IEEE SW Test Workshop
Semiconductor Wafer Test Workshop

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Probe Mark Inspection As Part of Quality and Reliability in Automotive Devices

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Outline

- Automotive Devices
- Probe Mark Damage Area vs. Bond Failure
- AVI Can Predict Failures
- Inspection Challenges and Solutions
- Magnification and Throughput
- Probe Mark Depth Measurement
- Reporting
- Conclusions

Overview

- TI manufactures automotive devices
- Yield requirement: <10ppm
- TI EBT tests and inspects all automotive wafers
- Practice – 100% test + 100% inspection
- Challenge – detecting all and only critical defects
- Solutions
  - Dedicated AVI for probe mark inspection
  - Probe mark depth measurement capability

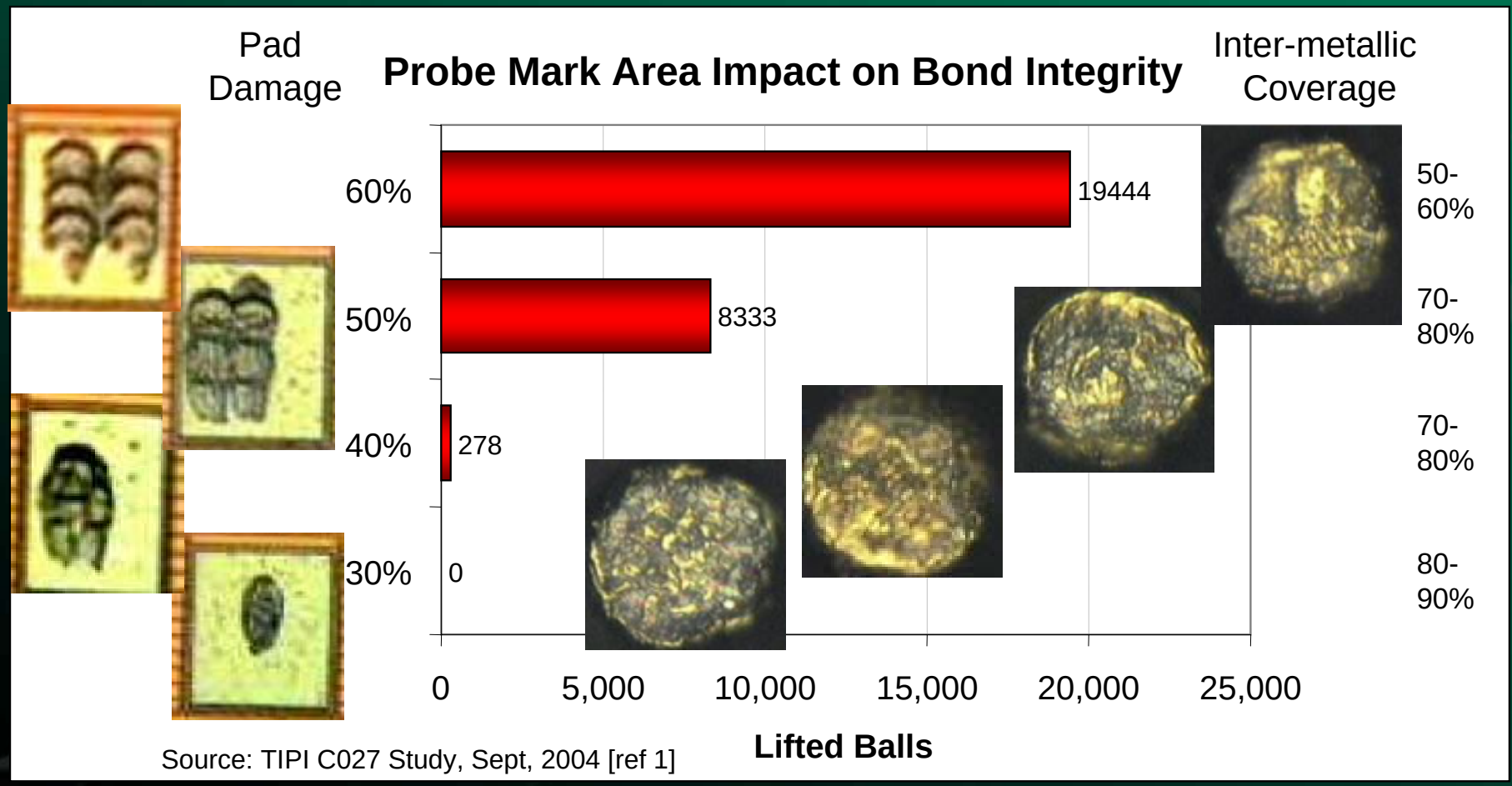
Typical Automotive Devices

- End applications using such mission-critical devices may include:
  - Electronic stability control
  - Engine controller
  - Supplemental restraining system
  - Anti-lock breaking system
  - Power steering

Automotive Requirements

- Defective part rate <10 ppm (>99.999%)
- No compromising of:
  - Wire bond integrity and reliability
  - Die hermeticity
  - Foreign materials
  - Mechanical damage

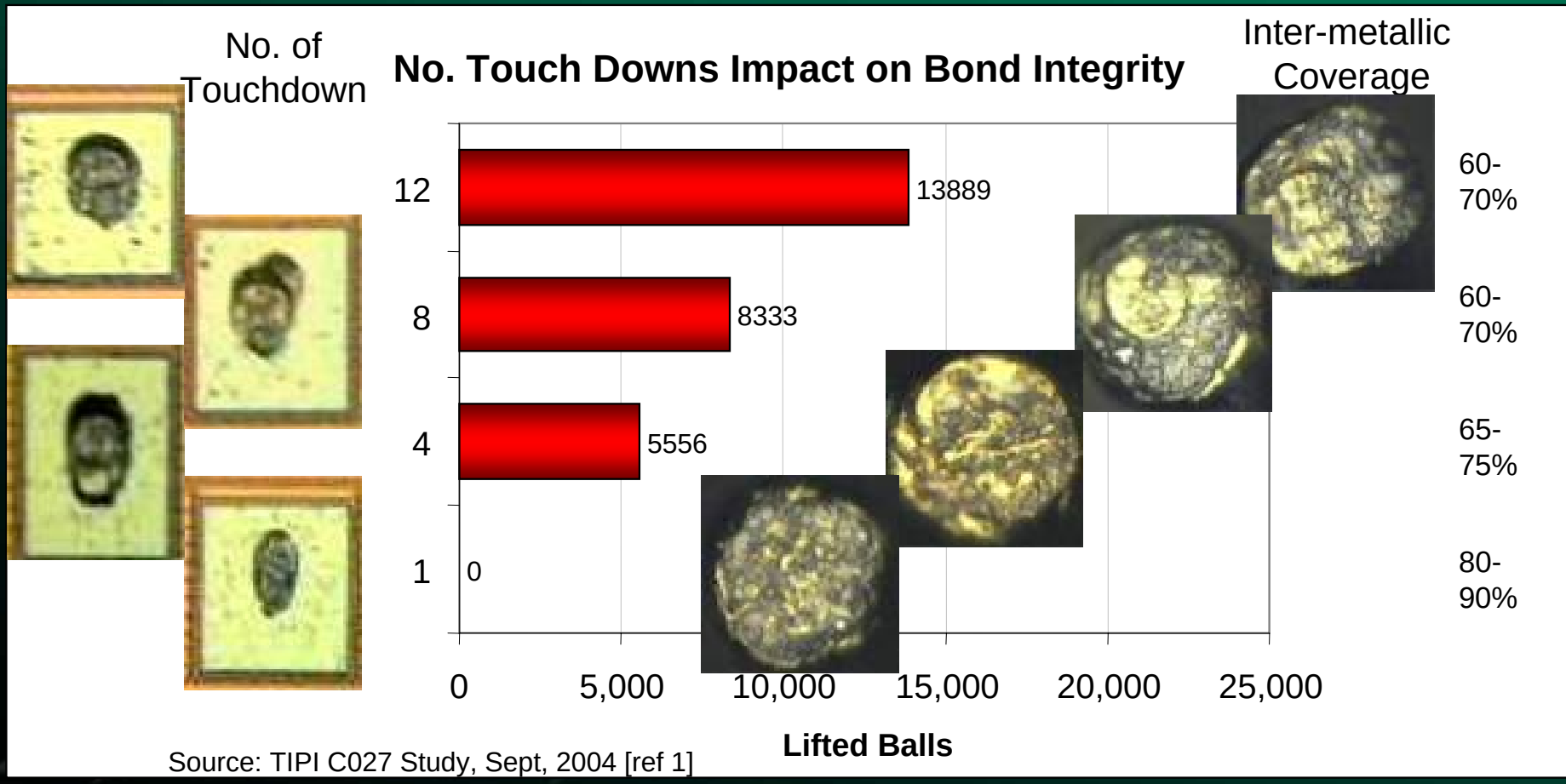
Damage Area vs. Bond Failure



Source: TIPI C027 Study, Sept, 2004 [ref 1]

- Pad damaged area correlates to reduced IMC ➔ Bond failure
- AVI can measure probe mark area vs. pad area on all pads

Damage Depth vs. Bond Failure



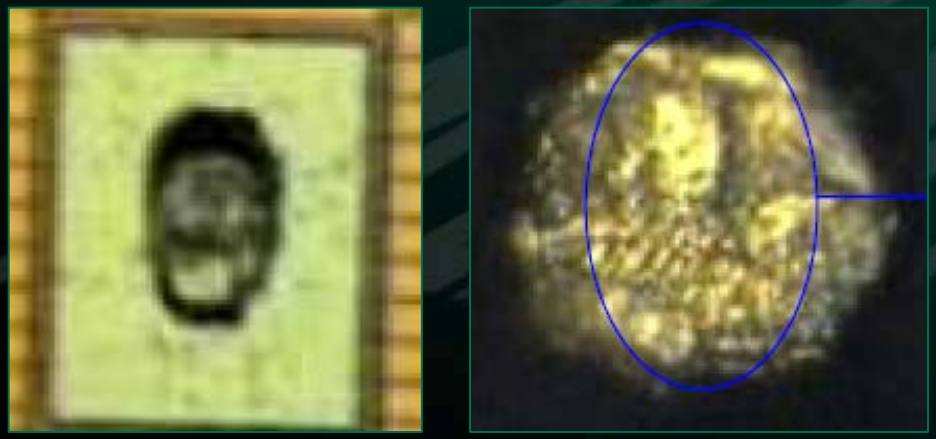
Source: TIPI C027 Study, Sept, 2004 [ref 1]

- Pad depth correlates to reduced IMC ➔ Bond failure
- AVI can measure probe mark depth on sampled pads

AVI Can Predict Failures

Visual Appearance **Reduced IMC**

Large PM Area



Deep probe mark

- Reduced available pad Al decreased inter-metallic coverage
  ➔ degraded bond reliability
- AVI with depth sensor can detect defects leading to these conditions

Source: TIPI C027 Study, Sept, 2004 [ref 1]

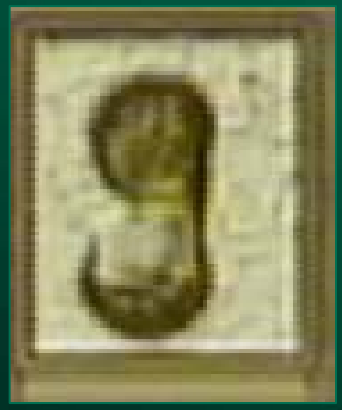
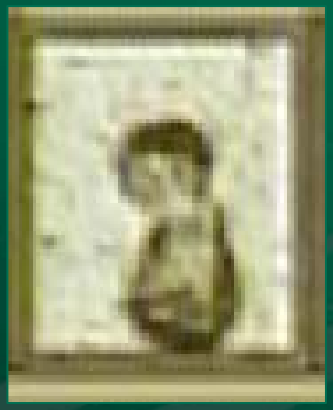
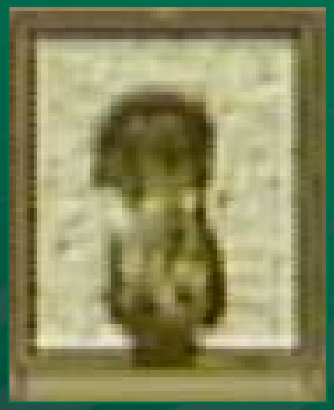
Inspection Protocols
(TI Automotive)

- 100% of dice tested electrically
- 100% of dice, including all pads, inspected for 2D surface and probe mark damage
- Sampled PM depth measurement
  – new capability (under development)

Inspection Challenges

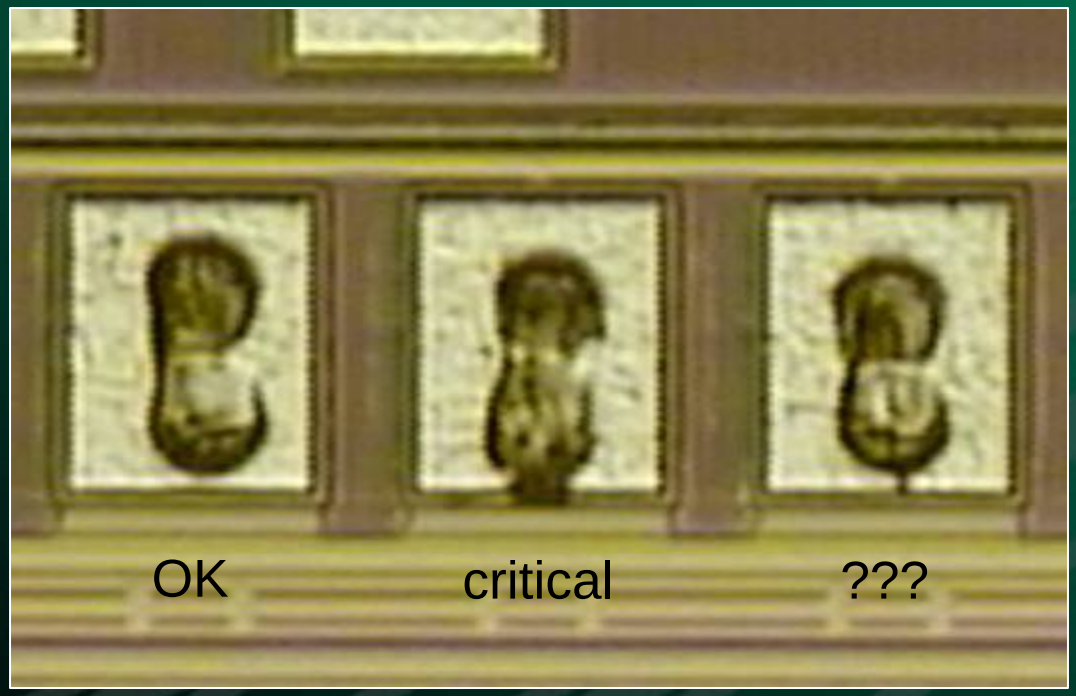
- Report all critical while ignoring non-critical defects
- Maintain high throughput and productivity
- Measure probe mark depth
- Deliver quantitative data for process control

2D Defect Definitions

Standard Applications	Non critical	Non critical	Critical
	PM allowed to touch passivation window, but not break out		
Automotive Applications	Non critical	Critical	Critical
	No contact of PM with passivation window		

Critical or Not?



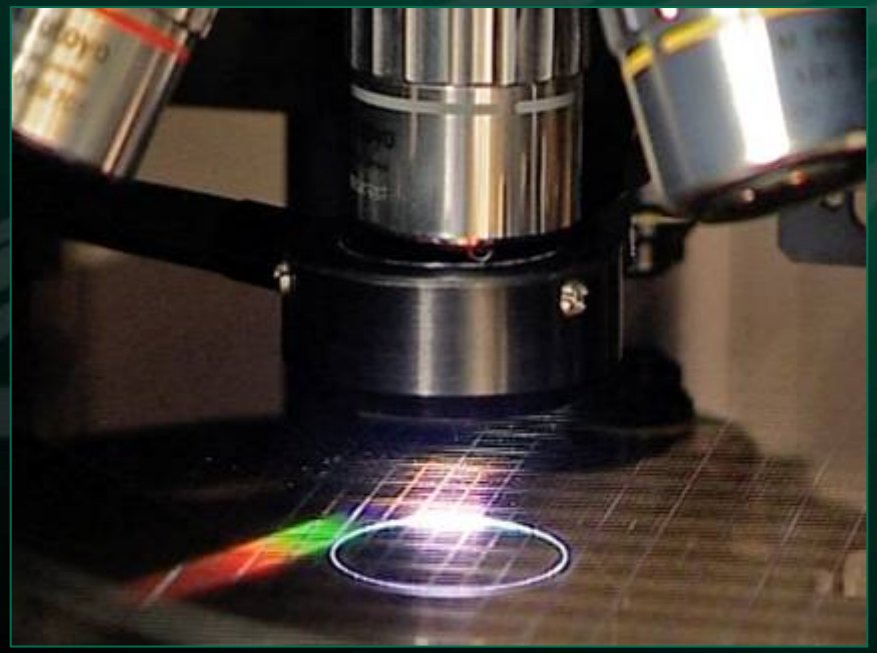
- *“The truth, whole truth and nothing but the truth”*
- Marginal cases are hard to tell.
- Qualitative detection may report many false alarms

Inspection Equipment in Use: Camtek Falcon 500

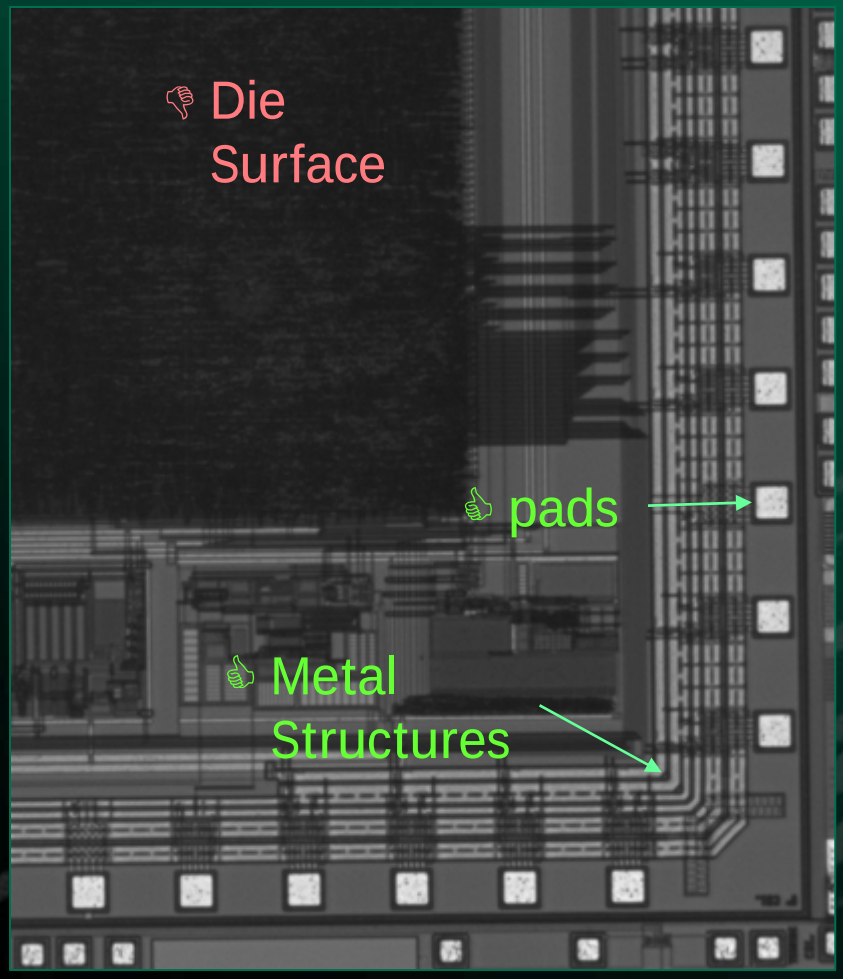
- Detection algorithms:
  - dedicated probe mark
  - surface
- Probe depth measure:
  - Chromatic confocal sensor

Inspection Equipment: Camtek Falcon 500 (cont)

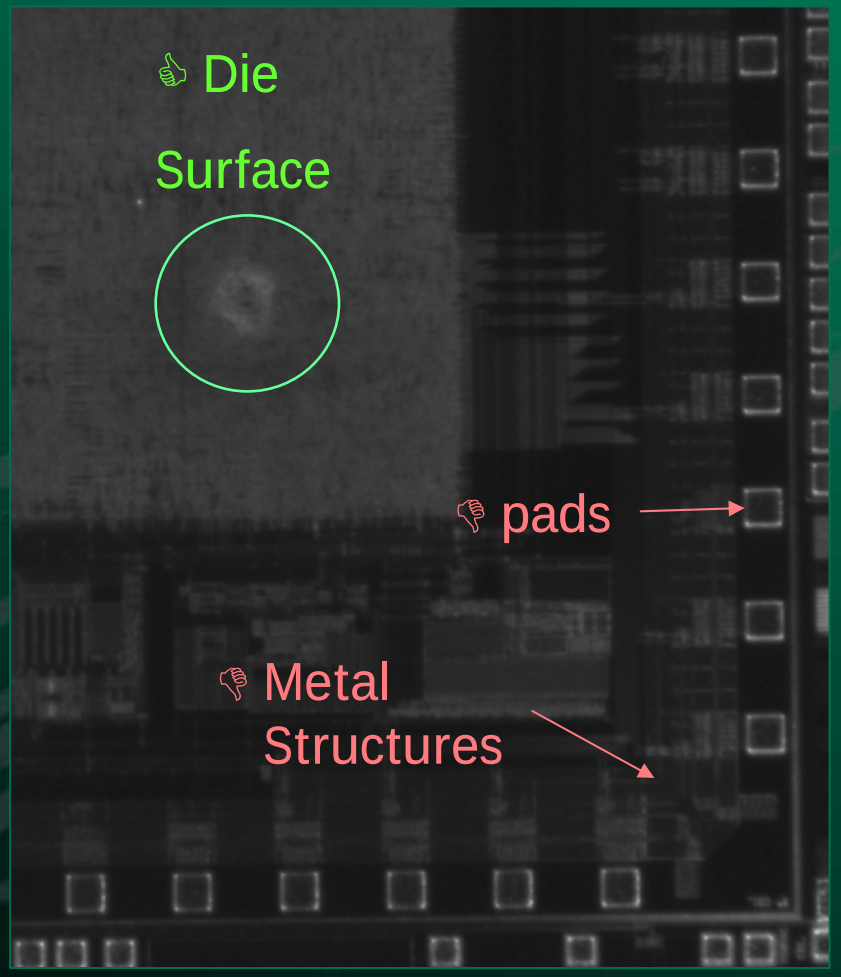
• Optical magnifications	x1	x2.5	x5	x10
• Optical resolution [µm/pix]:	9	3.6	1.8	0.9
• Illumination:	balanced bright and dark field (continually programmable)			



Lighting: Bright + Dark Field

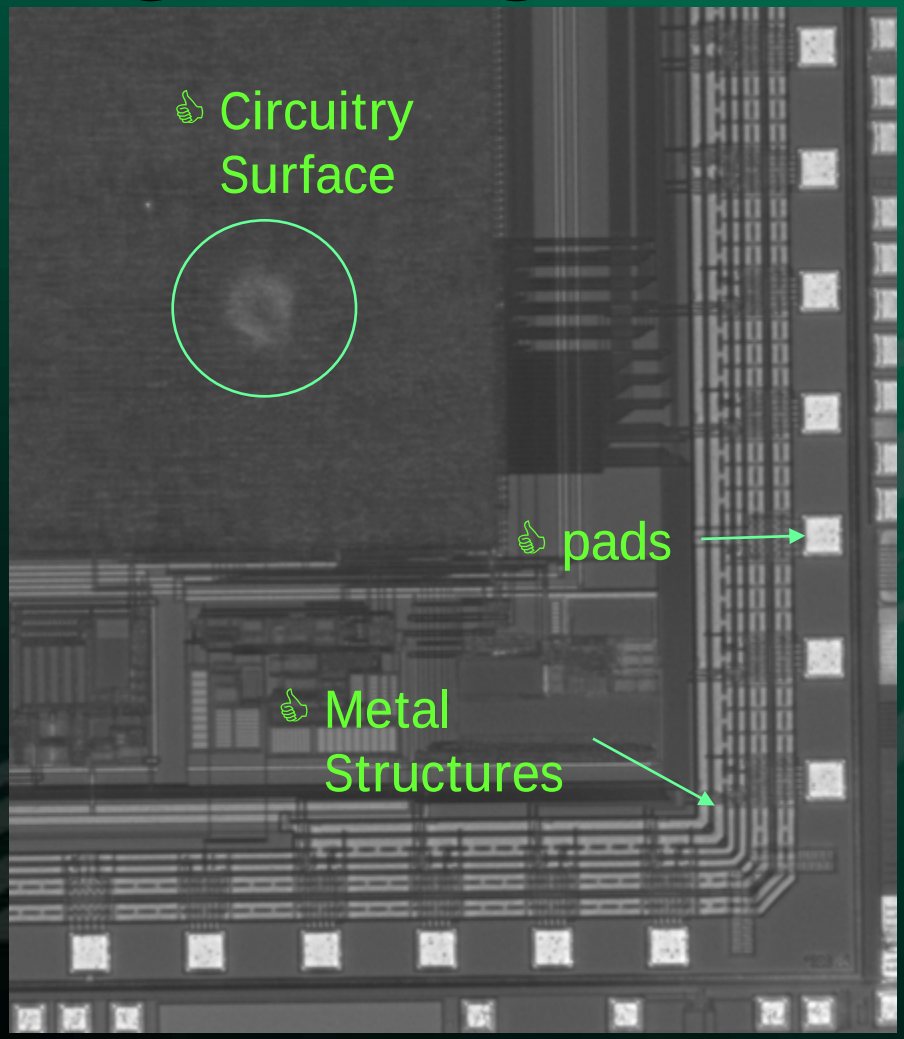


Bright Field



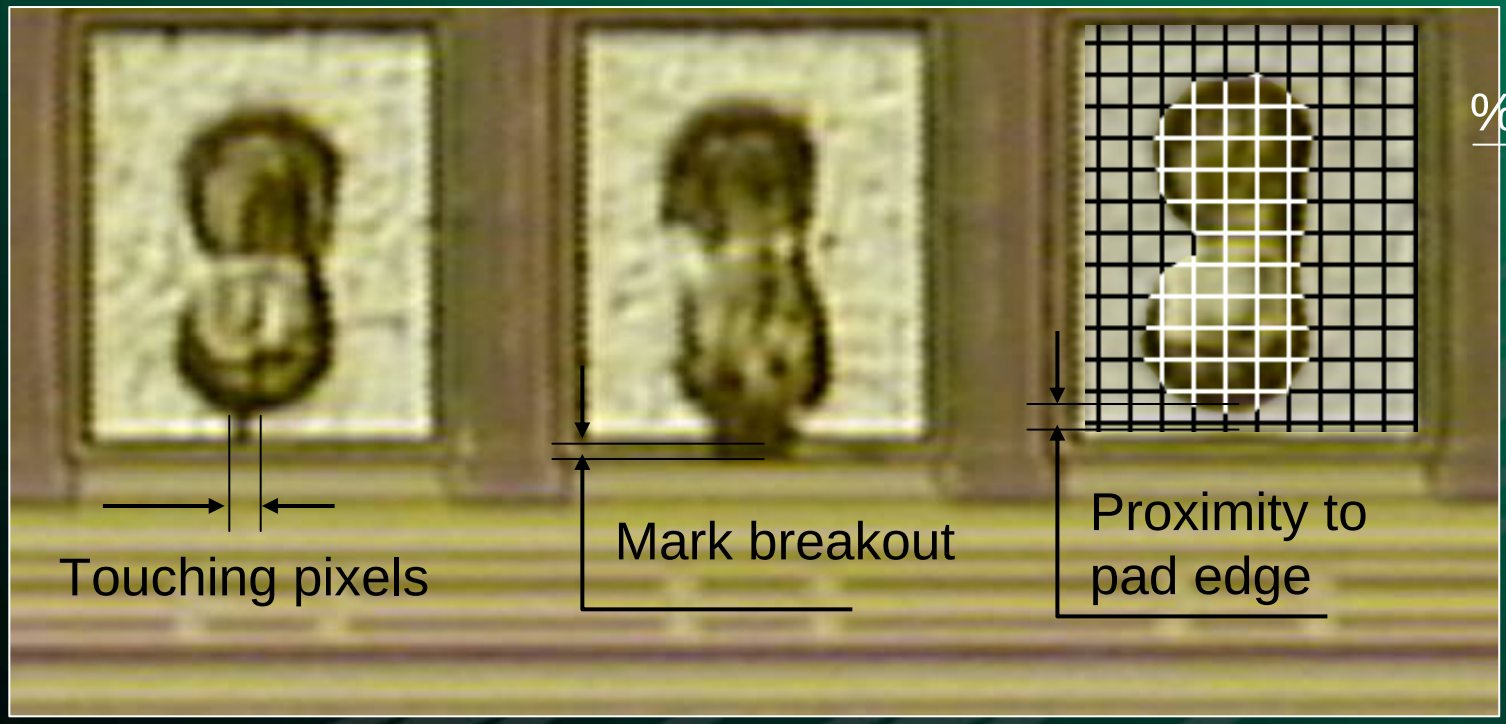
Dark Field

Lighting – Bright + Dark Field



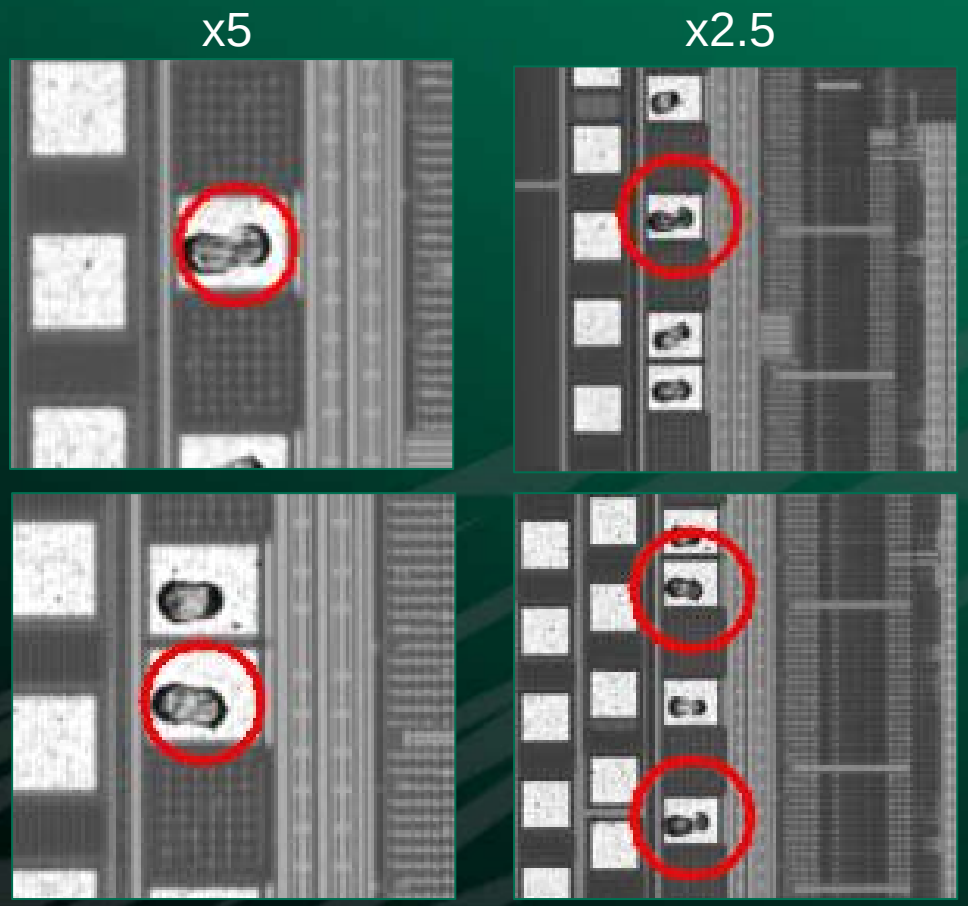
Bright Field + Dark Field

Solution – Multiple Criteria



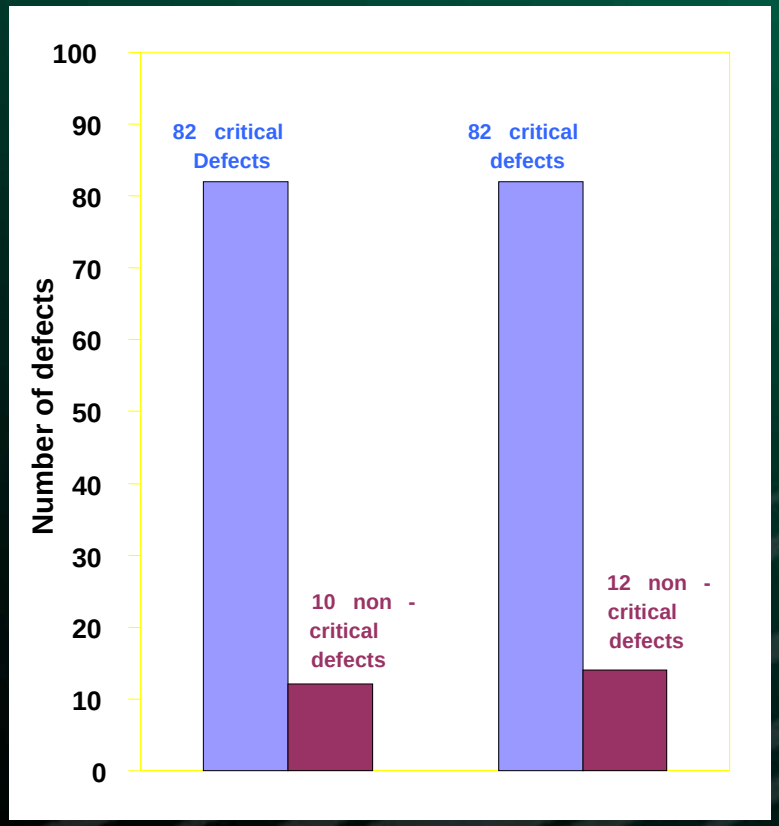
- Independent criteria enable exact filtering of defect
- Boolean conditions allow more consistent reporting

Magnification and Throughput



New algorithms enable reliable detection at lower magnification
→ 160% higher throughput

Detection Ability Comparison

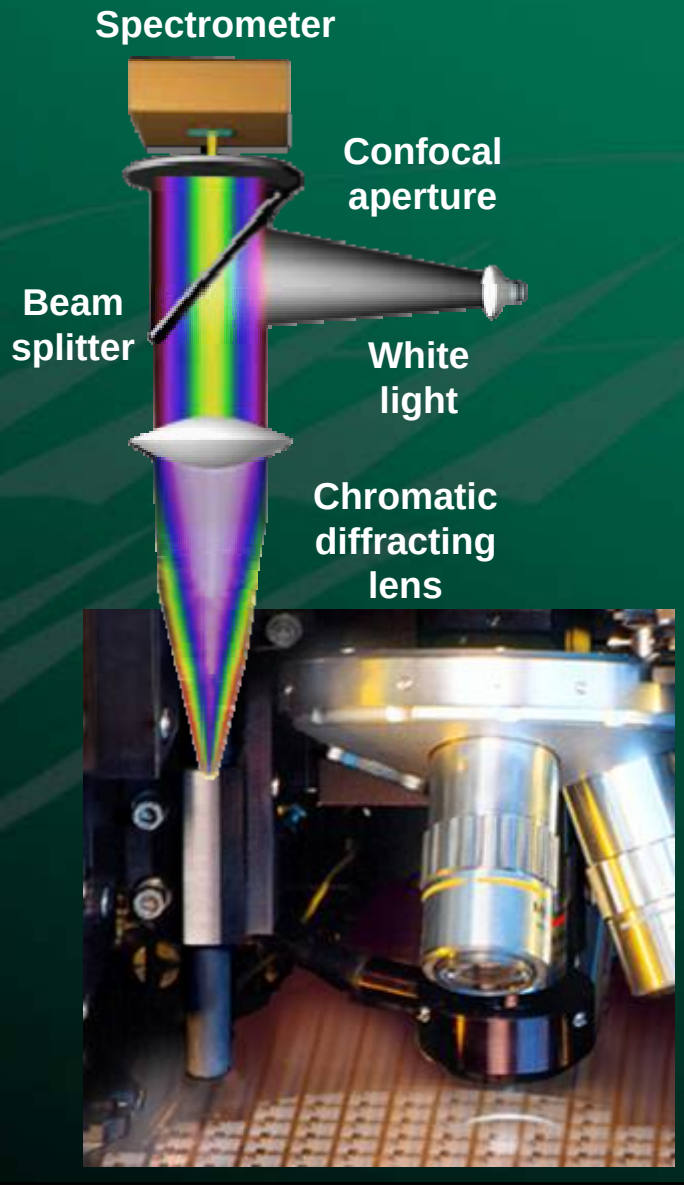


	Reference	Mag x5	Mag x2.5
Known defects	82		
Total defects detected		92	94
Real detected defects		82	82
Escape rate		0	0
False defects		10	12
Detection rate		100%	100%

All critical defects detected at both Mag x2.5 and Mag x5.

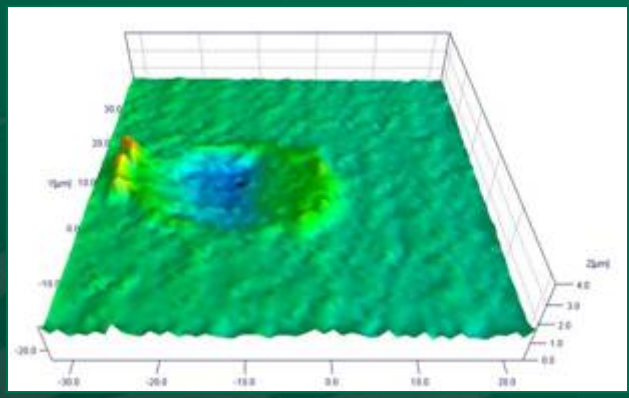
Chromatic Confocal Sensor (CCS)

- Special height sensor under development for TI:
  - Beam diameter 2 µm
  - Resolution 0.005 µm
  - Accuracy 0.02 µm
  - Repeatability @3σ 0.1 µm
  - Range 110 µm
- Optional system integrated into Falcon 500 model

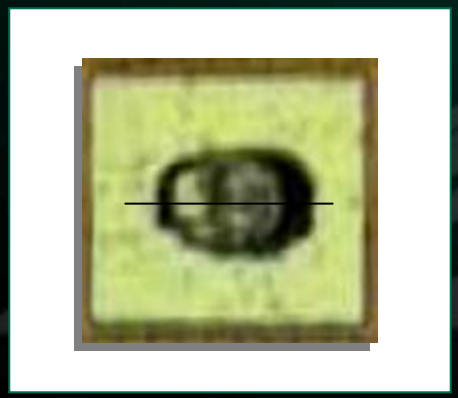


Probe Mark Depth Measurement
with Special CCS

1x Touch down

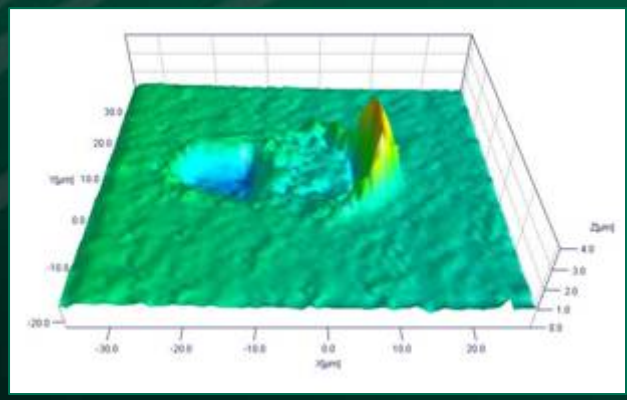


3x Touch downs

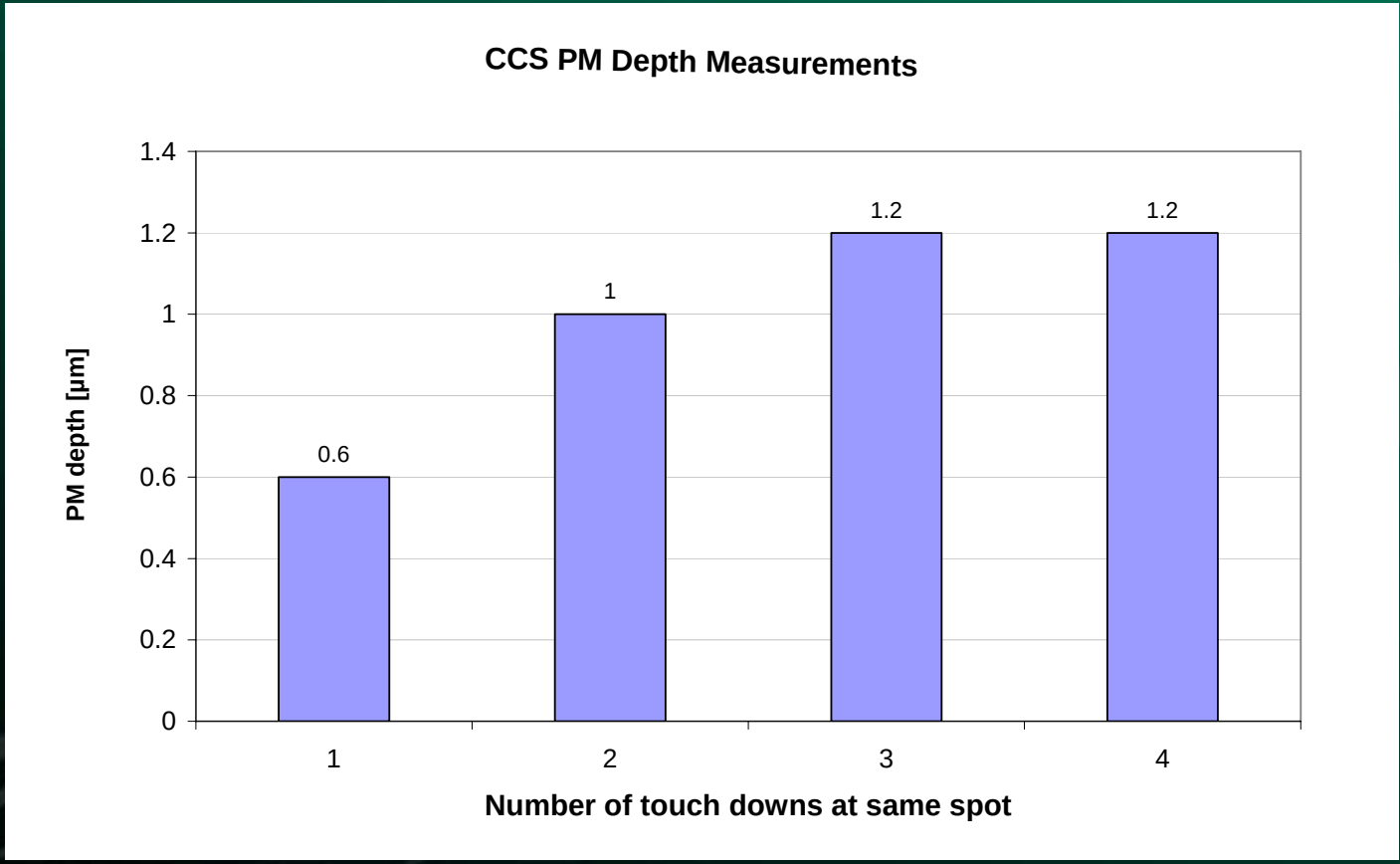


Depth profile

3D profile

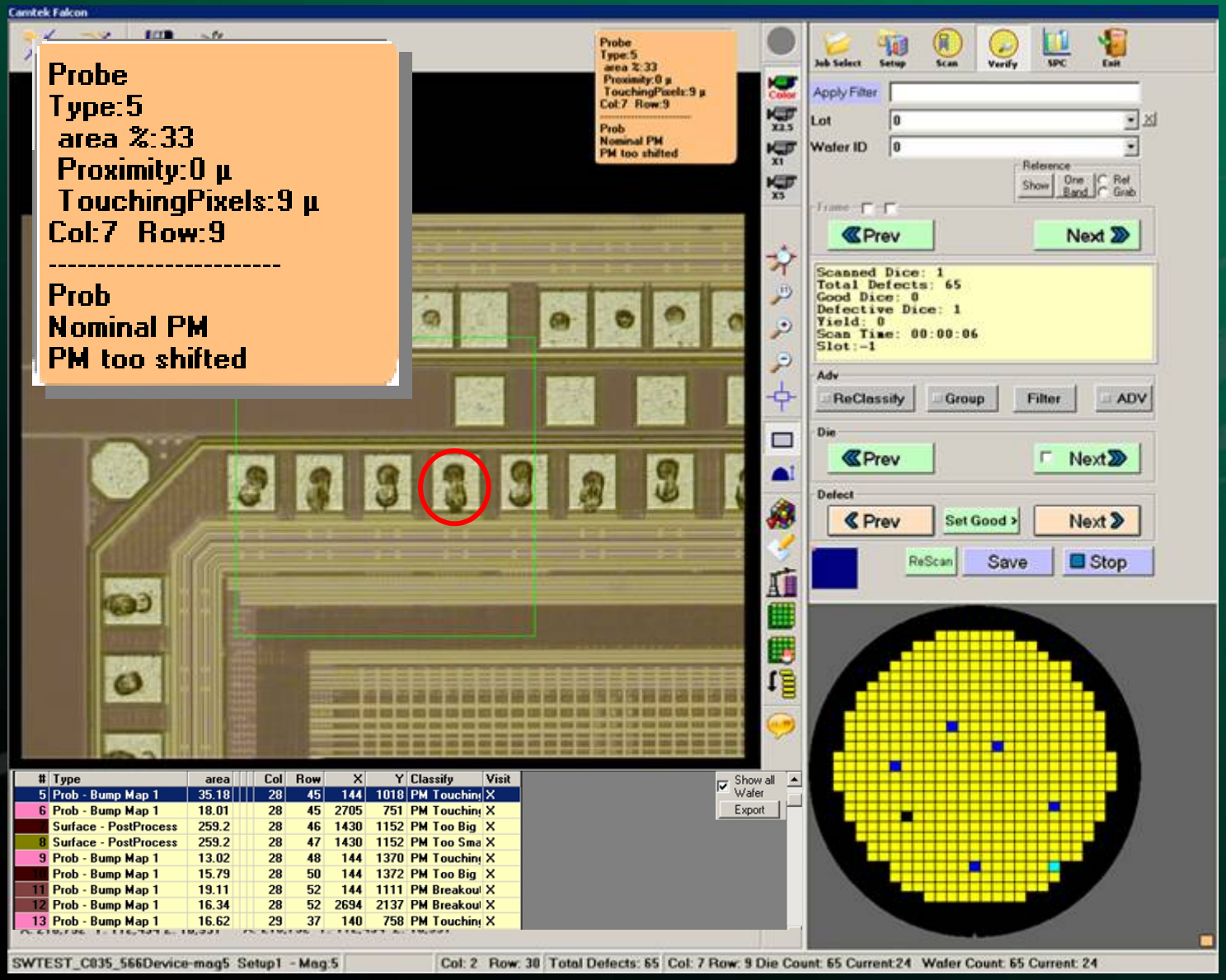


PM Depth vs. Touch Down Count



- CCS shows ability to measure PM depth
- Plateau above 3 TDs – possibly bottoming out on barrier metal?

Reporting


Camtek Falcon
Probe
Type:5
area %:33
Proximity:0 µ
TouchingPixels:9 µ
Col:7 Row:9
Prob
Nominal PM
PM too shifted
Job Select
Setup
Scan
Verify
SPC
Exit
Apply Filter
Lot
Wafer ID
Reference
Show
One Band
Ref Grab
Prev
Next
Scanned Dice: 1
Total Defects: 65
Good Dice: 0
Defective Dice: 1
Yield: 0
Scan Time: 00:00:06
Slot:-1
Adv
ReClassify
Group
Filter
ADV
Die
Prev
Next
Defect
Prev
Set Good >
Next
ReScan
Save
Stop
Show all Wafer
Export
Type area Col Row X Y Classify Visit
5 Prob - Bump Map 1 35.18 28 45 144 1018 PM Touchin X
6 Prob - Bump Map 1 18.01 28 45 2705 751 PM Touchin X
7 Surface - PostProcess 259.2 28 46 1430 1152 PM Too Big X
8 Surface - PostProcess 259.2 28 47 1430 1152 PM Too Sma X
9 Prob - Bump Map 1 13.02 28 48 144 1370 PM Touchin X
10 Prob - Bump Map 1 15.79 28 50 144 1372 PM Too Big X
11 Prob - Bump Map 1 19.11 28 52 144 1111 PM Breakou X
12 Prob - Bump Map 1 16.34 28 52 2694 2137 PM Breakou X
13 Prob - Bump Map 1 16.62 29 37 140 758 PM Touchin X
SWTEST_C835_566Device-mag5 Setup1 - Mag:5
Col: 2 Row: 30 Total Defects: 65 Col: 7 Row: 9 Die Count: 65 Current:24 Wafer Count: 65 Current: 24

Conclusions

- TI's automotive devices must meet <10 dppm
- Probing related damage degrades wire bond reliability
- Visual and measurable PM features correlate with pad damage and subsequent bond failure
- Camtek Falcon 500 used at TI to detect probing related damage on 100% of automotive products
- Dedicated multiple algorithms enable reliable detection at lower magnification → higher throughput
- Integrated depth measurement capability shows promise for probing process characterization and monitoring

References

1. TI Internal report “C027 Probe Damage Spec Qualification”, TIPI, Sept 15, 2004 Update
2. Hotchkiss, G. et al “Probing and Wire Bonding of Al capped Cu Pads”, *Proceedings IEEE 40th Int’l Reliability Symposium,* Dallas TX, 2002, pp140
3. Hotchkiss, G. et al “Effects of probe damage on wire bond integrity” *Proceedings ECTC,* Orlando, FL, 2001, pp1175
4. Roy, R. “Probe-mark inspection”, *Test and Measurement World”,* May 2007, pp 37

Acknowledgements

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Thank You

for

your attention