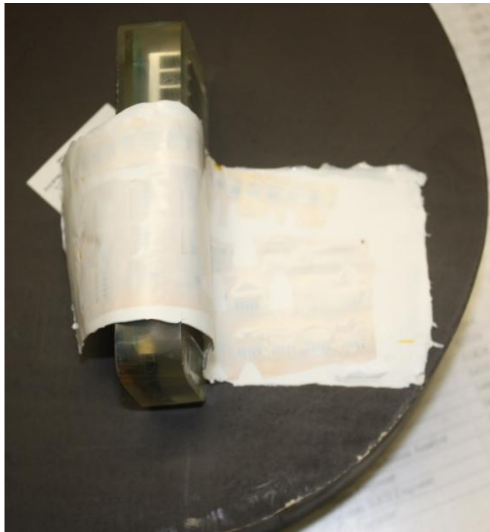
PDMS Coatings

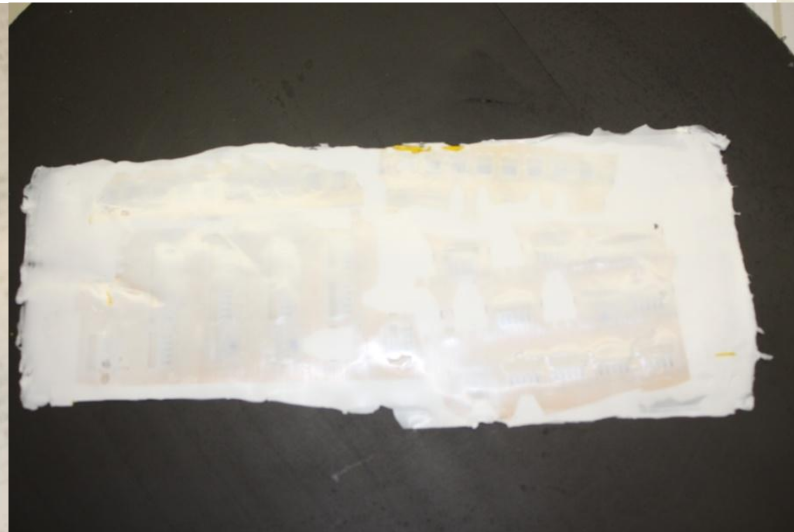
Flexible electronics

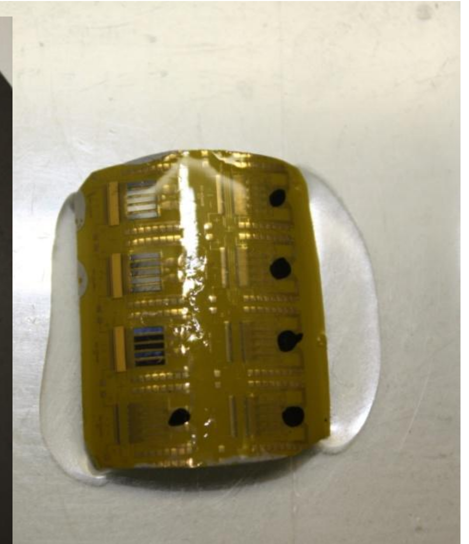
(Assembled substrates)

PDMS Coating

Conformal electronics



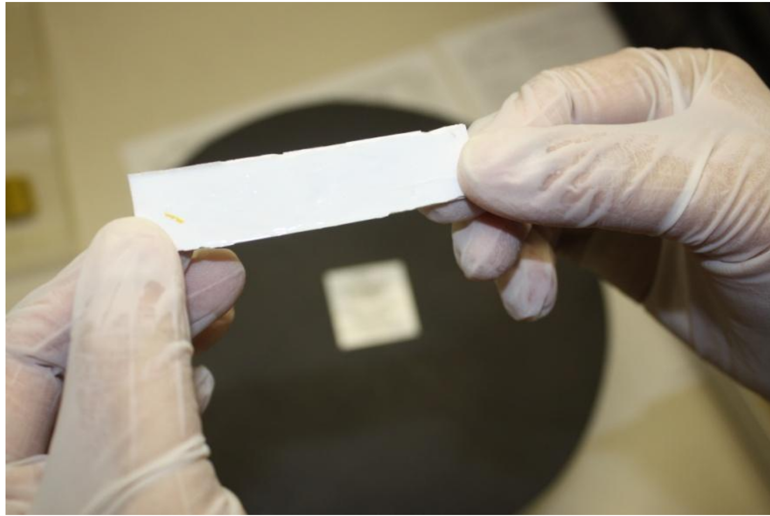




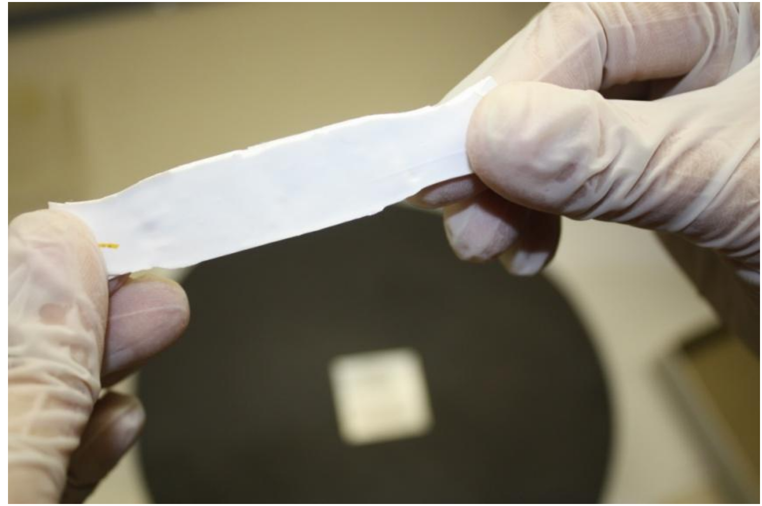
Filled PDMS

Pure transparent PDMS

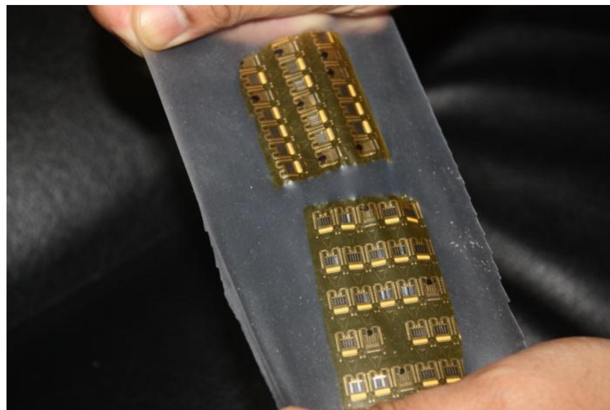
PDMS Coatings
Before and after stretching

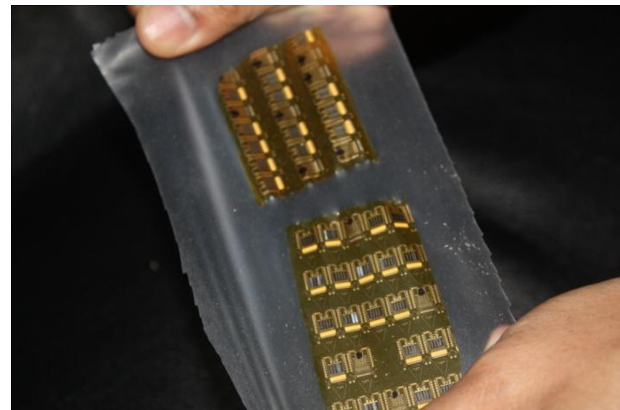


Before stretching



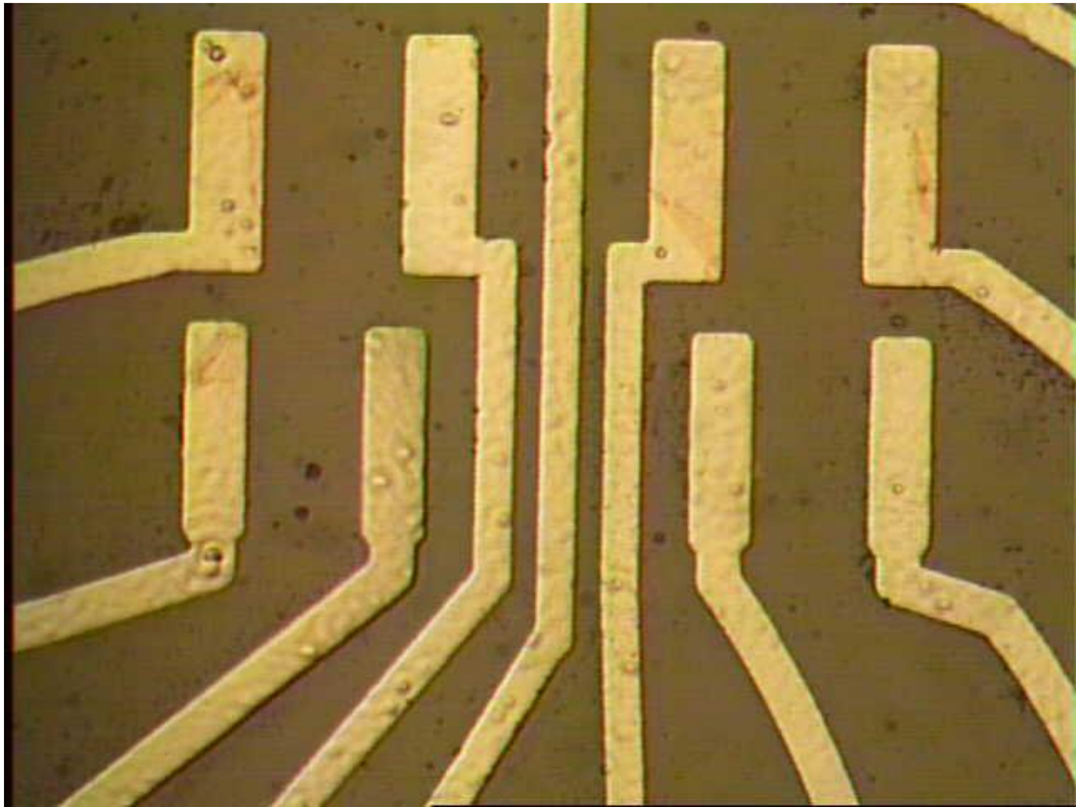
Stretched PDMS





Stretched PDMS

Water Soluble PVA Substrate



Summary

Electronics Packaging for Medical Devices demand novel substrate materials, ultra high density assemblies and unique form factors.

Widespread practical implementation requires:

- Implementation of low-cost, high volume manufacturing techniques like roll-to-roll.
- Biocompatible material sets and supply chain.

Thank you for your attention!