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Expanding Capabilities of Traditional Cantilever Technology To Meet Advanced DRI Fine Pitch Probe Requirements

Presenter: Bill Williams, Freescale Semiconductor
FMTC Probe Mgr. and Sr. Member Technical Staff
Final Manufacturing Technology Center
Co-Authors: Tony Angelo, S.S. Yan, Al Ferguson, Susan Downey, Alvin Youngblood

SWTW 2004
June 8, 2004

Launched by Motorola
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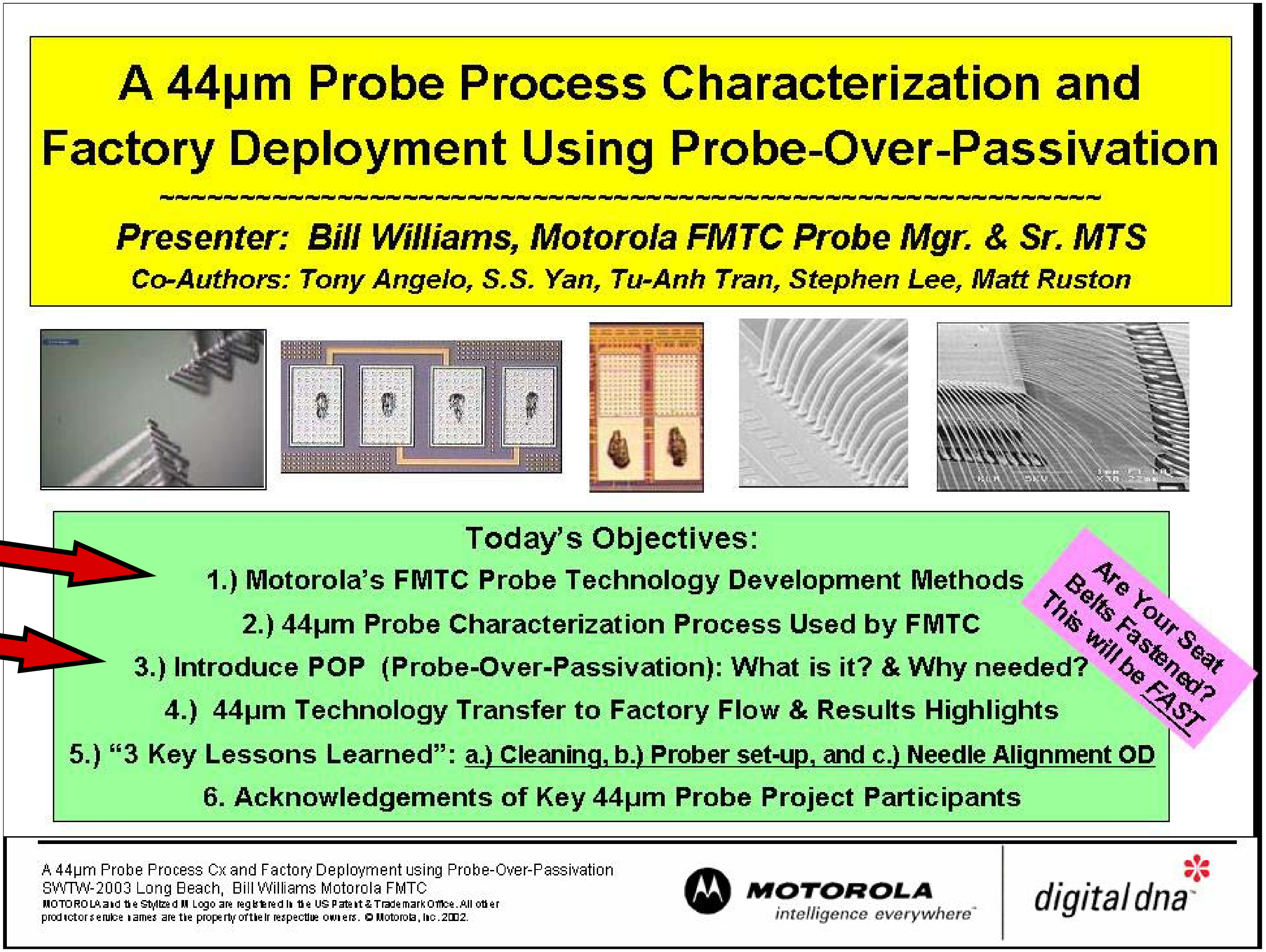
Objectives / Outline:

- Freescale Semiconductor is a subsidiary of Motorola
- Recap 2003-SWTW paper on 44um Fine Pitch Probe
  - High level Review of FMTC Assessment Process & Methods
  - Review POP technology (Probe Over Passivation)
- Highlights 3 major new Probe Thrusts
  - 37um Fine Pitch Developments – Standard Single Row Inline
  - What is Fine Pitch DRI? Why does it exist? What are the issues?
  - 57um Dual Row Inline (DRI) Developments
  - 47um Dual Row Inline (DRI) Developments (** beyond design rules!)
  - Share Comparative Results from Development Thrusts
- Conclusions, Future Work & Thanks!

Title Page - Recap of 2003 SWTW Paper

Recap From 2003-SWTW



A 44µm Probe Process Characterization and Factory Deployment Using Probe-Over-Passivation

Presenter: Bill Williams, Motorola FMTC Probe Mgr. & Sr. MTS

Co-Authors: Tony Angelo, S.S. Yan, Tu-Anh Tran, Stephen Lee, Matt Ruston

Today's Objectives:

1.) Motorola's FMTC Probe Technology Development Methods

2.) 44µm Probe Characterization Process Used by FMTC

3.) Introduce POP (Probe-Over-Passivation): What is it? & Why needed?

4.) 44µm Technology Transfer to Factory Flow & Results Highlights

5.) "3 Key Lessons Learned": <u>a.) Cleaning, b.) Prober set-up, and c.) Needle Alignment OD</u>

6. Acknowledgements of Key 44µm Probe Project Participants

Are Your Seat Belts Fastened? This will be <u>*FAST*</u>

A 44µm Probe Process Cx and Factory Deployment using Probe-Over-Passivation
SWTW-2003 Long Beach, Bill Williams Motorola FMTC

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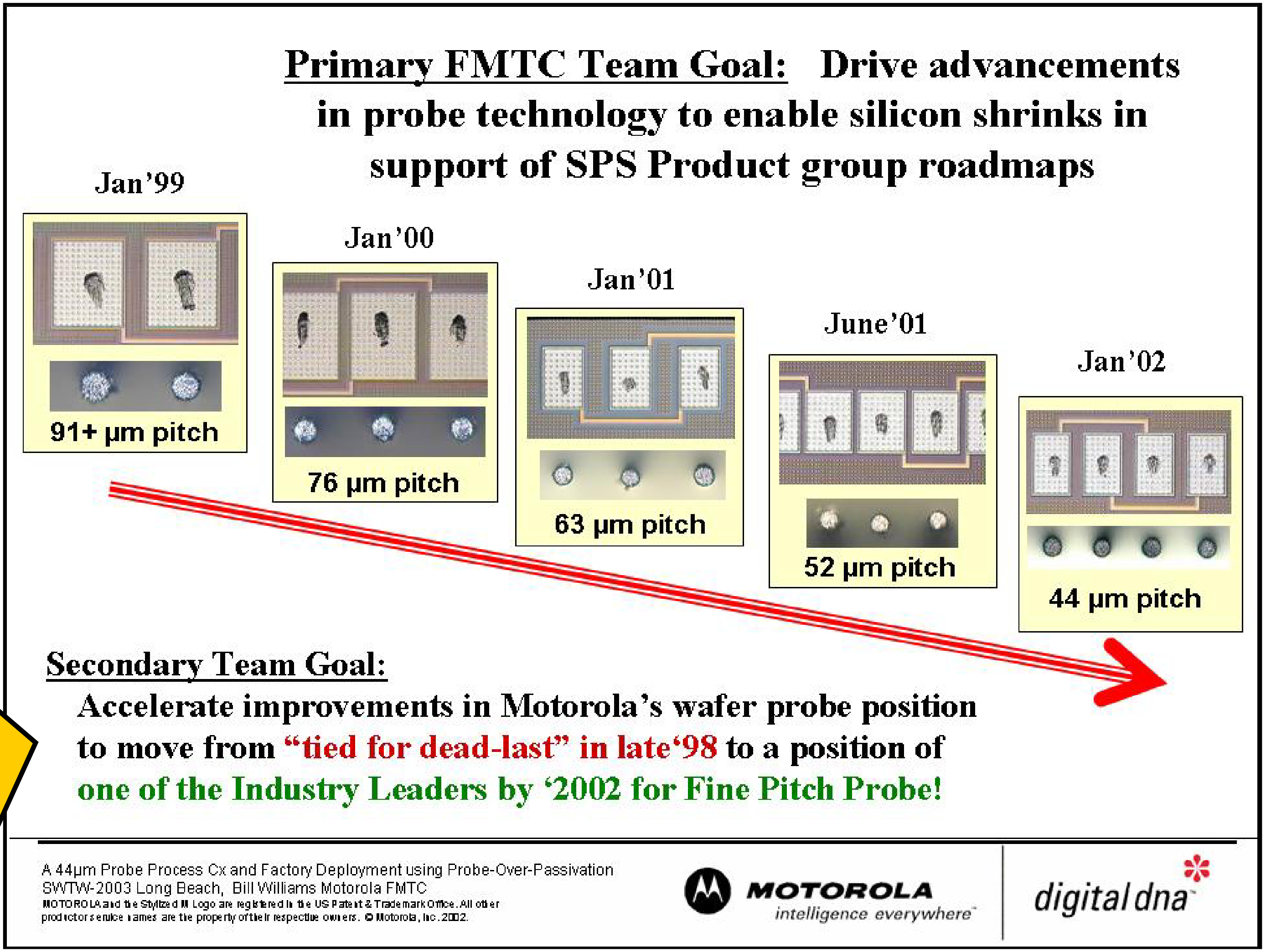
Goals Page - Recap of 2003 SWTW Paper

Recap From 2003-SWTW



Primary FMTC Team Goal: Drive advancements in probe technology to enable silicon shrinks in support of SPS Product group roadmaps

Jan'99

91+ µm pitch

Jan'00

76 µm pitch

Jan'01

63 µm pitch

June'01

52 µm pitch

Jan'02

44 µm pitch

Secondary Team Goal:

Accelerate improvements in Motorola's wafer probe position to move from "tied for dead-last" in late'98 to a position of one of the Industry Leaders by '2002 for Fine Pitch Probe!

A 44µm Probe Process Cx and Factory Deployment using Probe-Over-Passivation
SWTW-2003 Long Beach, Bill Williams Motorola FMTC

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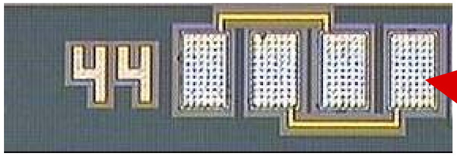
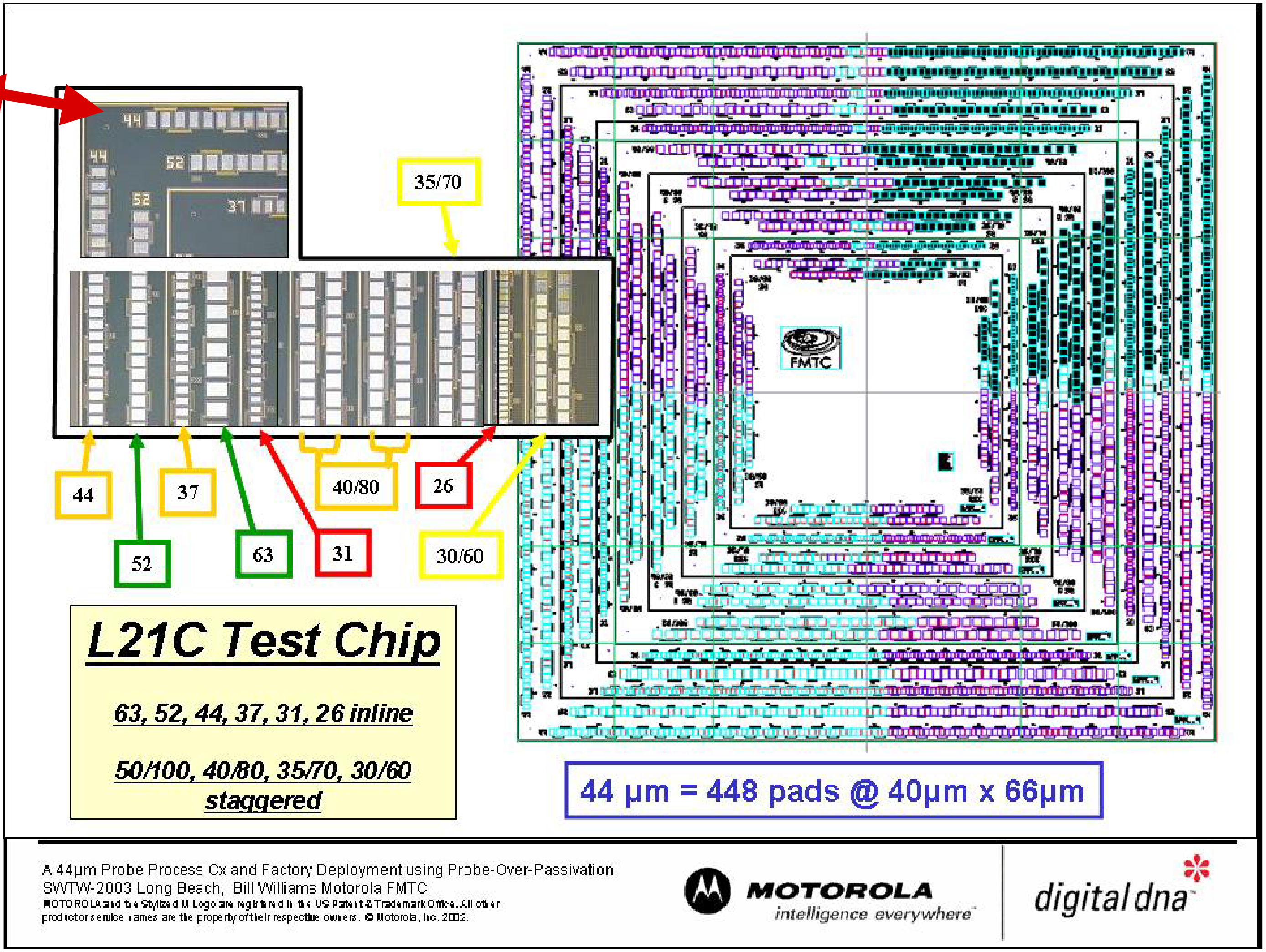
This Was My Team's True Motivation

L21C Test Chip - Recap of 2003 SWTW Paper



Note the pads are “daisy chain”

Recap From 2003-SWTW



L21C Test Chip

63, 52, 44, 37, 31, 26 inline

50/100, 40/80, 35/70, 30/60 staggered

44 µm = 448 pads @ 40µm x 66µm

A 44µm Probe Process Cx and Factory Deployment using Probe-Over-Passivation
SWTW-2003 Long Beach, Bill Williams Motorola FMTC

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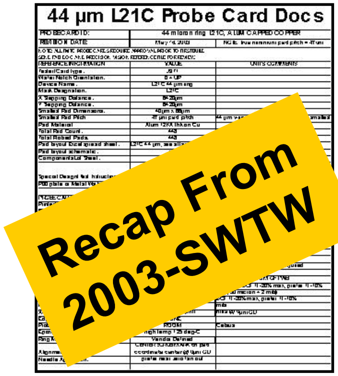
FMTC Fine Pitch Probe Process Development:

Fine Pitch, Alum Capped Copper and Direct Probe on Copper Recap info

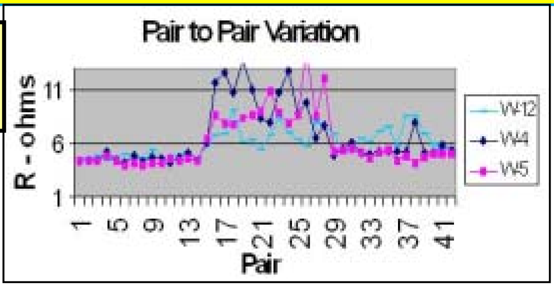

44 µm L21C Probe Card Docs

Recap From 2003-SWTW

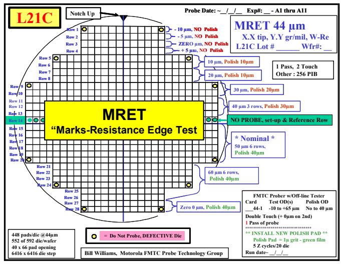
Step 1.) Define & Obtain Probe Hardware

Step 4.) Electrical Test & Contact Resistance

~125K resistance data points / L21C wafer



2.) Prep DOE and Probe Wafers



Probe Date: ~__/__/__ Exp#: __ - A1 thru A11

MRET 44 µm
X.X tip, Y.Y gr/mil, W-Re
L21C Lot # ______ Wfr#: __

- 10 µm, NO Polish
- 5 µm, NO Polish
ZERO µm, NO Polish
+ 5 µm, NO Polish
10 µm, Polish 10µm
20 µm, Polish 10µm
30 µm, Polish 20µm
40 µm 3 rows, Polish 30µm
NO PROBE, set-up & Reference Row
* Nominal *
50 µm 6 rows, Polish 40µm
60 µm 6 rows, Polish 40µm
Zero 0 µm, Polish 40µm

1 Pass, 2 Touch
Other : 256 PIB

FMTC Prober w/Off-line Tester

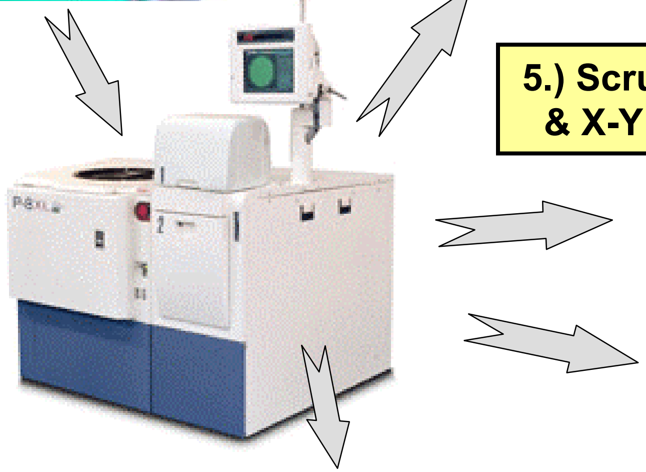
Card	Test OD(s)	Polish OD
___44-1	-10 to +65 µm	No to 40 µm

Double Touch (+ 0µm on 2nd)
1 Pass of probe
****
** INSTALL NEW POLISH PAD **
Polish Pad = 1µ grit - green film
5 Z cycles/20 die
Run date~ __/__/__

448 pads/die @44µm
552 of 592 die/wafer
40 x 66 pad opening
6416 x 6416 die step

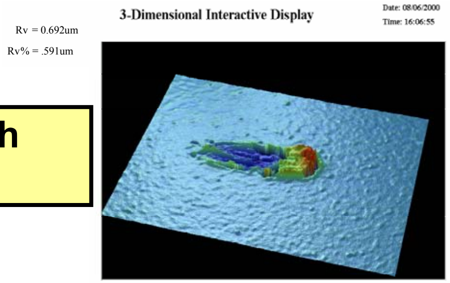
○ = Do Not Probe, DEFECTIVE Die

Bill Williams, Motorola FMTC Probe Technology Group



5.) Scrub Size & X-Y Cpks

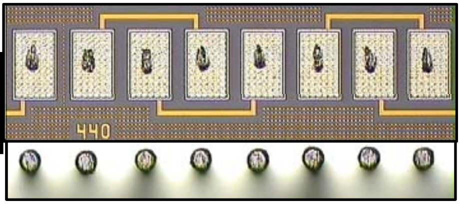
Scrub Length Process Capability	Cp	CpK	Mn Pad L	Delta Pad
25 Deg-C -S	1.33	1.17	120	+24
25 Deg-C +S	1.84	1.58	92	-4
135 Deg-C -S	1.06	0.67	171	+75
135 Deg-C + S	1.80	1.55	94	-2



6.) 3-D Depth Analysis

3.) Photo doc Scrubs & Probes

~ 1600 Photos/5Wfr-DOE



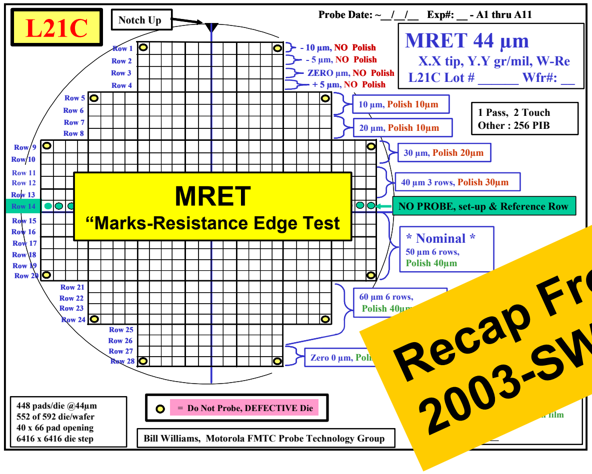
44 µm

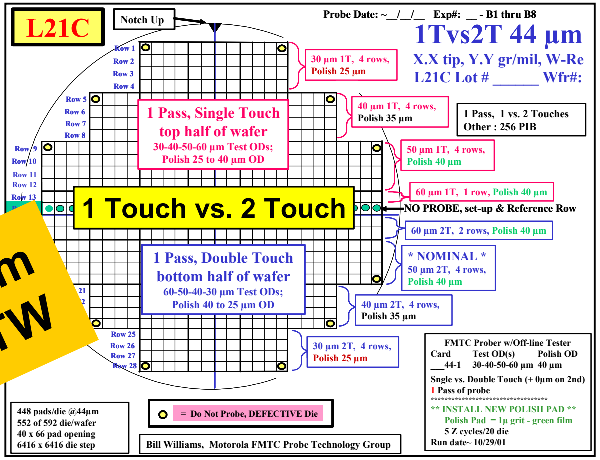
7.) Acid Dip Testing

7.) Transfer Recipe, Process & Methods to Production Site

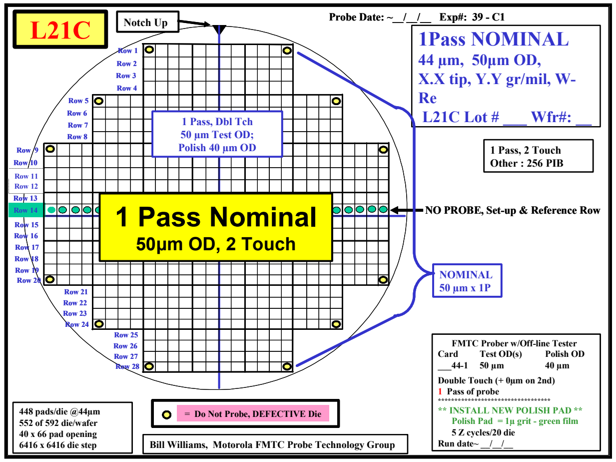
6 Wafer Maps: - Recap of 2003 SWTW Paper

MRET, 1T vs. 2T, 1Pass Nominal, 3 Pass Nominal, 1-6Pass Heavy60, 1Pass Nominal



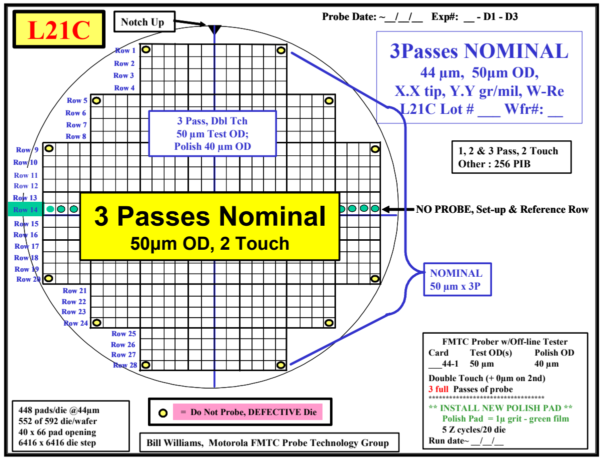


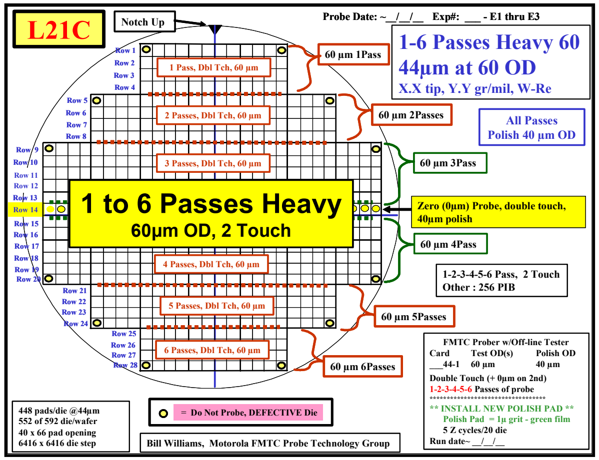
Recap From 2003-SWTW

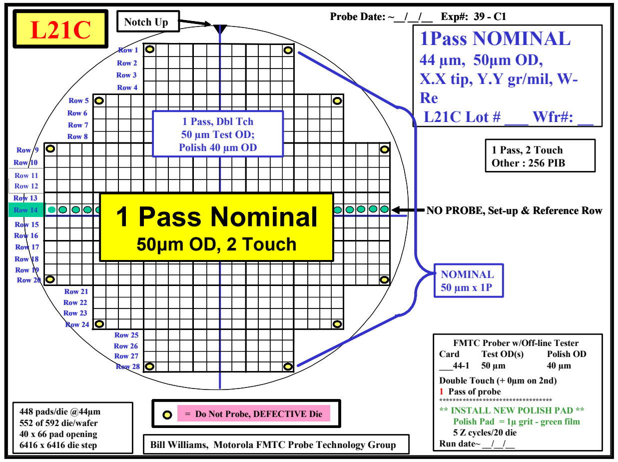


MRET, 1T vs. 2T, 1Pass Nominal, 3 Pass Nominal, 1-6Pass Heavy60, 1Pass Nominal

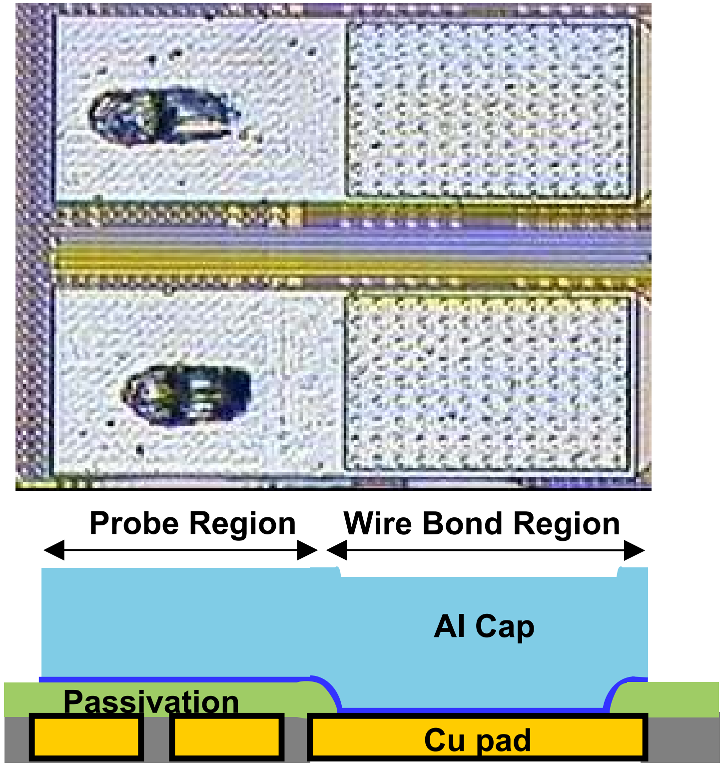
*** Then when successful = MANY Assembly Wafers of 1Pass & 3Pass*







What is POP? & Why Is It Used? – Recap of 2003



Probe Over Passivation Bond Pad

POP is "Probe-Over-Passivation"

We define it as a "Novel Method of Separating Probe and Wire Bond Regions Without Increasing Die Size".

POP is easily implemented on Alum Capped Copper pad wafer designs and may be adapted to others.

POP saves die size!

Benefits:

- Eliminate Cu exposure due to heavy probe marks
- Eliminate probe and wire bond interference
- Create longer bond pad but DO NOT increase die size
- Requires 1 mask change: Al Cap
- Low cost solution
- Ease of implementation on existing and new products

Challenges:

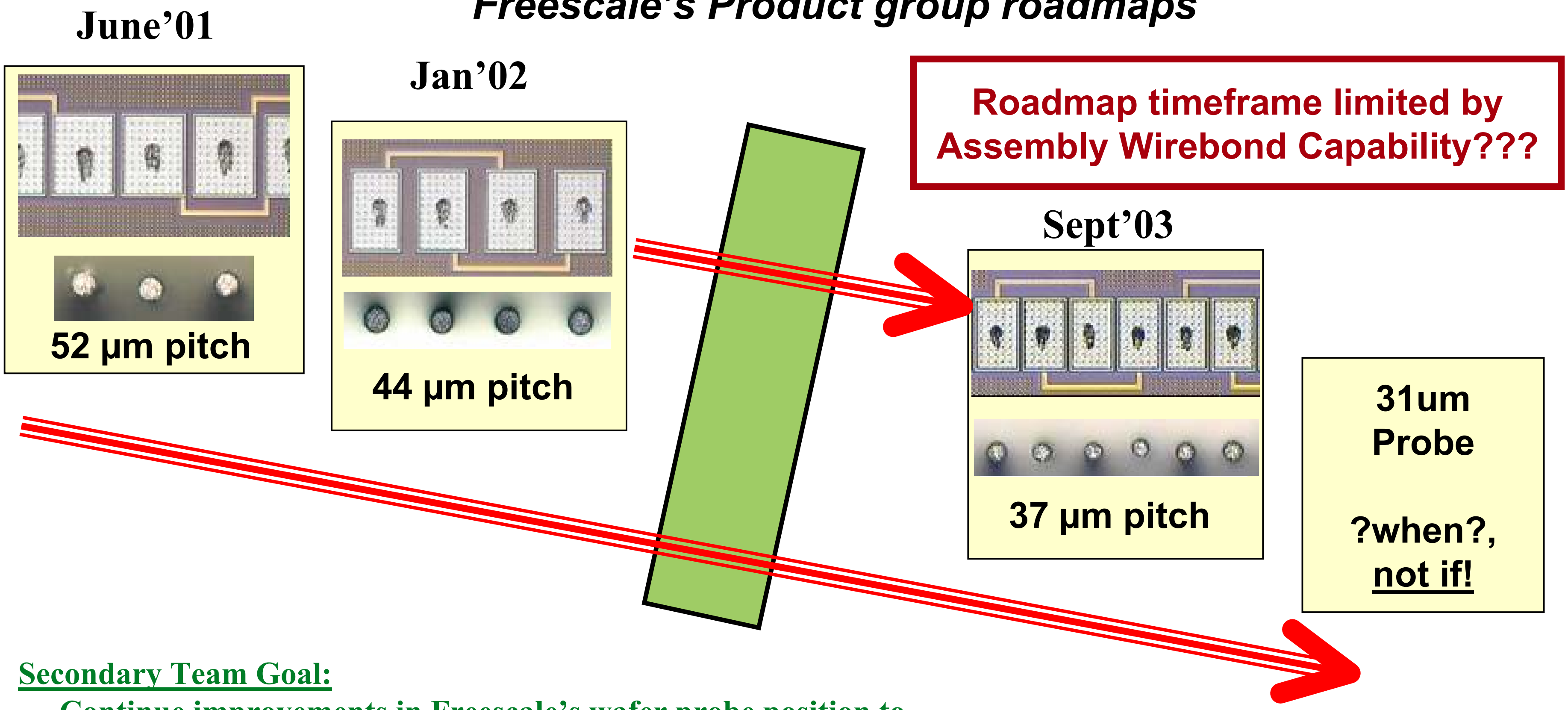
- Develop Probe Over Passivation (POP)
- Monitor passivation cracking risk

For a detailed paper on POP (Probe-Over-Passivation) see an ECTC-2003 paper titled "Novel Method of Separating Probe and Wire Bond Regions Without Increasing Die Size"
by Tu Anh Tran, Lois Yong, Stephen Lee, Bill Williams and Jody Ross

37um Fine Pitch Development Updates

37um Fine Pitch Thrust Development

Primary FMTC Team Goal:* *Drive advancements in probe to enable silicon shrinks in support of Freescale's Product group roadmaps



June'01

52 µm pitch

Jan'02

44 µm pitch

Roadmap timeframe limited by Assembly Wirebond Capability???

Sept'03

37 µm pitch

31um Probe

?when?,
<u>not if!</u>

<u>Secondary Team Goal:</u>

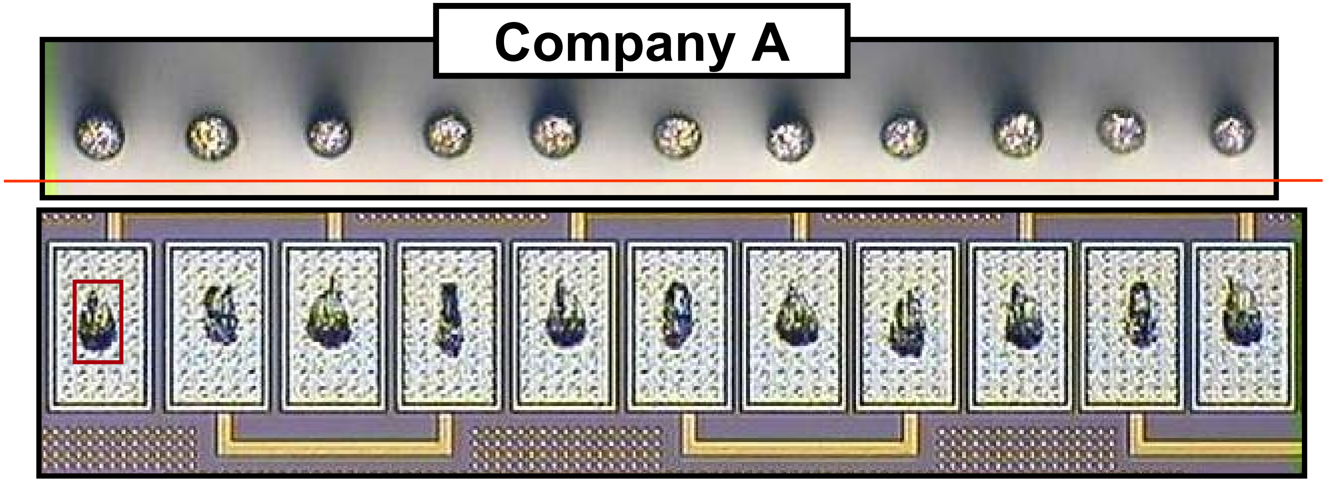
Continue improvements in Freescale's wafer probe position to remain at, or near, the Industry Leadership for Fine Pitch Probe!

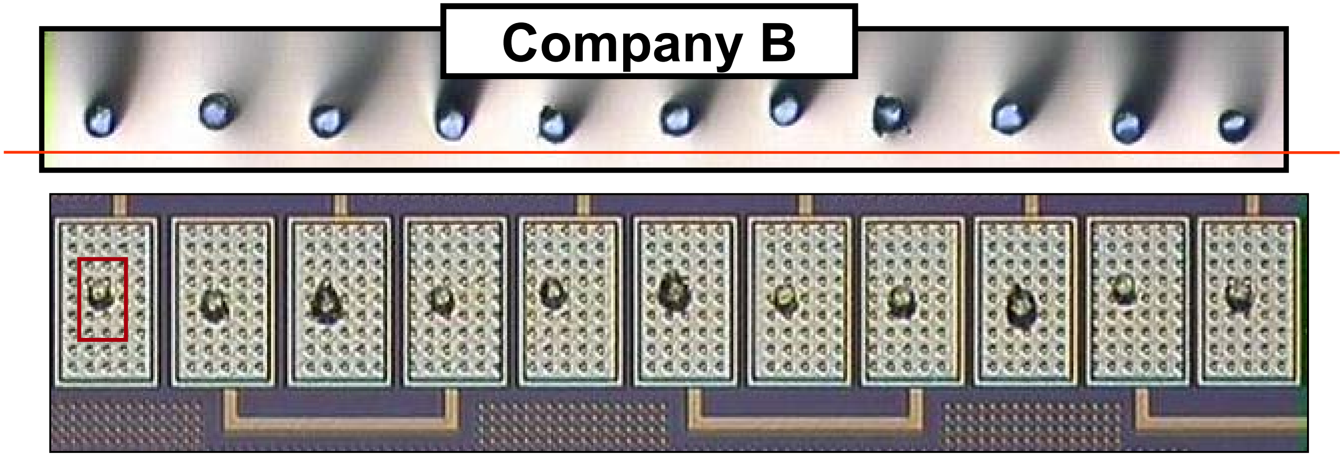
37um Comparisons:
Probe Pin "free state" and Scrub Alignment

☐ = 1/4 of pad Scrub Limit

Key Responses:

- Probe Alignment X-Y-Z
- Tip Diameter & Shape
- Scrub Placement
- Scrub Uniformity
- Scrub Size <25%





37um Comparisons: Electrical by Pad Pair and by Die

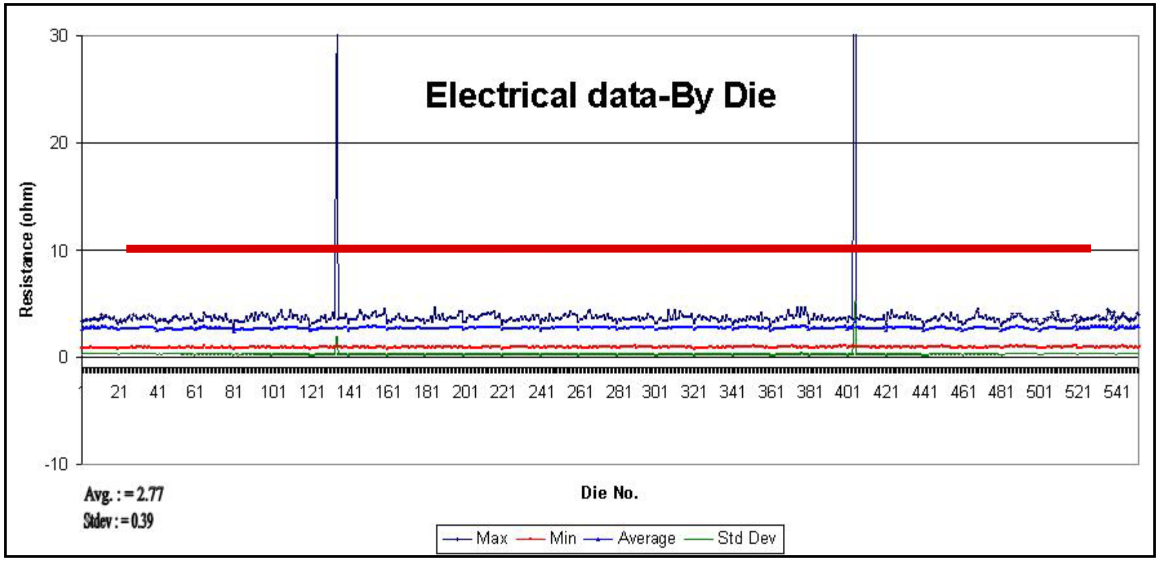
Electrical Responses:

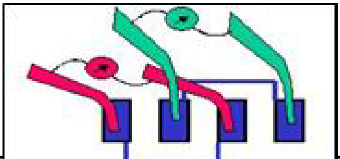
- Loop Res < 10ohm = Good

  Pad Pair Res & Std Dev.

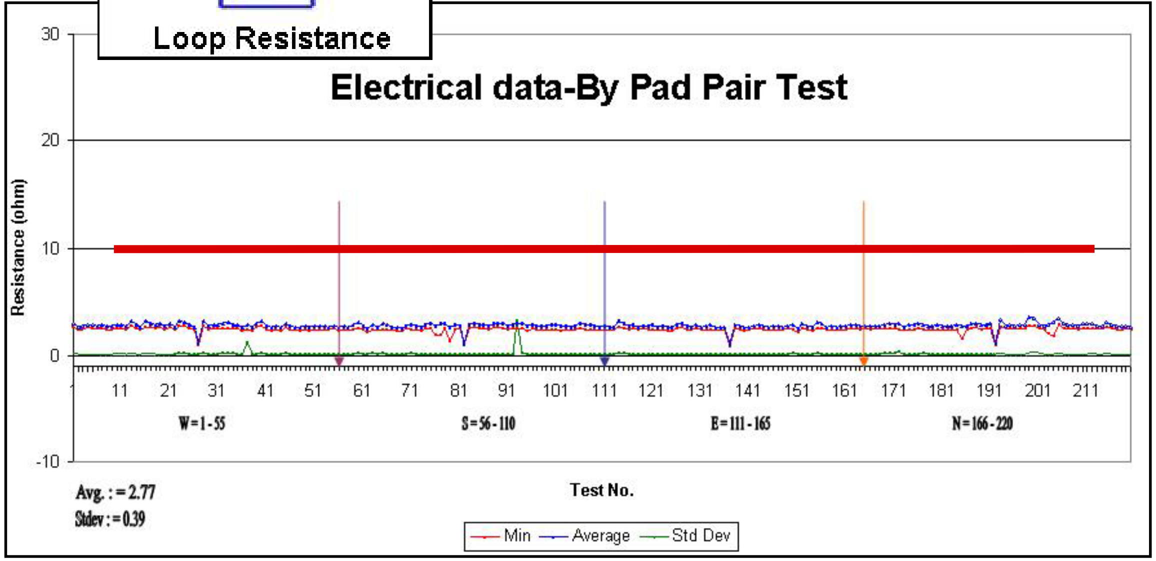
  Die Res Max >10 = Fail die

  Die Res Min, Ave, Std Dev.





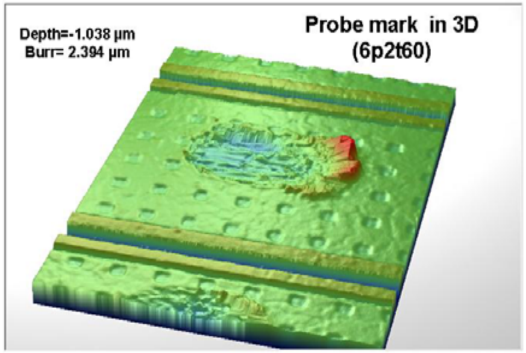
Loop Resistance



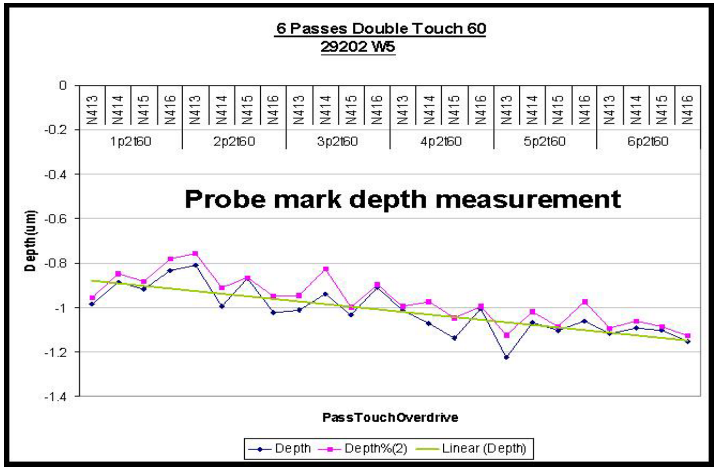
"Best In Class" Electrical Results ~ Company B

37um Scrub Cpk and Scrub Depth Comparisons

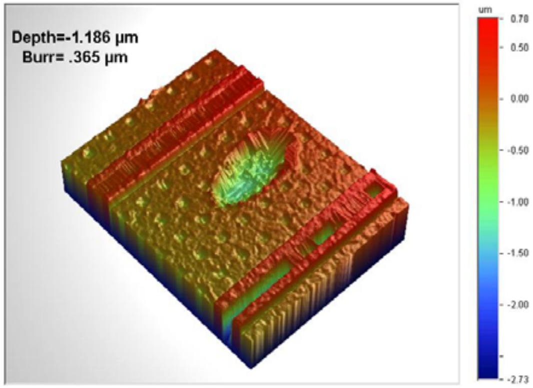
1 Pass Nominal
Y-Cpk = 1.80
X-Cpk = .78



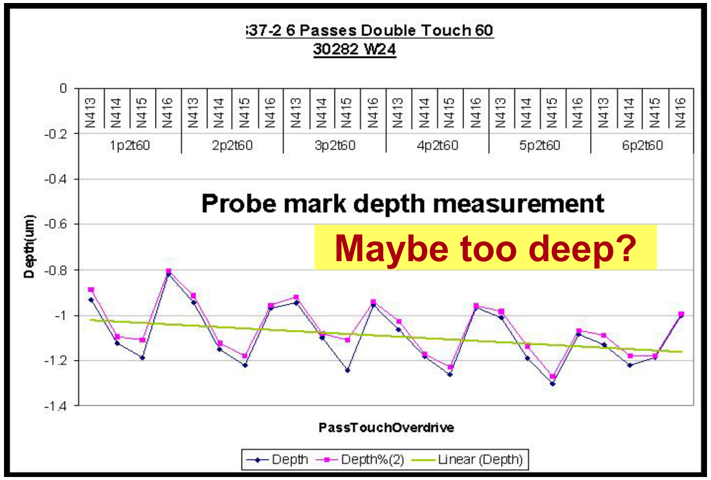
Company A



1 Pass Nominal
Y-Cpk = 1.92
X-Cpk = .90



Company B



Maybe too deep?

57um & 47um Dual Row Inline (DRI) Probe Development

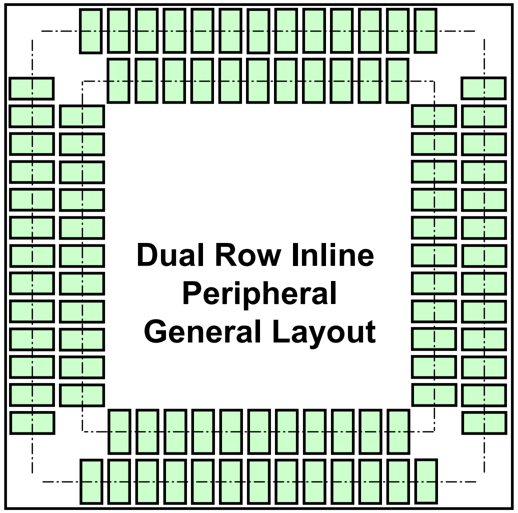
What is Fine Pitch DRI? Why does it exist? What are the issues?

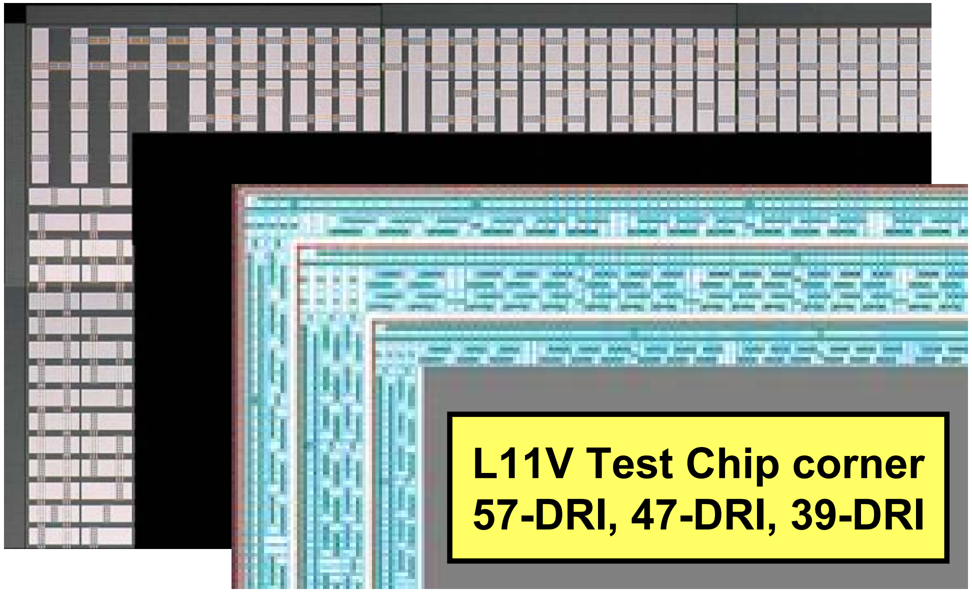
57um Dual Row Inline (DRI) Developments

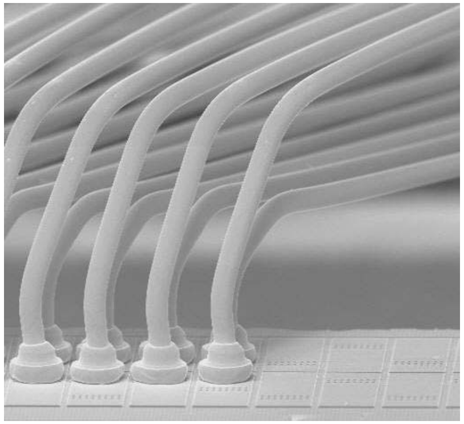
47um Dual Row Inline (DRI) Developments (** beyond design rules!)

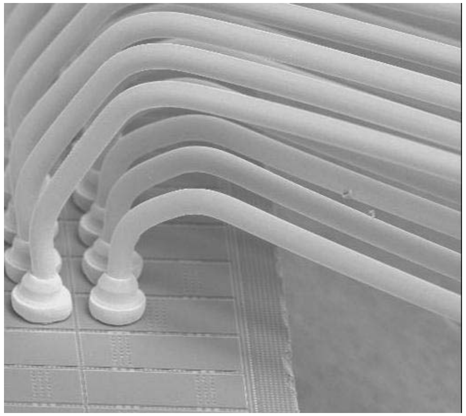
Share Comparative Results from Development Thrusts

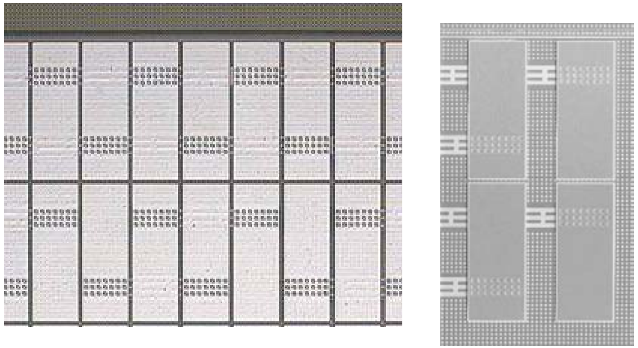
What is Fine Pitch Dual Row Inline? & Why?




L11V Test Chip corner
57-DRI, 47-DRI, 39-DRI





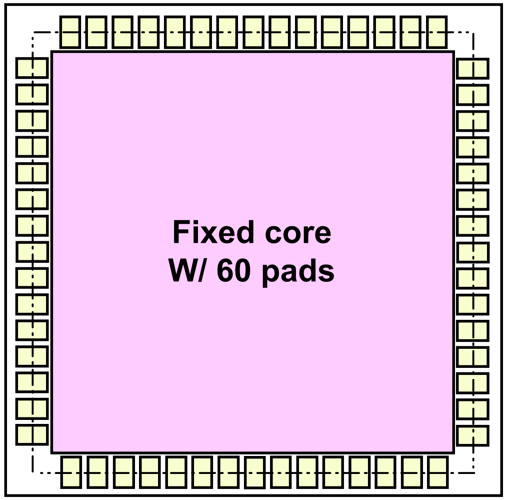

47um Dual Row Inline
Fine Pitch Pads
44um x 130um

Design Comparisons

What is Fine Pitch Dual Row Inline? & Why?

Ultra Fine Pitch

- Beyond Wirebond Capability
- Difficult Probe Card Design
  - Small Dia wire & Probe tips
  - Beyond metrology equip.

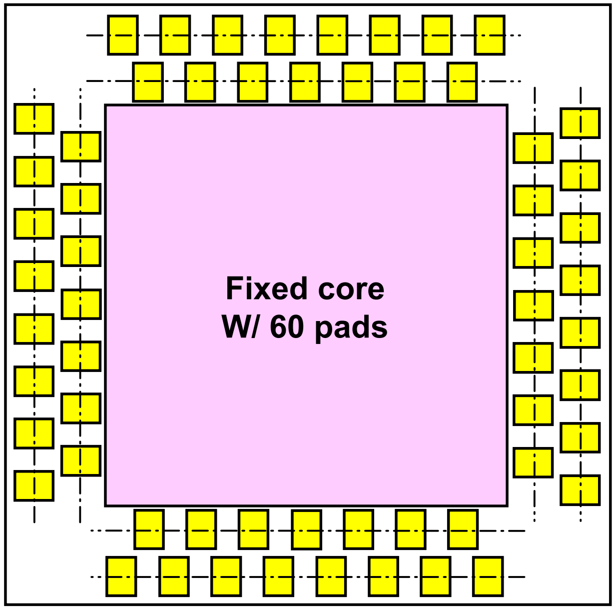


"Ultra Fine Pitch"
Single Row
Peripheral Inline

i.e. 44um or 37um

Non-POP 2 Row Staggered

- Good Wirebond Capability
- Good Probe Card Design
  - Large Dia wire & Probe tips
- Increases die size !!!!!!!!

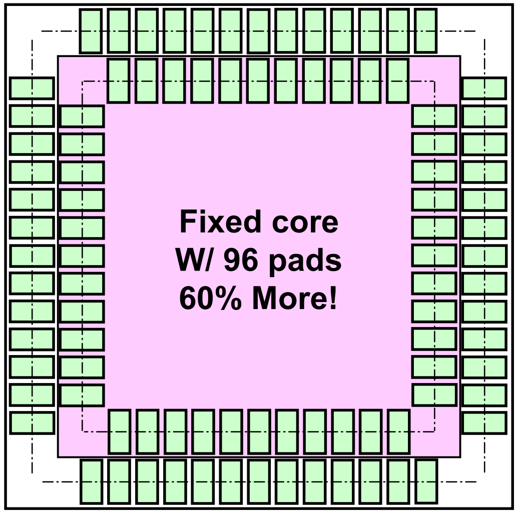


"Moderate Fine Pitch"
2 Row w/ Offset
Dual Row Staggered
Peripheral

i.e. 45/90 or 40/80 or 35/70

POP 2 Row Inline (DRI)

- Good Wirebond Capability
- Fair Probe Card Design
  - Medium Dia wire & Probe tips
- Slight die size increase!
- Staggered is optional



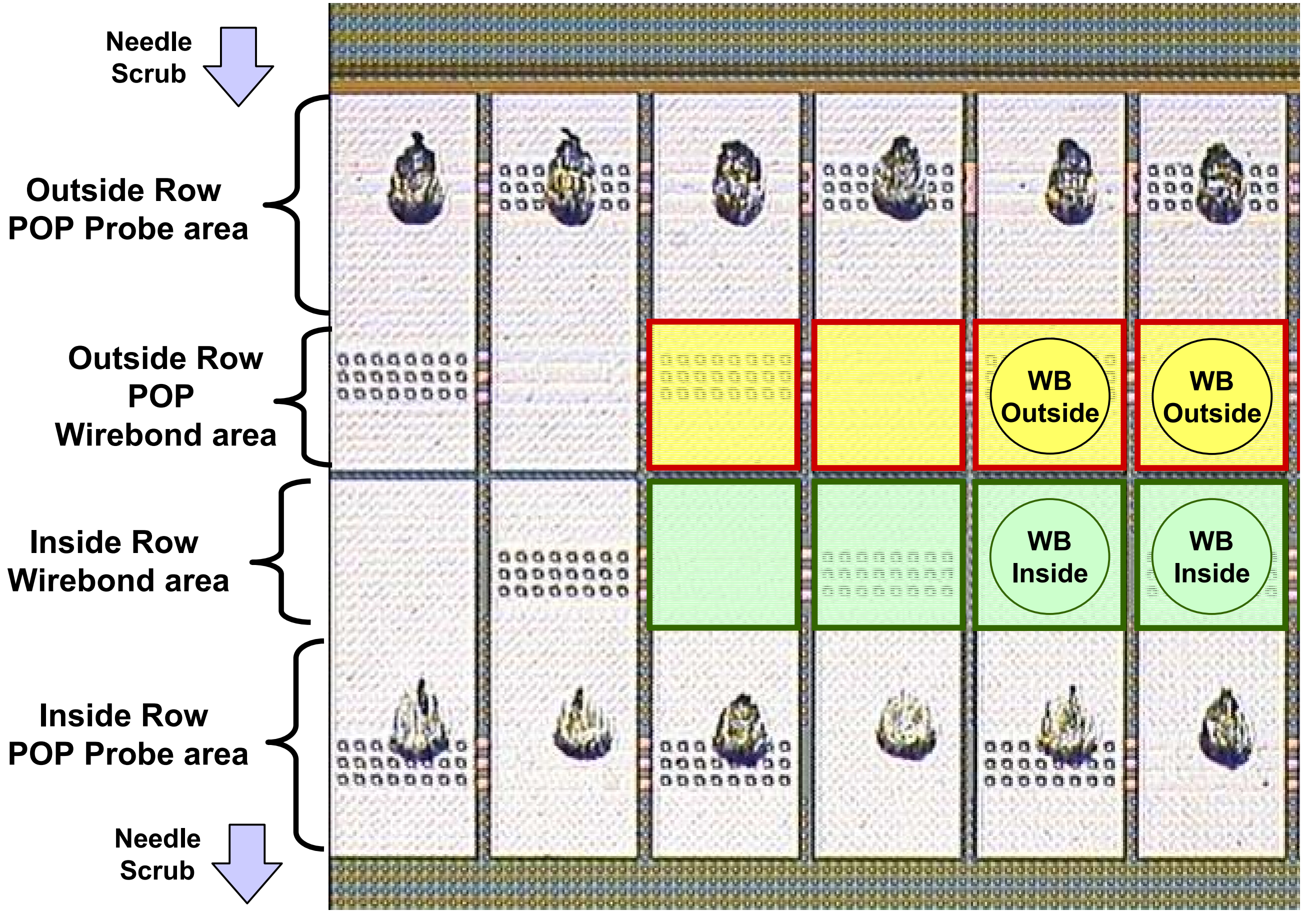
"Very Fine Pitch"
2 Row Zero Offset
Dual Row Inline
Peripheral

i.e. 57umDRI or 47umDRI

Dual Row Inline With Probe Over Passivation (POP)

POP Designated Wirebond areas vs. Probing areas

Die Edge



Needle Scrub

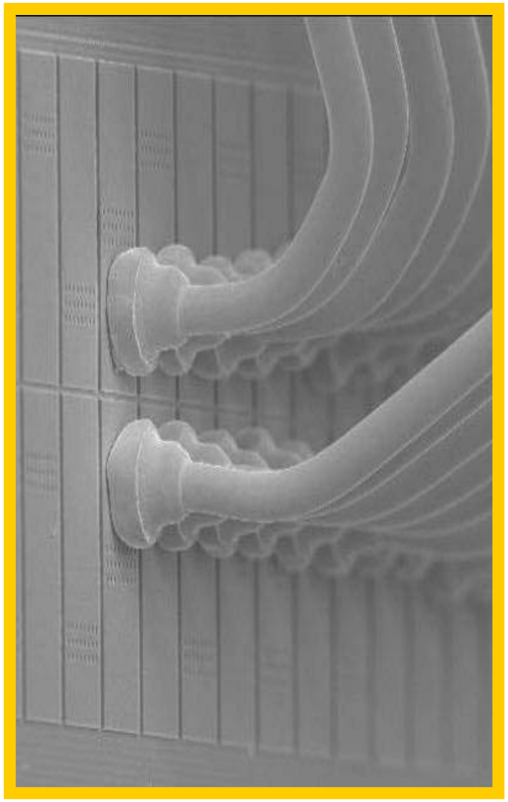
Outside Row POP Probe area

Outside Row POP Wirebond area

Inside Row Wirebond area

Inside Row POP Probe area

Needle Scrub



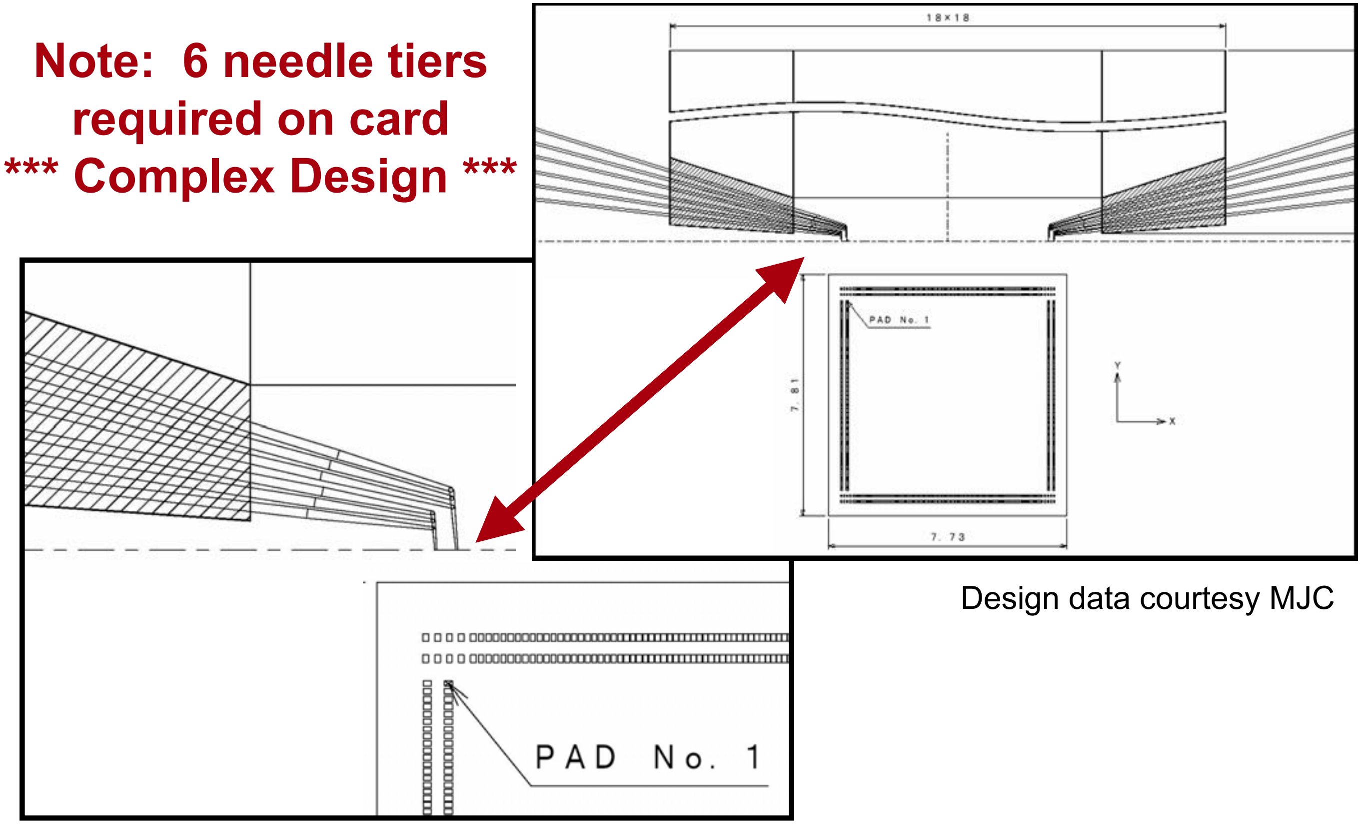
Note: Scrubs are from 6-Passes of Heavy Double Touch probe on 57um DRI

Design Issue: Complexity of Dual Row Inline (DRI)

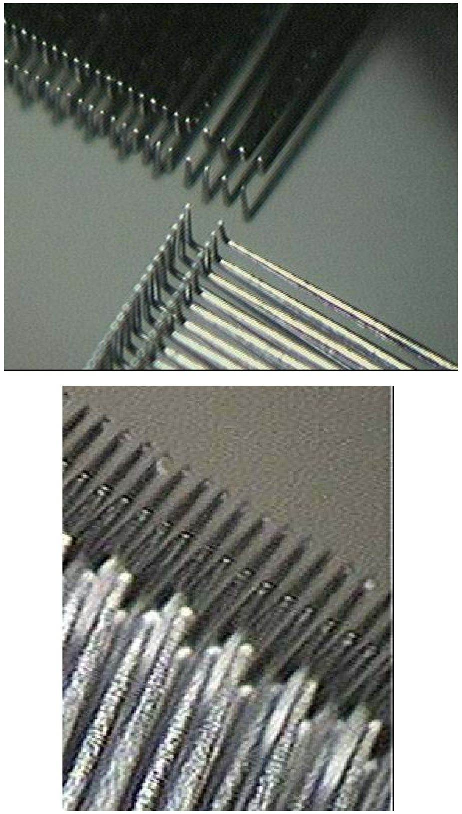
57um DRI = 880 pads
47um DRI = 968 pads

Serious example of 10# of Stuff in a 5# Bag!

Note: 6 needle tiers required on card
***** Complex Design *****

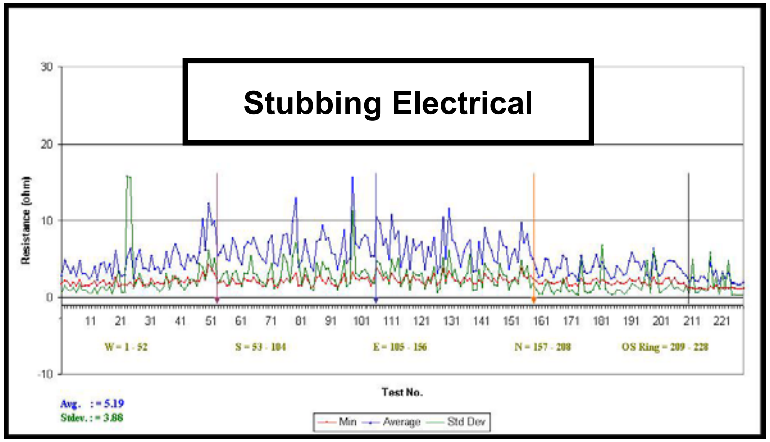


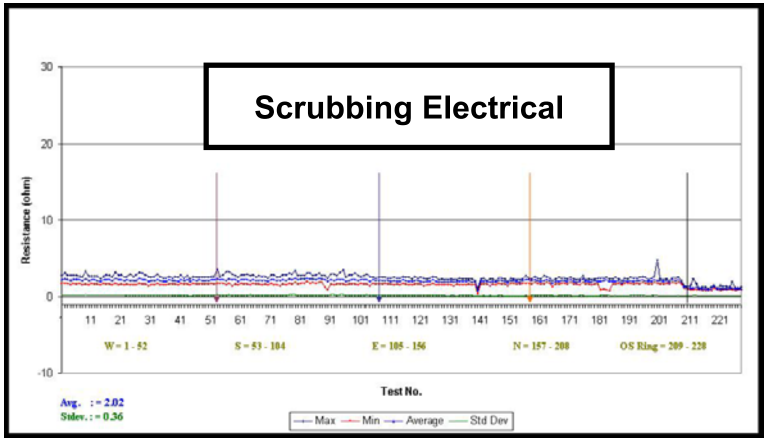
Design data courtesy MJC

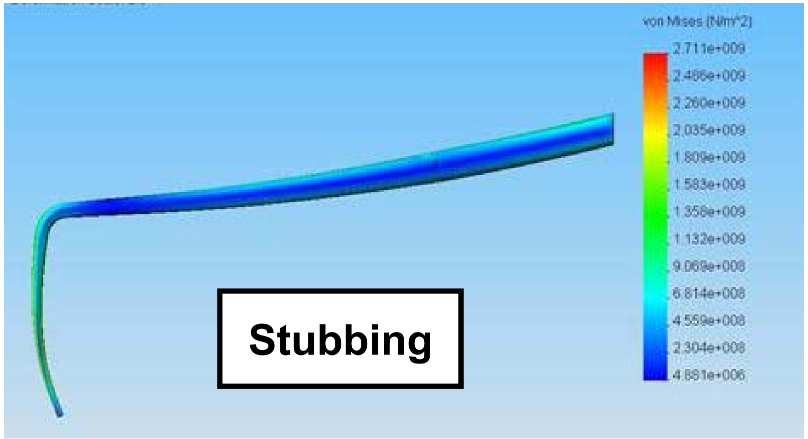


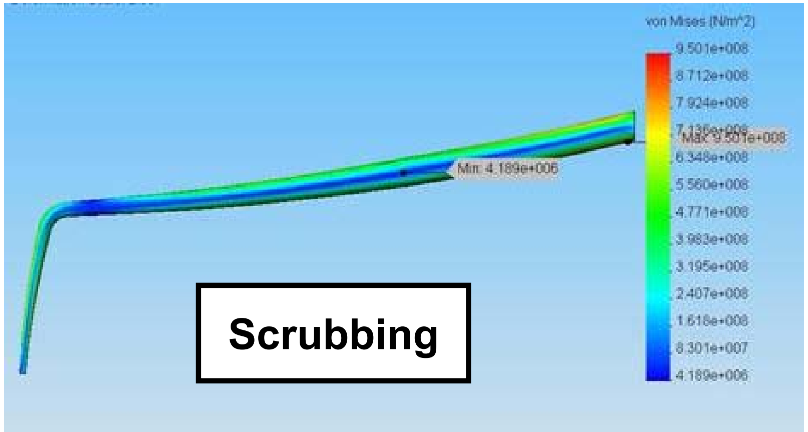
Design Issue: Stubbing vs. Scrubbing Probes

High Tier count increases tip length = risk of stubbing too much!

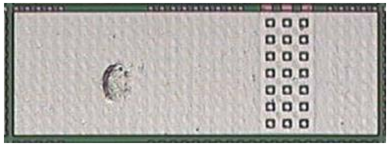


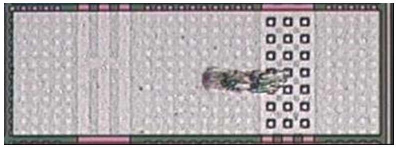






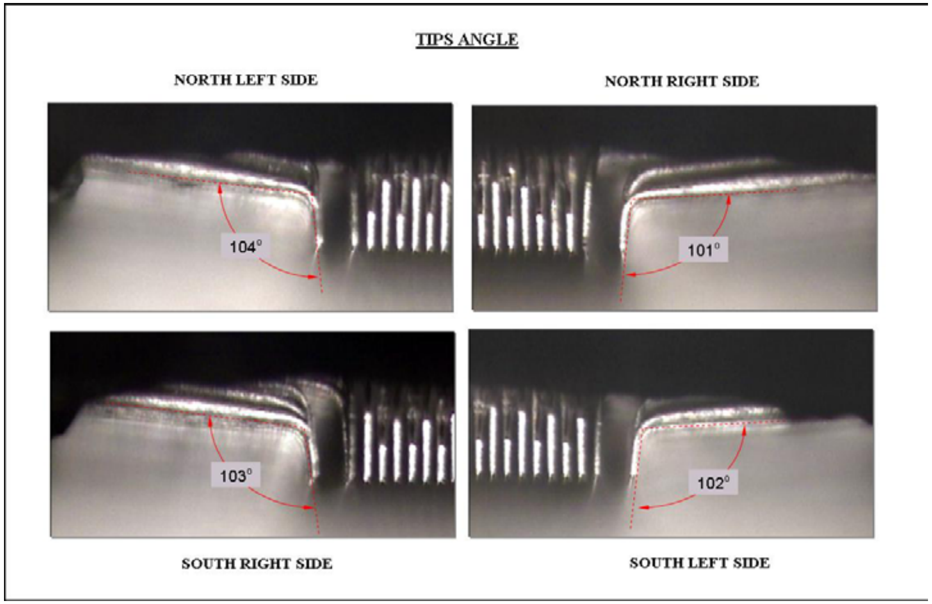
FEA courtesy of Probe Logic

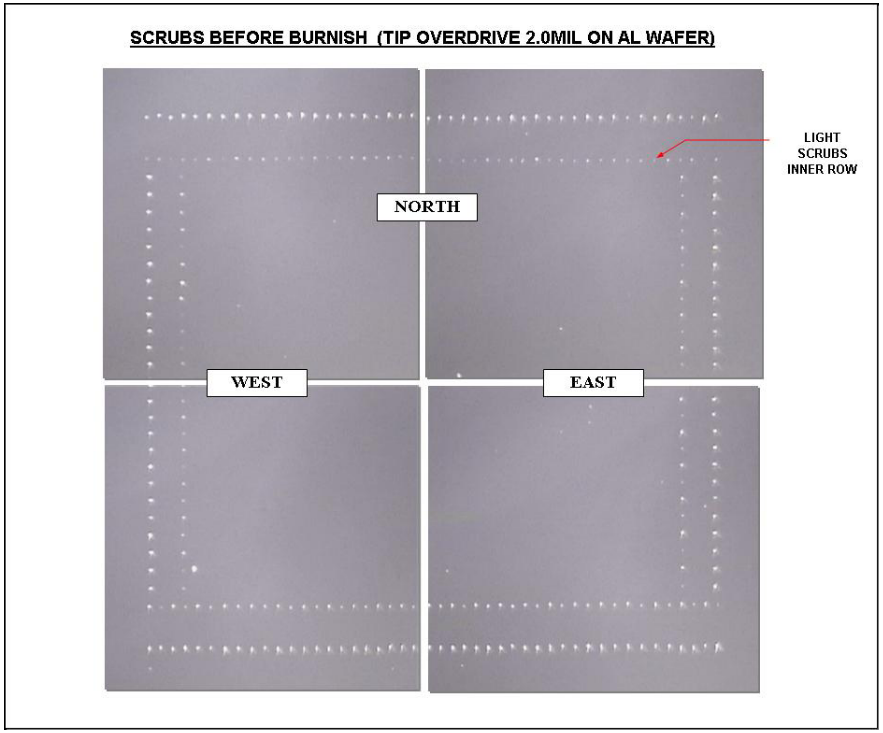




Dual Row Inline (DRI) Design Issues: Balanced Contact Force

Numerous Needle Layers combined with necessary long tip lengths and various approach angles causes serious issues controlling Balanced Contact Force (BCF).

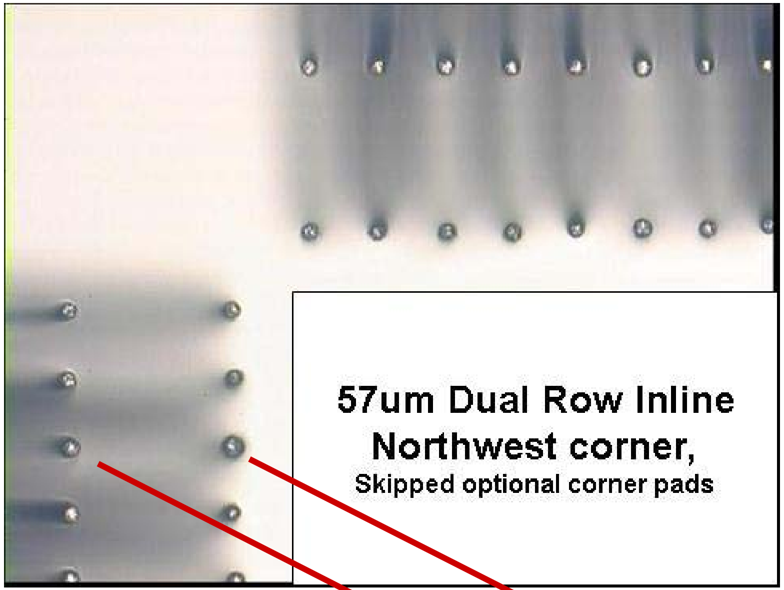




Pin Angle analysis vs. Scrub courtesy of K&S

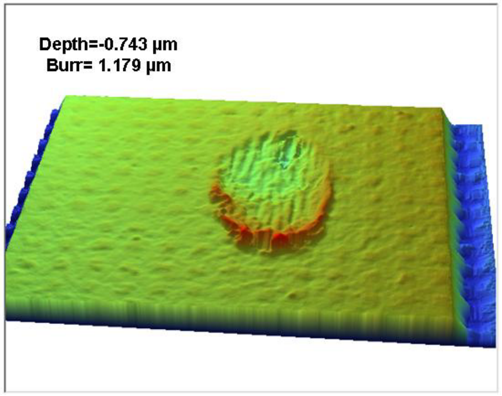
PROBE RESULTS L11V Test Vehicle

Dual Row Inline-57P Probed Pads 1pass 50 OD Nominal Probe card



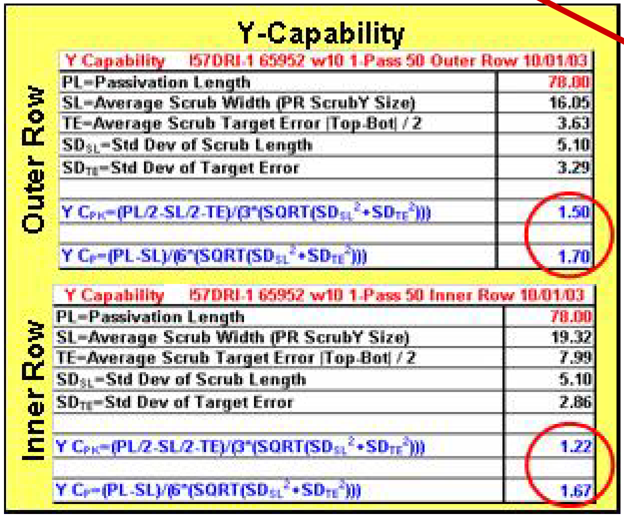
57um Dual Row Inline Northwest corner,

Skipped optional corner pads



Depth=-0.743 µm

Burr= 1.179 µm



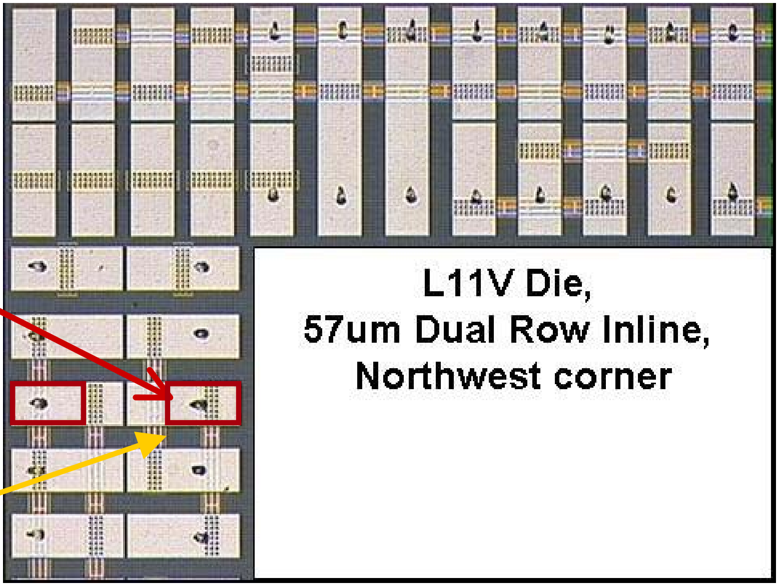
Y-Capability

Outer Row

Y Capability I57DRI-1 65952 w10 1-Pass 50 Outer Row 10/01/03	
PL=Passivation Length	78.00
SL=Average Scrub Width (PR ScrubY Size)	16.05
TE=Average Scrub Target Error |Top-Bot| / 2	3.63
SD_{SL}=Std Dev of Scrub Length	5.10
SD_{TE}=Std Dev of Target Error	3.29
Y $C_{PK}=(PL/2-SL/2-TE)/(3*(SQRT(SD_{SL}^2+SD_{TE}^2)))$	1.50
Y $C_{P}=(PL-SL)/(6*(SQRT(SD_{SL}^2+SD_{TE}^2)))$	1.70

Inner Row

Y Capability I57DRI-1 65952 w10 1-Pass 50 Inner Row 10/01/03	
PL=Passivation Length	78.00
SL=Average Scrub Width (PR ScrubY Size)	19.32
TE=Average Scrub Target Error |Top-Bot| / 2	7.99
SD_{SL}=Std Dev of Scrub Length	5.10
SD_{TE}=Std Dev of Target Error	2.86
Y $C_{PK}=(PL/2-SL/2-TE)/(3*(SQRT(SD_{SL}^2+SD_{TE}^2)))$	1.22
Y $C_{P}=(PL-SL)/(6*(SQRT(SD_{SL}^2+SD_{TE}^2)))$	1.67



L11V Die,

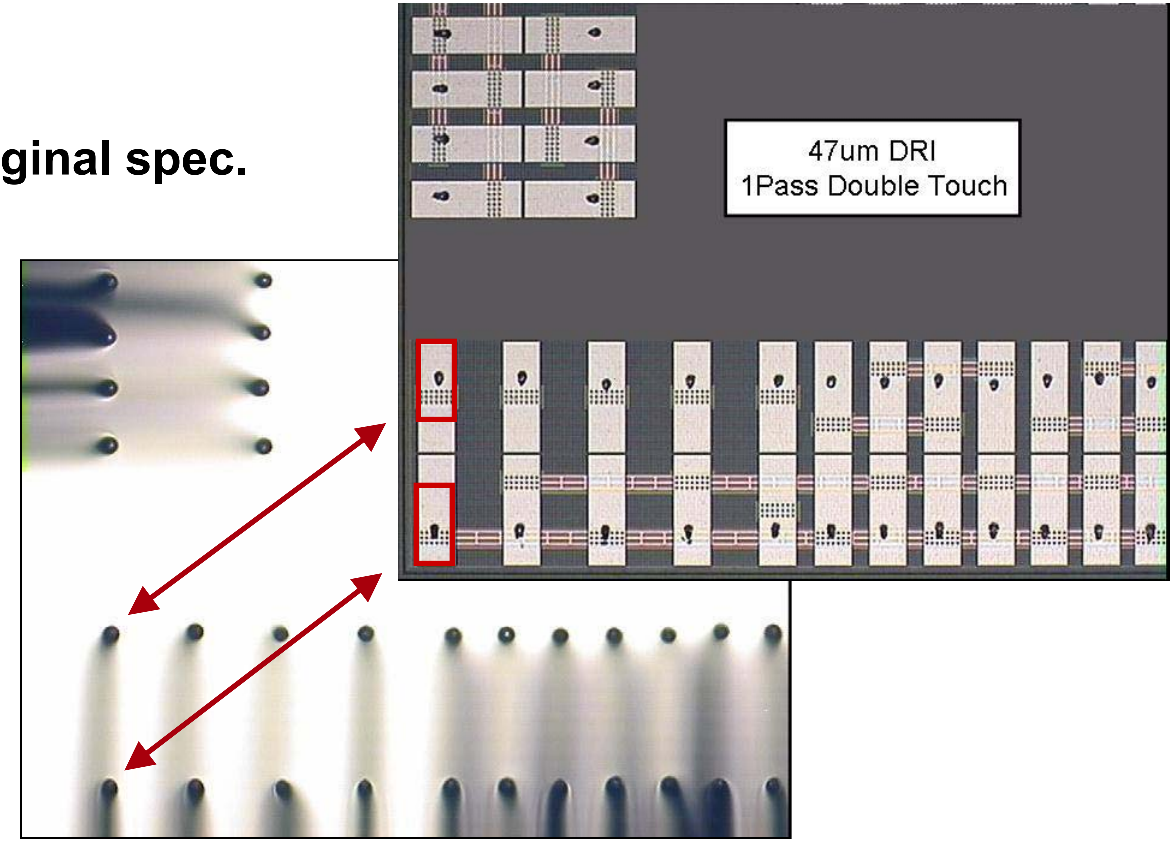
57um Dual Row Inline,

Northwest corner

Results: 47um Dual Row Inline ISSUES! & ISSUES! & ISSUES!

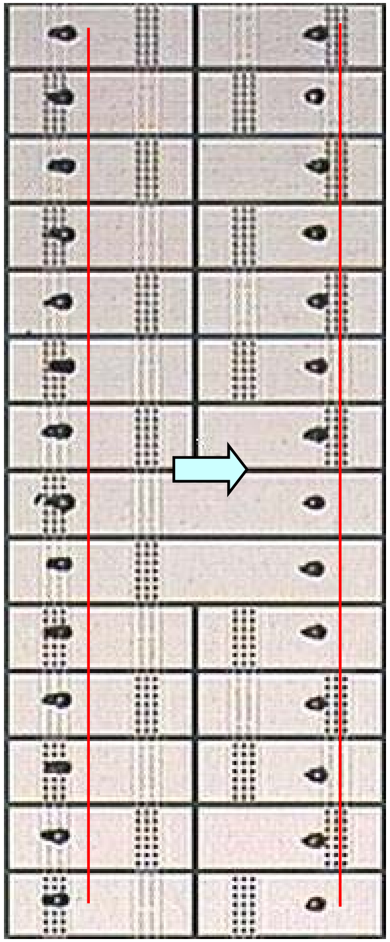
- The Dual Row “row to row spacing” combined with Fine Pitch caused design rule violations at suppliers
  - – so, we shared failure risk!
- Wire diameters reduced
- Pin Taper rates changed
- Tip Diameters reduced
- Resultant Force below original spec.
- Corner Keep-outs defined

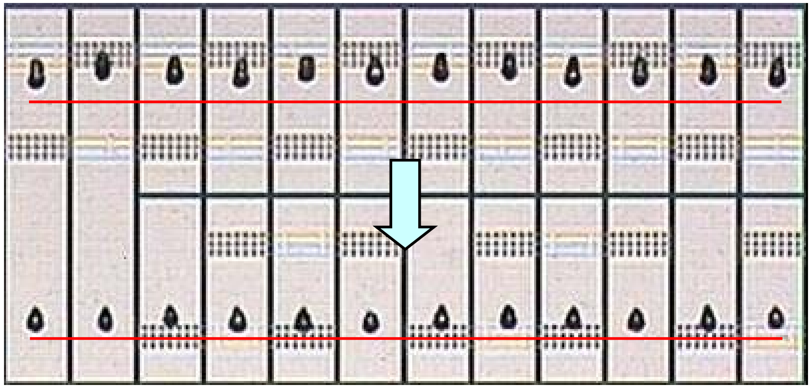
- Outcome Results have been <u>FANTASTIC!</u>
- @ Multiple Suppliers!
- Limited data – much more to come!



Results: 47um Dual Row Inline – Scrubs

Scrub Direction

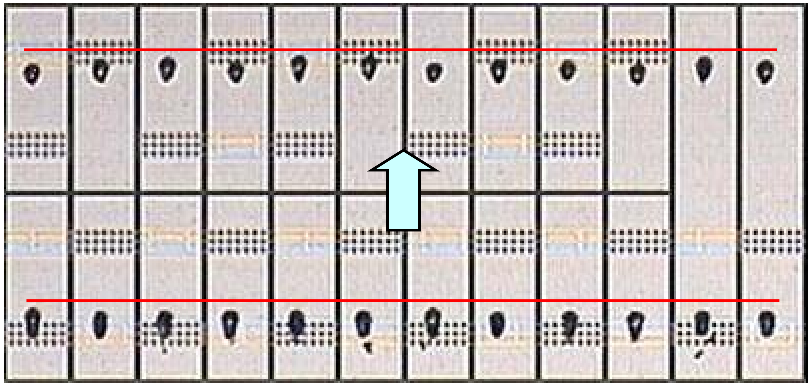


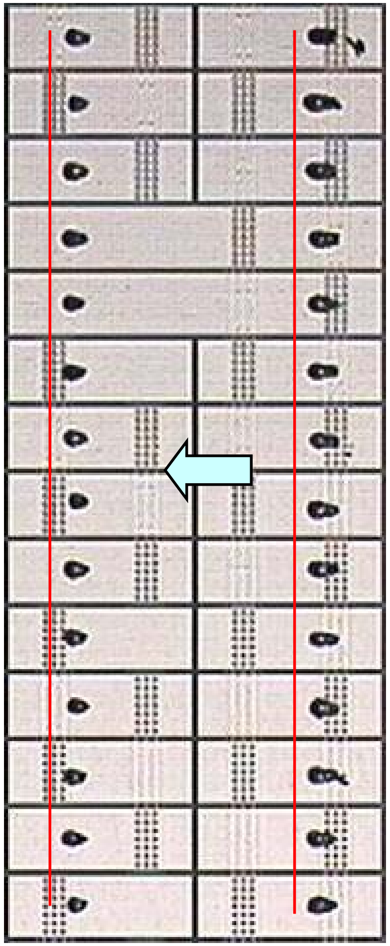


Probe mark photo 1 Pass Nominal

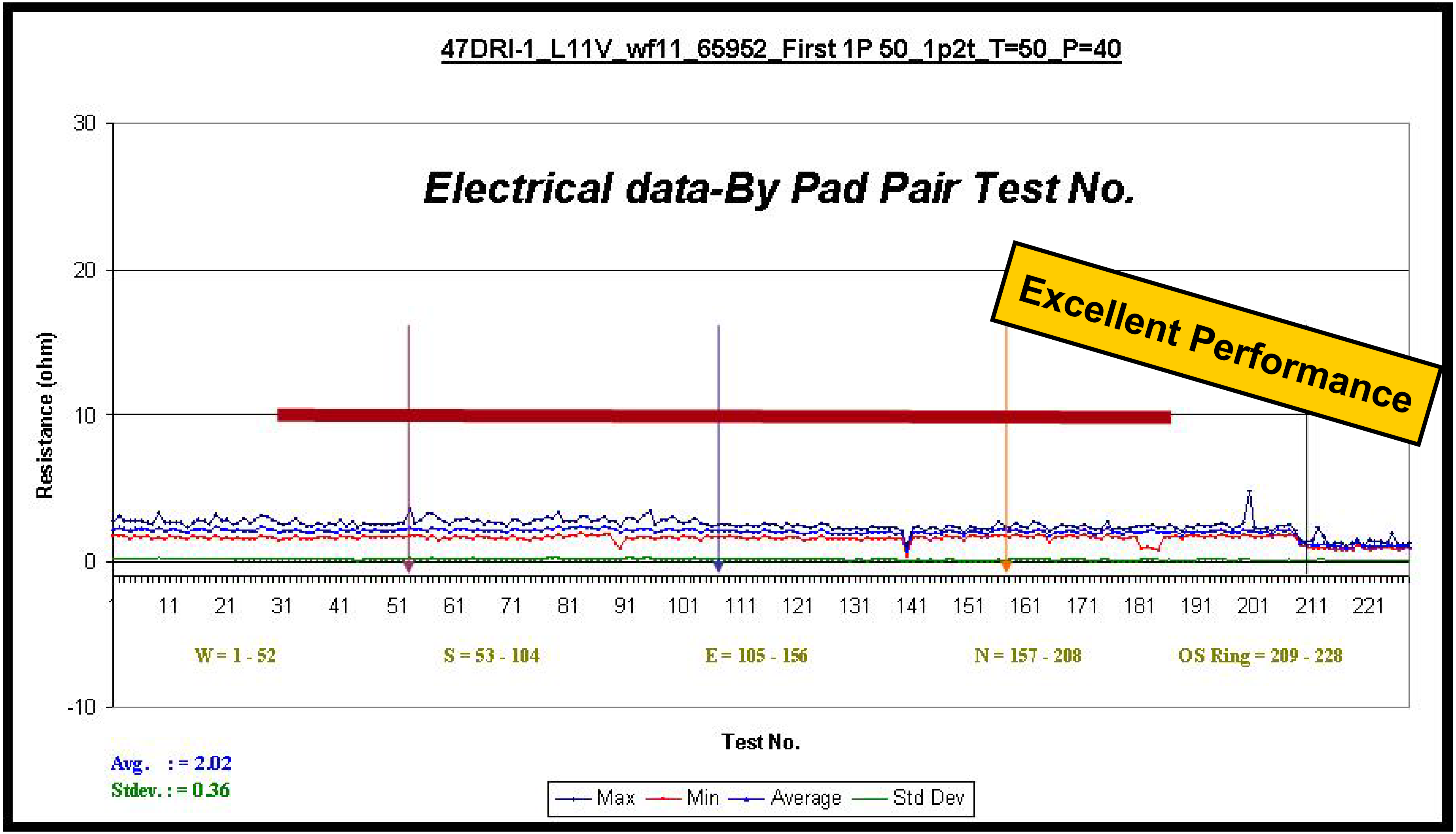
****** <u>EXCELLENT PLACEMENT!</u> ******

(Remember there are 968 pins! @47um)

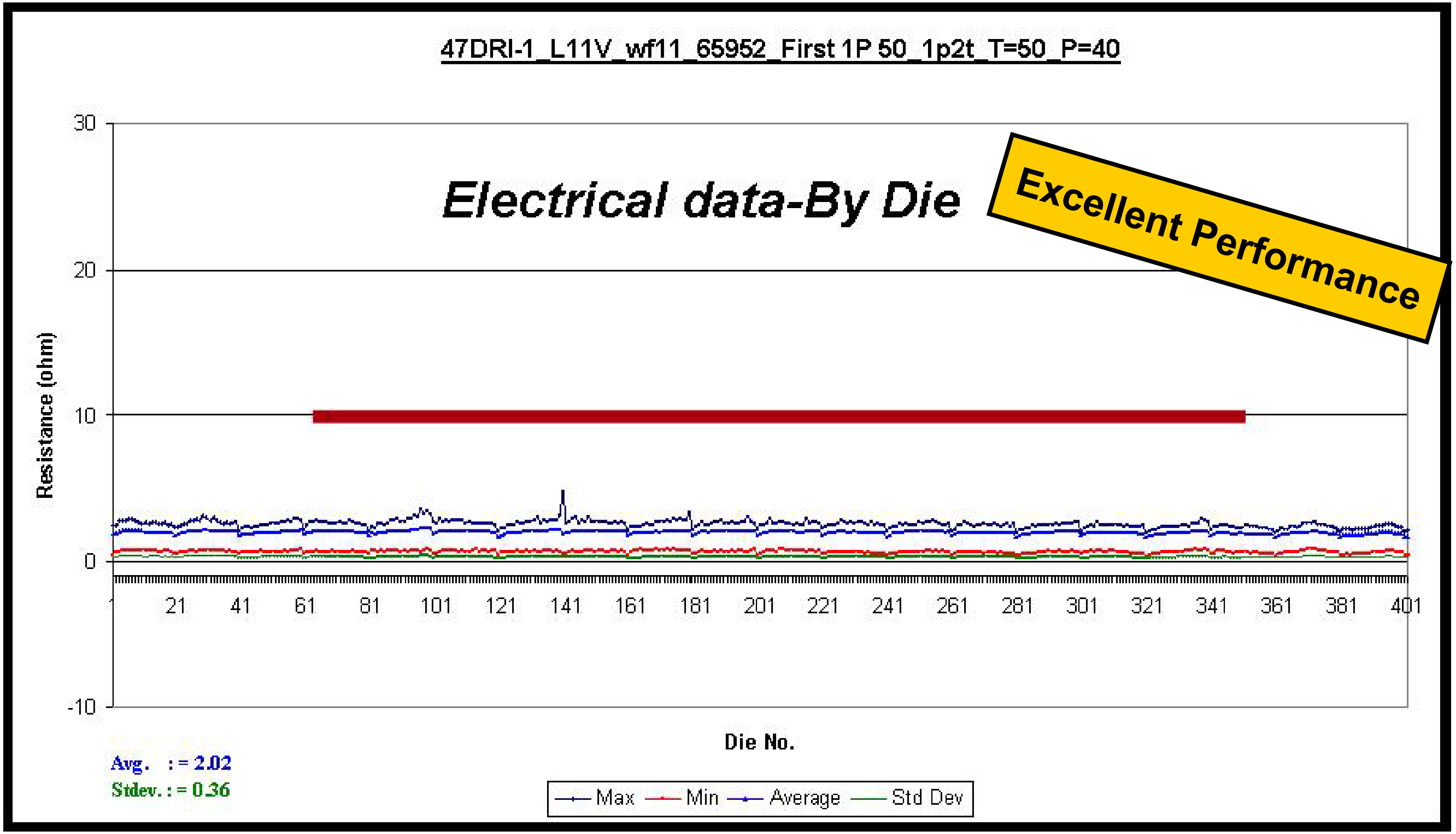




Results: 47um Dual Row Inline – Electrical by Pair



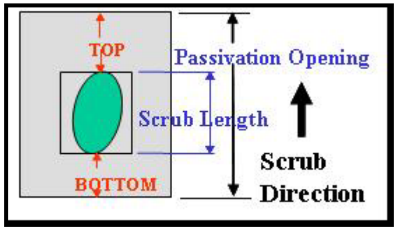
Results: 47um Dual Row Inline – Electrical by Die



Excellent Performance

Bill Williams FMTC Probe Technology Development Group

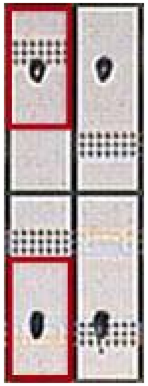
Results: 47um Dual Row Inline – Cpk Placement



Mechanical Capability Data

47um Dual Row In-Line Design First 1-Pas

Excellent Performance



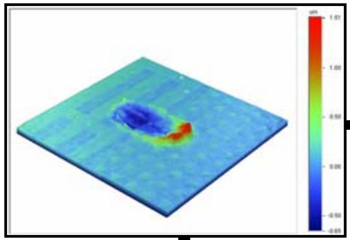
Y-Cpk for Various Pad Lengths

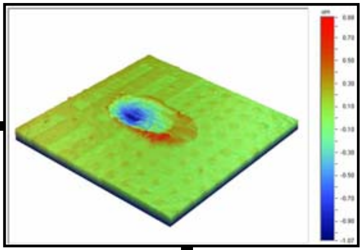
	Outer				Inner			
PL=Passivation Length	66.00	76.00	84.00	86.00	66.00	76.00	84.00	86.00
SL=Average Scrub Length (PR ScrubY Size)	16.92	16.92	16.92	16.92	16.92	16.92	16.92	16.92
TE=Average Scrub Target Error |Top-Bot| / 2	2.95	2.95	2.96	2.96	2.48	2.47	2.48	2.48
SD_{SL}=Std Dev of Scrub Length	4.14	4.14	4.14	4.14	4.14	4.14	4.14	4.14
SD_{TE}=Std Dev of Target Error	2.31	2.35	2.39	2.40	1.93	1.95	1.98	1.98
Y $C_{PK}=(PL/2-SL/2-TE)/(3^*(SQRT(SD_{SL}^2+SD_{TE}^2)))$	1.52	1.86	2.13	2.20	1.61	1.97	2.26	2.33
Y $C_P=(PL-SL)/(6^*(SQRT(SD_{SL}^2+SD_{TE}^2)))$	1.73	2.07	2.34	2.41	1.79	2.15	2.44	2.51

X-Cpk for Various Pad Widths

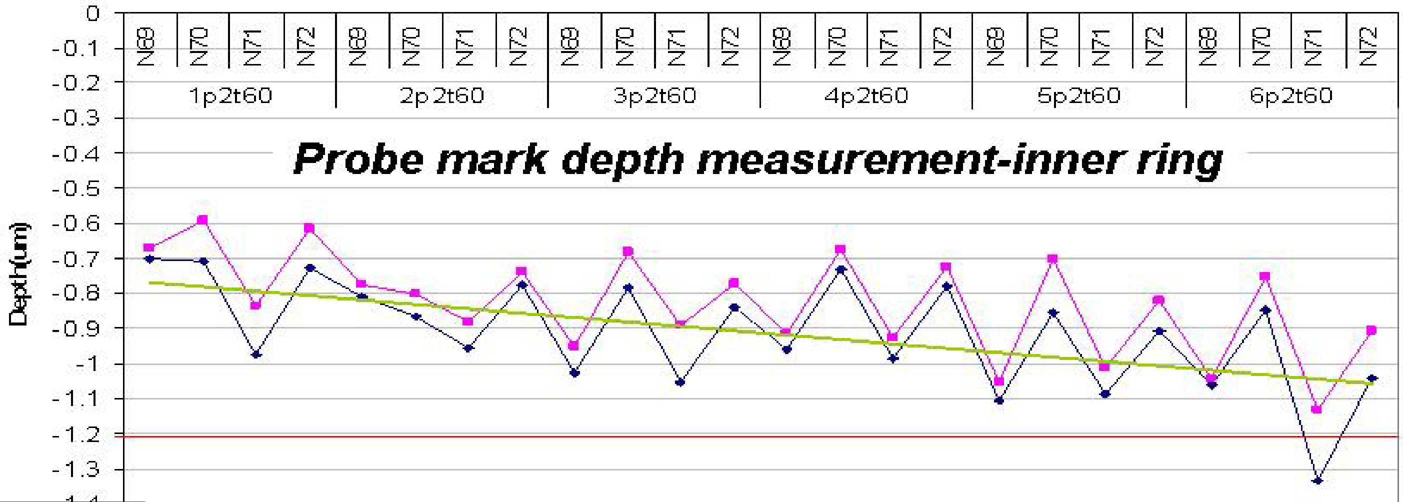
	Outer		Inner	
PW=Passivation Width	40.00	44.00	40.00	44.00
SW=Average Scrub Width (PR Scrub X Size)	11.15	11.15	11.15	11.15
TE=Average Scrub Target Error |Left-Right| / 2	2.27	2.28	1.94	1.95
SD_{SW}=Std Dev of Scrub Width	1.65	1.65	1.65	1.65
SD_{TE}=Std Dev of Target Error	1.86	1.88	1.44	1.44
X $C_{PK}=(PW/2-SW/2-TE)/(3^*(SQRT(SD_{SW}^2+SD_{TE}^2)))$	1.63	1.89	1.90	2.20
X $C_P=(PW-SW)/(6^*(SQRT(SD_{SW}^2+SD_{TE}^2)))$	1.93	2.19	2.20	2.50

Results: 47um Dual Row Inline – Scrub Depth



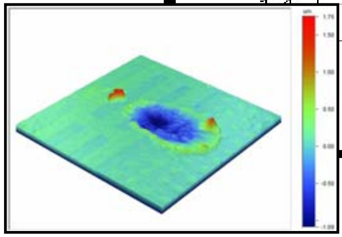


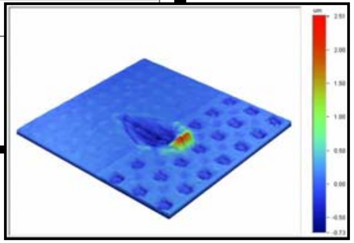
DRI47-1 6 Passes Double Touch 60
65952 W15-Inner Ring



PassTouchOve

Depth
Depth%(2)





Very Good Performance

Conclusion Observations:

Based on the FMTC evaluations, only the best cantilever probe card suppliers are able to meet our requirements and support expansion into "Fine Pitch – Dual Row – High Pad Count" and the "Ultra Fine Pitch" probe requirements.

Traditional Cantilever Probe has finally moved Probe Capability back to being ahead of Wirebond Capability …. <u>but only slightly!,</u>
…. <u>so don't relax yet!</u>

Bill Williams, Freescale FMTC Probe Mgr
Freescale Semiconductor

Acknowledgements

Future Work Planned
Deploy 37um FP to factories
Develop 31um on 448 pads
Deploy 47um DRI to factories
Triple Row 47um High Pin Count
Probe Polish Material Optimization

Fine Pitch Probe

There are <u>many</u> groups supporting the Fine Pitch Probe effort, my sincere apologies to any of those I have neglected to highlight !

FMTC Assembly Development Fine Pitch Wire bond Team

FMTC Fine Pitch Probe Development Group

FMTC Asia Assembly Support

WBSG Product Team

TSPG Product Team

NPI Austin Test OHT

NCSG Product Team

Key Probe Supplier Support Team Participants:

You know who you are! & I say to you ……

Thanks! Domo Arigato! Great Work!

You are the keys to these successes and future development!

Thanks for your Attention!

?? Questions ??

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