Interconnect Issues for a Compact Si-W Calorimeter

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Si/W ECal R&D Collaboration

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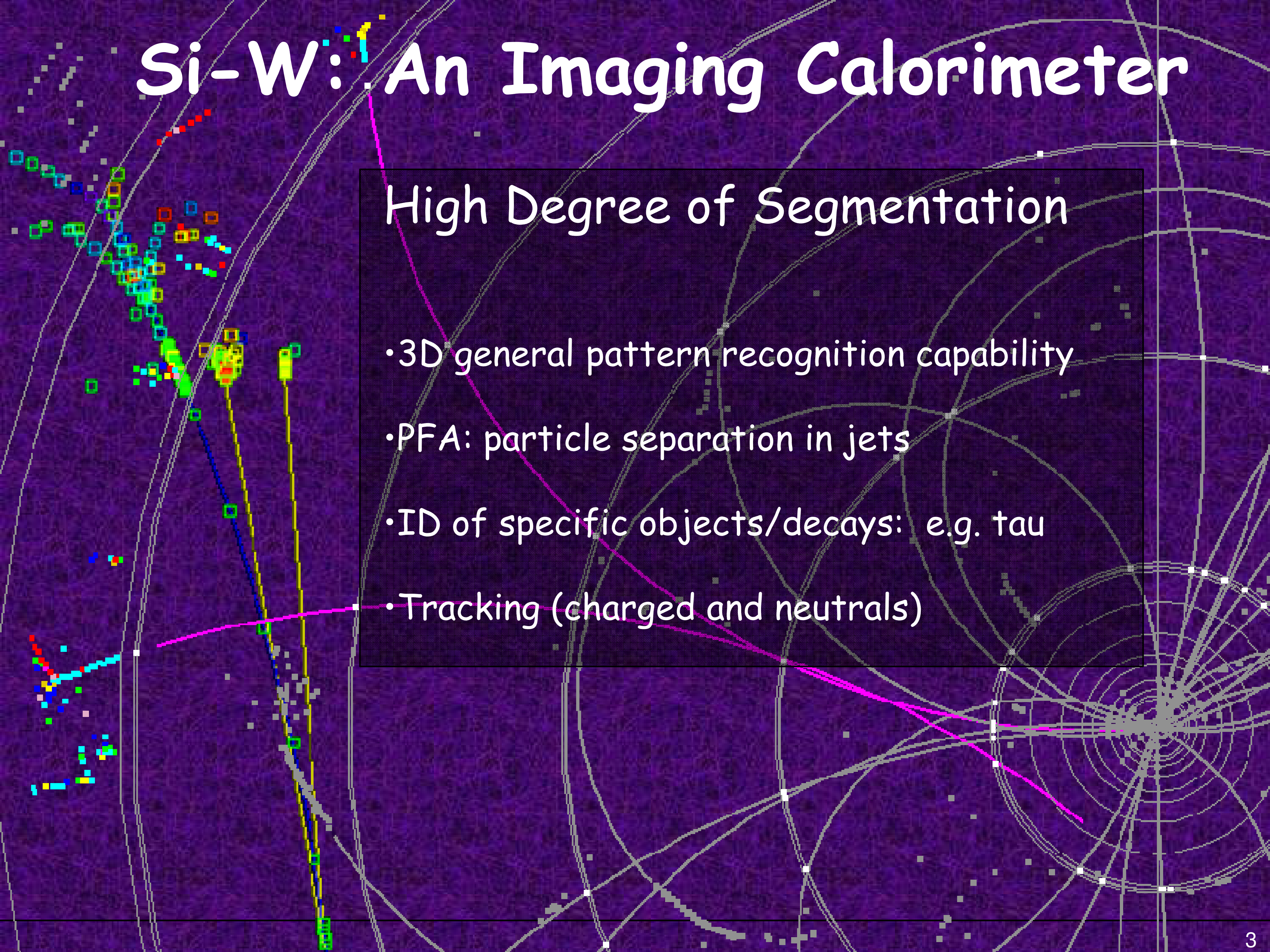
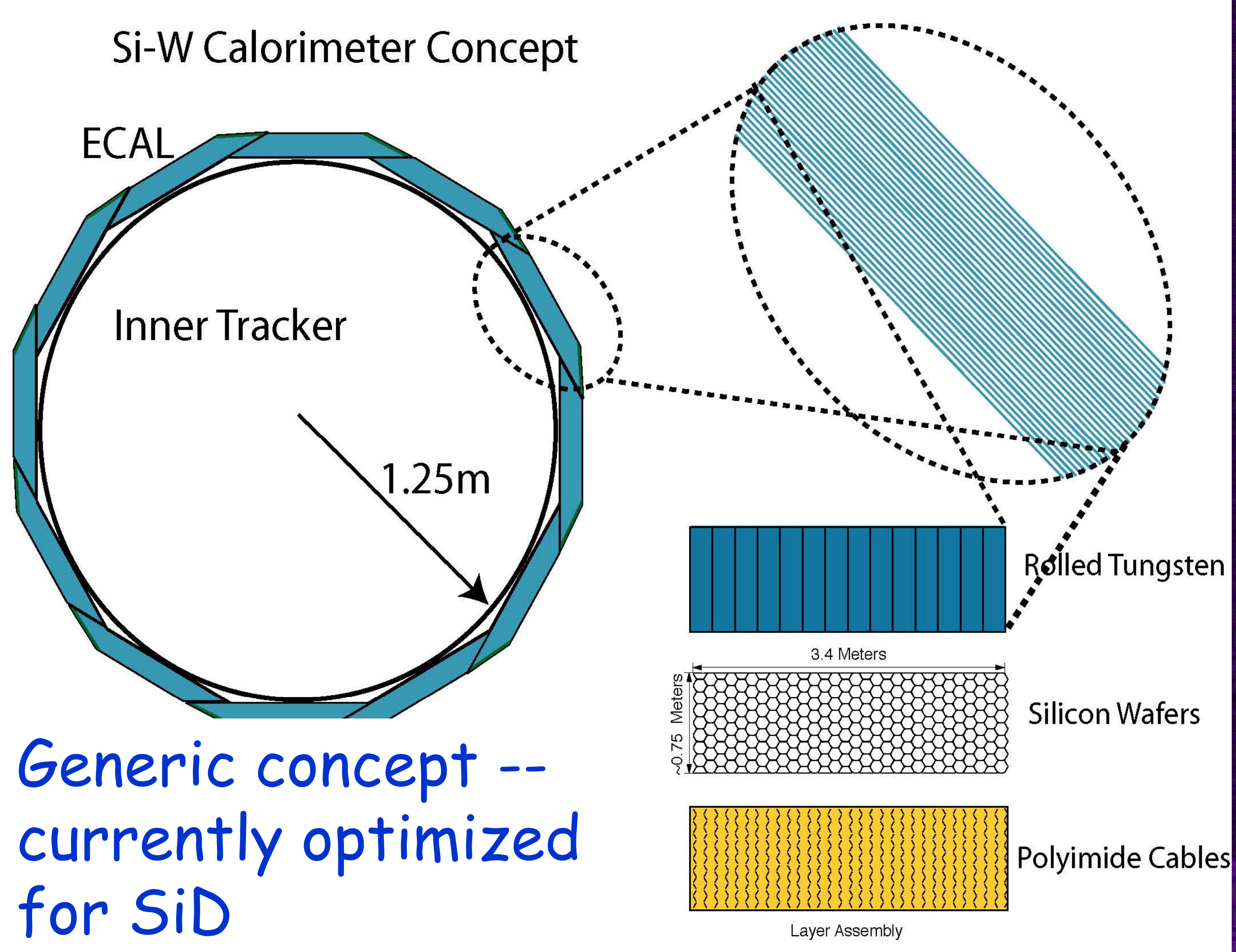
Si-W: An Imaging Calorimeter



High Degree of Segmentation

- 3D general pattern recognition capability
- PFA: particle separation in jets
- ID of specific objects/decays: e.g. tau
- Tracking (charged and neutrals)

Si-W Calorimeter Concept



Generic concept -- currently optimized for SiD

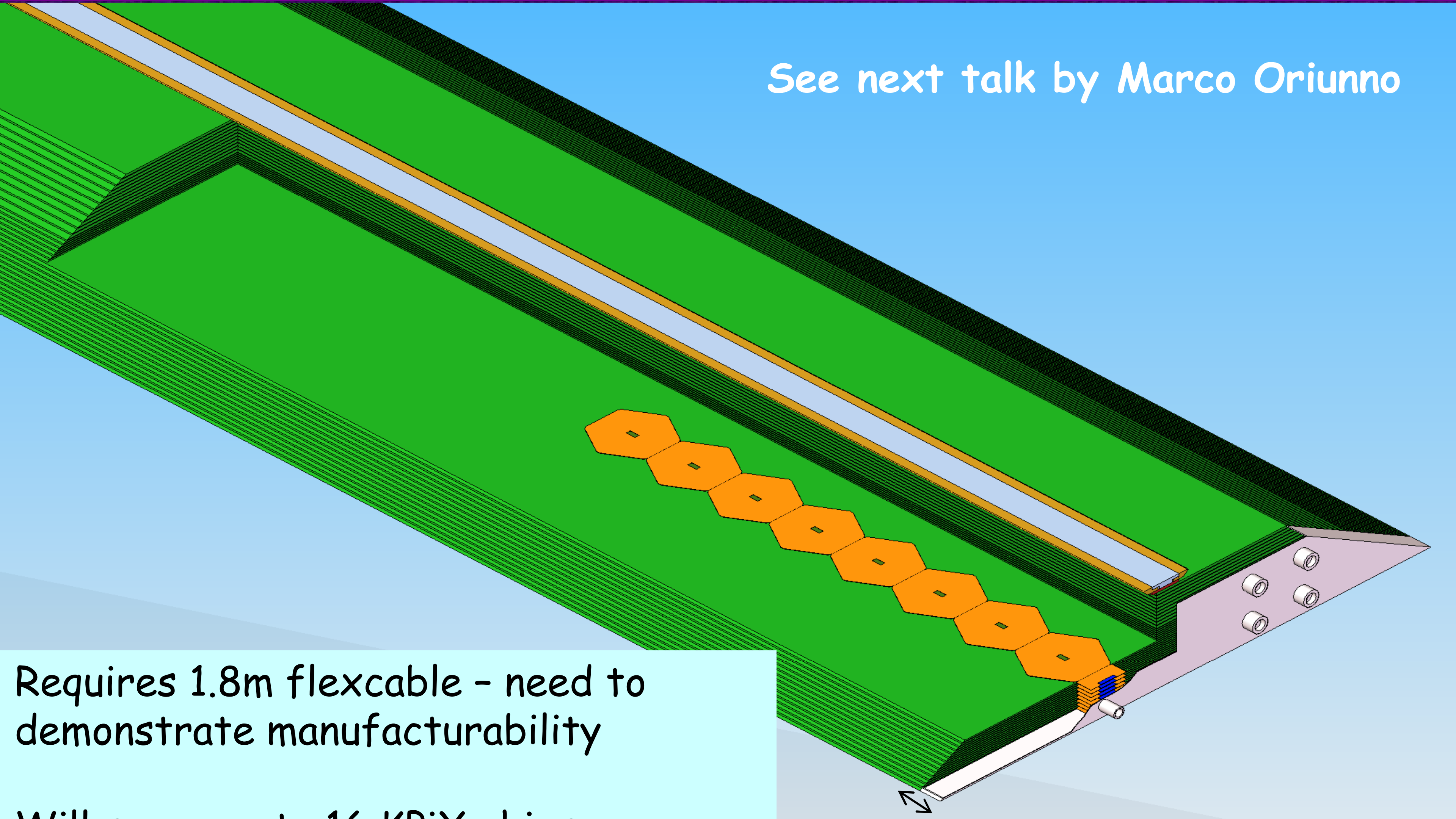
Baseline configuration:

- transverse seg.: 13 mm^2 pixels
- longitudinal seg: $(20 \times 5/7\ X_0)$ + $(10 \times 10/7\ X_0)$

$\Rightarrow$ **17%/sqrt(E)**

- 1 mm readout gaps $\Rightarrow$ 13 mm effective Moliere radius

Module Design



See next talk by Marco Oriunno

40mm

Requires 1.8m flexcable – need to demonstrate manufacturability

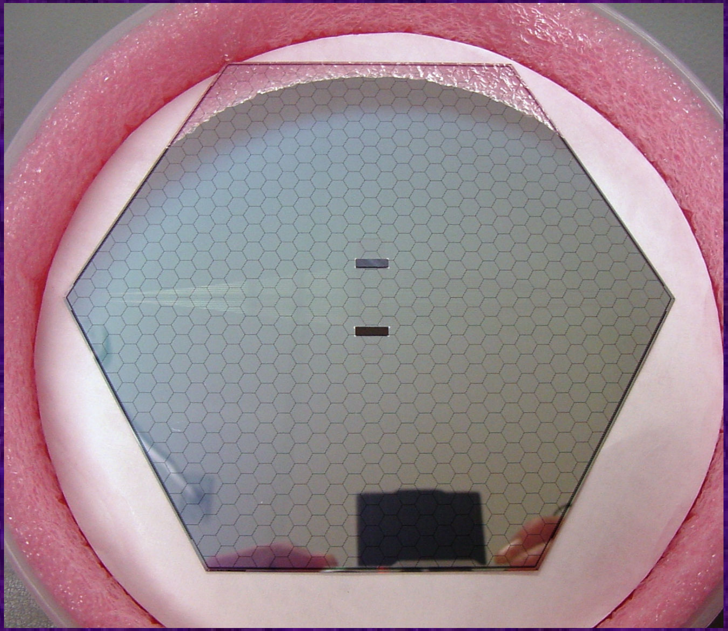
Will serve up to 16 KPiX chips

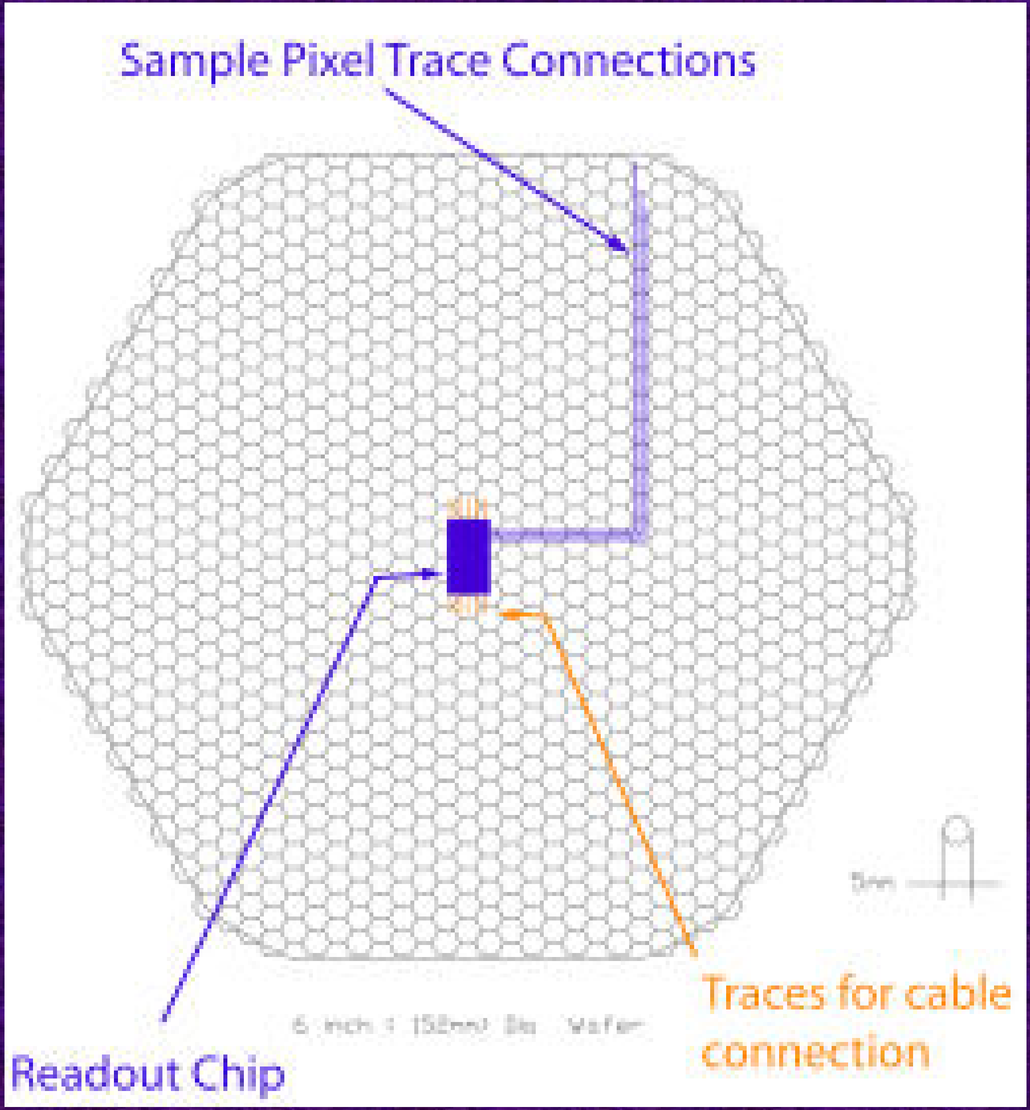
~200 cables/connectors per side

Si Detector

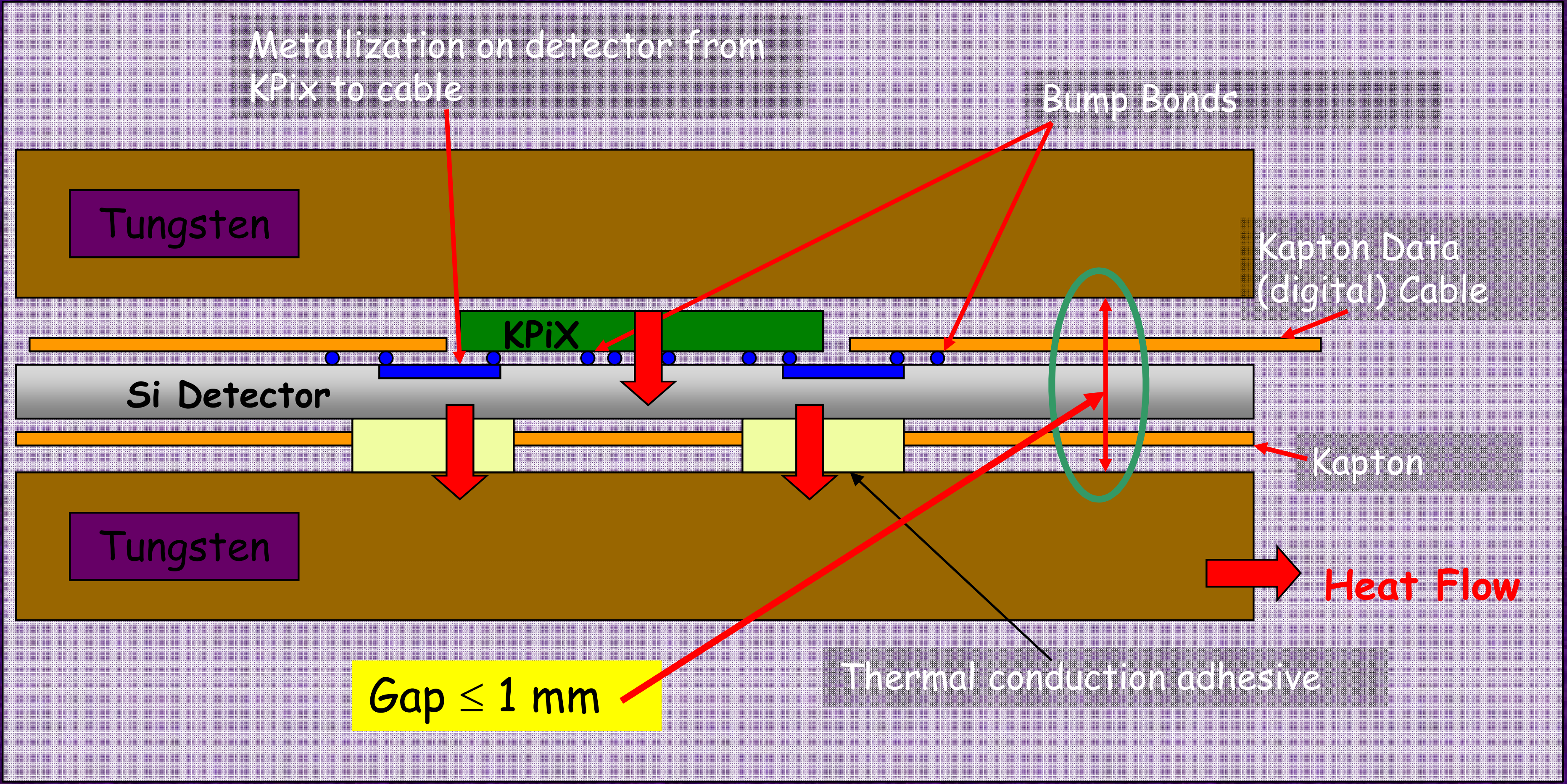
Wafer

- 6 inch wafer
- 1024 13 mm² pixels
- Hamamatsu Prototype (ver2) sensors in hand (40 wafers)



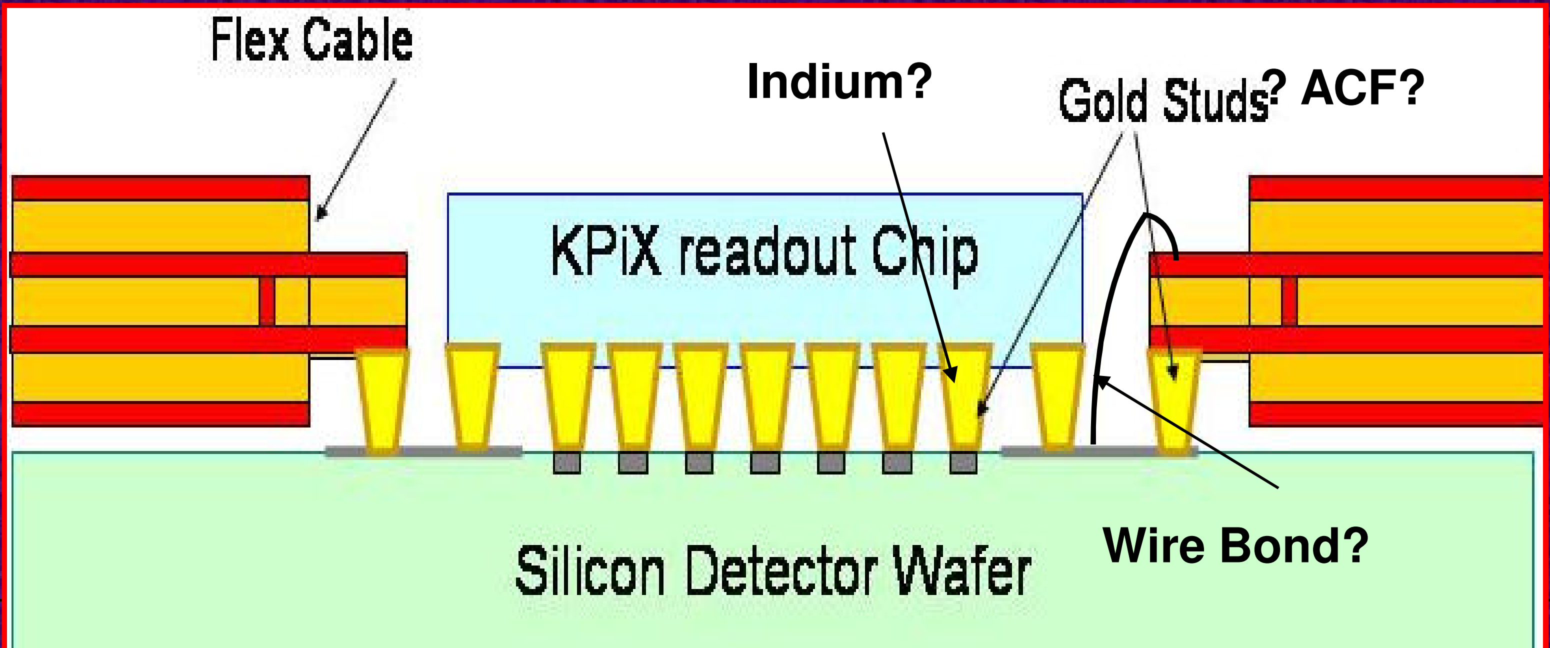


Readout gap cross section (schematic)



Interconnect issues: Technologies being considered

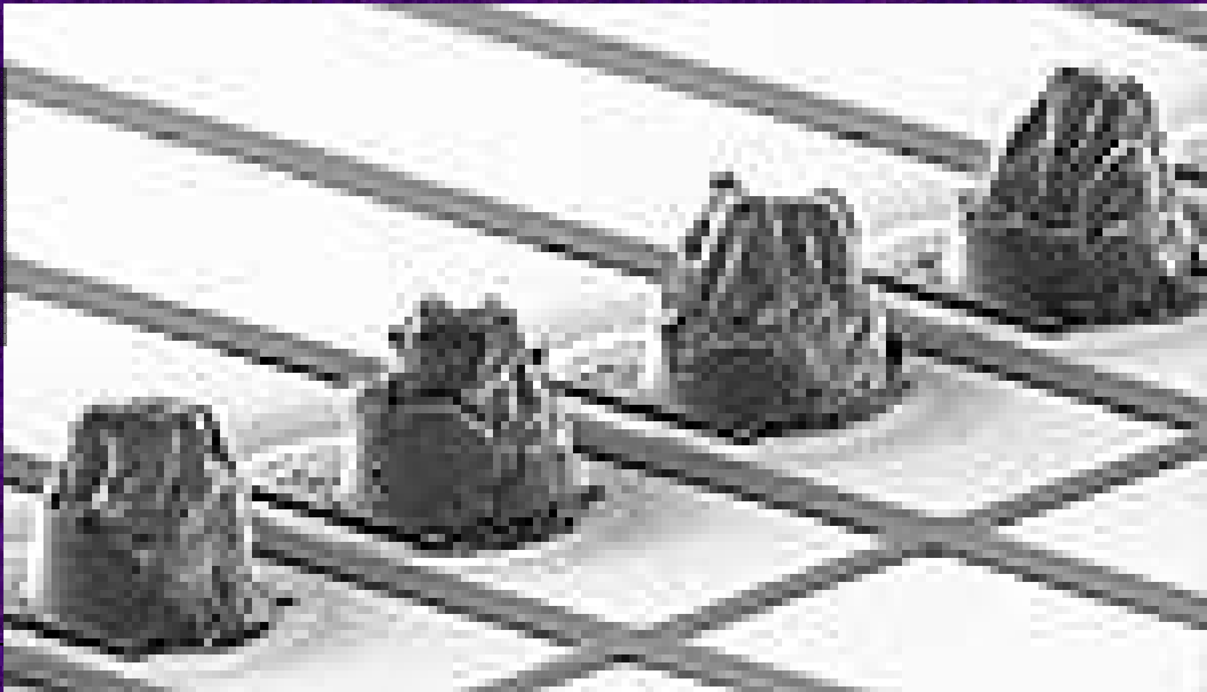
	Prototyping	Production
KPiX to Sensor	Gold Stud Bonding	Indium Bump Bonding
Flex Cable to Sensor	Wire Bonding Conducting Epoxy ACF/Gold Stud	ACF Bonding



Indium Bump Bonding

Indium Bump Bonding is a mature/commercial technology. UC Davis has developed the process for prototyping purposes. The campus operates a Class 100 clean room (10,000+ sq. ft.) and several pieces of specialized equipment.

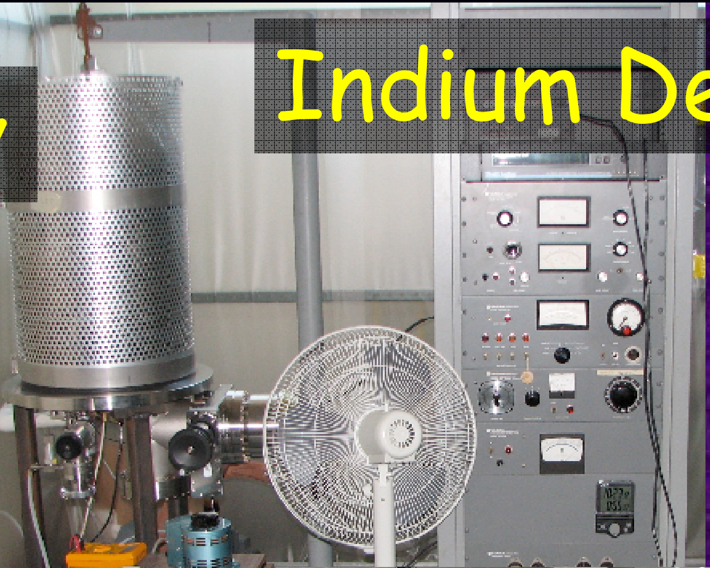
Recent ARRA funding will significantly upgrade the lab and its capabilities.



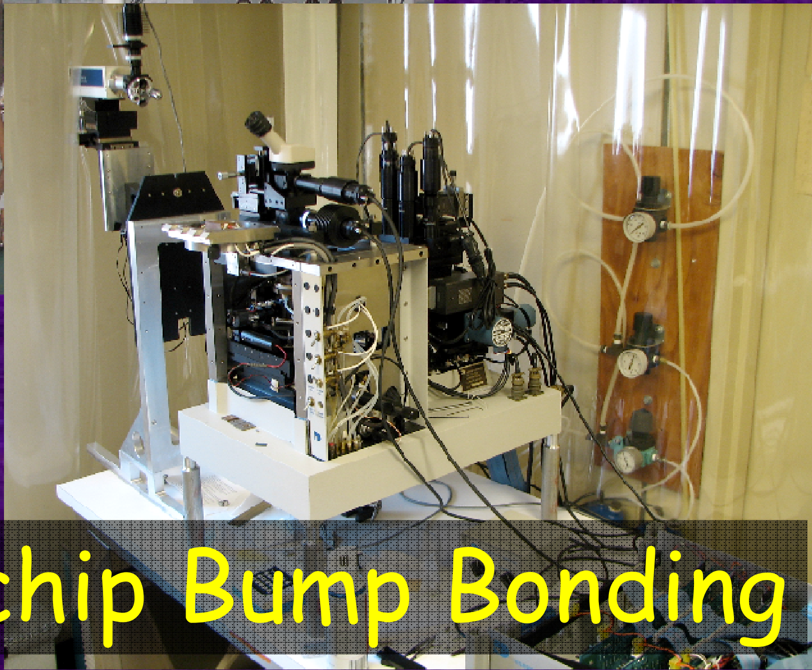
Indium Bumping: All steps done in-house

Photolithography

Indium Deposition



Ti/W Sputter



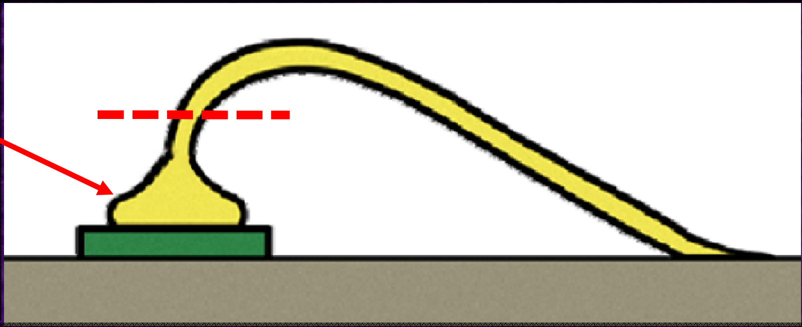
Flip-chip Bump Bonding

Gold Stud Bump Bonding

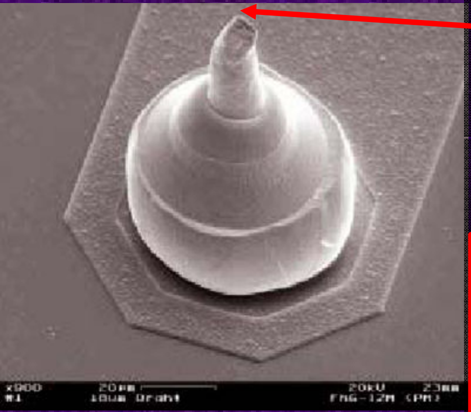
- An attractive option for prototyping because individual small chips are difficult to handle for Indium bumping.
- Several vendors (e.g. Palomar, K&S Accubump, West Bond).
- Upgraded Davis lab will have Gold Stud bumping capabilities.

Gold Stud Growth

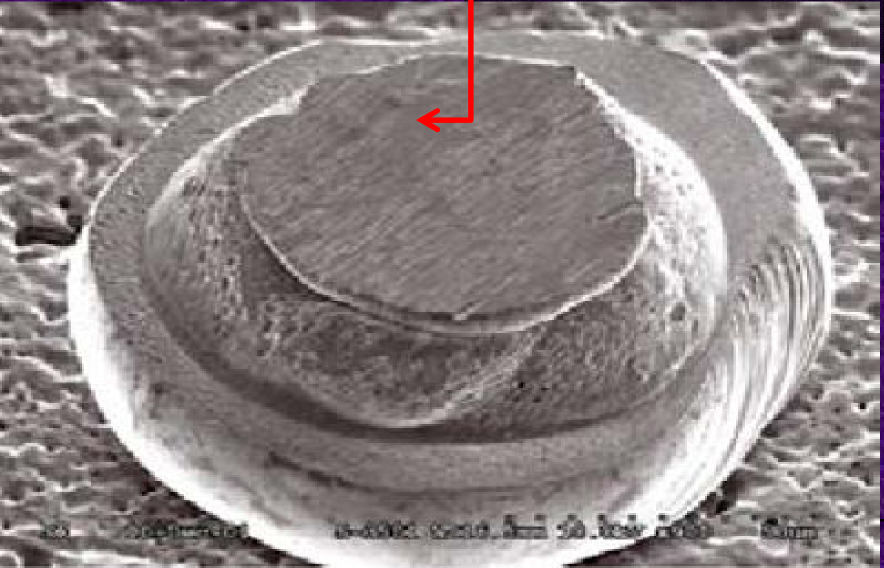
Step 1: A ~25 µm gold wire is bonded to the pad.

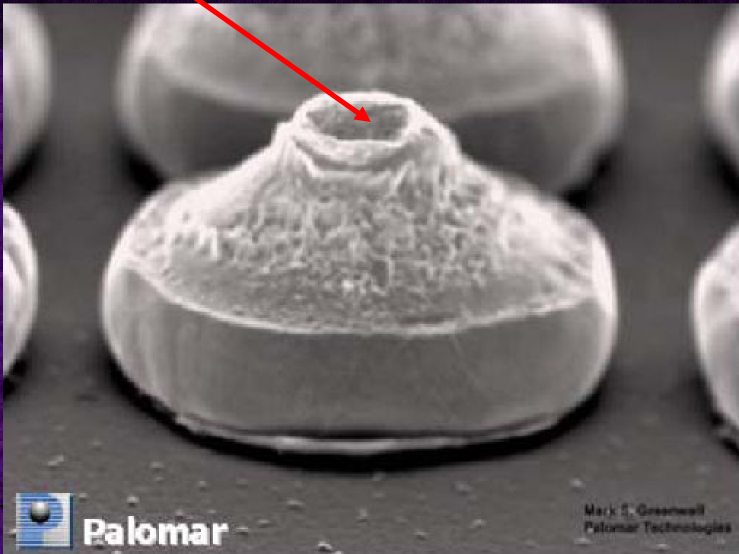


Step 2: The wire is snapped off.

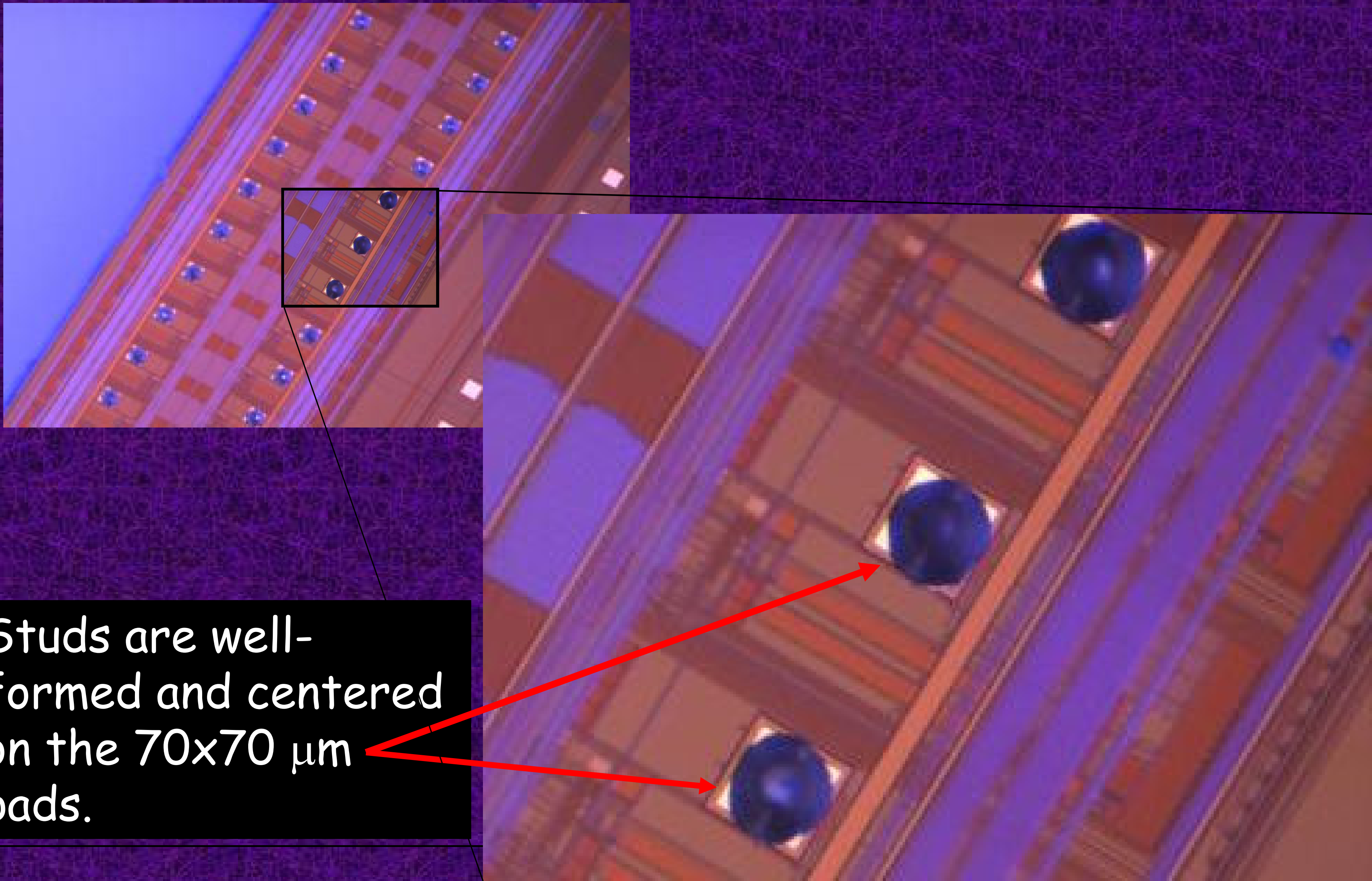


Step 3: The stud is "coined" (flattened) to provide a better shape. Alternately, the wire is pushed back into the ball after snapping. The result is a matted surface.



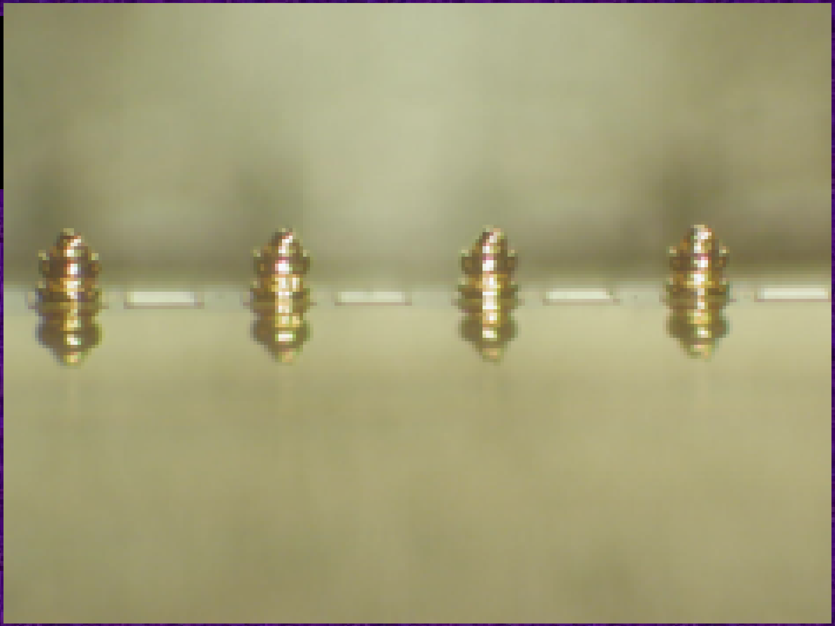


KPiX with Gold Studs

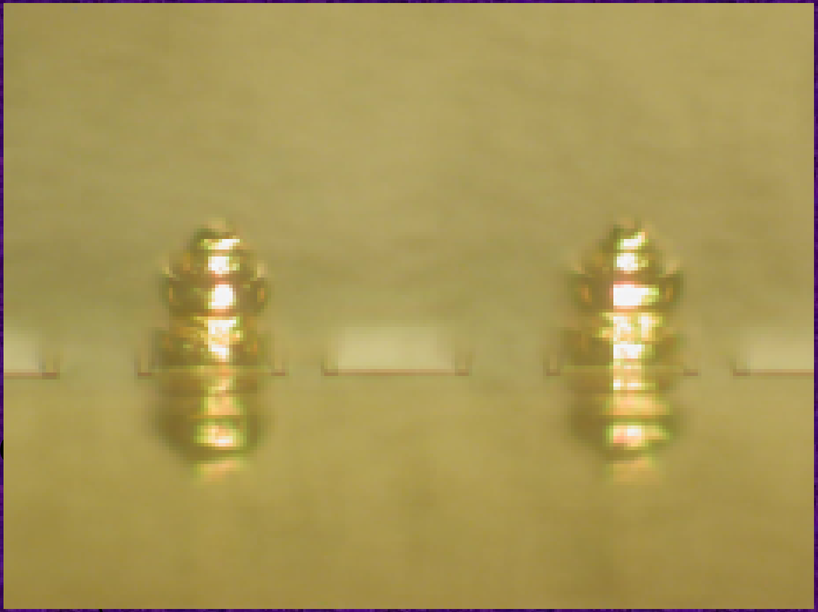


Studs are well-formed and centered on the 70x70 μm pads.

Double Studs



In



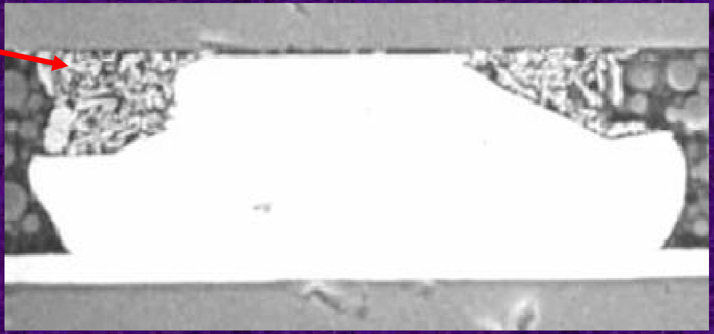
	ball diameter - um	*ball height - um*	*shear strength - grams*
count	10	10	10
average	58.4	66.0	21.0
stdev	1.0	.76	1.1
Cpk	1.8	3.1	1.8

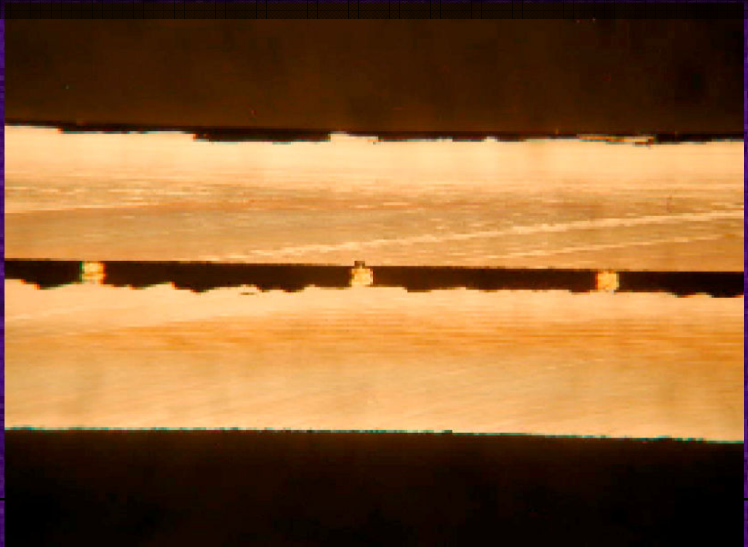
Adhesive Attachment

Palomar Technologies:

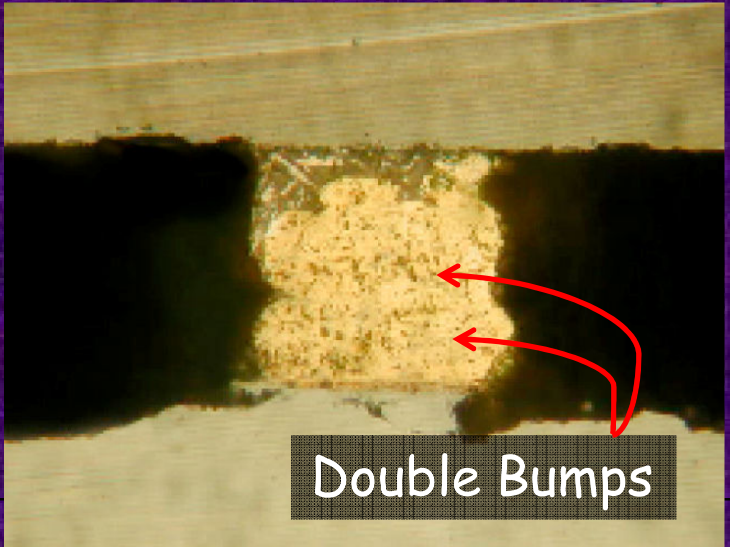
The tips of the studs are dipped into a conductive epoxy.
(Alternately, epoxy "dots" can be dispensed on the opposite wafer).

After a flip-chip alignment, the chips are compressed.

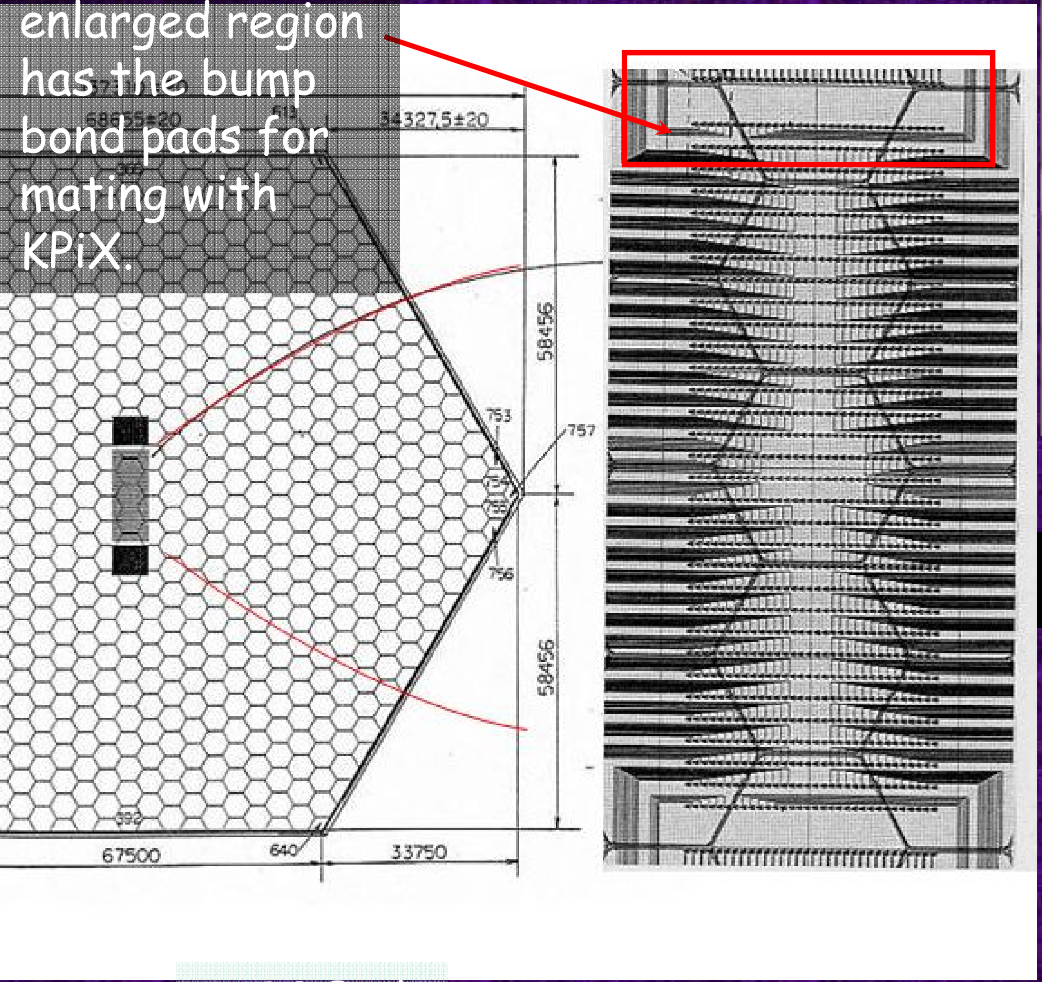




Cross sections after slicing

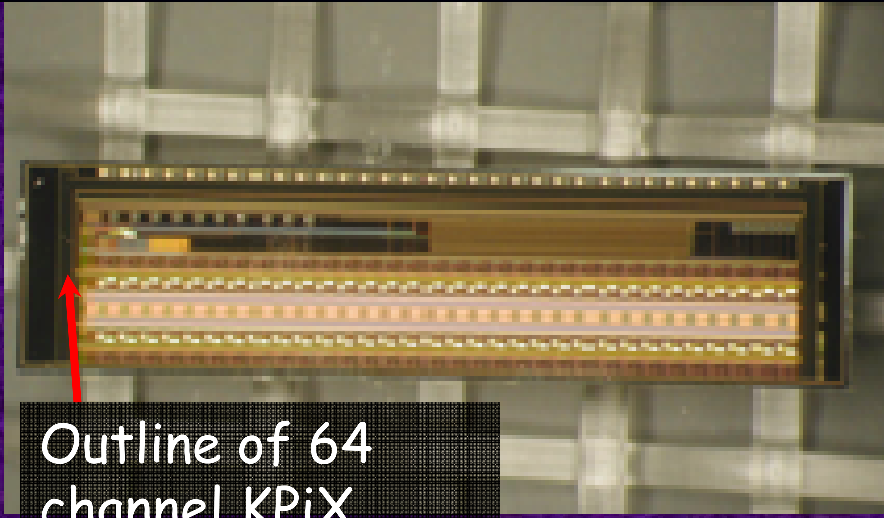


Bump Bonding KPiX Prototypes

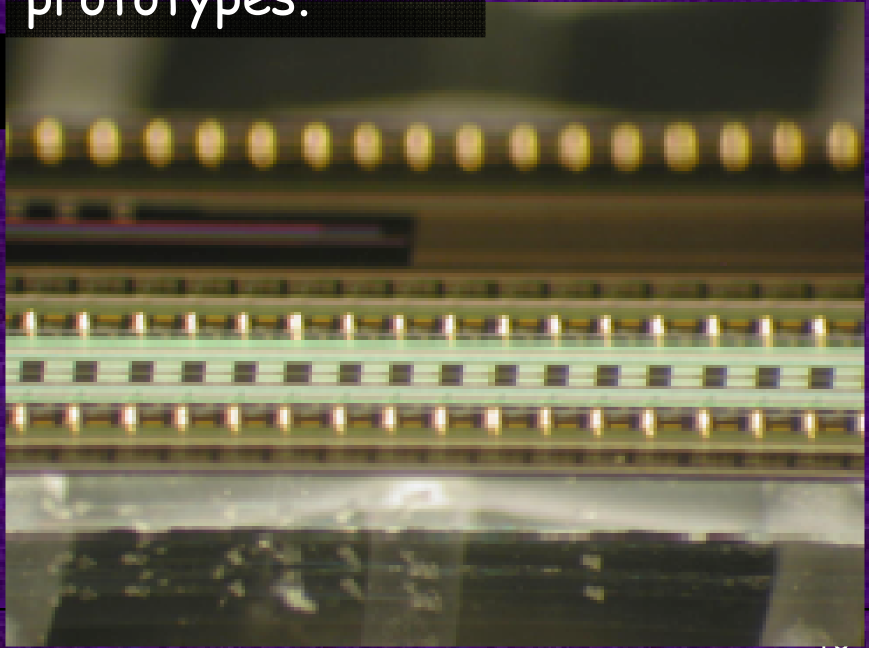


This central enlarged region has the bump bond pads for mating with KPiX.

32 Pads
x 32 Rows
1024 pix



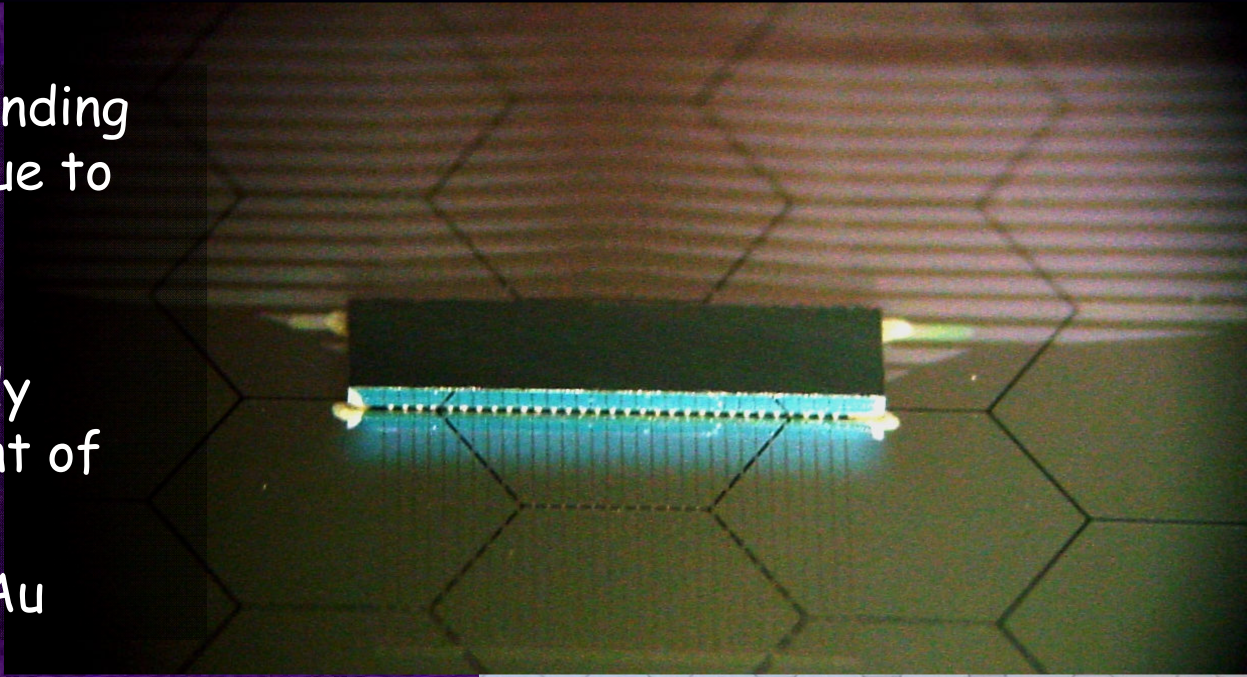
Outline of 64 channel KPiX prototypes.

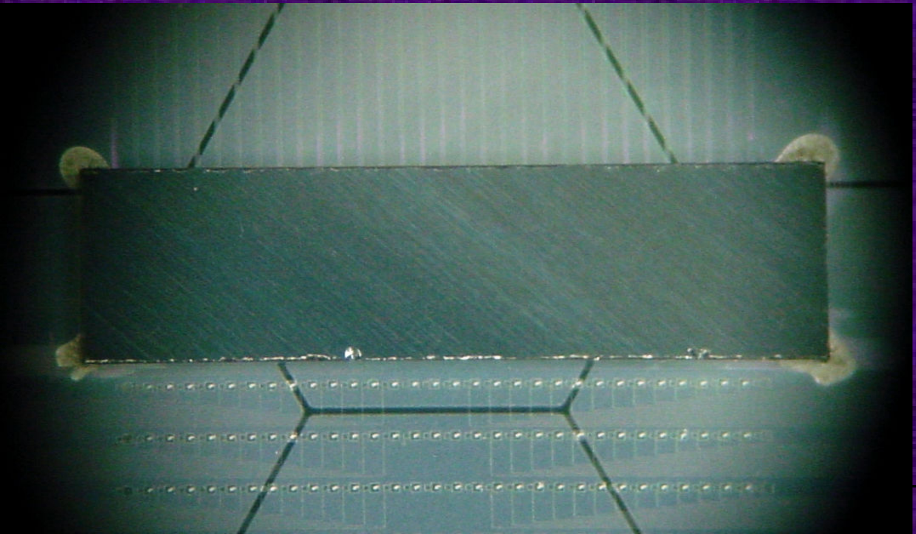


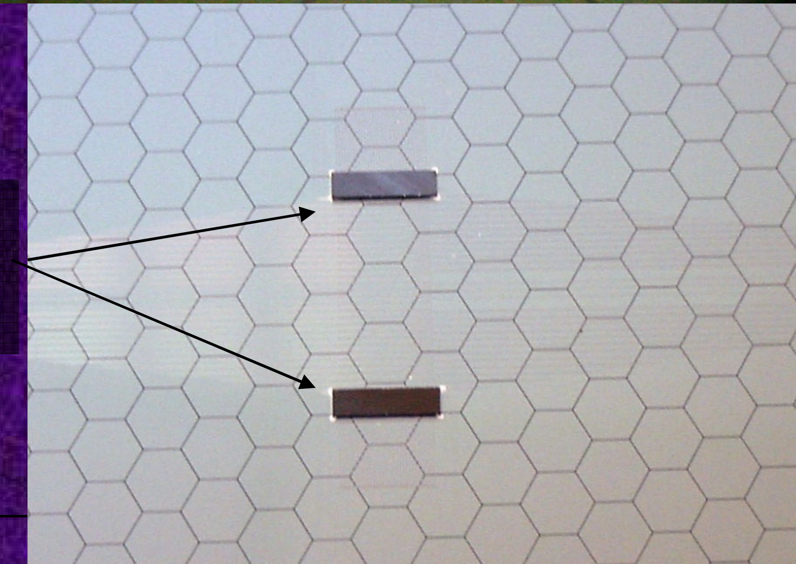
Bump Bonding KPiX to Hamamatsu

- Initial gold-stud bump-bonding trials had mixed results due to surface oxidation.

- Efforts underway to study optimum surface treatment of Hamamatsu wafers.
- Candidates: Ti-W, Ti-N, Au







KPiX Chips

ANISOTROPIC CONDUCTIVE FILMS

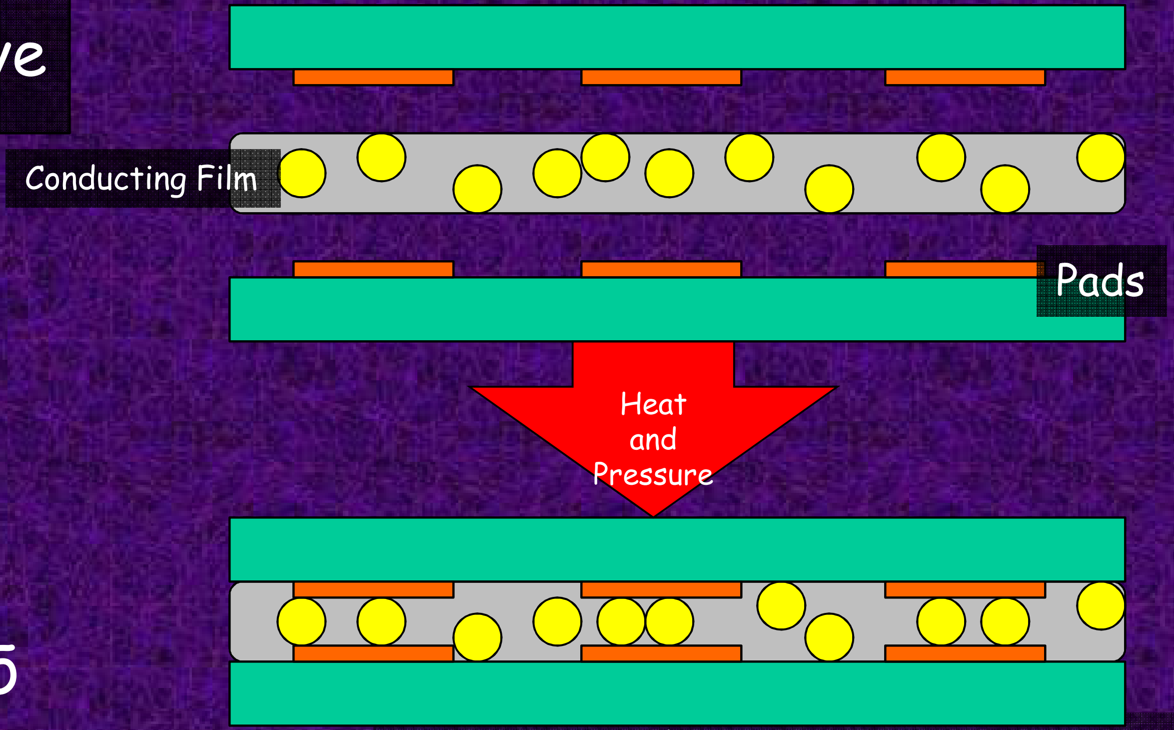
Z-Axis Conducting Adhesive

3M: 7303 ACF Adhesive

~45 μm particles
~75 μm film thickness

≥250 μm pad pitch

Bonding Conditions:
140°C @ 260 PSI for 25 secs



Cairns et al, SID Digest, 2001

Contact resistance ≤0.2 Ω (for flex-cable to PC board).
≤0.2 Ω maintained after 80°C for 1000 hours or 25°C for 4 yrs

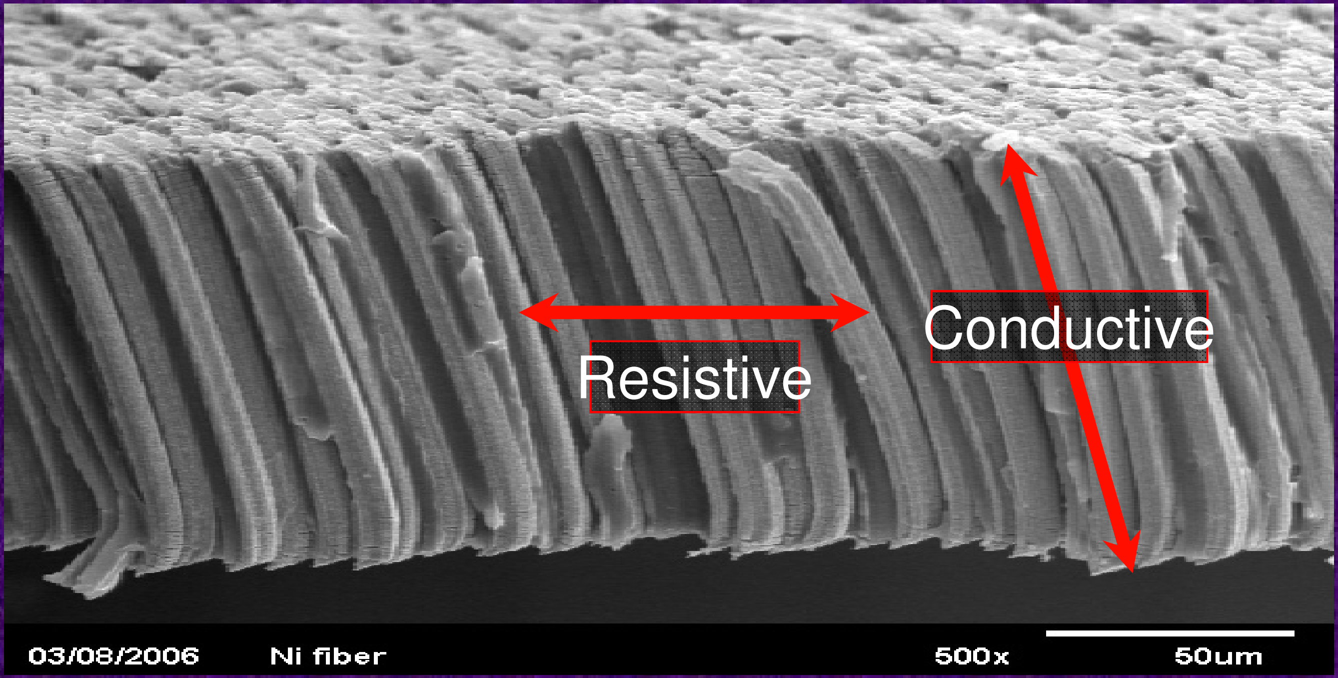
Flex cable to wafer attachment is not common => R&D.

Thermoplastic Conducting Adhesive

Btechcorp:

Metal fibers in a matrix
~2 x 10^7 fibers/in^2

Low Cure pressure: 50 psi

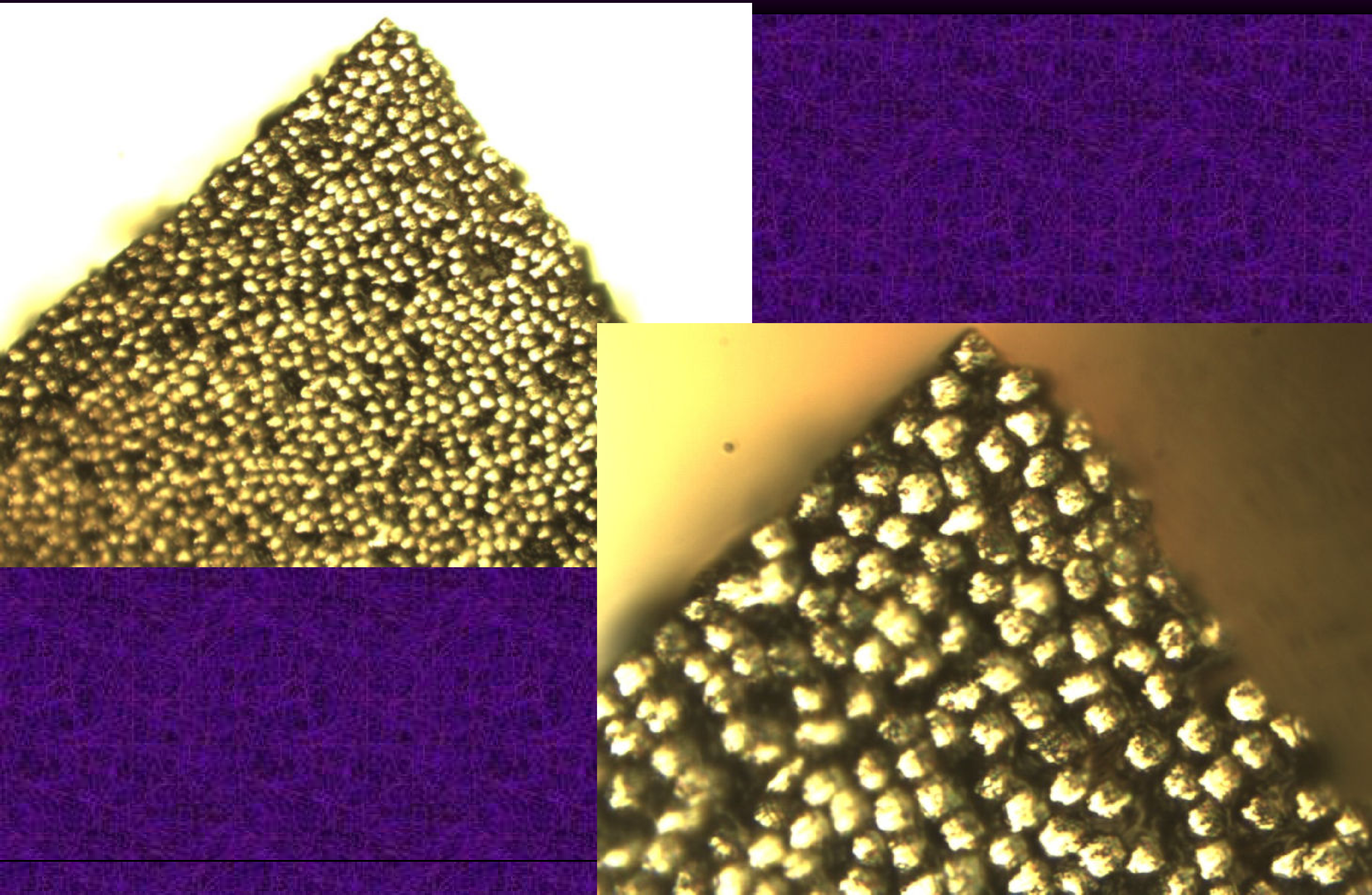


Nickel fiber structure.

Thermal Conductivity ≥ Cu. Smaller resistance

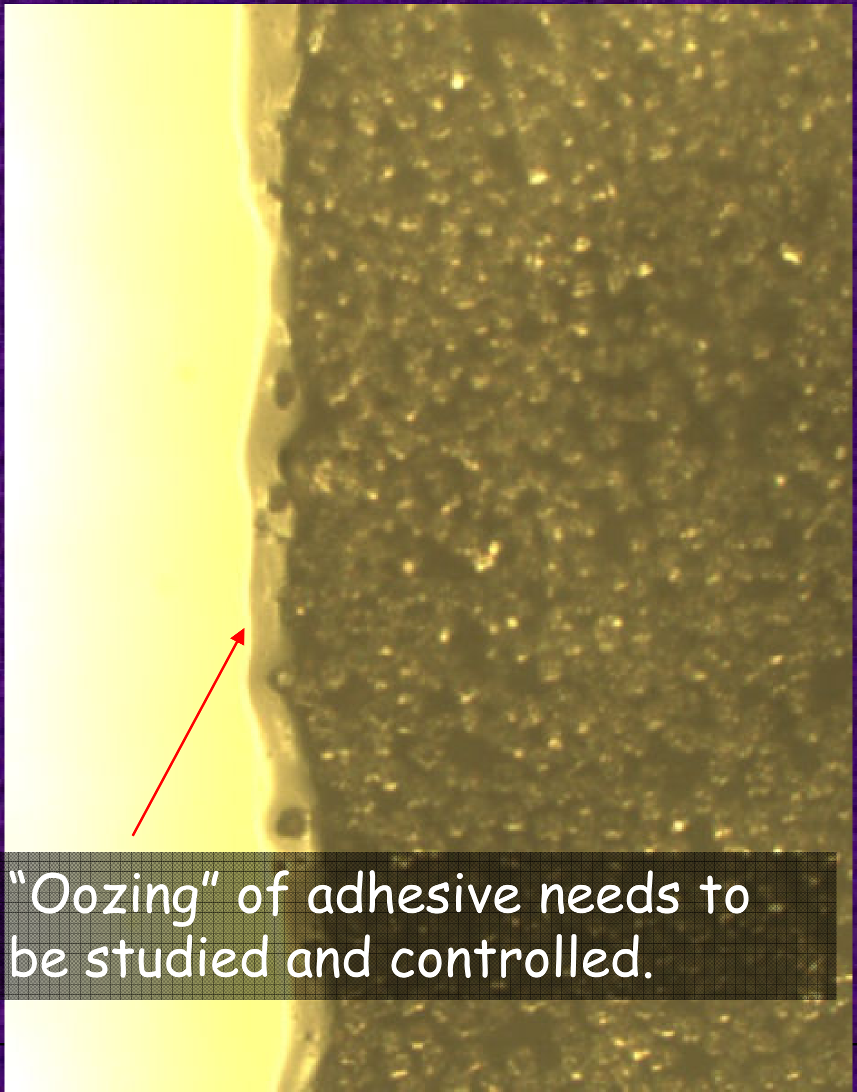
Cheaper.

ACF Up Close

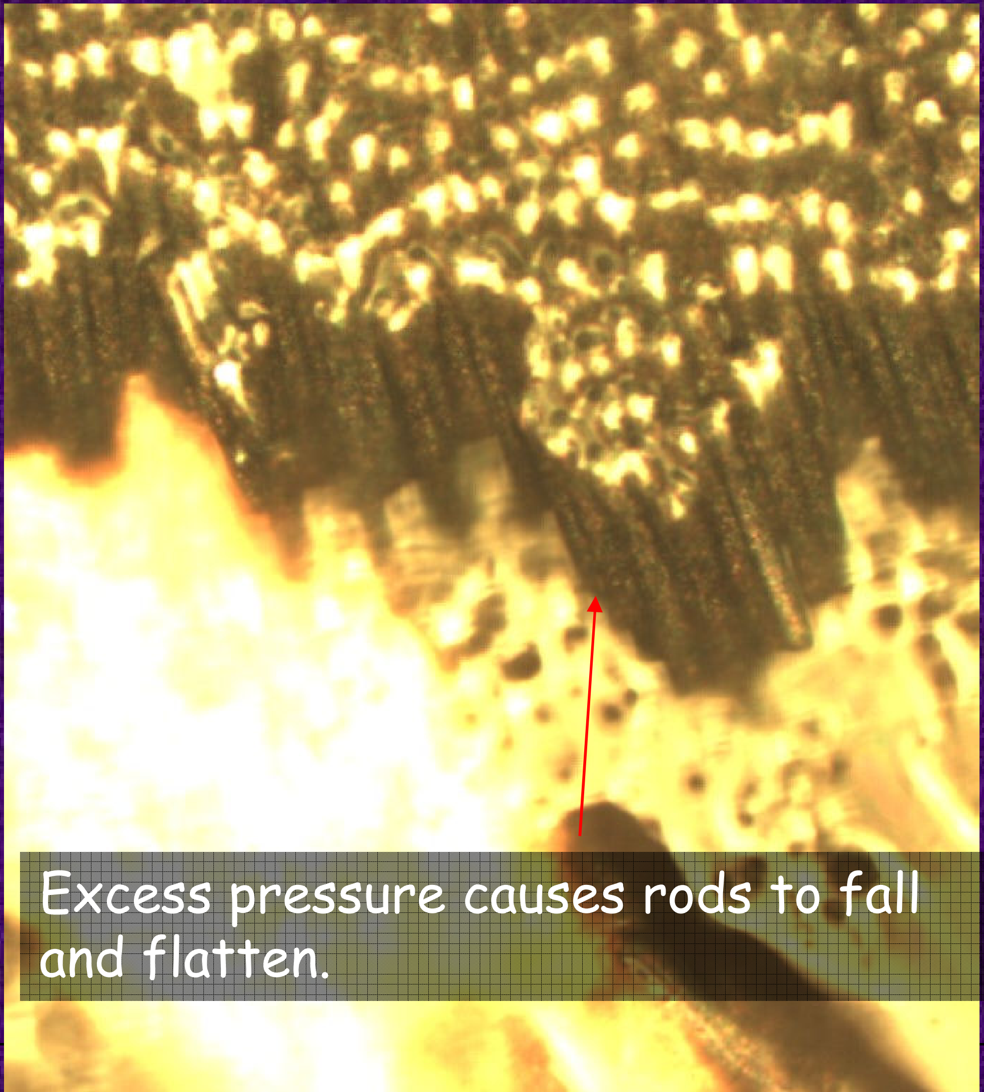


Possible problems in ACF Bonding

- **ACF bonded to transparent glass** allows for observation under a microscope

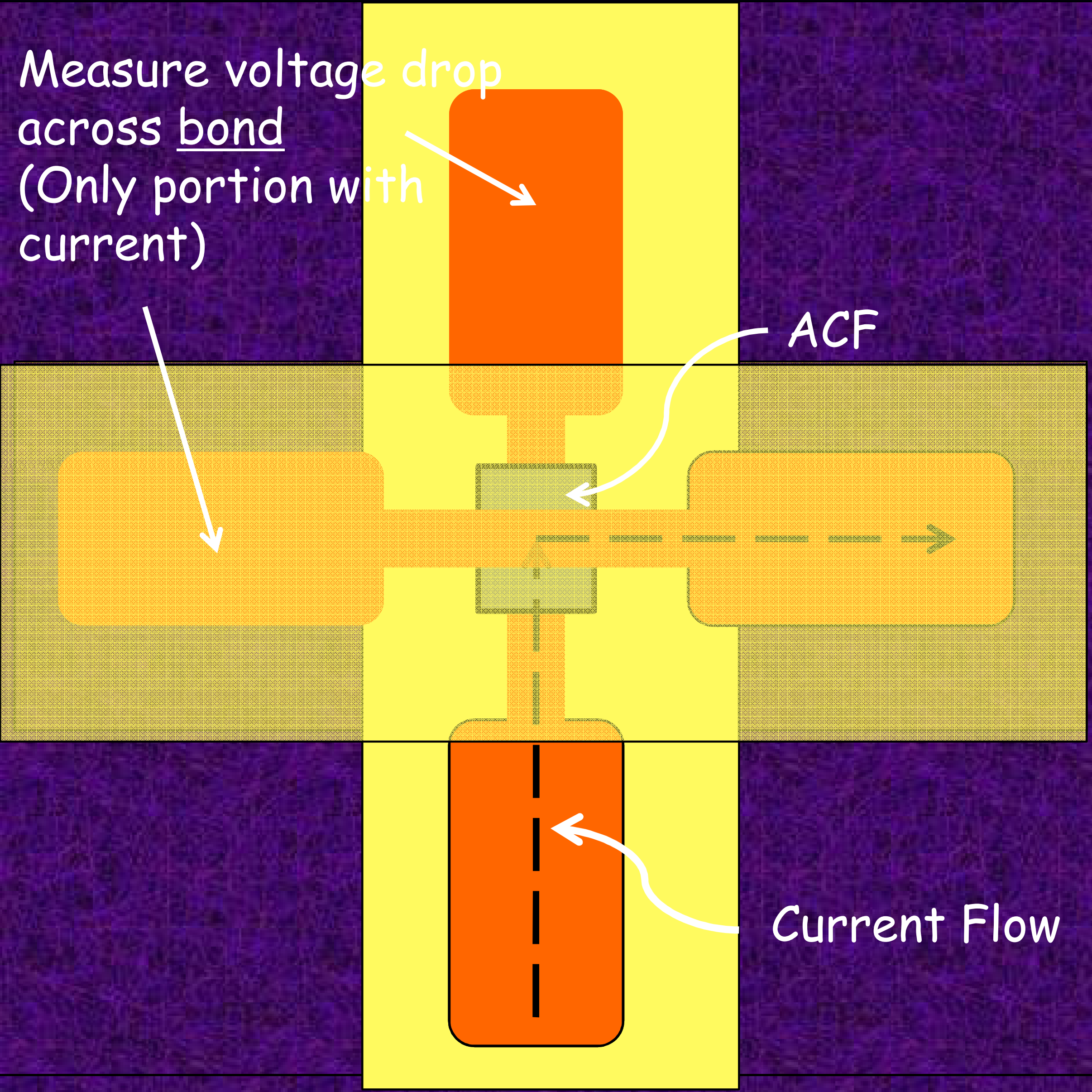


"Oozing" of adhesive needs to be studied and controlled.



Excess pressure causes rods to fall and flatten.

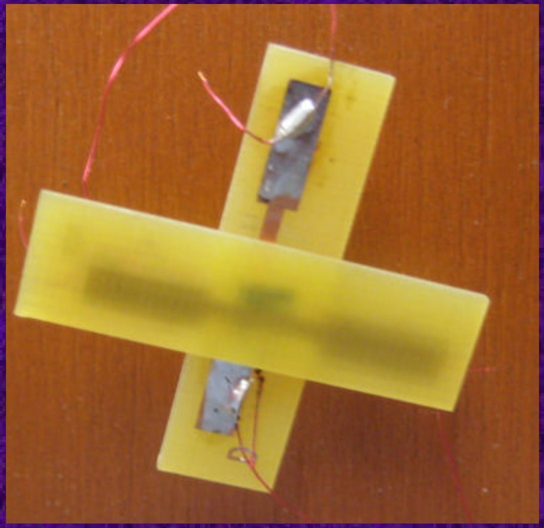
Test Setup: “4 point” R measure

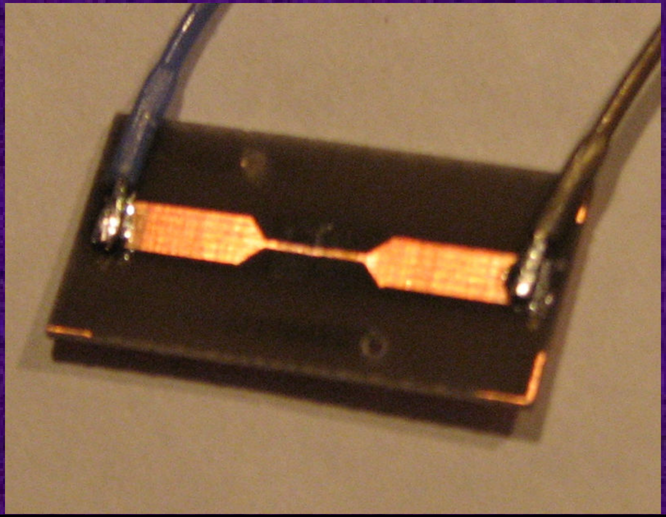


Measure voltage drop across bond
(Only portion with current)

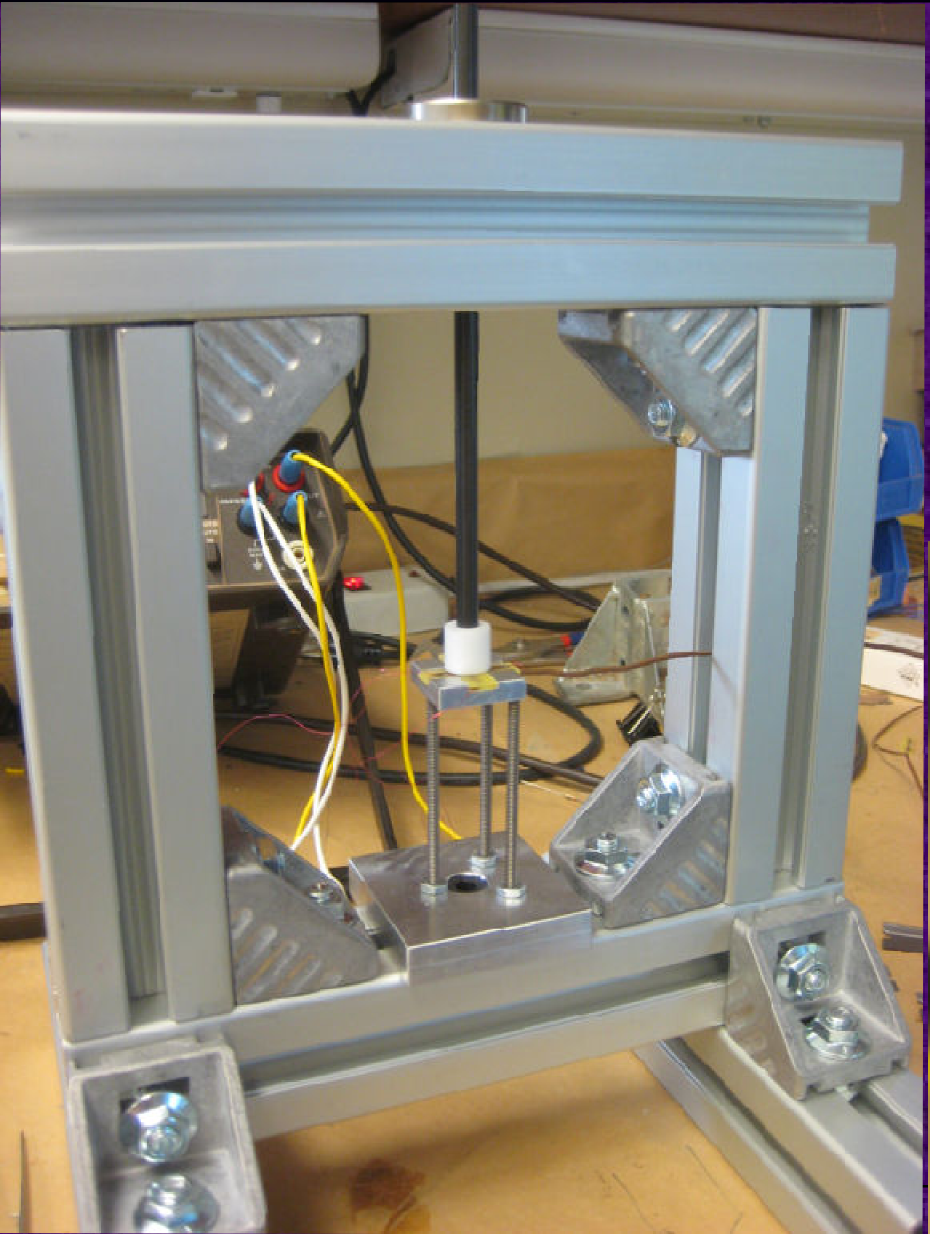
ACF

Current Flow



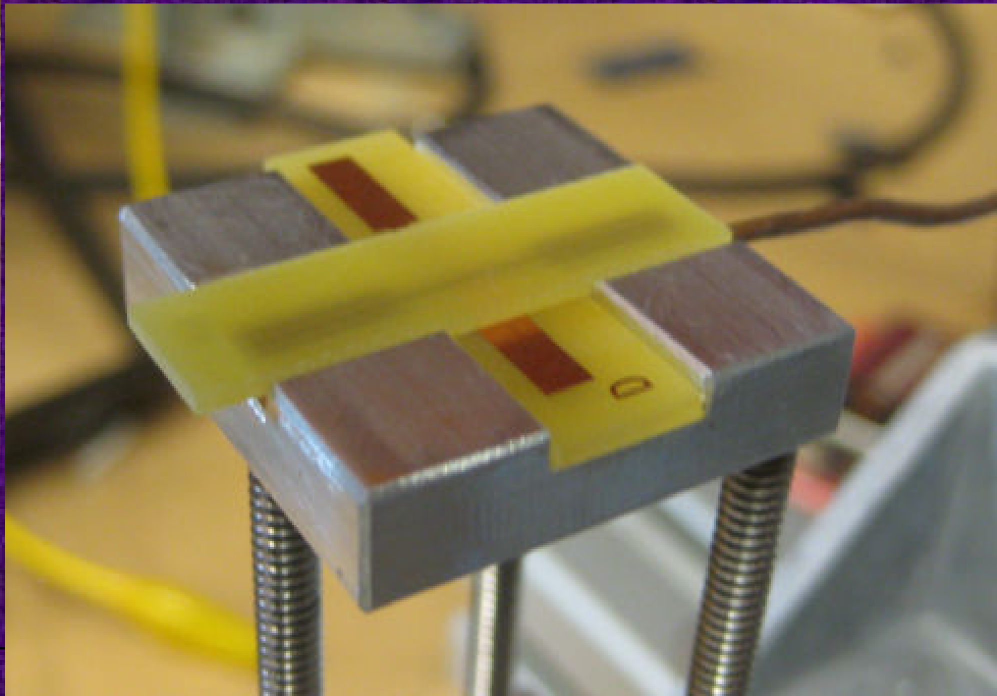


Jig for Forming the Connection

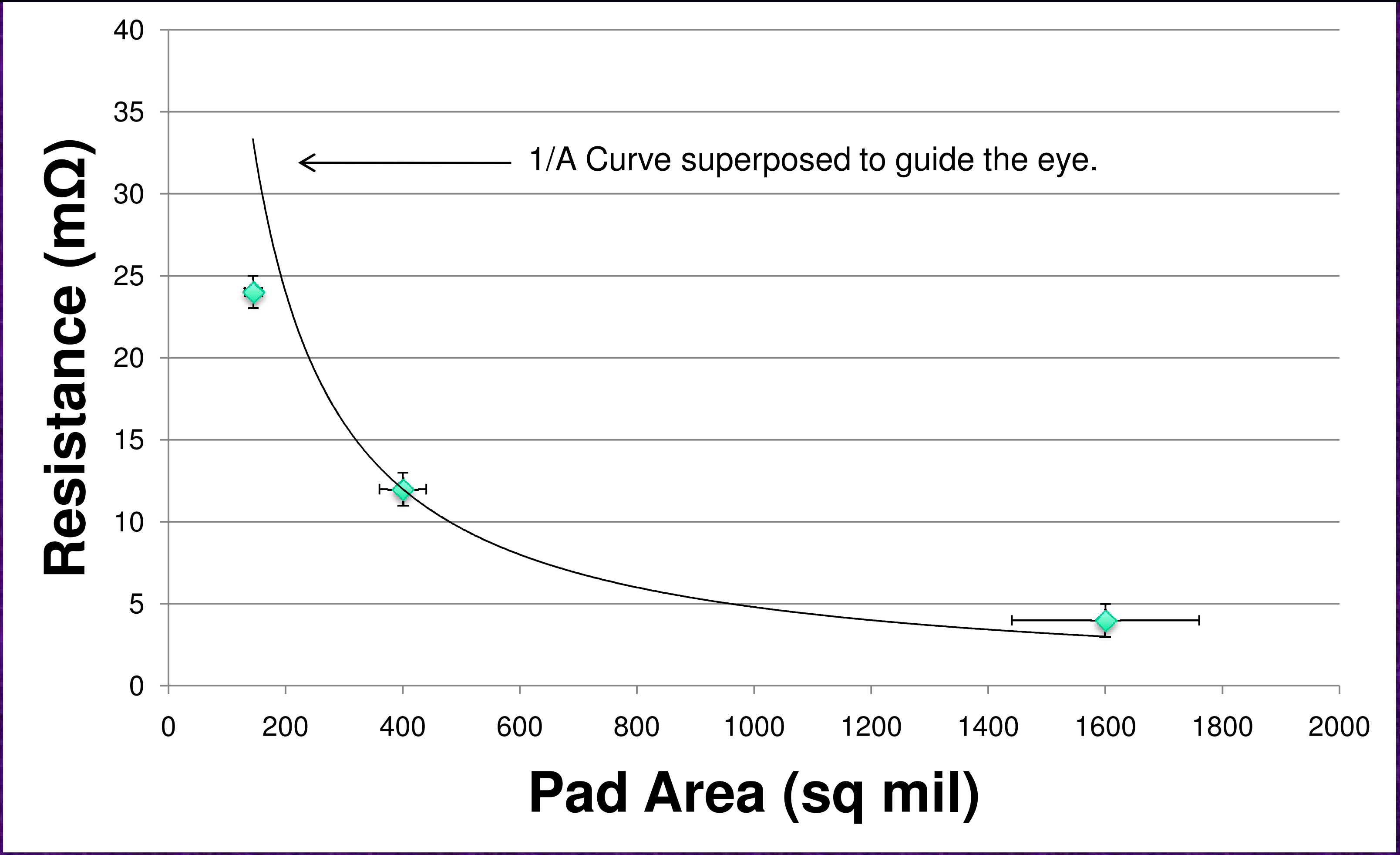


Temperature and pressure control and readback.

Duration and ramp-up/ramp-down are also factors.

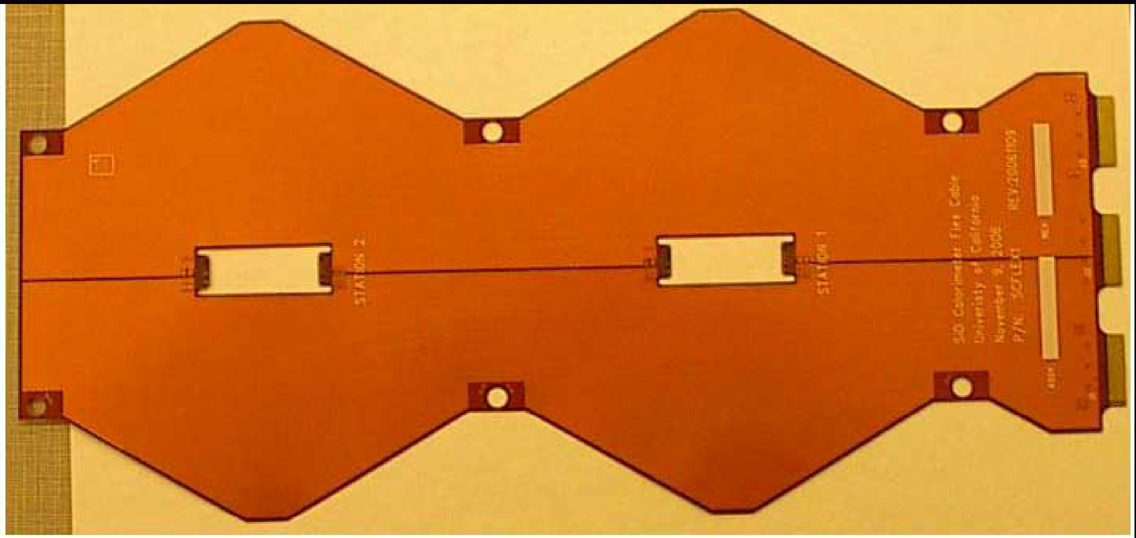


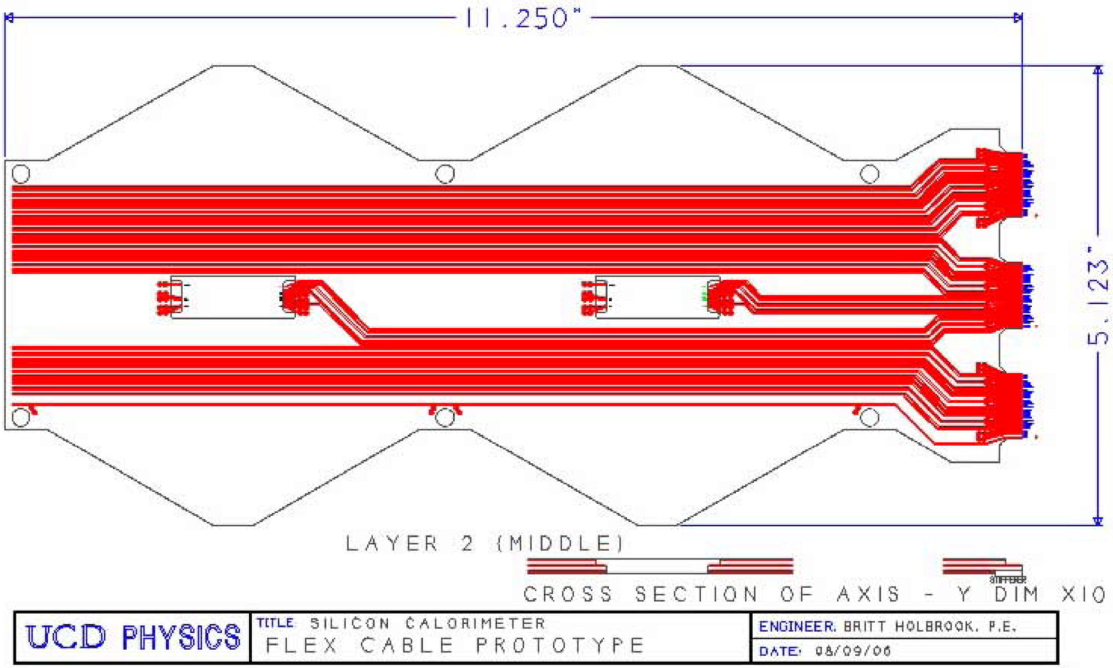
Initial Results



The results are promising. Goal for Flex Cable pads (100 sq mil) is ~100 mΩ, which is achievable.

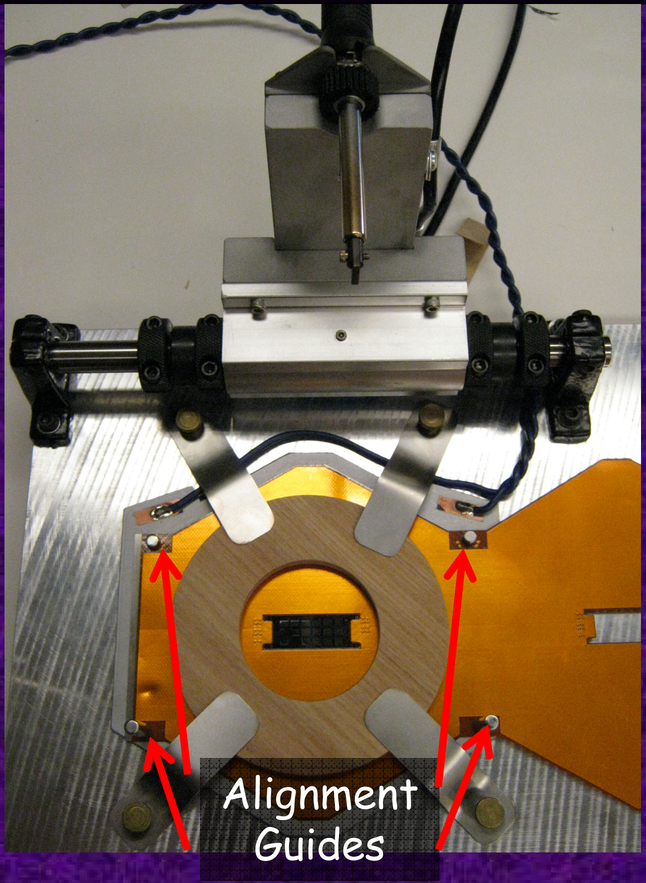
Readout flex cable





- Second prototype tested well with no problems:
  - 2 chip stations
  - Buried digital signal layer between power and ground planes
  - Two "lips" per KPiX from the buried layer.
- For 16 station cable:
  - A second vendor identified (produced long cables for EXO).

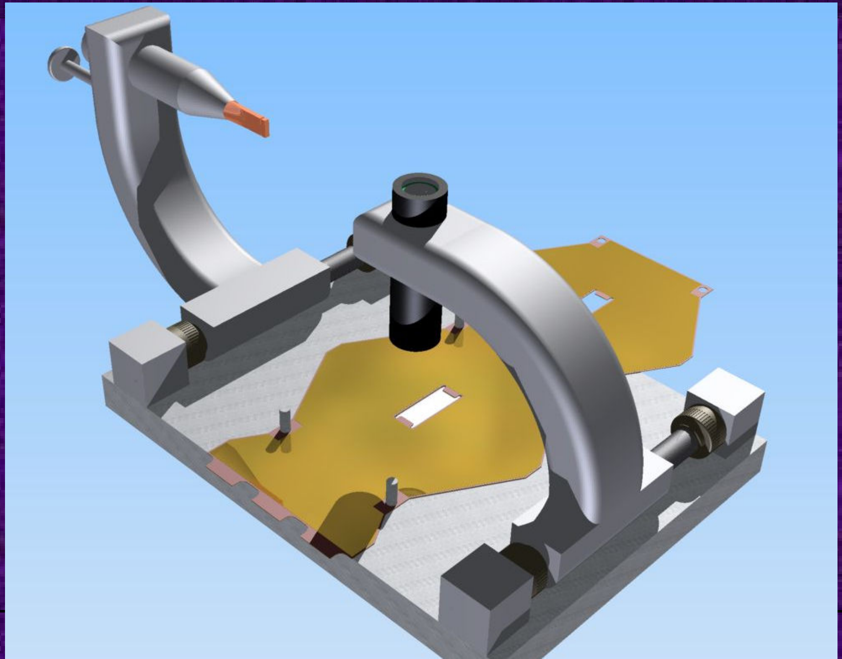
Prototype Bonding Jig



Swinging heating arm.

Adjustable Factors:

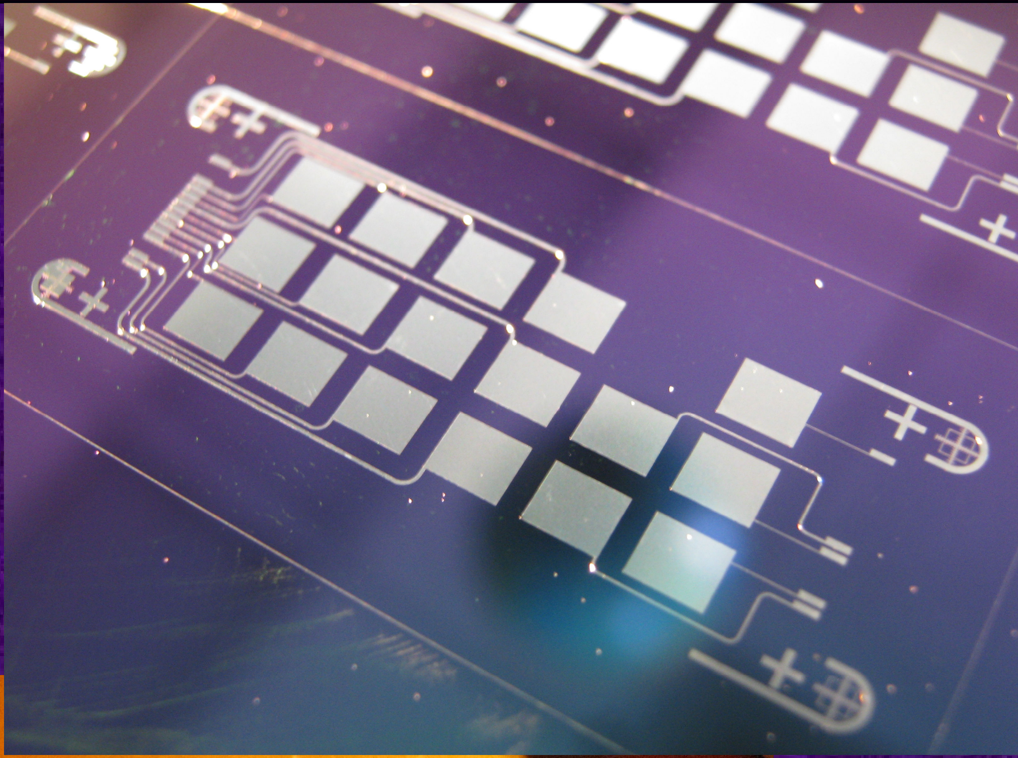
- Preheat wafer and flex cable.
- Tip temp
- Tip position
- Tip angle
- Pressure



ACF manufacturer supplies ideal parameters. Testing requires adjustment toward them.

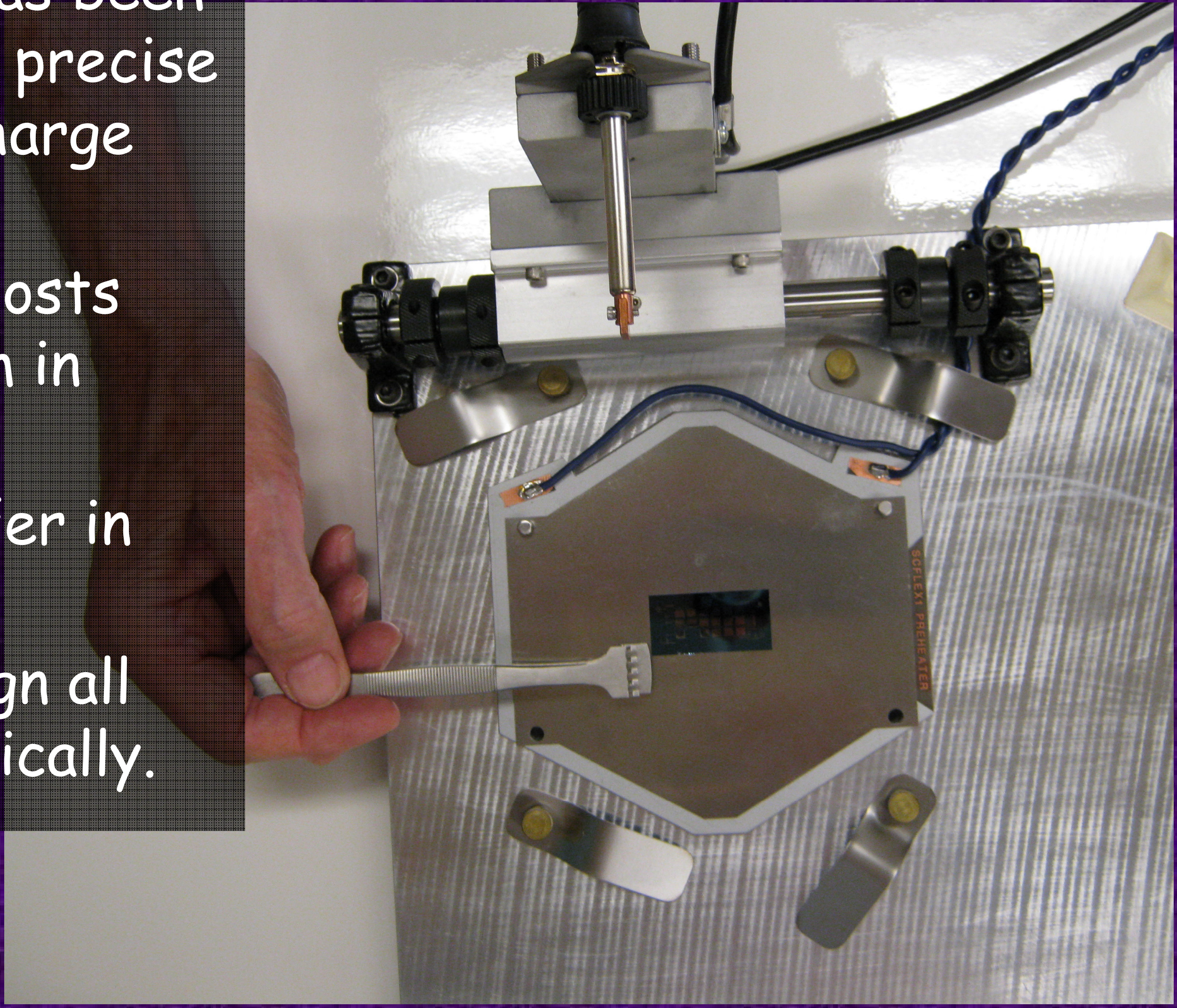
Test Wafer

- Hamamatsu wafers too expensive to test on.
- Ti-W test wafer mimics the read portion of the Hamamatsu wafer.
- Large pads for read out where bump bond positions would be.



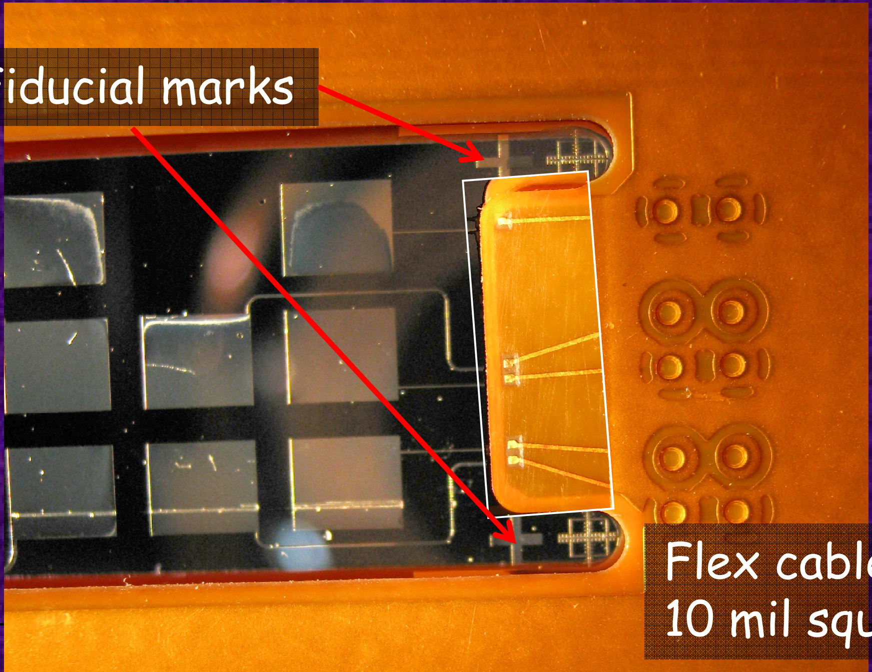
Wafer alignment via EDM shim

- A metal shim has been produced using precise electrical discharge machining
- Jig alignment posts hold metal shim in place.
- Shim holds wafer in cutaway.
- Guide posts align all pieces automatically.



Precision Alignment

- ACF does not need alignment.
- Flex cable and wafer do.

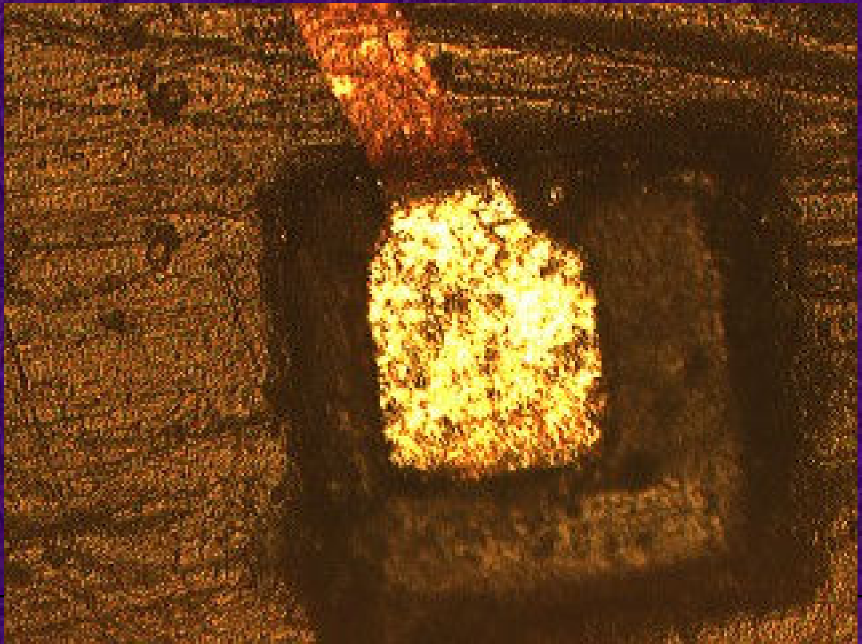


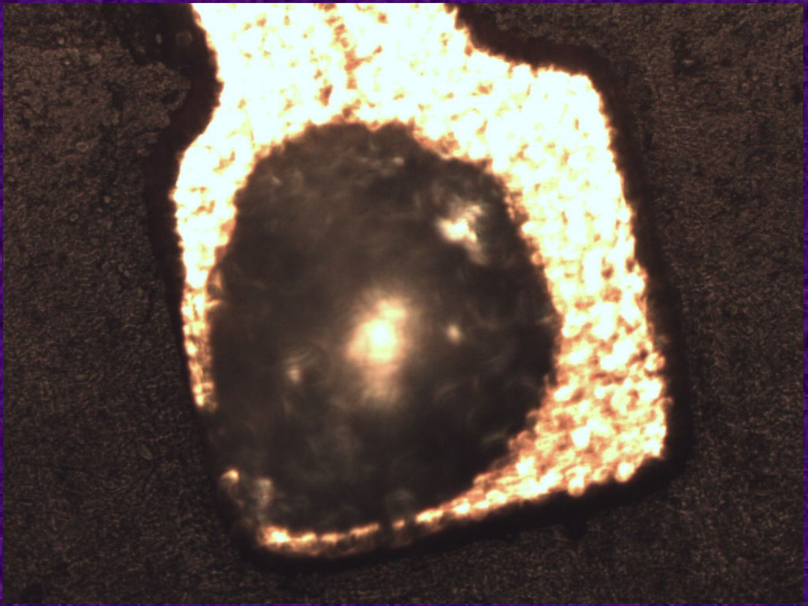
Fiducial marks

Flex cable pads revealed.
10 mil square pads

Silver Epoxy

- A flaw in flex cable design was discovered. Groups of pads existed 20 μm deep in overlay well left over from gold deposition.
- Manual removal of overlay (young eyes).

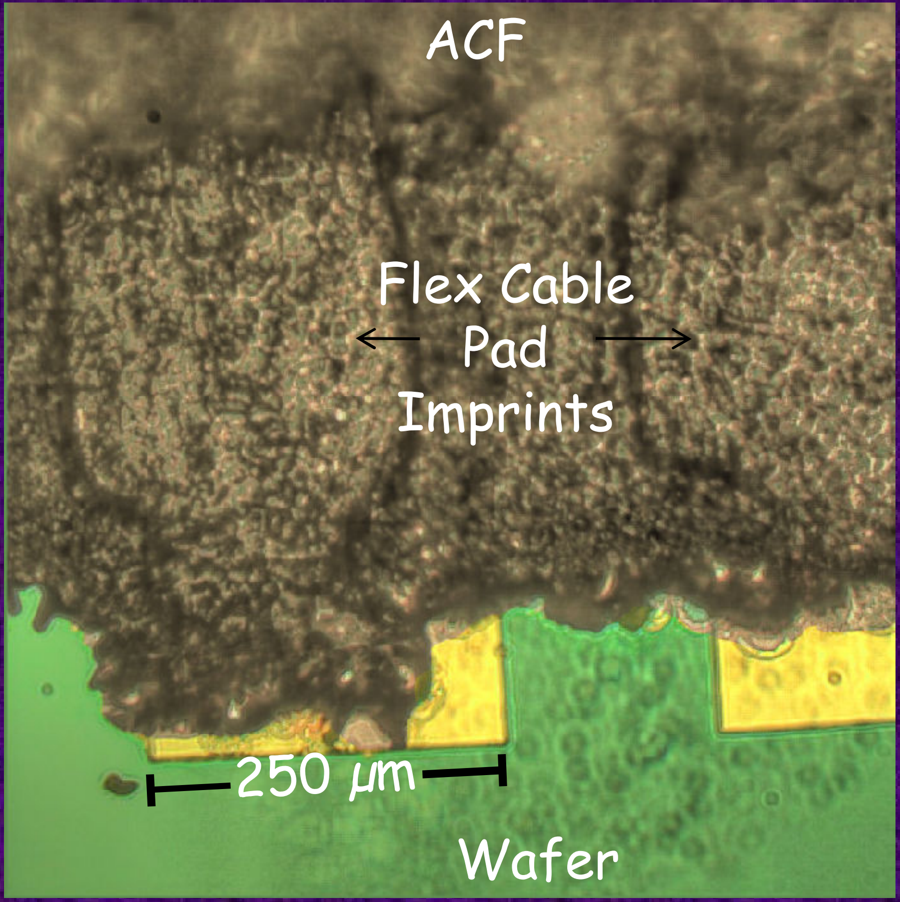




Successful flex cable to new gold test wafer. Continuity from wafer through flex cable for all channels.

First results from ACF Attachment

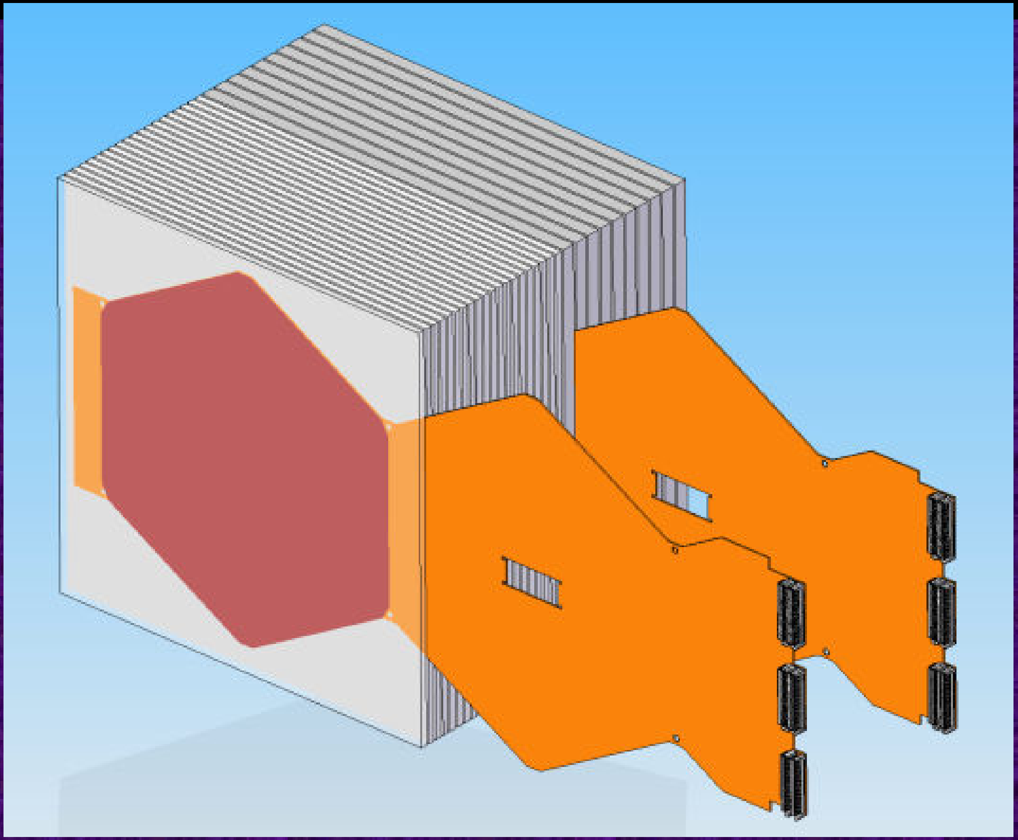
- Flex cable and wafer do.
- Flex cable, jig, and wafer all align to ±20 microns.
- Full cable to be bonded in stages.



Indentation on ACF from Flex Cable pads after detachment of bonding surfaces.

Summary

- The R&D for Si-W interconnect technology is progressing steadily.



Next Steps

- Further investigation of bonding parameters
- Silver Epoxy: study of surface metallization

Near-term Goal

- Construct a "Tower": full-depth (30 layer), single-wafer wide module with 1024 channel KPiX chips bonded to sensor wafers and read out via flex cables. => Test Beam.