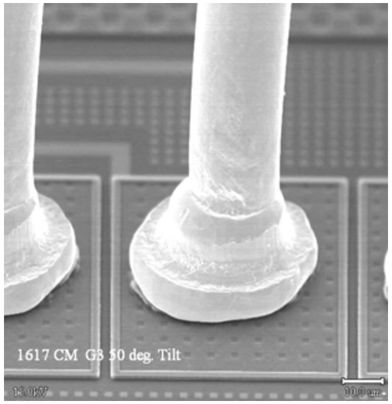

Building the Framework of an Integral Process to Ensure Fine Pitch Probe with Fine Pitch Wirebond

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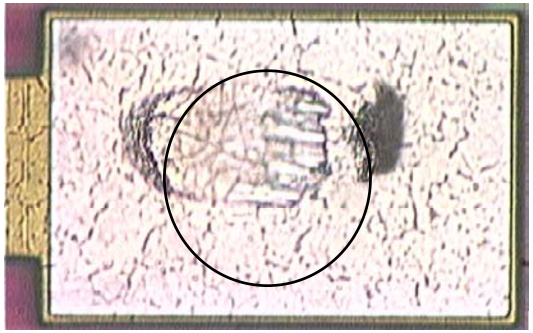
Presentation Overview

- **Fine Pitch Wirebond & Probe Interaction Background**
  - Impact of Probe Mark on Fine Pitch Bonding
  - NPI with Fine Pitch Probe & Bonding needs
- **Previous Wirebond Study with Fine Pitch NPI**
  - Probe mark sizes resulting from production probe
  - Wirebond integrity degraded by probe mark size
- **Current Wirebond Experiment Integrated with Controlled Probe**
  - Design of Experiment, desired responses and sampling
  - Probe test settings
  - Probe tip and probe mark measurements
  - Wirebond test settings
  - Intermetalic growth results
  - Ball shear, wire pull, lifted metal, surface contamination results
  - Experiment Summary
- **Successful Probe and Wirebond Integration for Fine Pitch**

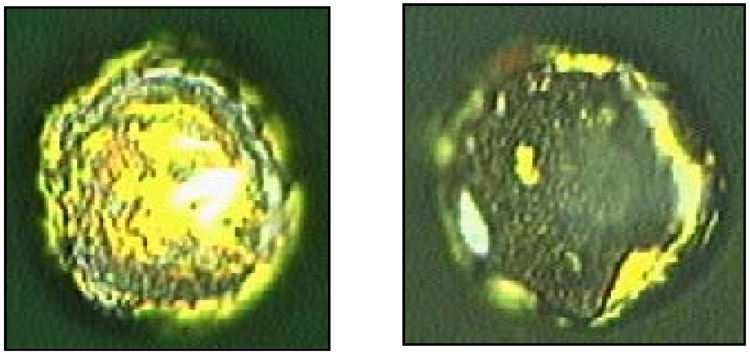
Probe Mark Limits Fine Pitch Bonding

“Large” Probe Mark
(with target ball)



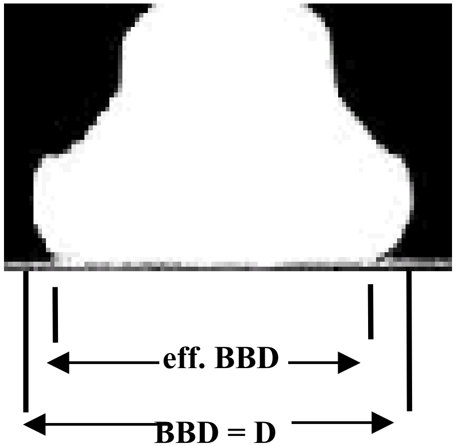
At small pad sizes the mark disturbs a significant portion of the bond area

Intermetallic (IMC) Formation
Impaired by Probe Mark



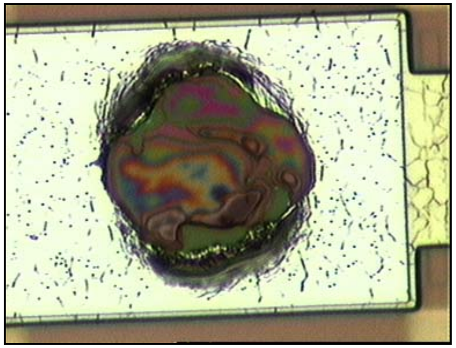
Poor IMC for <u>probed</u> die

Good IMC for <u>unprobed</u> die



The effective bond diameter (actual pad contact area) is even smaller than the ball bond diameter (BBD)

Wirebond Characteristics Degraded



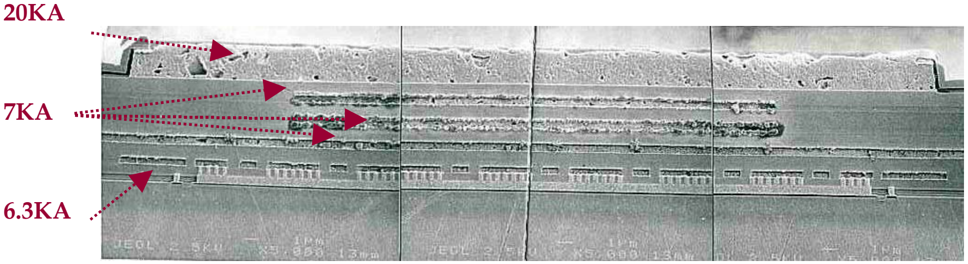
Lifted Metal

Lifted metal, as well as non-sticks and lower shear strength can result

NPI is Fine Pitch Bonding Challenge

KEY NPI FEATURES

- ➢ Pad Opening - 60 x 90µm
- ➢ Minimum Pad Pitch - 66µm
- ➢ Minimum Wire Pitch - 63µm
- ➢ No TiN layer under Al pad

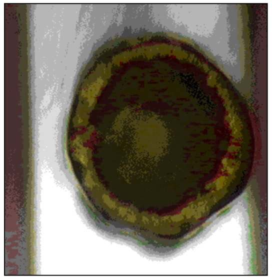


NPI Bond Pad Cross Section
MOS 13 Hip4 0.25 µm CMOS core Al technology

IMPACT

- Fine pitch wirebonding required
  - – Smaller Ball Bond Diameter: 43µm
    - Accurate placement at fine pad pitch
    - Larger 50µm ball has 1.31% defect rate
  - – Thinner Au Wire Diameter: 1.0mil
    - Required for fine wire pitch bonding

Ball Size	Cpx
43um	1.53
50um	0.65



Ball placement failure

- Lack of TiN barrier layer may reduce pad integrity and contribute to metal lift

Prior Wirebond CZ with Probed Dice

- Uncontrolled Probe Marks Disturb Majority of a 43um ball area

	X	Y	Z	Probe Area	Probe/Ball Area
Average	24.3	46.3	1.7	1125	77%
Maximum	29.0	57.1	2.0	1656	114%
Minimum	20.1	36.3	1.0	730	51%

- Large Probe Marks Degrade Small Ball Bond Performance
  - Larger ball has greater shear strength, low occurrence of lifted metal
  - Probe Mark Limits Intermetallic Growth with Smaller ball
    - Smaller ball has a high occurrence of lifted metal
    - Smaller ball shear strength decreases after PMC
    - Further optimization decreased smaller ball lifted metal to 1.86%, though still unacceptable

Ball Size	PMC	Shear Strength (gm)	Std Dev	Shear per Area (gm/mil^2)	% Lifted Metal
43um	Before	20.55	1.8	6.7	
	After	18.96	0.7	6.2	13.8%
50um	Before	24.86	3.0	5.8	
	After	33.19	2.7	7.8	0.2%

Controlled Probing Wirebond Experiment

Mixed Full Factorial DOE

Factors

- Ball size - 43 & 50µm
- # of probe touchdowns (0-control, 1, 3, 6)
- Cantilever probe tip hardware (0.8, 1.0, 1.2 - reference)

Sample Size

- 480 units (18 Cells)
- 3 Wafers from MOS-13

Constants

- Fine Pitch Wirebonder (43 & 50µm ball settings)
- 272 PBGA Substrates

Responses

- Probe mark size for 1, 3, & 6 touchdowns
- Ball Shear Strength - Before & after PMC
- Rip Test - Before & after PMC
- Ball Diameter - Before & after PMC
- Wirepull - Before & after PMC
- 100% Inspection (Non-stick)
- Cratering after wirebond
- % IMC
- Moisture Sensitivity (MSL 3 - 240C) - Delamination

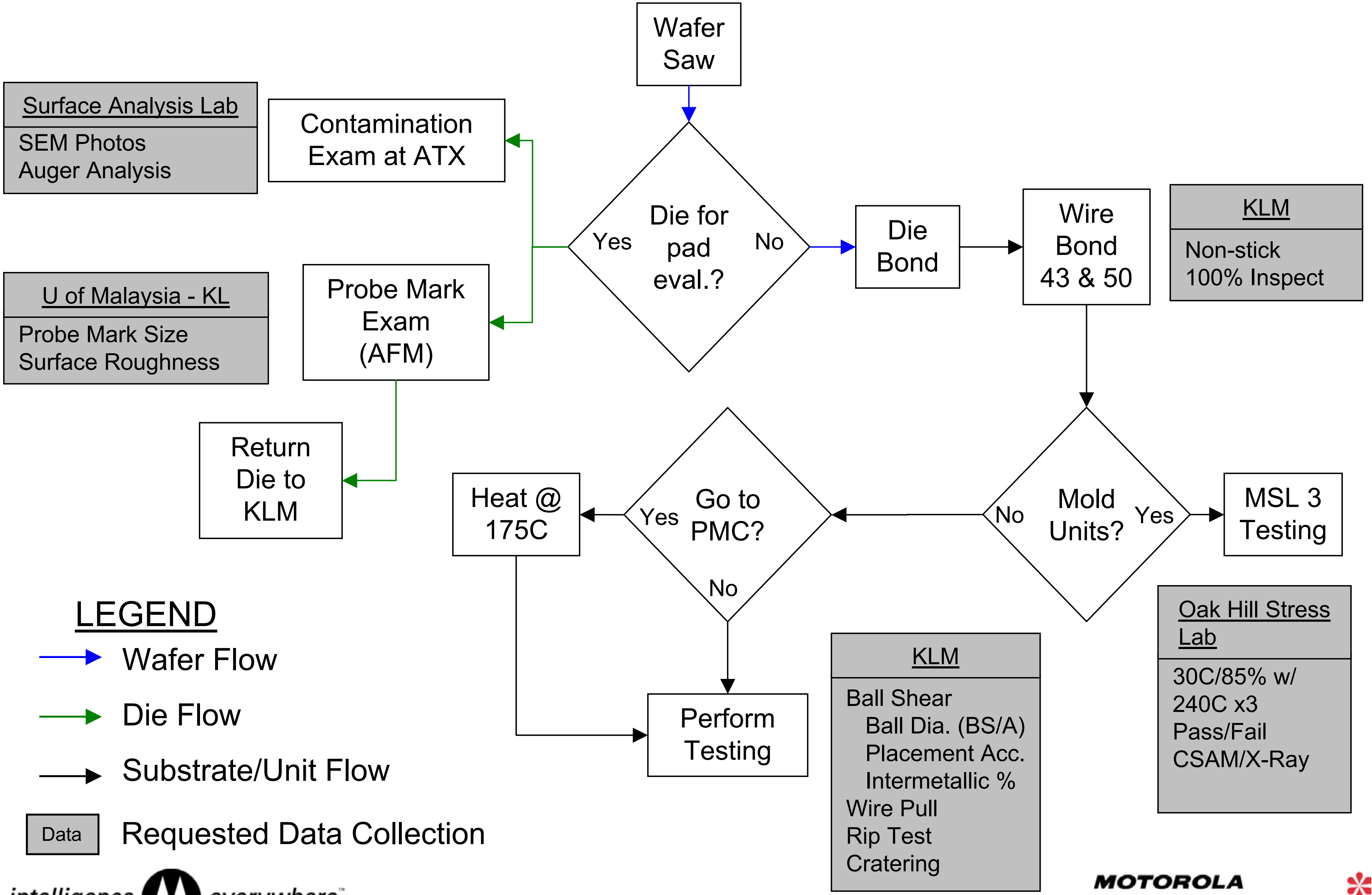
Test Cell Breakdown

	Cell #	# of Probe TouchDowns	Probe Tip Diameter	Ball Bond Diameter	# of Strips*		
					No PMC	PMC	Molded
No Probe	1	0	N/A	43	2	2	1
	2	0	N/A	50	2	2	1
	3	1	1	43	2	2	1
	4	1	1	50	2	2	1
	5	1	0.8	43	2	2	1
	6	1	0.8	50	2	2	1
	7	3	1	43	2	2	1
	8	3	1	50	2	2	1
	9	3	0.8	43	2	2	1
	10	3	0.8	50	2	2	1
Worst Case Only Case w/ Non-stick (6 Lifted Pad)	11	6	1	43	2	2	1
	12	6	1	50	2	2	1
	13	6	0.8	43	2	2	1
	14	6	0.8	50	2	2	1
Reference	15	unknown	1.2	43	2	2	1
	16	unknown	1.2	50	2	2	1

*** - 6 Units per Strip**

3 Cases per Cell

Data Collection Flow Chart



Wafer Saw

Die for pad eval.?

Yes

No

Contamination Exam at ATX

Surface Analysis Lab

SEM Photos
Auger Analysis

Probe Mark Exam (AFM)

U of Malaysia - KL

Probe Mark Size
Surface Roughness

Return Die to KLM

Die Bond

Wire Bond 43 & 50

KLM

Non-stick
100% Inspect

Mold Units?

No

Yes

MSL 3 Testing

Oak Hill Stress Lab

30C/85% w/
240C x3
Pass/Fail
CSAM/X-Ray

Go to PMC?

Yes

No

Heat @ 175C

Perform Testing

KLM

- Ball Shear
  - Ball Dia. (BS/A)
  - Placement Acc.
  - Intermetallic %
- Wire Pull
- Rip Test
- Cratering

LEGEND

Wafer Flow

Die Flow

Substrate/Unit Flow

Data — Requested Data Collection

Test Case Sampling

Test	Measurement	Instrument	Sampling Per Case
Ball Shear	Force (gm), Mode	Dage 4000	8 Units – 40 balls/unit
Ball Placement /Diameter	x1, y1, x2, y2	Fine Focus Microscope	6 Units – 8 balls/unit
Rip Test	# with Lifted Metal, # of Lifted Ball	Hook	2 Units – all wires
Wirepull	Force (gm), Mode	Dage	8 Units – 40 wires/unit
Intermetallic Formation	% IMC	Fine Focus Microscope	1 Unit – 3 balls/unit
Cratering	# of cratered pads	Fine Focus Microscope	1 Unit – all pads
Probe Mark Size	dx, dy, dz	AFM	1 die/quadrant – min & max mark
Probe Mark Size	dx, dy	Fine Focus Microscope	3 Units – 10 pads/unit
Auger Analysis	Contaminants		5 die/quadrant

Notes:

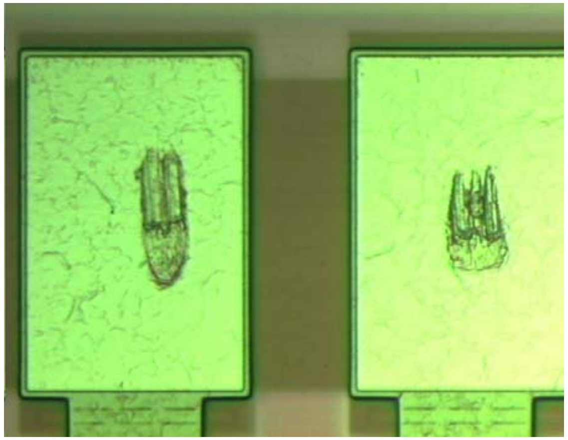
- 264 die pads per unit available
- Sample sizes based upon KLM NPI specifications, and the minimum necessary to gather significant data

Test Cell Probe Settings

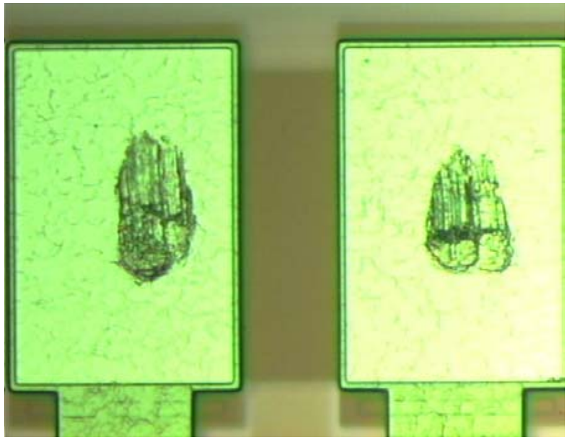
Nominal Probe Tip Diameter	0.8 mil	1.0 mil	1.2 mil
Probe Tip Diameter Tolerance	+/- 0.3mil		
Probe Card Vendor	Probe Technology - Duraprobe		
Contact Force	1.3 gm/mil		unknown
Overdrive	65µm (from 1st Touch)		unknown
Polish Frequency (Online)	Every 150 dice (3 touches at 25µm)		unknown

– 1.2 mil Probe Card probed dice were uncontrolled and the settings unknown

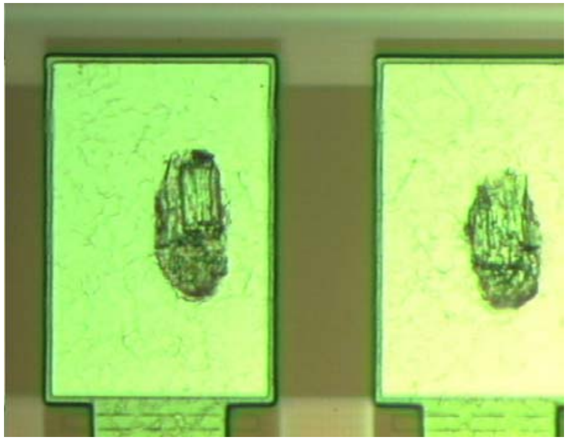
Result: Sample 0.8 mil Probe Tip Marks



1 TD



3 TD's



6 TD's

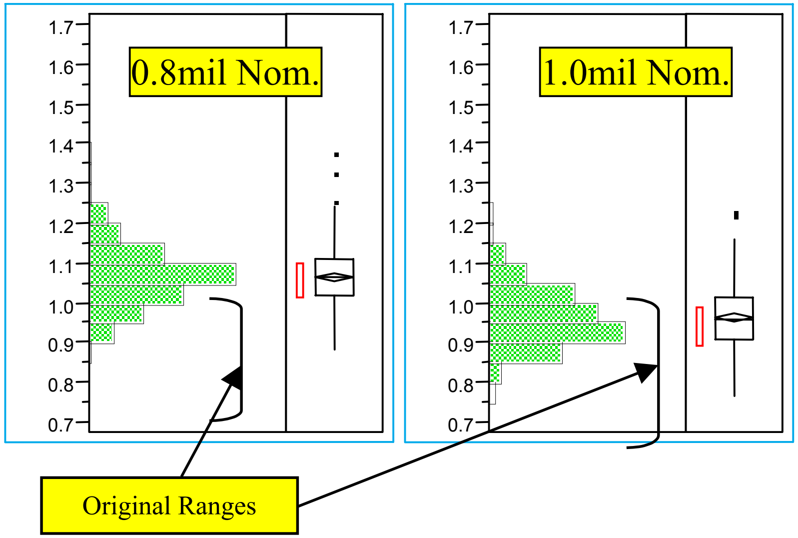
Actual Probe Tip Diameter Description

Probe Card Analyzer Tip Measurements

	0.8 mil	1.0 mil
Maximum	1.06	1.02
Minimum	0.68	0.61

- Pareto of original tip sizes unavailable
- Significant tolerance on probe tips allows for large and overlapping ranges
- Tip measurements are not consistent between analyzers, accurate values difficult to define
- 0.8 mil probe card tips worn by subsequent production use (1.0 mil card not used subsequently)

Subsequent Tip Measurements

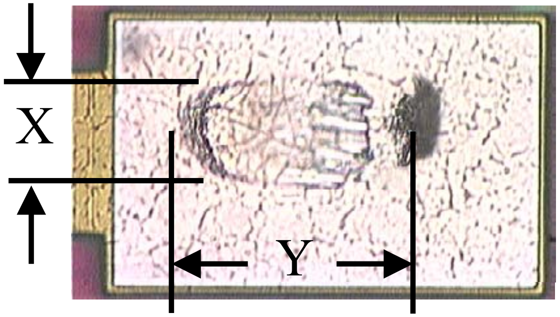


Original Ranges

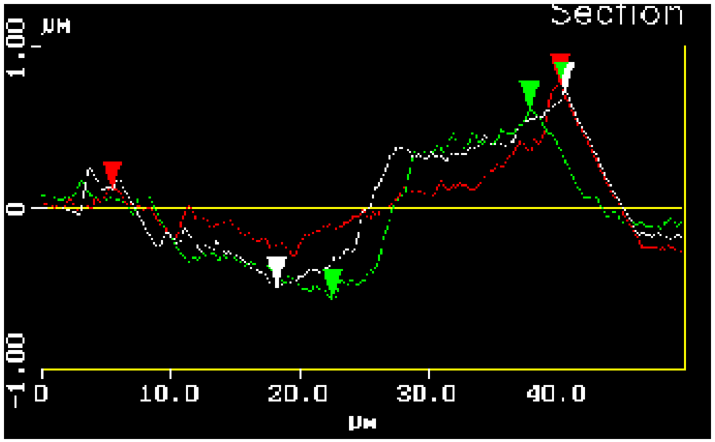
	0.8 mil	1.0 mil
Maximum	1.3890	1.2370
Median	1.0658	0.9594
Minimum	0.8867	0.7701
Mean	1.0675	0.9657
Std Dev	0.0747	0.0749

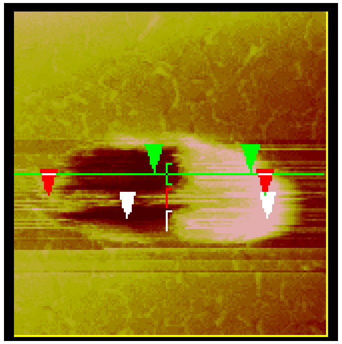
Probe Mark Area Measurements

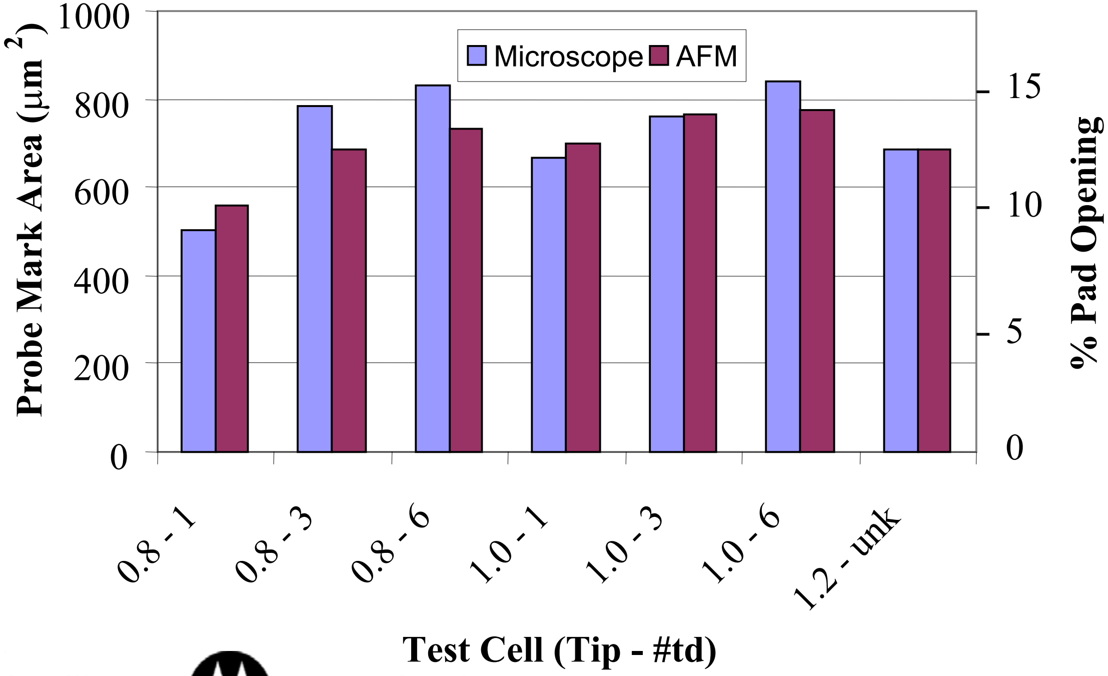
Microscope Measurements



AFM Measurements

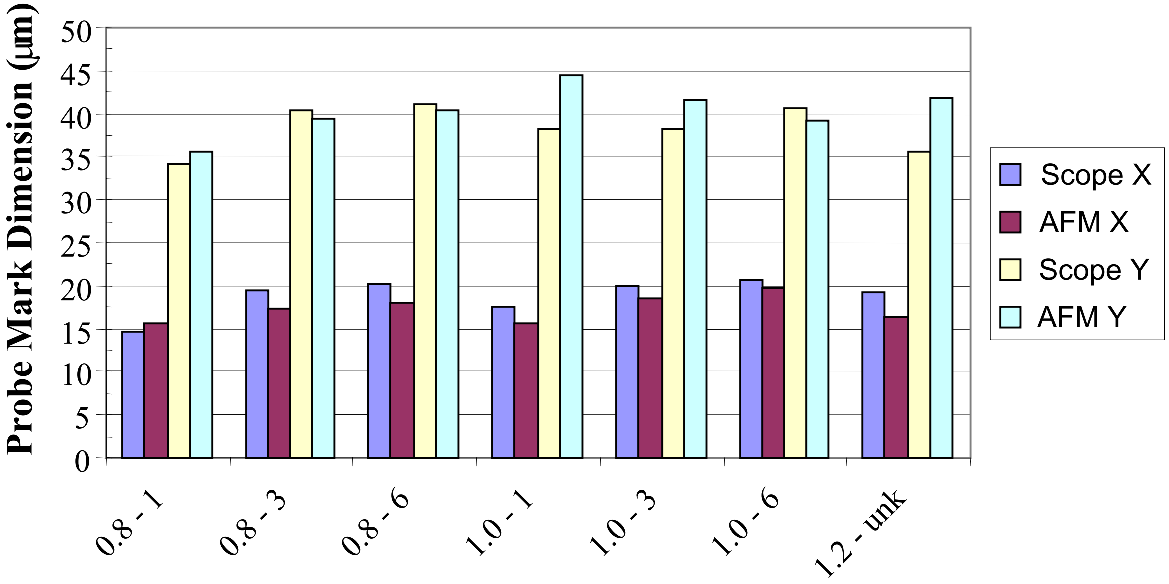


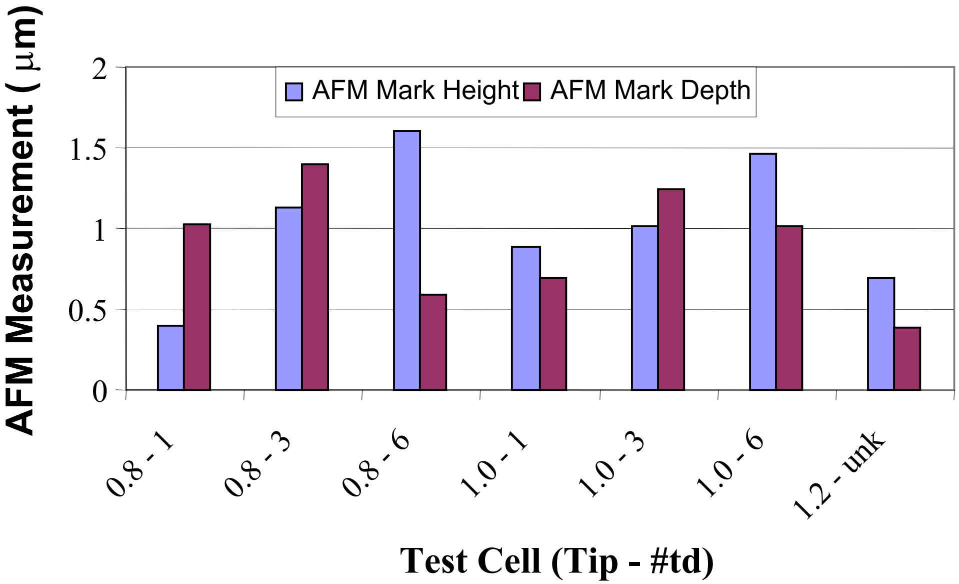




- Area correlates to tip size and number of touchdowns
- Interpretation of precise AFM measurements very subjective
- Uncontrolled probed wafer (1.2 mil) not the worst case as expected
- Probe sizes smaller than previous probing

Limitation of Probe Mark Measurements





- Due to expense, AFM sample size has to be limited
- Limited to six linear measurements, chosen by the operator
- AFM depth measurements inconsistent (dependent on interpretation)
- A less expensive and simpler method is needed to gather Z-direction data

Wirebond Assembly Test Settings

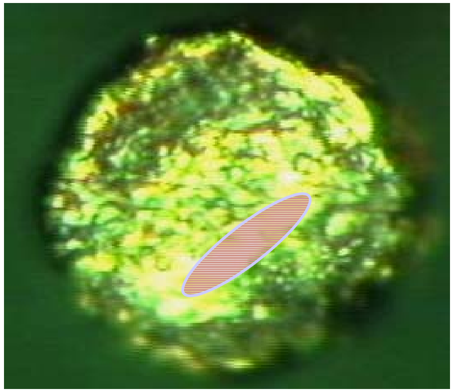
- To form 43 and 50um ball bonds, different settings were required, the resulting wirebond results may not be directly comparable

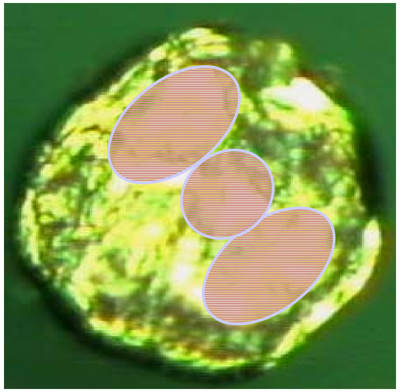
Wirebonder	Fine Pitch Capable	
Wire Type	Gold	
Wire Diameter (μm)	25	
Ball Diameter (μm)	43	50
Capillary	414FD-2031	SBNE-30ZA
Ball Bond Force (mN)	210	190
Ball Ultrasonic Power (%)	12.2	10.6
Ball Impact Force (mN)	300	280
EFO Current (mA)	50.24	32.8
EFO Time (ms)	0.4	0.6

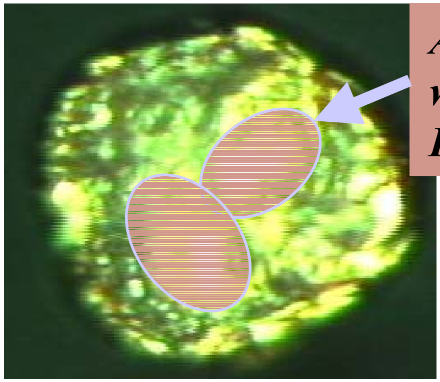
- The above table notes most of the important factors which were different for the two ball bond sizes

Intermetallics Reduced by Touchdowns

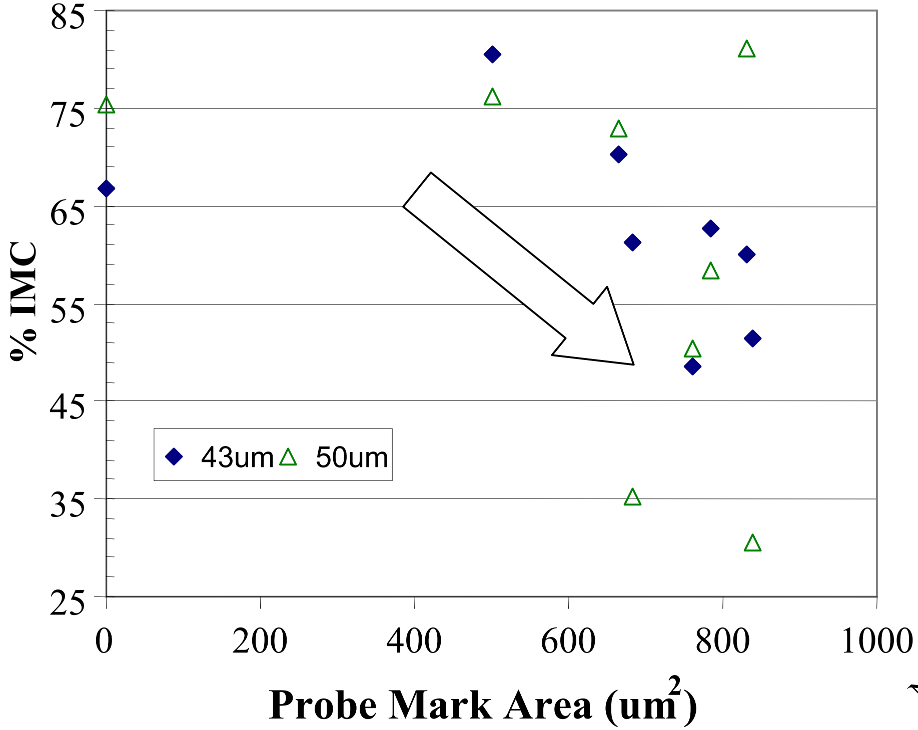
Sample
0.8 mil
probed
ball bonds

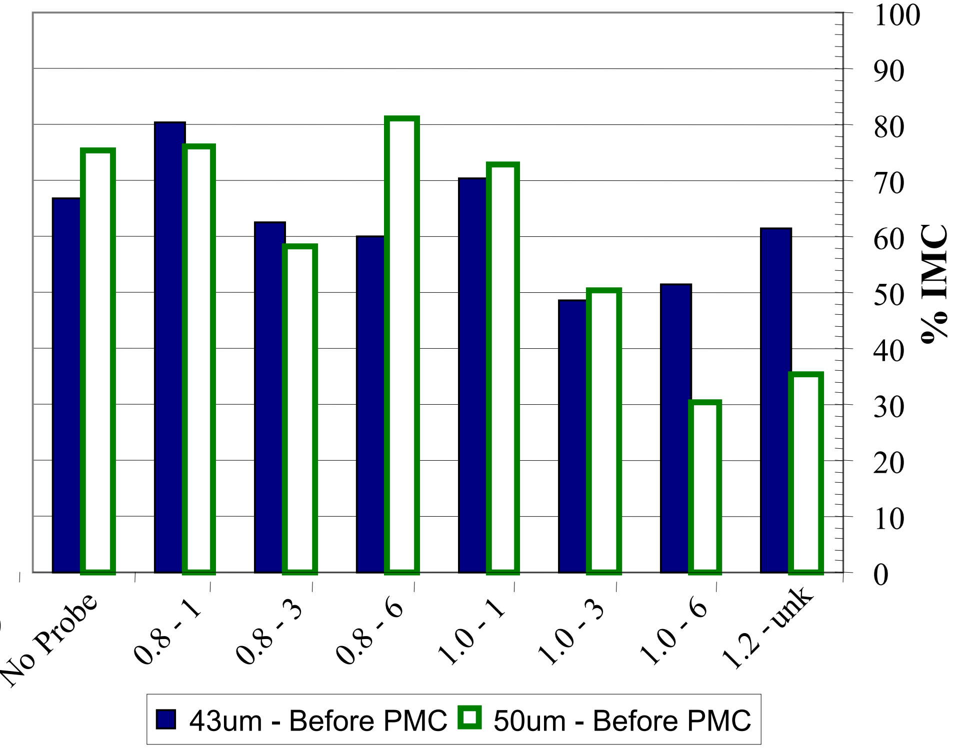

1 TD


3 TD's


6 TD's

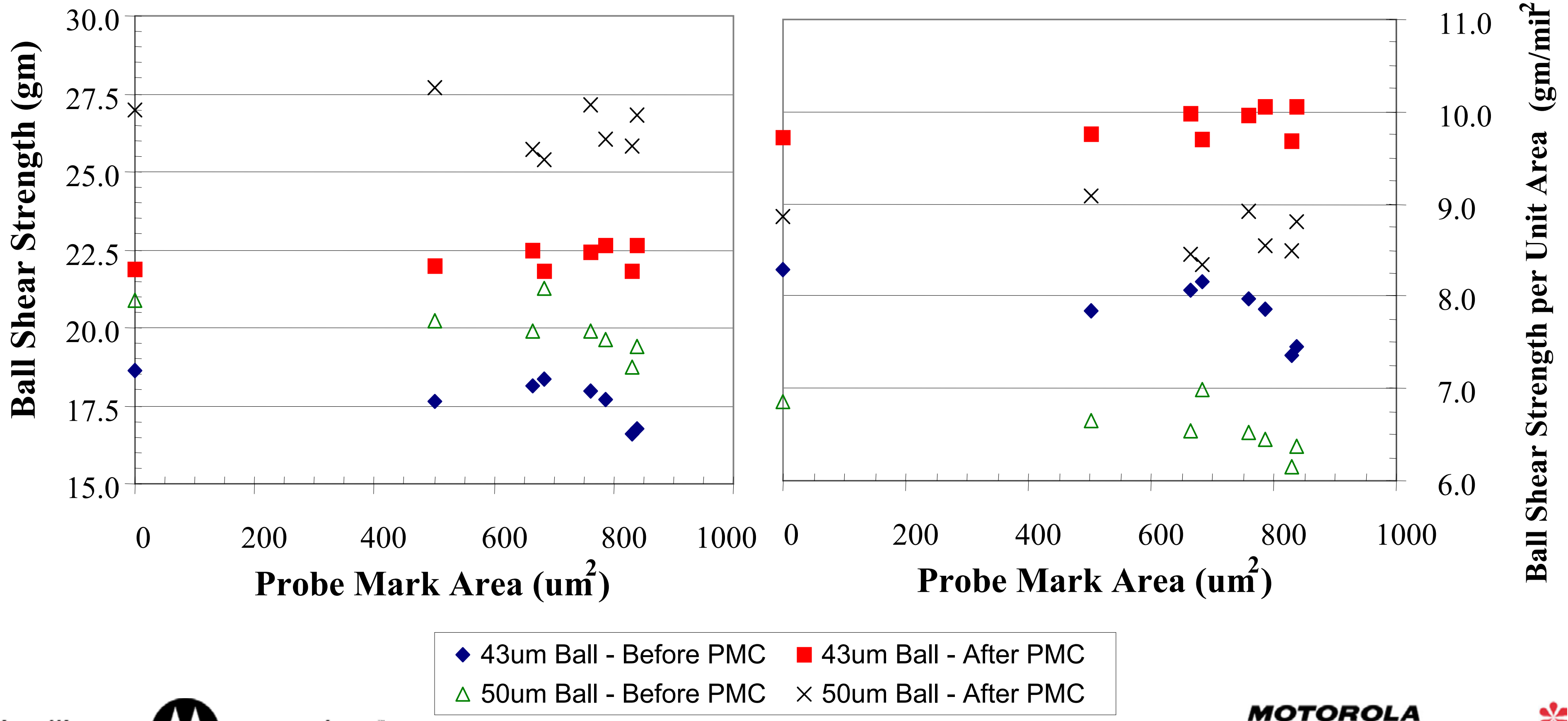
Areas without IMC





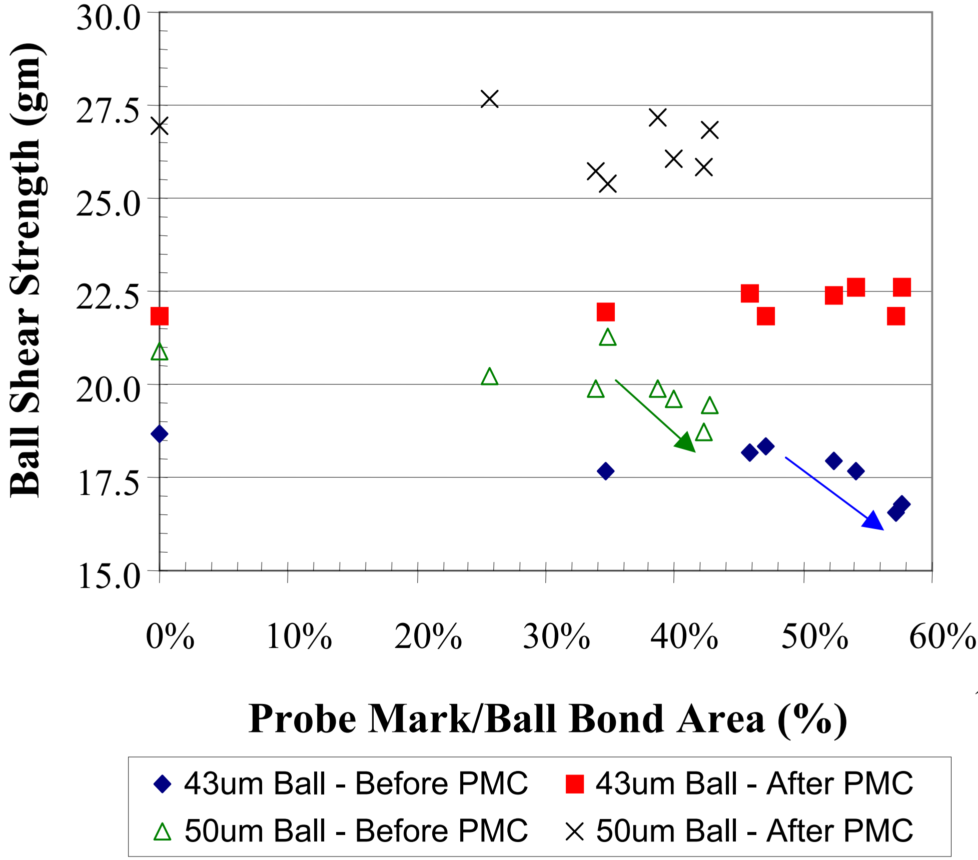
Probe Mark Area Relation to Shear Strength

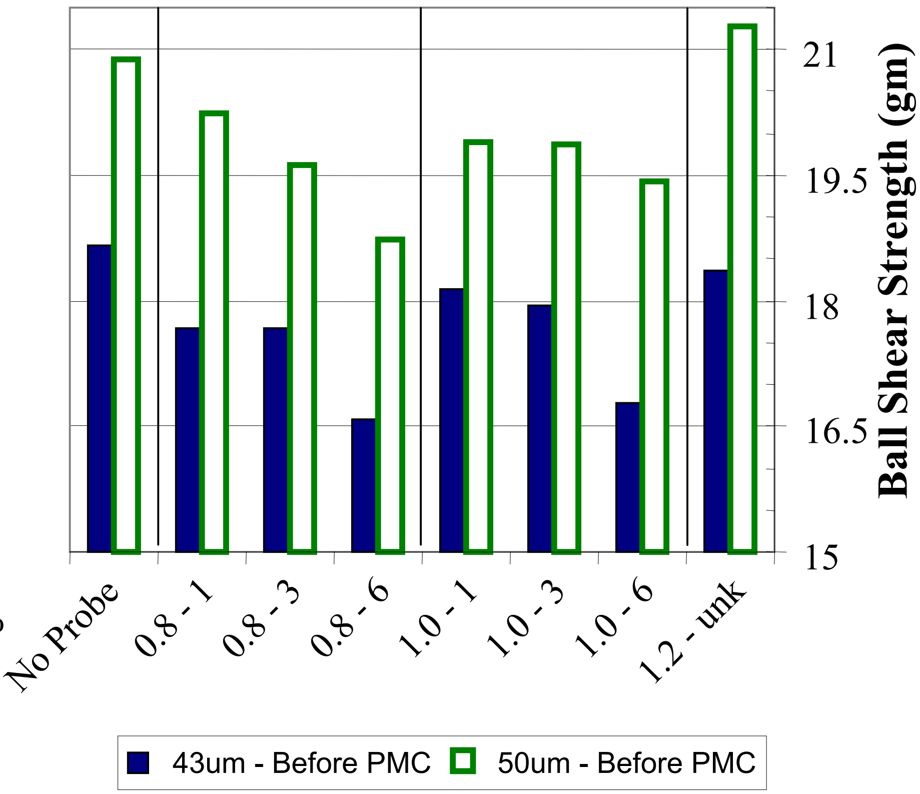
- Strength degraded by probe mark area (fine focus microscope measurements), particularly before PMC
- Strength increases after PMC, diminishing effect of probe mark
- 43um and 50um bond strength per unit area do not overlap, larger diameter ball has lower shear strength per unit area



Further Shear Relation to Probe Mark

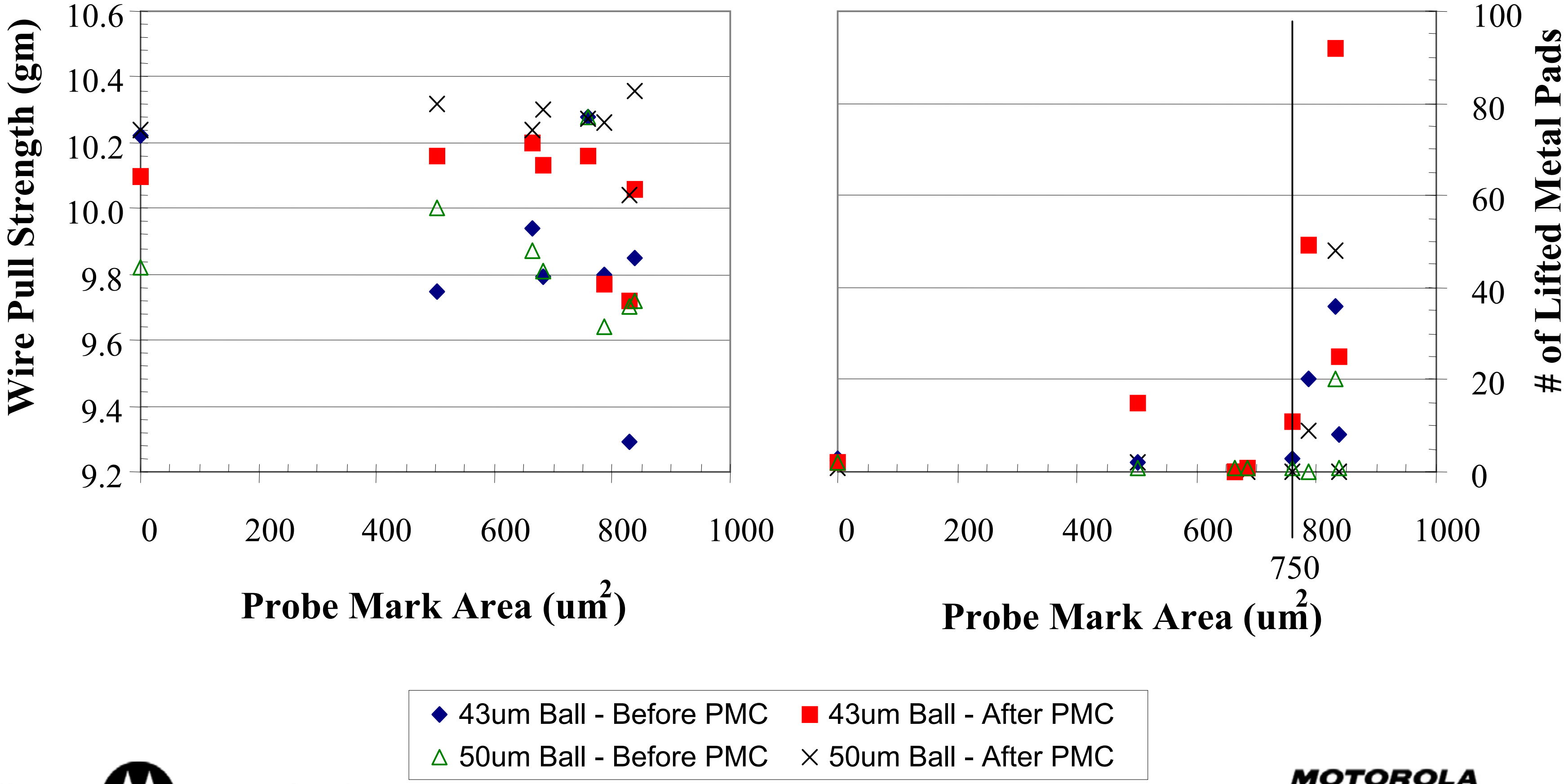
- Before PMC, the 50um bond strength degrades at a smaller ratio of probe mark to ball bond area than the 43um bond (43um > 50%, 50um > 38%)
- 0.8 mil probed bonds have lower strength than 1.0 mil probed bonds for each number of touchdowns before PMC (except the 50um ball at 1 touchdown)





Wire Pull and Rip Test Results

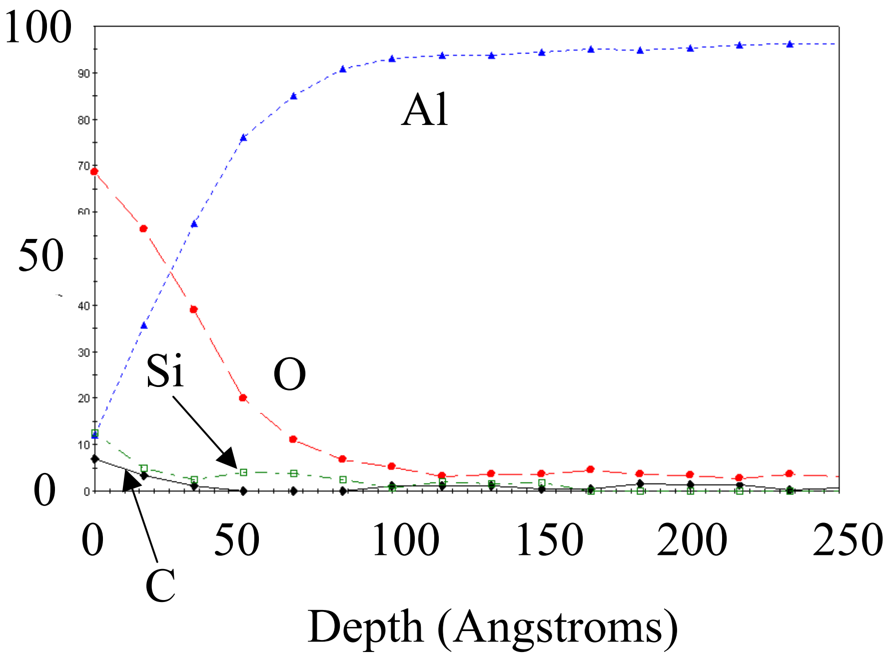
- The Probe Mark only significantly degrades the 43um ball bond Wire Pull Strength before PMC
- Occurrence of lifted metal pads increases dramatically with Probe Mark Area (particularly over 750um^2) and especially after PMC



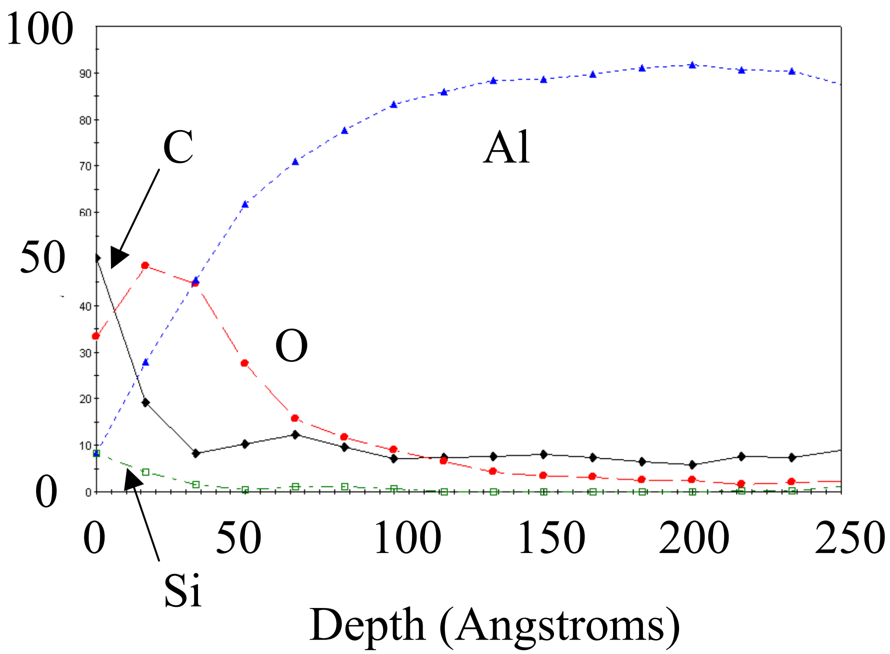
Surface Contaminant Analysis

- Auger analysis did not reveal foreign material or contamination
- A normal thickness of Aluminum Oxide found
- Older 1.2mil probed wafer had less surface oxygen and more carbon than the newer 0.8 and 1.0mil probed wafer

0.8 mil probed wafer

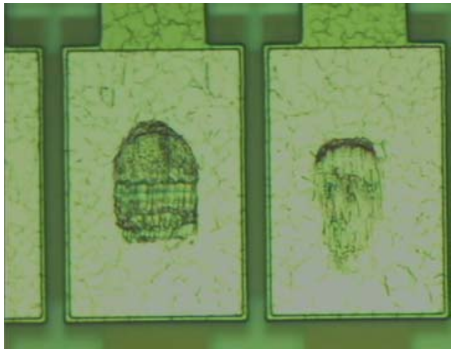


1.2 mil probed wafer



Summary of Experimental Results

- **Tests show degradation of wirebond strength is a function of probe mark area and ball bond size, however, the range of damage does not appear large enough to establish significant relationship**
  - Non-stick at wirebond only seen on one cell (1.0mil tip, 6 td's, 43um ball)
  - Drop in strength from no probe to max probe size not very large, minimum strength still acceptable
  - No failures found after Jedec MSL 3-240C soaking
  - Subsequent production lots revealed much larger probe marks



- **The probe mark area is a function of the number of probe touchdowns**
  - Limitation specification needed at probe on number of touchdowns
  - Wirebond data shows six touchdowns creates too much damage
- **The 0.8 mil nominal probe tip gives smaller probe marks in most cases, versus the 1.0 mil nominal probe tip, but not all**
  - Need to correlate actual probe tip to resulting mark area rather than the nominal dimension (insufficient due to wear and tolerance)

Successful Fine Pitch Deployment Requires an Integration of Probe and Assembly

- **As pitch decreases, the probe tip size, number of touchdowns, and probe settings degrade the wirebond integrity**
  - Assembly and Probe must characterize probe mark damage to wirebond characteristics to optimize both processes
  - Production probe specifications should be established based on fine pitch characterization to place a limit on probe tip diameter and number of touchdowns for a given pad and ball bond size
- **Communication between Probe and Assembly Engineering crucial**

Additional Work Required

- Establish accuracy of Wafer-level probe mark measuring system, for mark characterization at the probe floor, separate from the prober
- Establish probe contact performance of 0.8 mil and smaller probe tips
- Establish the 0.8 & 1.0 mil probe tip wear rate to define lifetime
- Gather probe damage depth and height data to further understand wirebond results

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Irene Wong

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Gloria Estrada