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Assessing Pad Damage and Bond Integrity for Fine Pitch Probing

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- Challenges of die shrinks using finer geometry processing include wafer test and packaging
- Ball bonding used to be the gating technology to go to finer pitches and smaller pad sizes
- Ball bonder machines have solved their problems and have machines for production down to 50 micron pitches
- Probe technology now becomes the bottleneck to get to finer pitches and smaller pad size devices
- Requires a new technology to meet these challenges

CHIP SHRINKS DRIVE THE CHANGES

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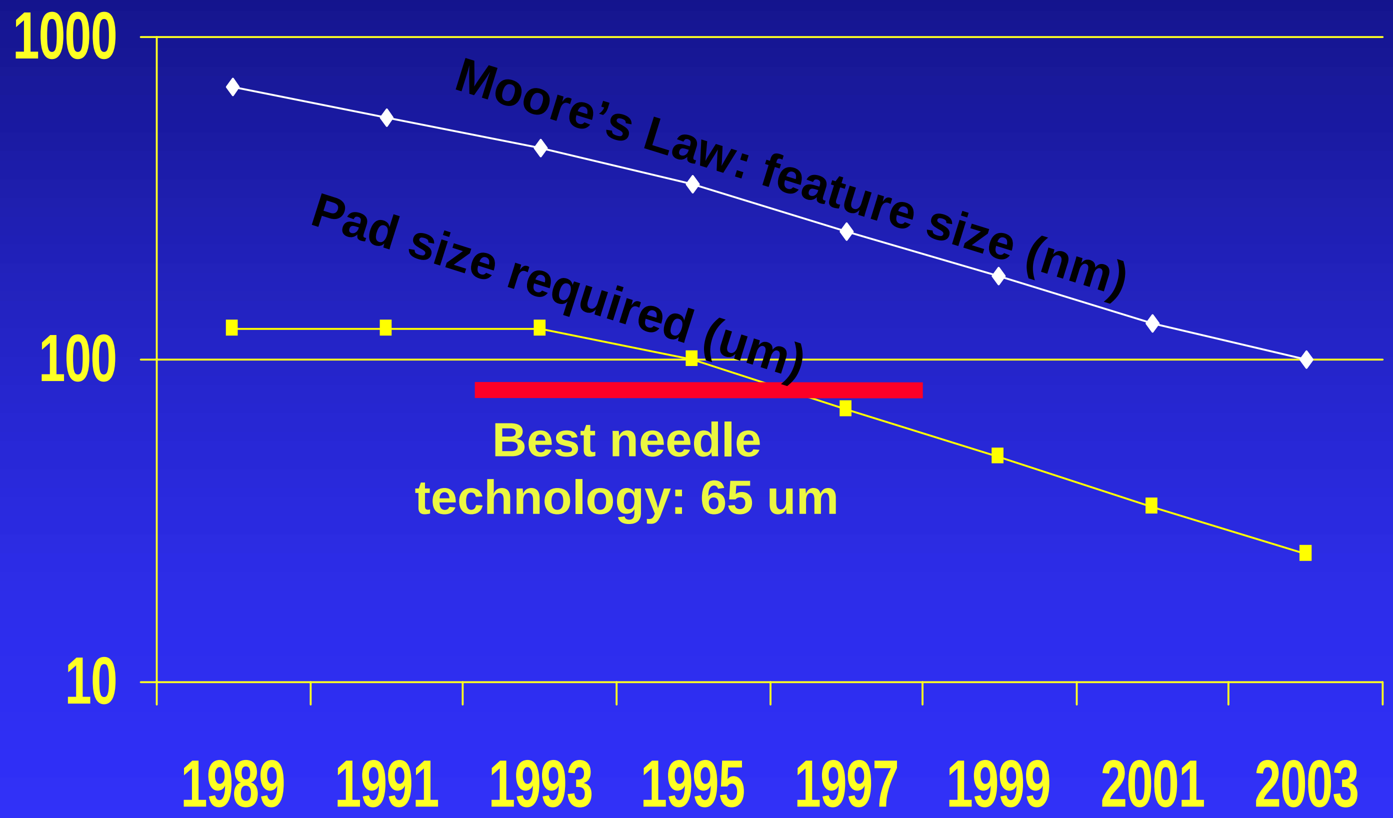

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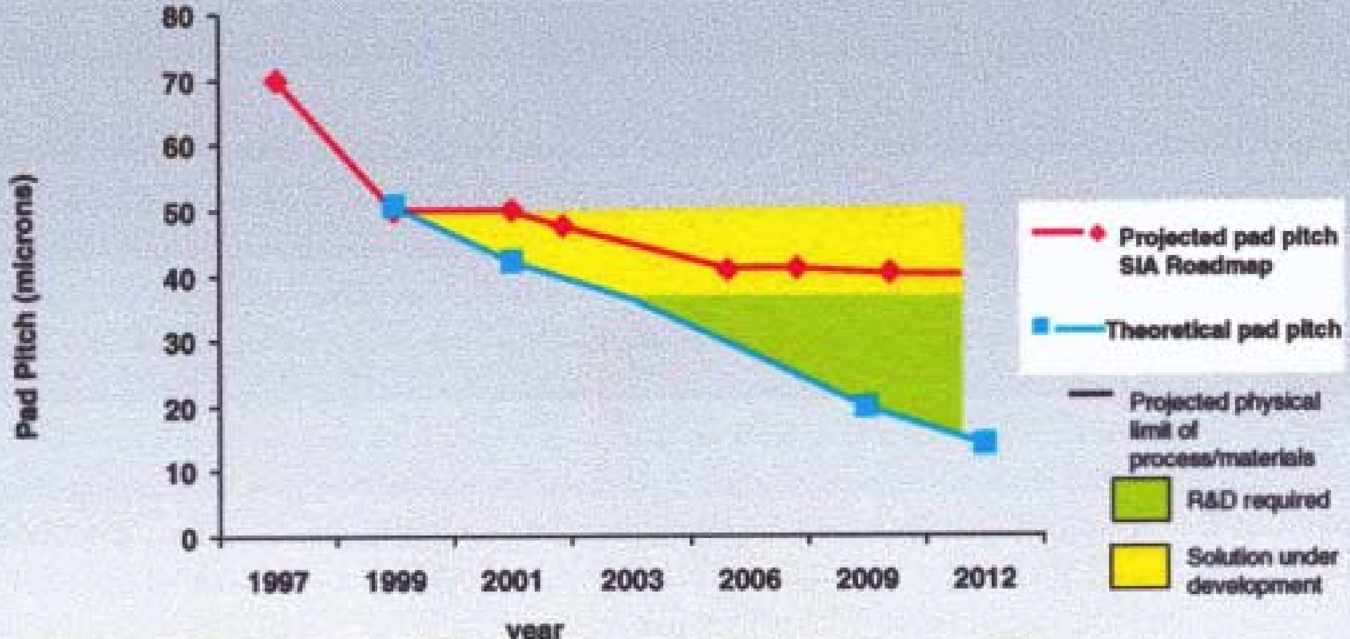
Pad Pitch Roadmap*



	1997	1999	2001	2003	2006	2009	2012
Fine line (µm)	0.25	0.18	0.15	0.13	0.1	0.07	0.05
% of reduction normalized		28%	17%	13%	23%	30%	29%
Projected pad pitch SIA	70	50	50	50	50	50	50
Theoretical pad pitch		50.4	42	36	28	19.6	14

*1998 SIA Roadmap

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Ball Bonding Technology has arrived to meet these challenges

Ball Bonder specifications required for 50 Micron Pitch

- Bonded Ball Size (BBS)
  - 36 microns for a 45 micron pad (50 micron pitch)
- Finer wire diameters (WD)
  - 21-23 microns
- Machine accuracy (MA)
  - ± 4 microns
- Capillary dimension (CD)
  - 35 microns

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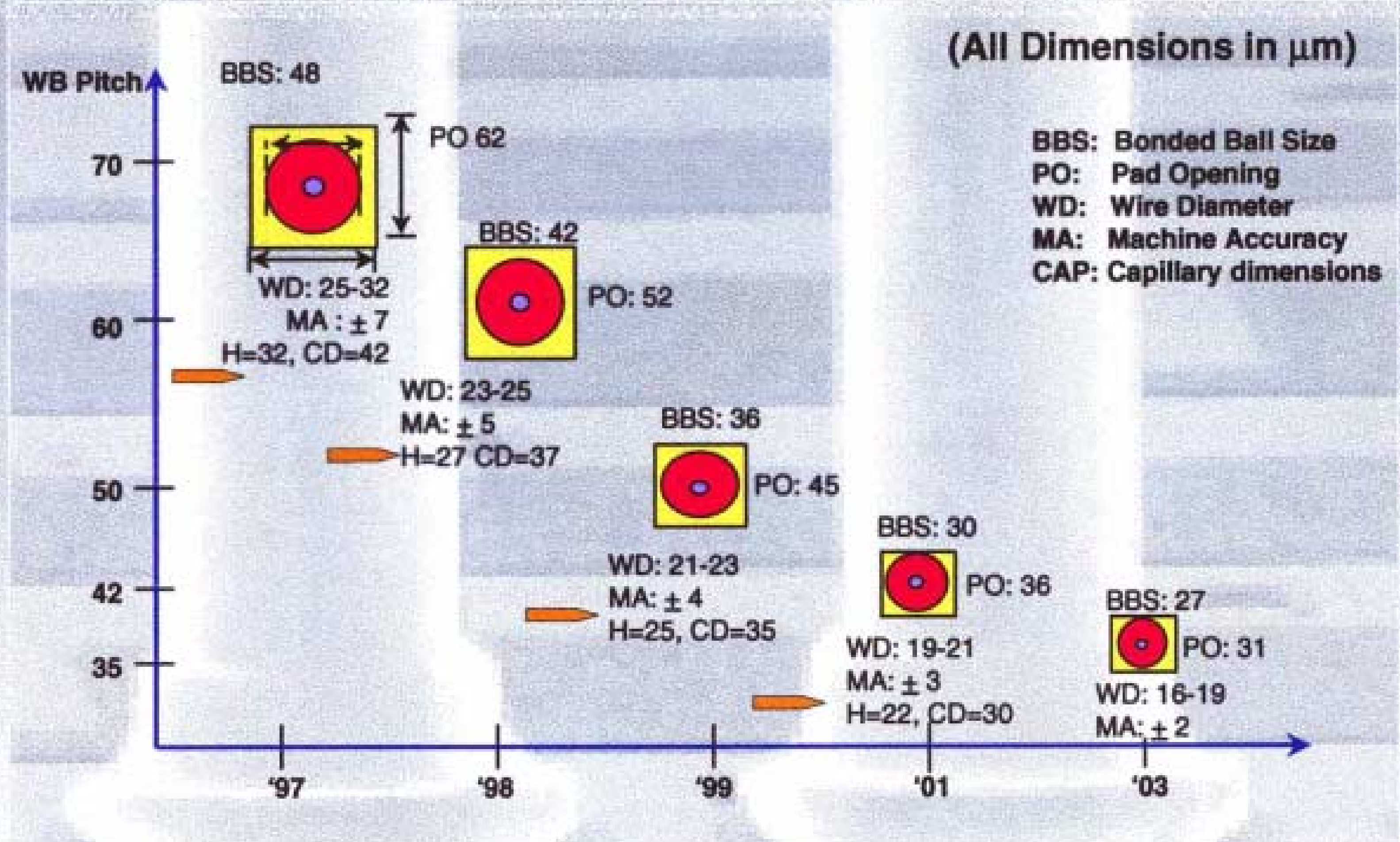
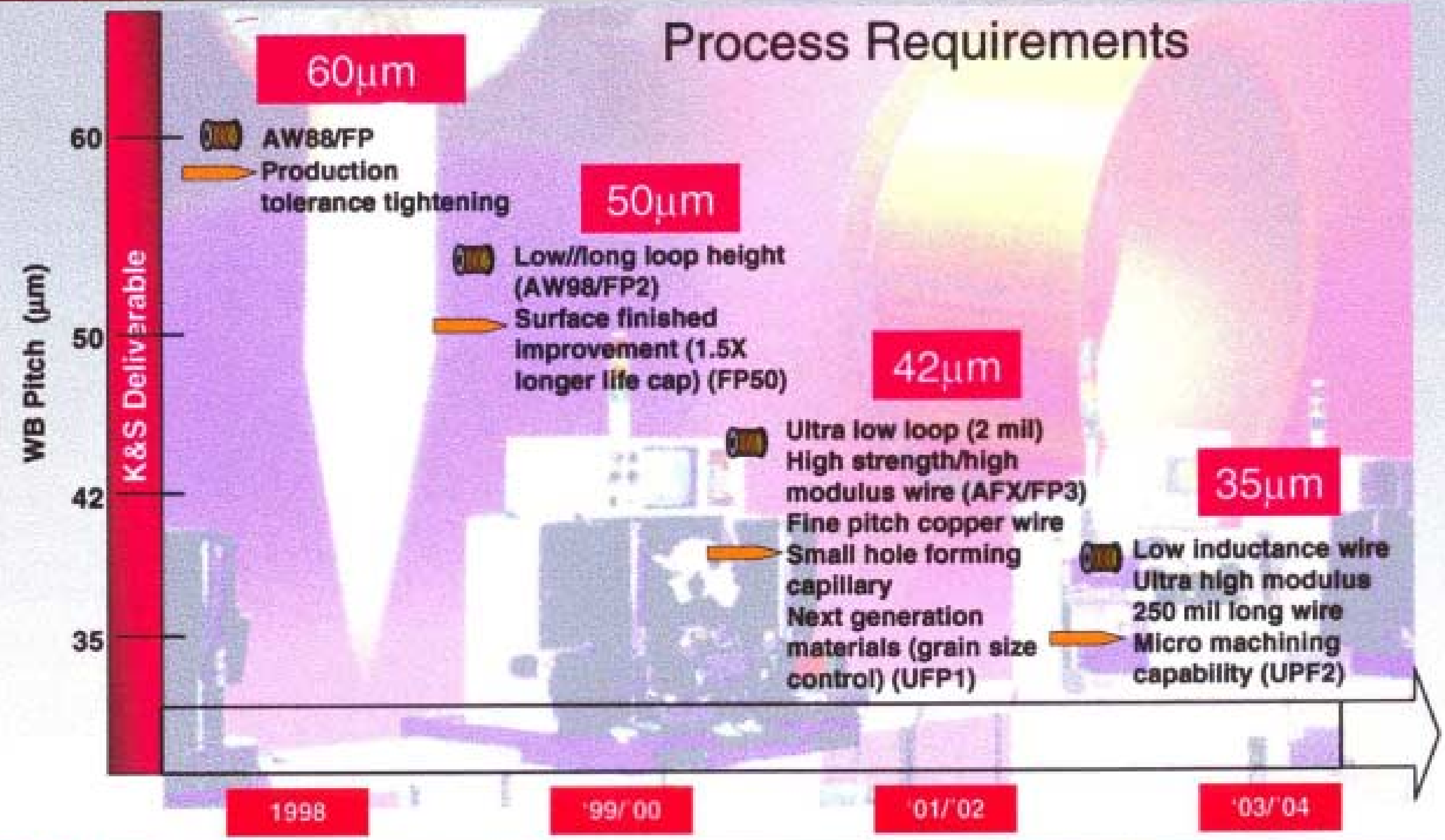
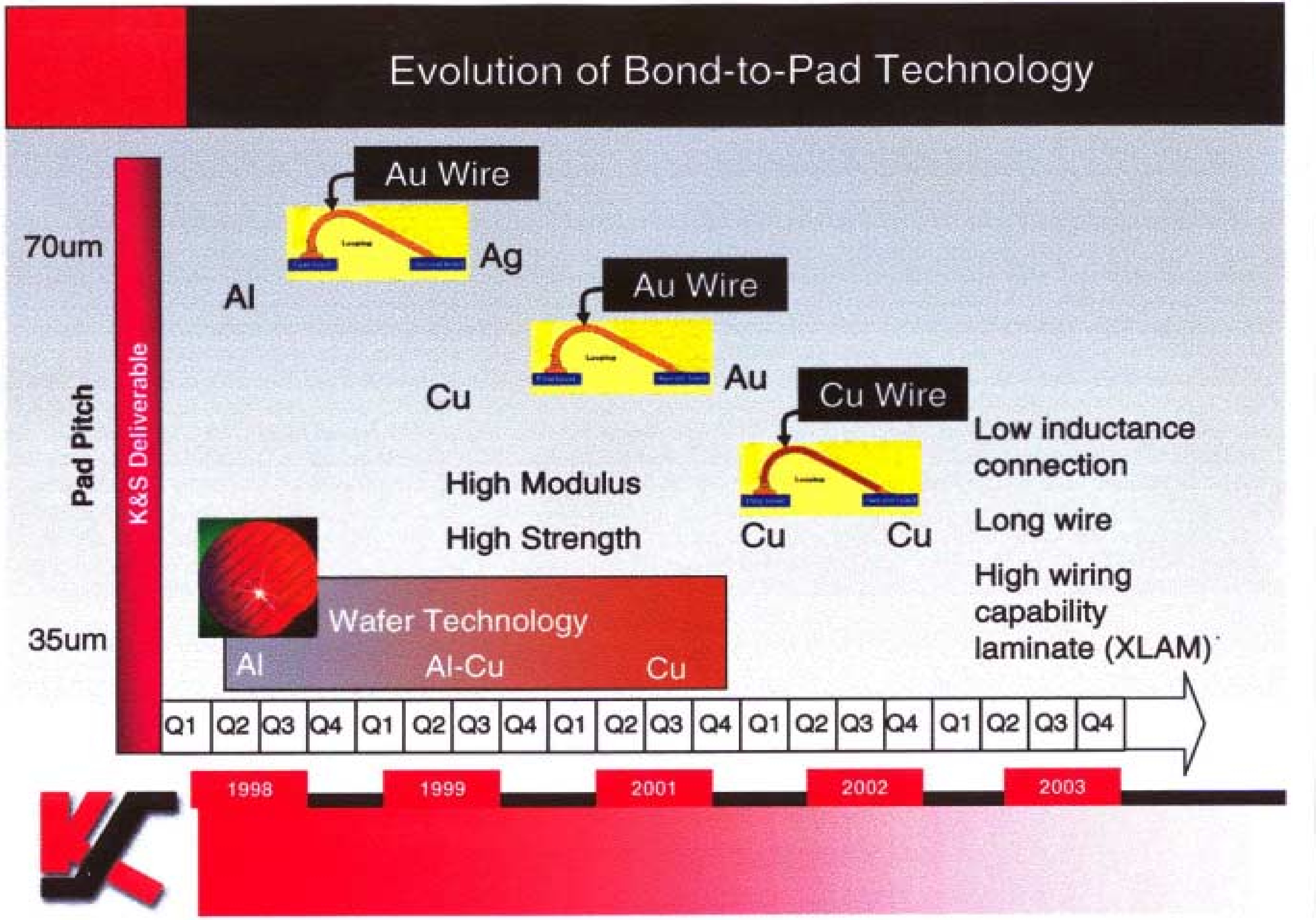
Process Requirement vs. Pad Pitch



Ball Bonding Materials Roadmap




Evolution of Bond-to-Pad Technology
Au Wire
70um
Ag
Al
Au Wire
Au
Cu
Cu Wire
Low inductance connection
High Modulus
High Strength
Cu
Cu
Long wire
High wiring capability laminate (XLAM)
Wafer Technology
35um
Al
Al-Cu
Cu
Pad Pitch
K&S Deliverable
Q1 Q2 Q3 Q4 Q1 Q2 Q3 Q4 Q1 Q2 Q3 Q4 Q1 Q2 Q3 Q4 Q1 Q2 Q3 Q4
1998
1999
2001
2002
2003

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Key Probe Parameters and Measurement Techniques

- Probe technology is key to being successful at wafer probing finer pitch devices
  - Placement accuracy (x-y dimensions)
  - Probe mark dimension and scrub length
    - Optical measurement techniques for dimension and placement accuracy
  - Pad damage from probe affects ball bond integrity and reliability
    - Stylus or optical profiler

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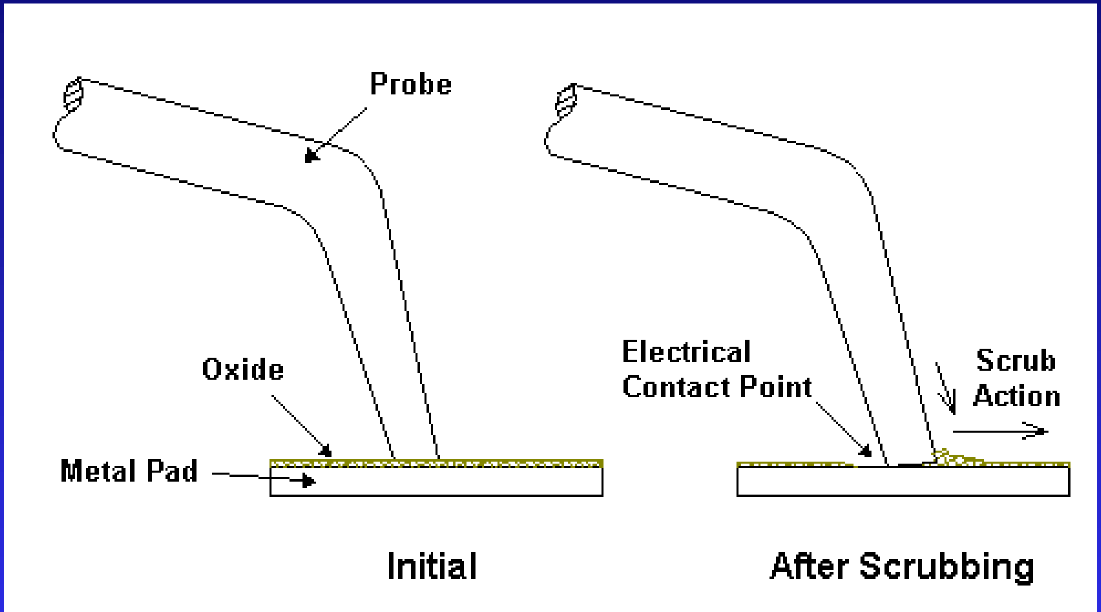
Epoxy Ring Probe needle

- Cantilever beam scrubbing action



- Typical tip diameter is 25 microns (1mil)
- Typical scrub length is 15 microns
- Typical x-y positional accuracy (± 5 micron)
- Probe mark uncertainty (25 + 15 + 10) = 50 microns

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Standard Epoxy probe marks: note marks close to the edge of the passivation

Enhanced needles tips to minimize probe mark, (80 micron pad size)

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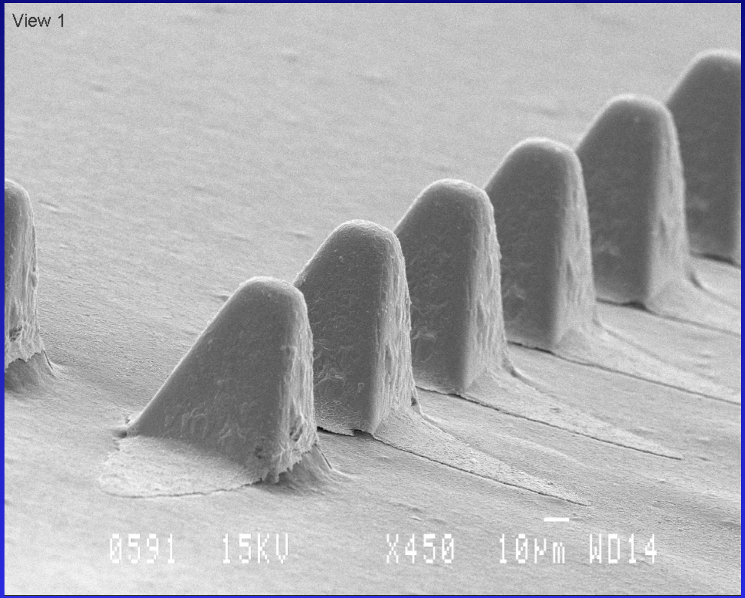
Different Pyramid Probe Tips

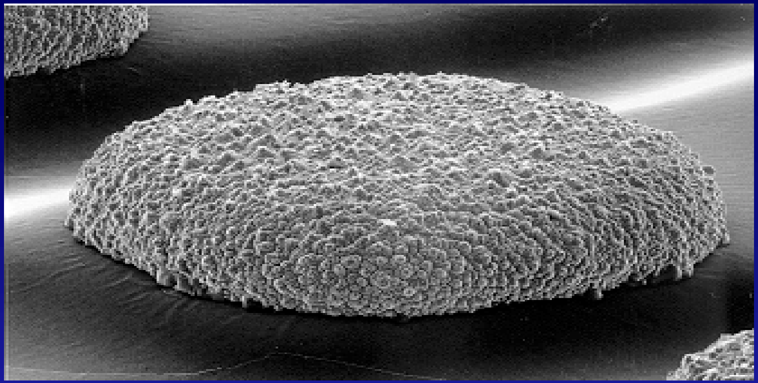


Probe tips for Al pads

•15 micron diameter

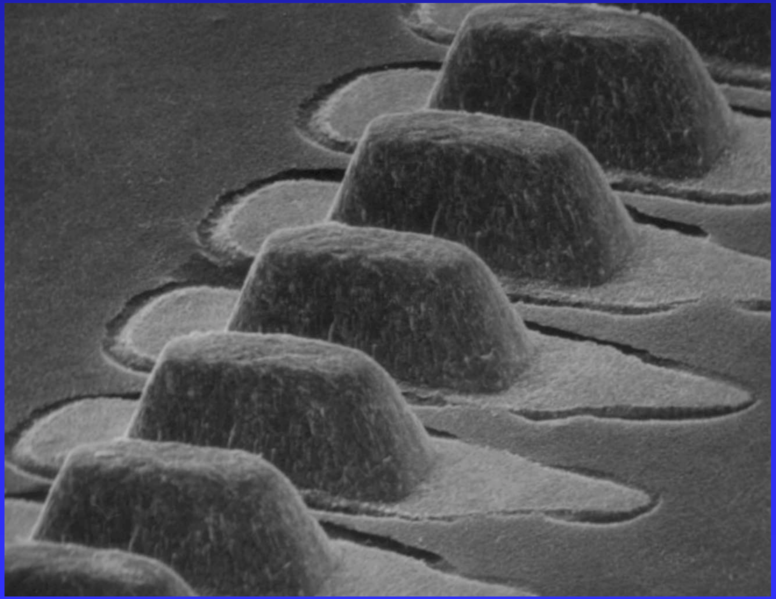
•60 micron tall

•80 micron pitch released production, have processed 40 micron pitch



Probe tips for Au pads and Solder bumps

•100 micron pitch, 60 micron contact area



Probe tips for gold bumps (LCD)

•50 micron pitch, 15 x 40 micron

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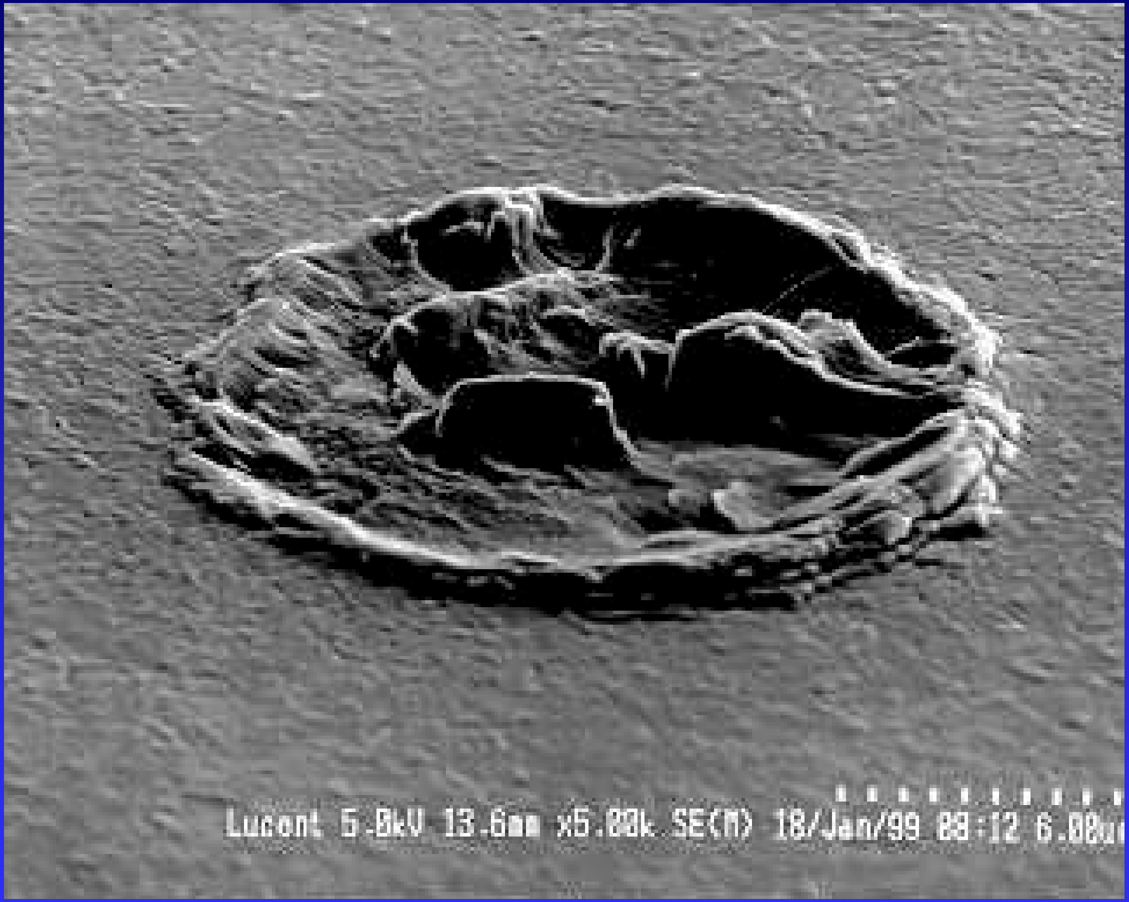
Pyramid Probe tip Al Scrub Marks



- Probe mark diameter- 15 microns
- 3 microns of scrub
- Total probe mark dimension in y direction of 18 microns
- X-Y placement accuracy of ± 2 microns

Pyramid VS Cantilever

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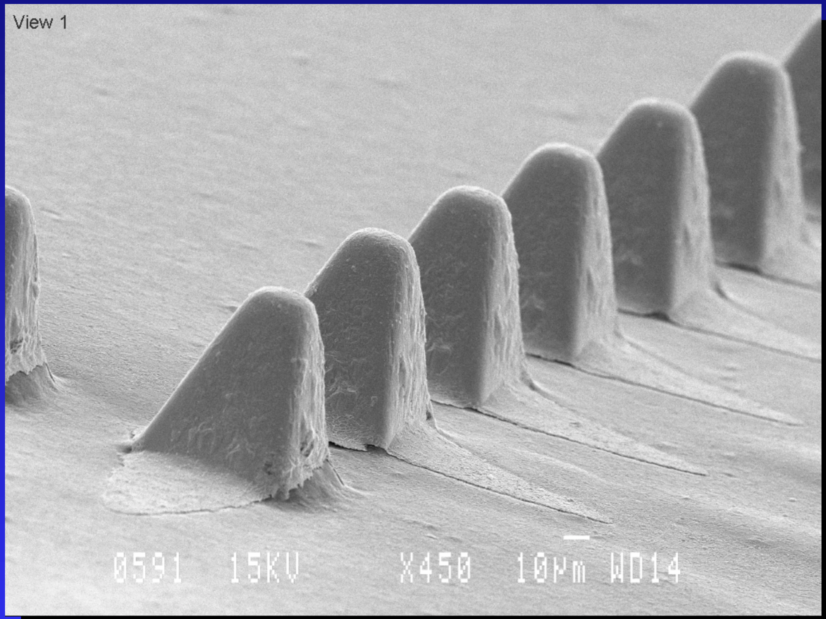
- SEM photo of needle tip and pyramid tip



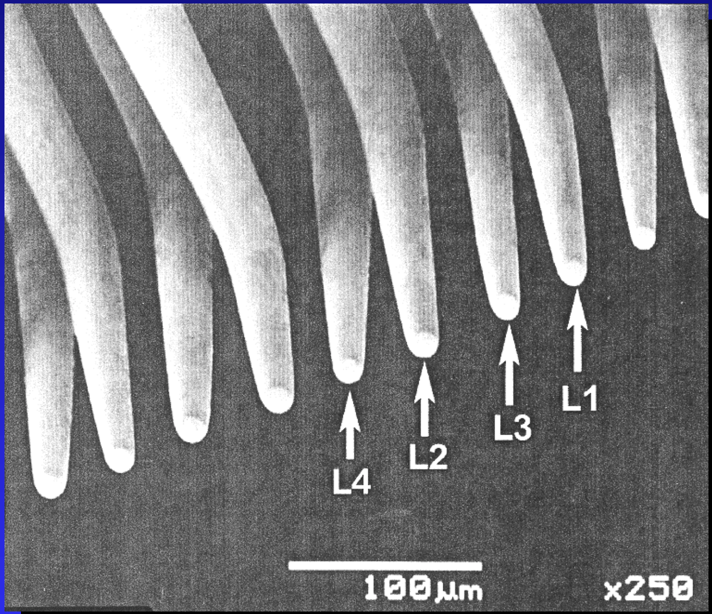


Photo-lithograph placed Pyramid Probe tips with 15 micron contact area at 60 micron pitch

Four tiers of needles mechanically placed to achieve 40 micron pitch

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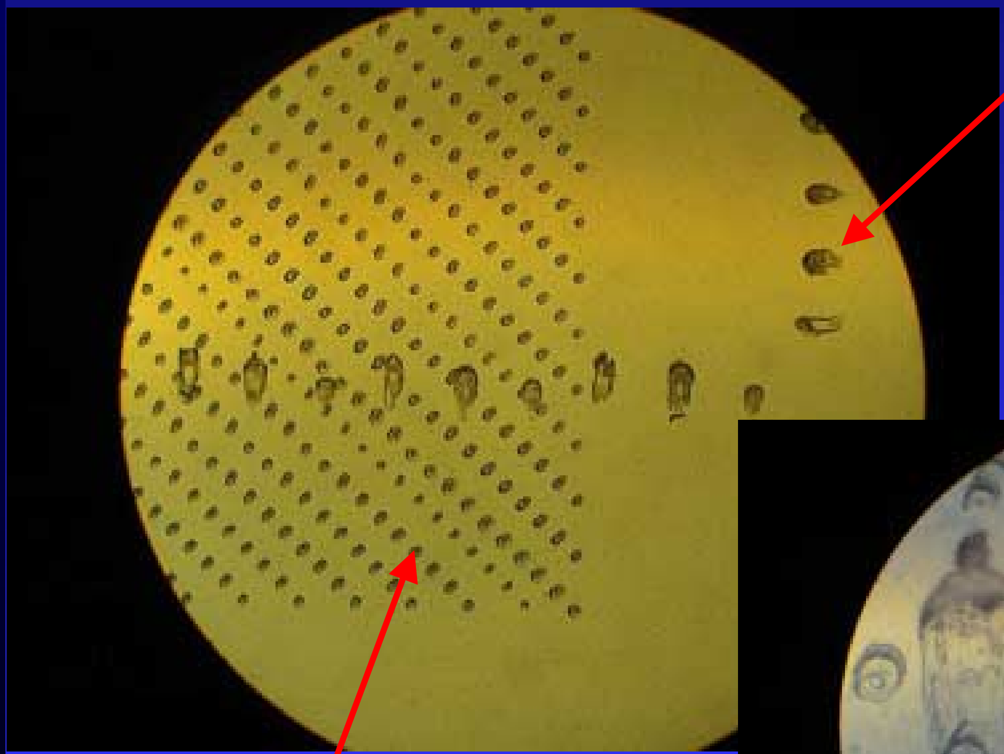
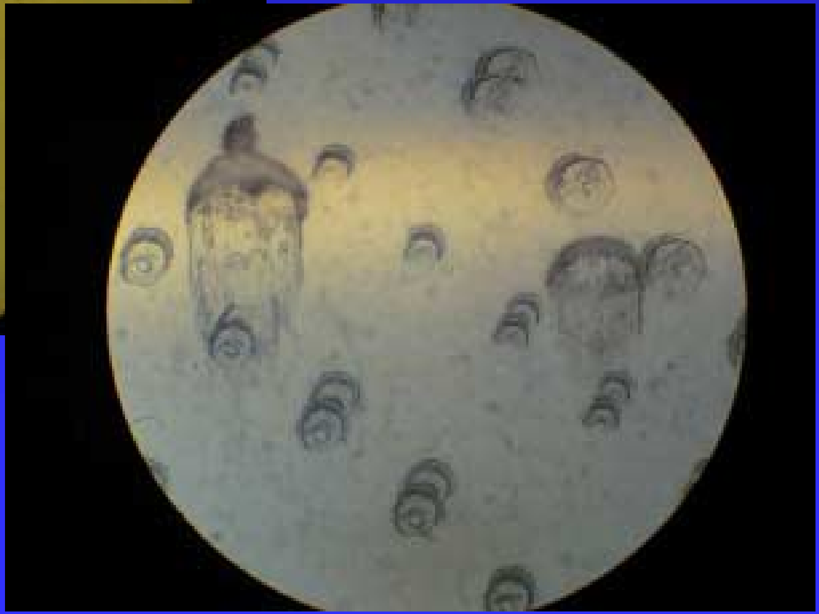
Pyramid Probe Marks vs Needle





Probe Mark Considerations

- **How much pad damage is to much damage?**

  Deformation of Bond Pad

  to

  Penetration to Under Pad Layers

  (Bond Pad over Active Circuit)

  (Low K Dielectrics)

  Long Term Reliability?

- **Current Approach**
  - **Modeling**
  - **Internal Test**
  - **Customer Test**
    - **Pad Materials vs Pad Thickness**
    - **Cap Materials over Cu Pads**
    - **Cu Pads**

Profile of a Pyramid Probe mark taken with an Optical Profiler

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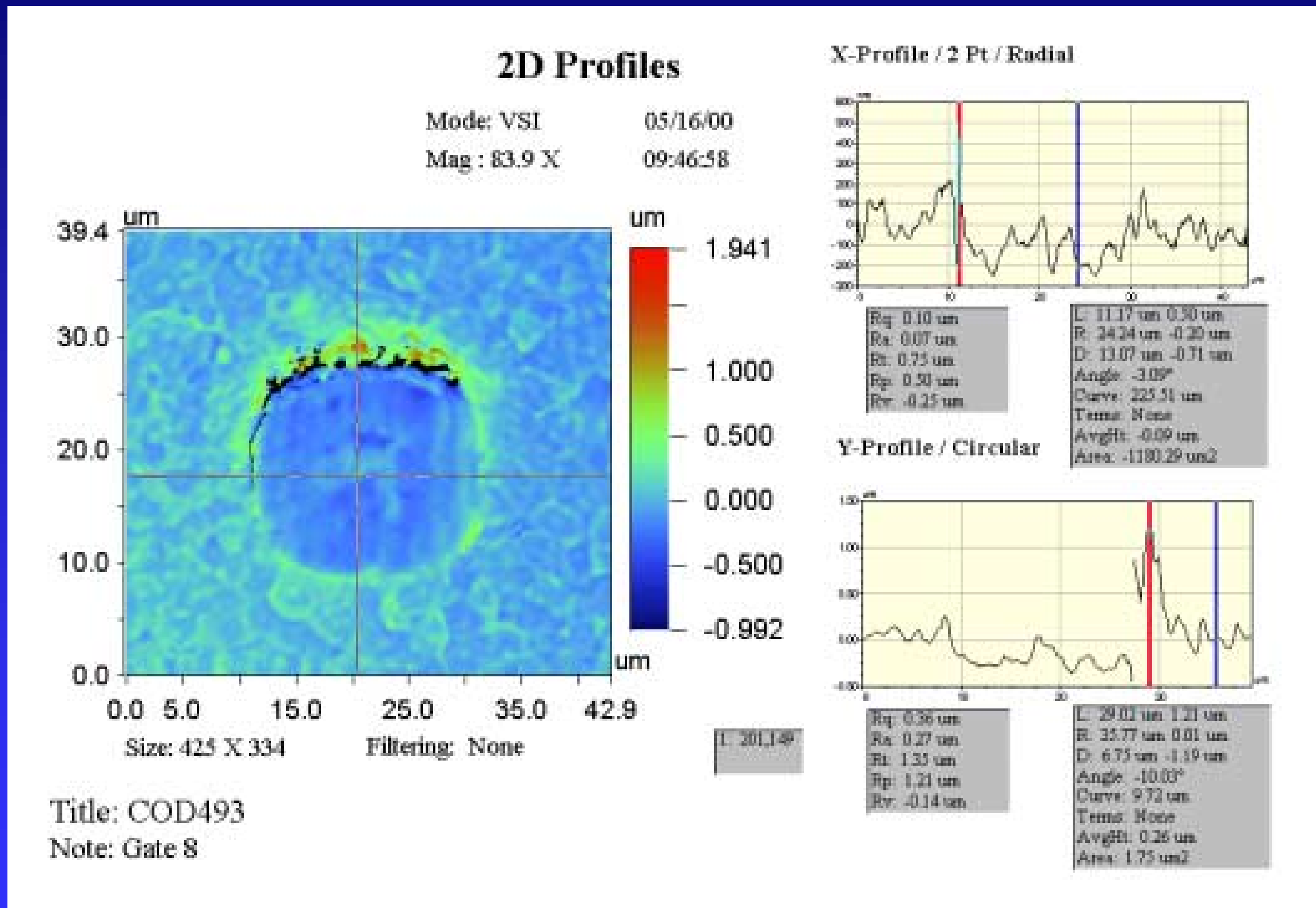

Wyko profiler, range of .1 nm to 5 mm, resolution .1 nm

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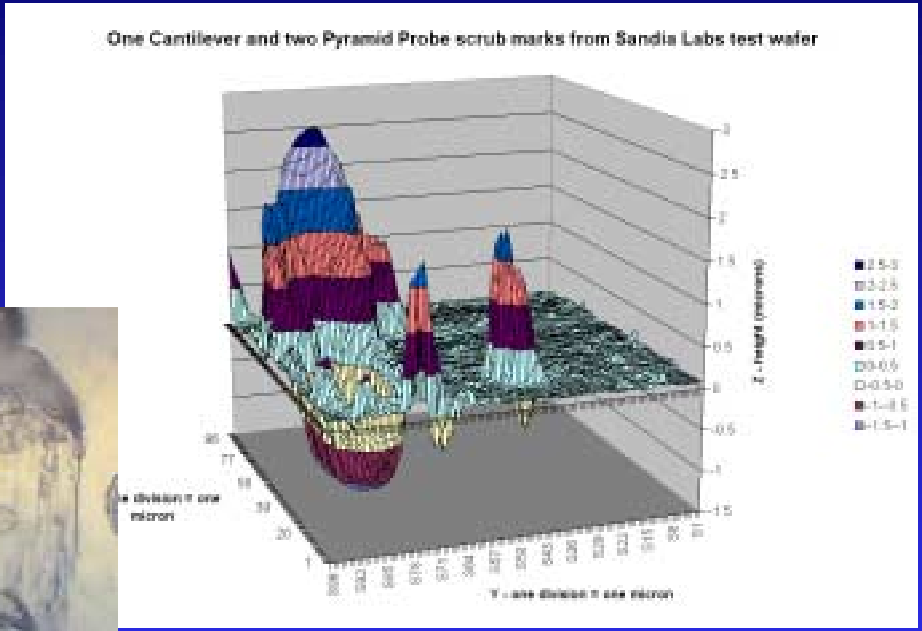
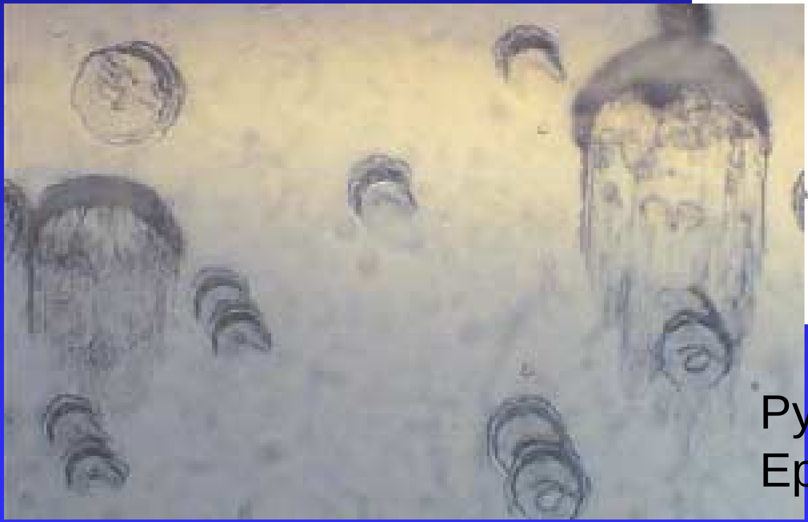
15 x Less Pad Damage

- Comparison of Pyramid vs Epoxy ring





Pyramid damage 85 cubic microns
Epoxy ring damage 1447 cubic microns

Pyramid Probe marks 15 x 20 microns

Epoxy ring marks 40 x 70 microns

Ball Bonding Update

Elements of Fine Pitch — Ball Bonds

Shear/unit area effect on IP

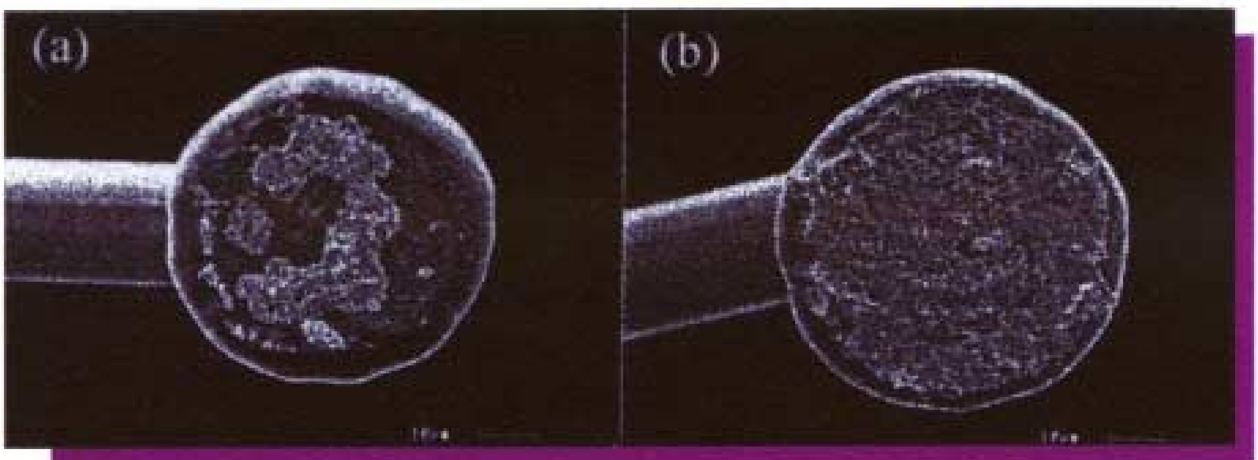
What shear / area is required for reliable bonding?

A direct correlation can be seen between shear / area and growth of intermetallic phases (IP)

$4.5\ g/mil^2 \cong$ 35% IP coverage

$5.5\ g/mil^2 \cong$ 55% IP coverage

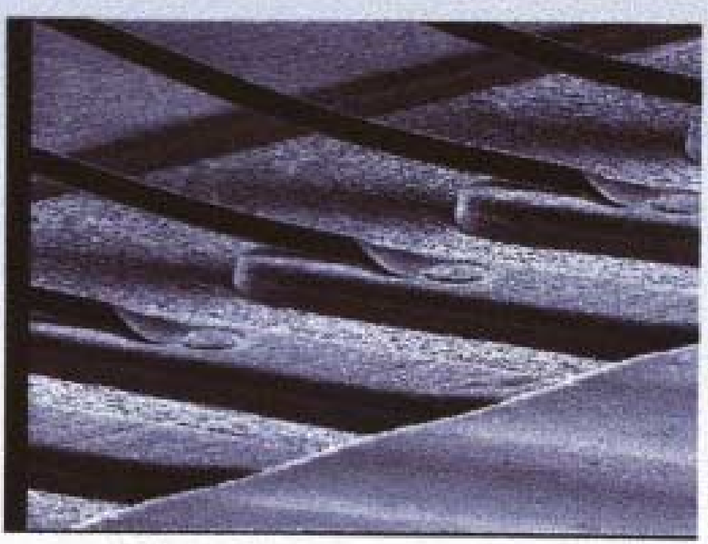
$6.5\ g/mil^2 \cong$ 75% IP coverage



35% IP, $4.5\ g/mil^2$ 75% IP, $6.5\ g/mil^2$

Cu Wire - Al Die

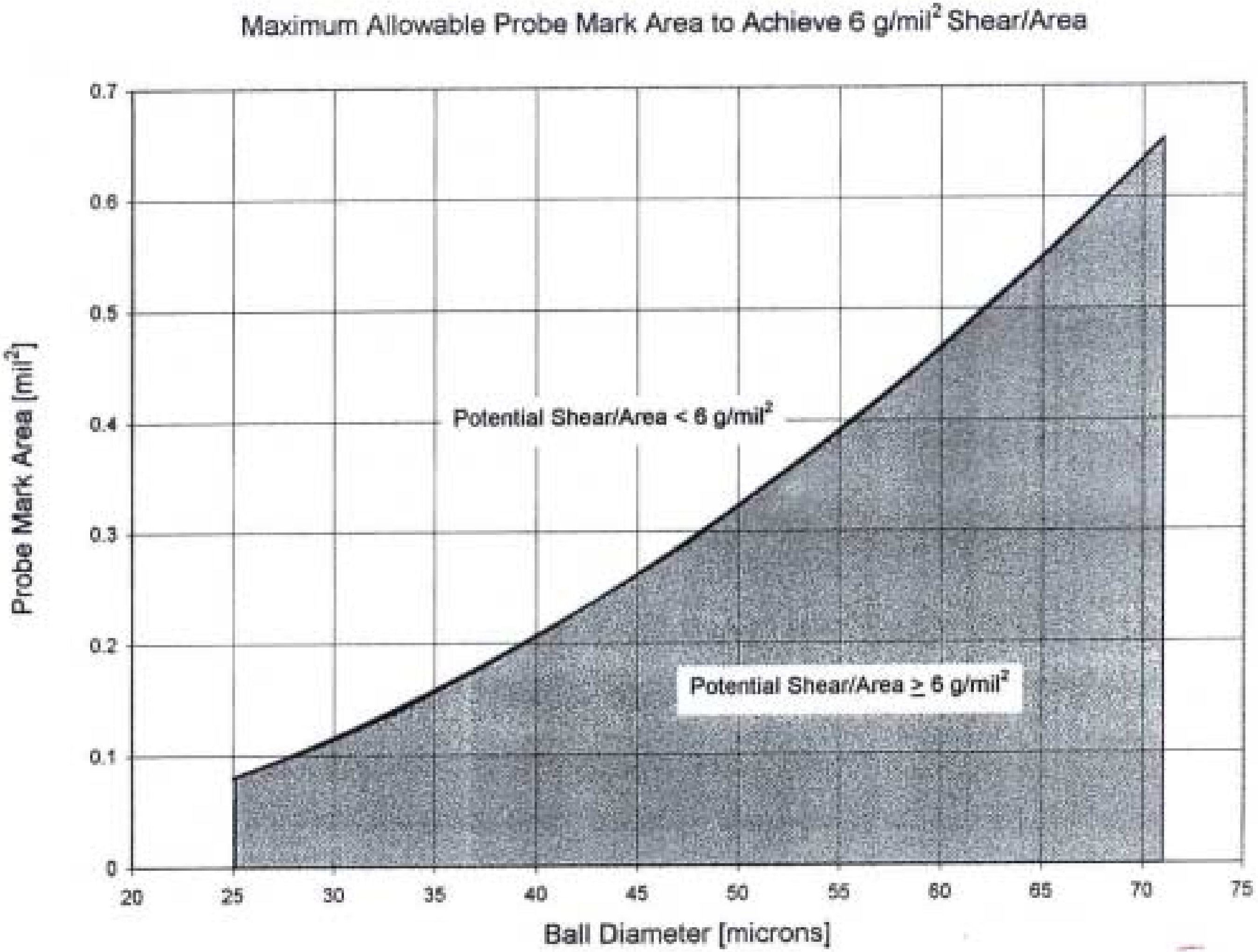
Program Status

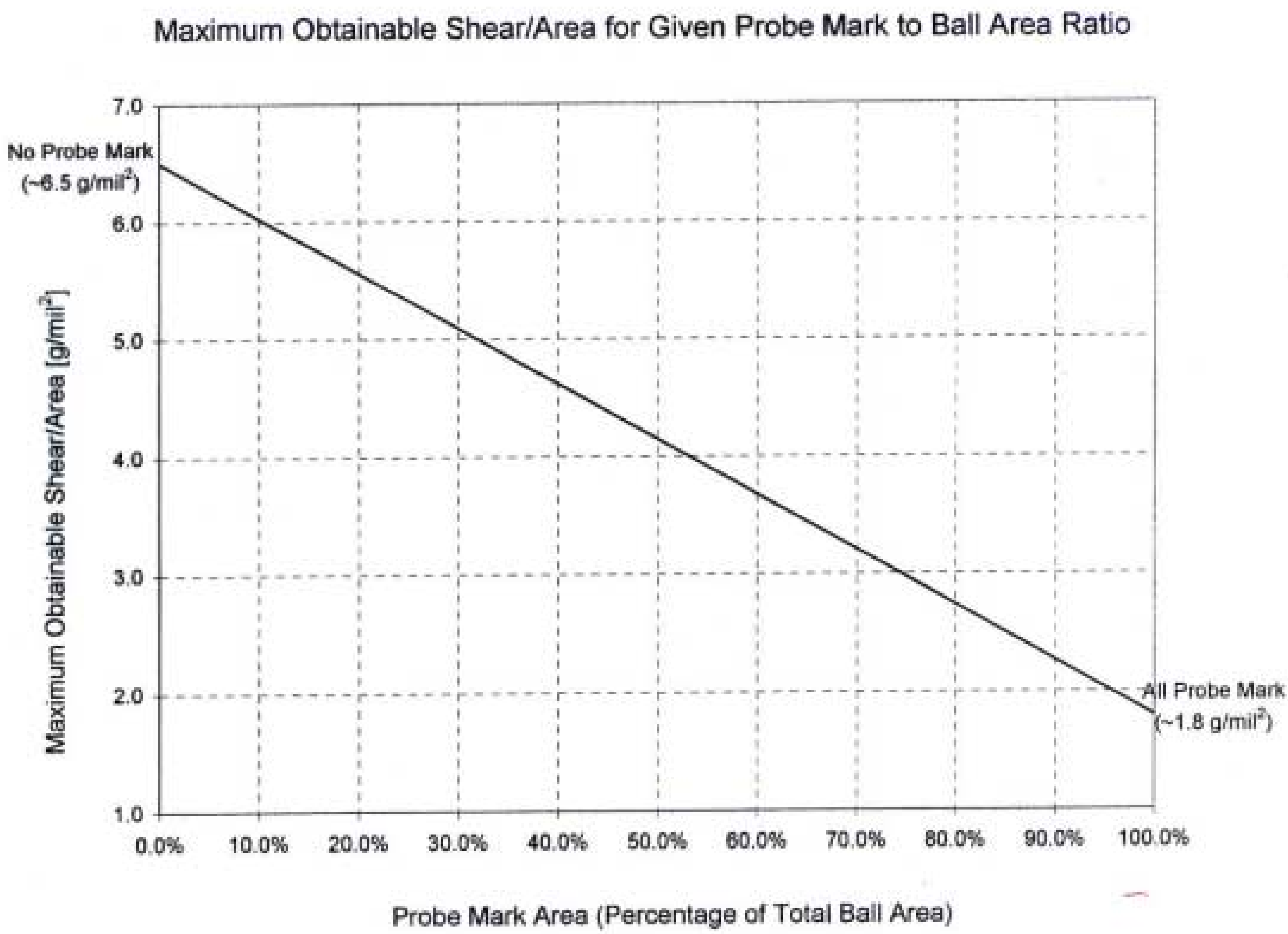


Ball Diameter: $\mu = 46.1\ \mu m$, $\sigma = 0.43\ \mu m$

Shear Strength: $\mu = 18.8g$, $\sigma = 1.1g$ (Shear/Area = $7.1g/mil^2$)

Pull Strength: $\mu = 10.7$, $\sigma = 1.1g$

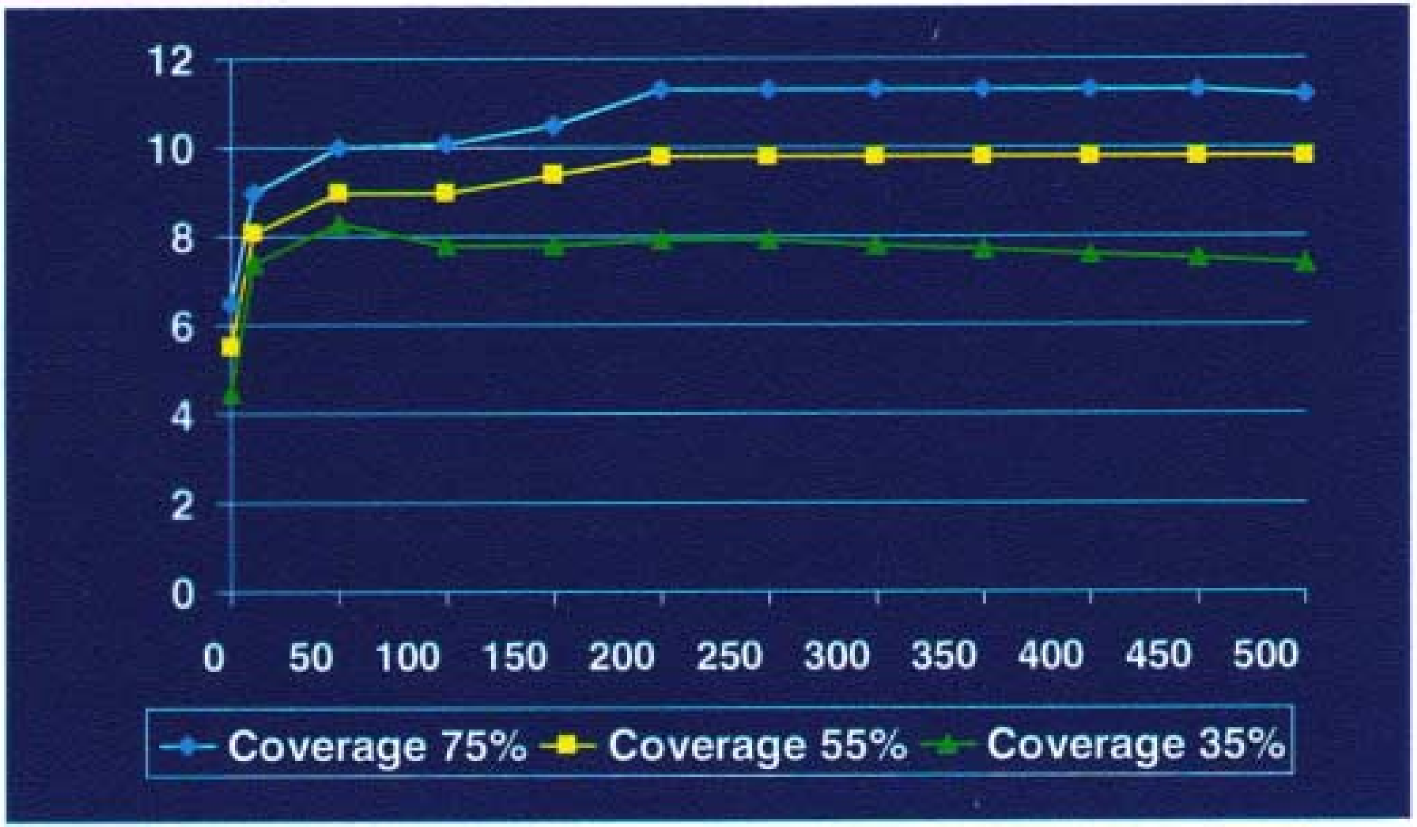

Maximum Allowable Probe Mark Area to Achieve 6 g/mil² Shear/Area
Probe Mark Area [mil²]
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Potential Shear/Area < 6 g/mil²
Potential Shear/Area ≥ 6 g/mil²
20
25
30
35
40
45
50
55
60
65
70
75
Ball Diameter [microns]



Maximum Obtainable Shear/Area for Given Probe Mark to Ball Area Ratio
No Probe Mark
(~6.5 g/mil^2)
All Probe Mark
(~1.8 g/mil^2)
Maximum Obtainable Shear/Area [g/mil^2]
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0%
10.0%
20.0%
30.0%
40.0%
50.0%
60.0%
70.0%
80.0%
90.0%
100.0%
Probe Mark Area (Percentage of Total Ball Area)

Elements of Fine Pitch — Ball Bonds

Shear/Unit Area vs. Aging Strength



Aging test with 4.5, 5.5, 6.5 g/mil^2 samples at 175°C in air.
Conclusion: 5.5 g/mil^2 represents shear strength increases over aging conditions.

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Conclusions

- There are tools to measure and quantify pad damage due to probing
- There are tests to determine ball bond strength and reliability
- Ball bond technology can meet existing road maps
- There are probe technologies available to insure minimal pad damage, which maximizes bond strength and reliability
- Ongoing experiments with K&S, Cascade Microtech, and customers to further determine parameters required to meet pitch and pad size roadmaps