SW Test Workshop
Semiconductor Wafer Test Workshop

Challenges of Minimizing Scrub Mark Depth While Maintaining Low Contact Resistance on Extremely Thin Probe Pads

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OUTLINE

- Background
- Contributing factors
- Examples
- Short-term solutions
- Technology gaps

FIVE BIG TECHNOLOGY TRENDS

Networking

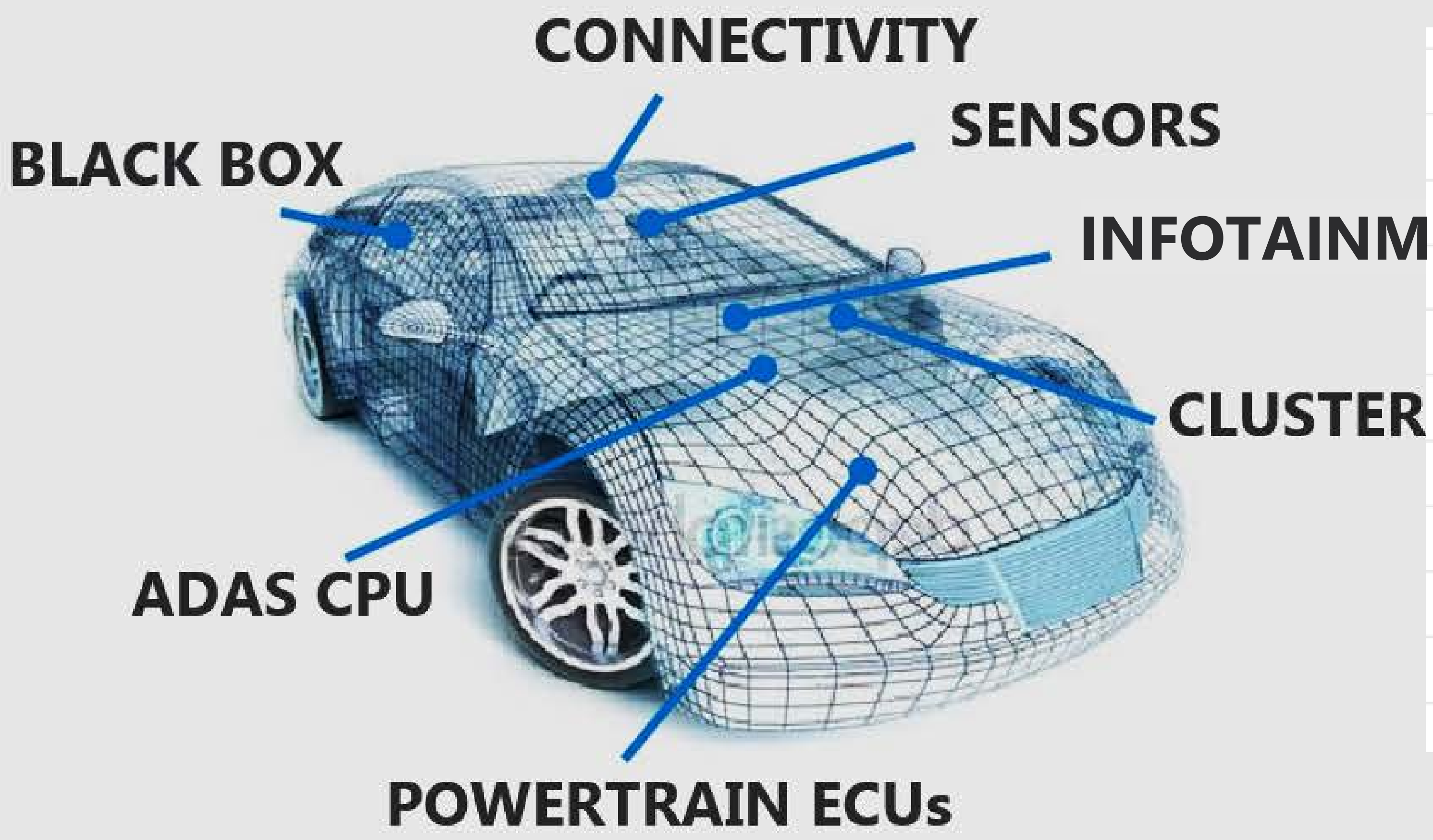
Machine To Machine

Mobile

Cloud

Big Data

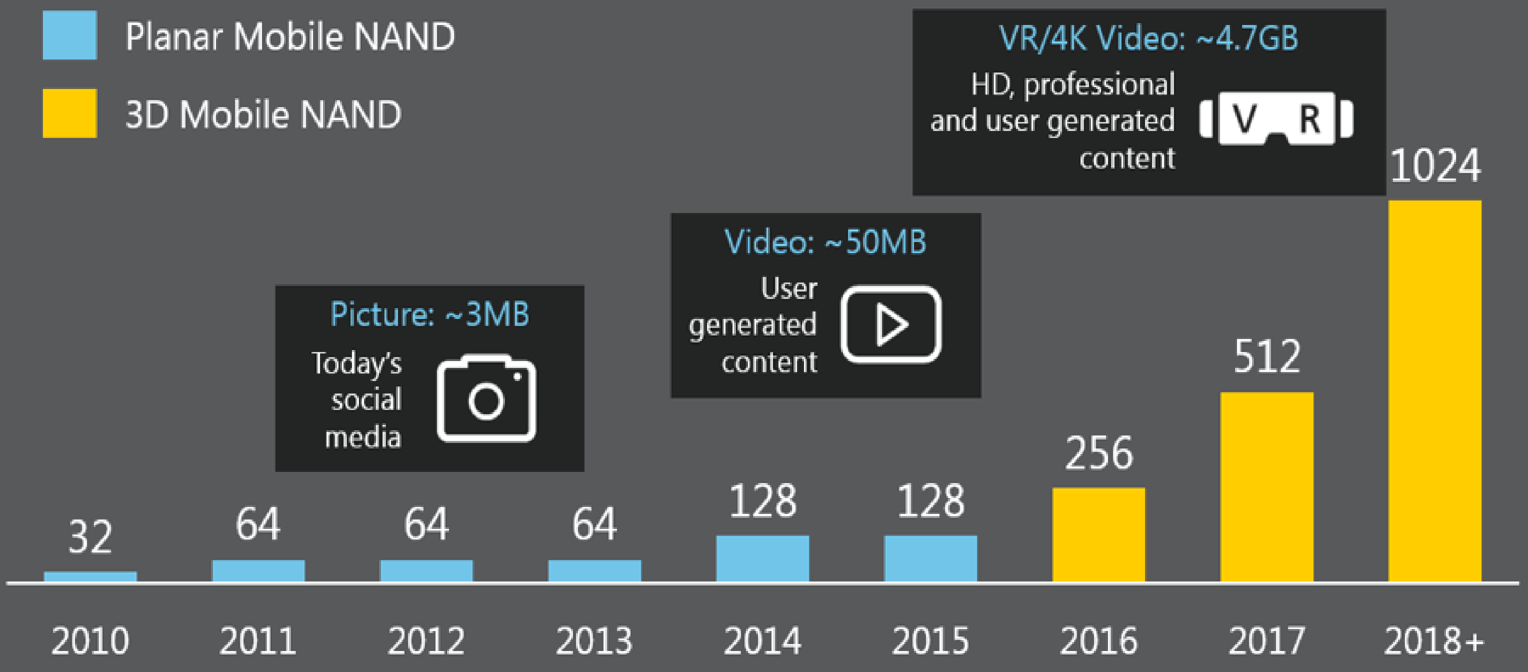
Automotive Memory Growth



Source: Micron and industry analysts

WHERE IS THIS LEADING US?

- **Higher chip density driven by**
  - Advancing process nodes, i.e. manufacturing cost reduction
  - Smaller package form factor
  - Customer requirements
- **Smaller, thinner probe pads driven by**
  - Improved functional performance
  - Lower power consumption
  - Customer requirements



Increasing need for memory requires high confidence, high yield die for stacking

Contributing Factors

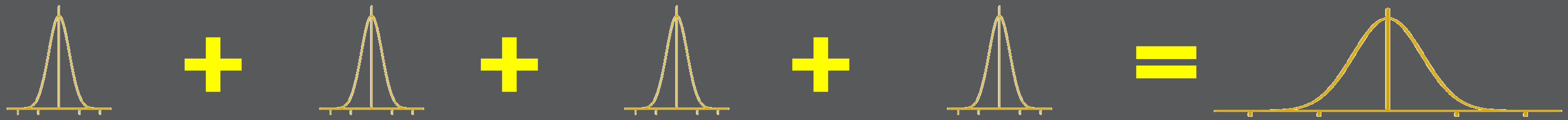
CHALLENGES

- **Increasing parallelism**
- **Shrinking pad size + smaller probe tips = pad damage**
  - $Pad\ Stress = \dfrac{\boldsymbol{Force\ of\ single\ probe}}{\boldsymbol{Probe\ tip\ area}}$
- **Reduced pad thickness**
- **Pad alloy variation**
- **Scrub characteristics**
- **Multiple scrubs per pad**
- **Lack of reliable, high-volume metrology tools**

PROCESS VARIATION

- **Memory process technology/variation**
- **Probe technology variation**
  - Probe tip size
  - Temperature
  - Probe force
  - Lifetime
  - Planarity

- **Probe scrub characteristics**

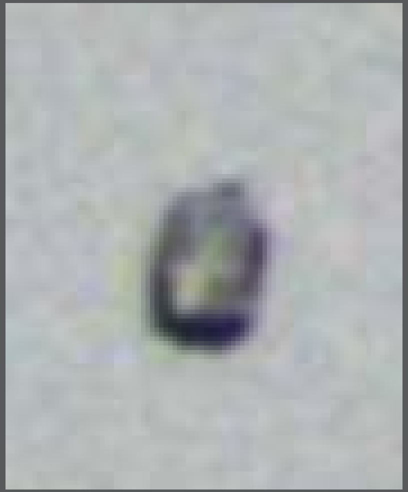


Tip Size + **Probe Force** + **Probe Overdrive** + **Product Pad Area and Depth** = **Probe Scrub Depth**

Status Quo

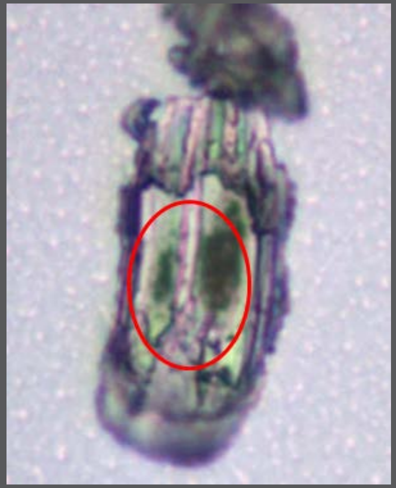
TODAY'S REALITY

Single TD
No Punch-through



Multiple TDs
No Punch-through

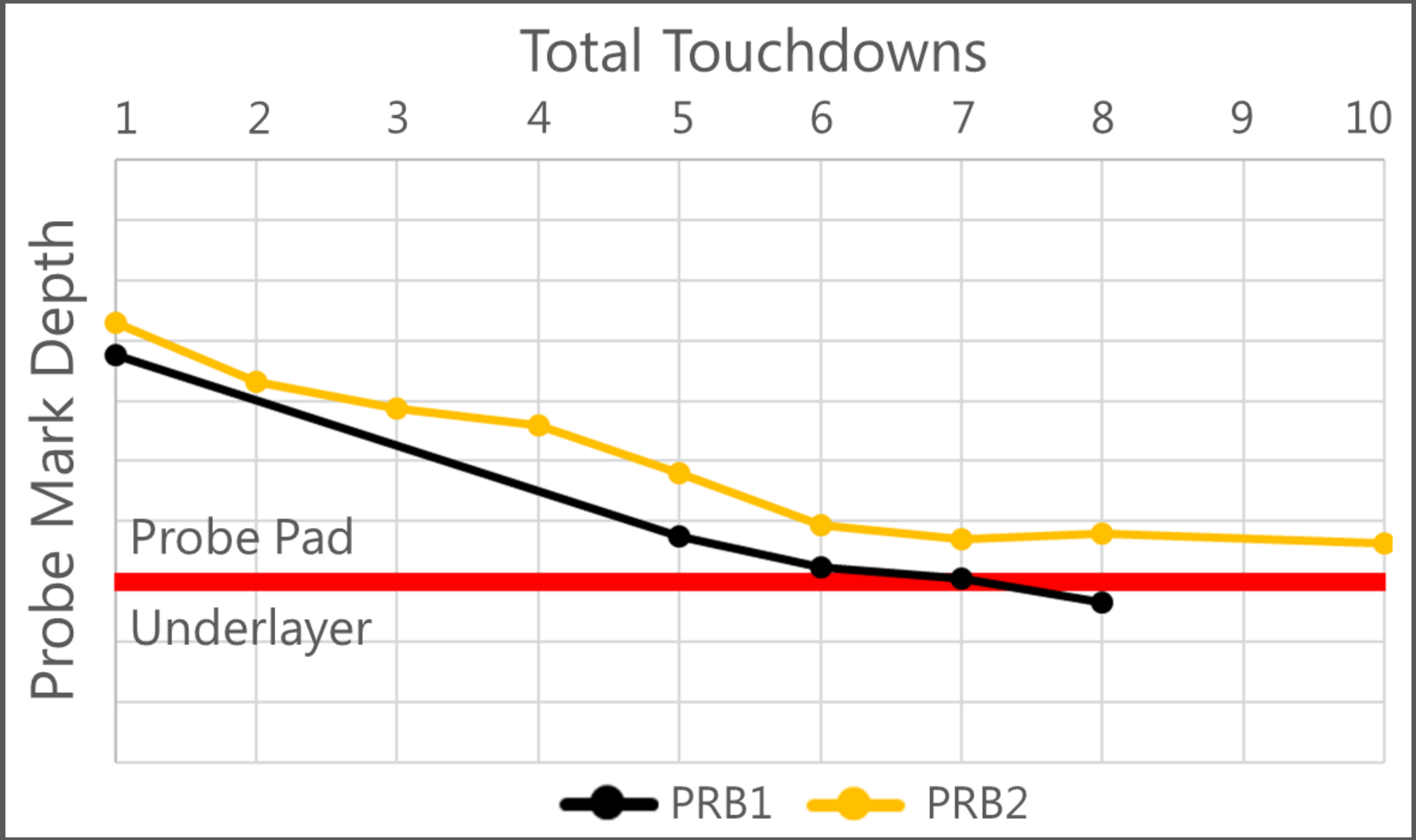
Multiple TDs
With Punch-through



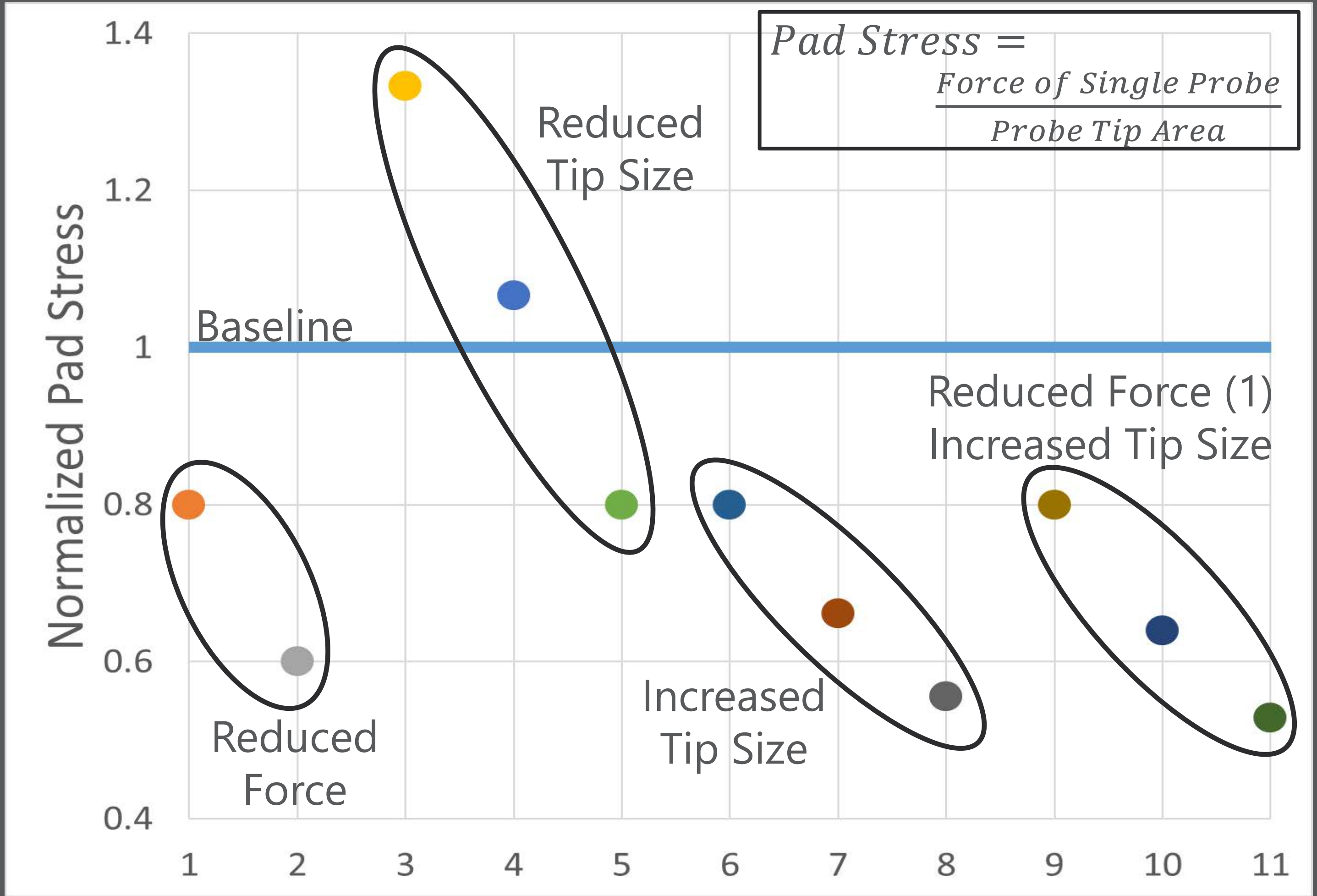
Not necessarily a reflection of Micron probe pads

TODAY'S REALITY

- 2 insertions consumes half of the probe depth
- Pad material displacement is a concern for wire and pillar bonding
- Underlayer integrity a concern after multiple insertions



PROBE STRESS SIMULATION

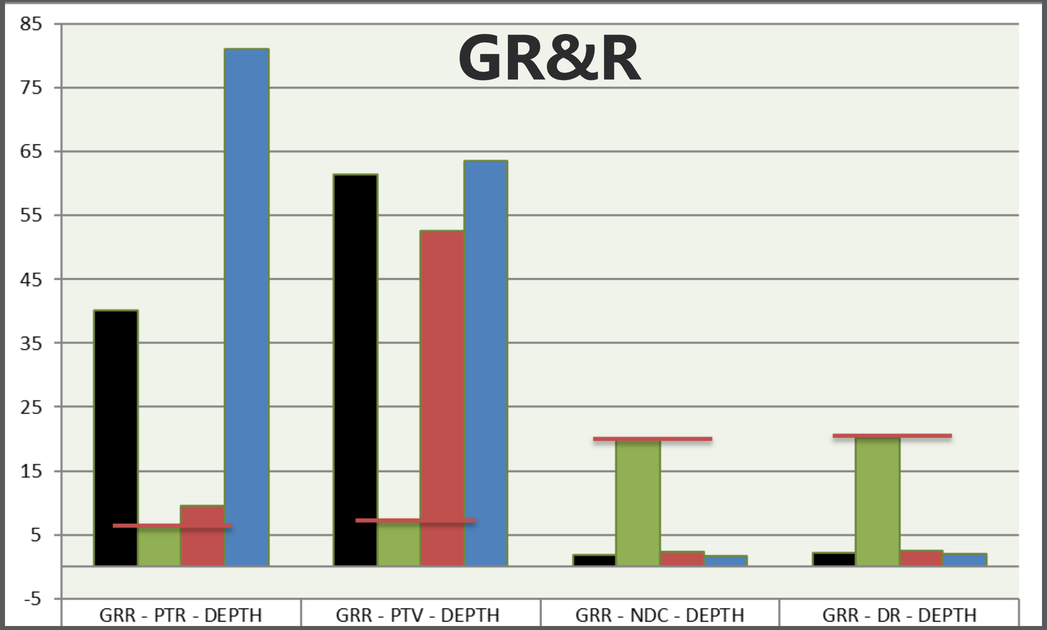


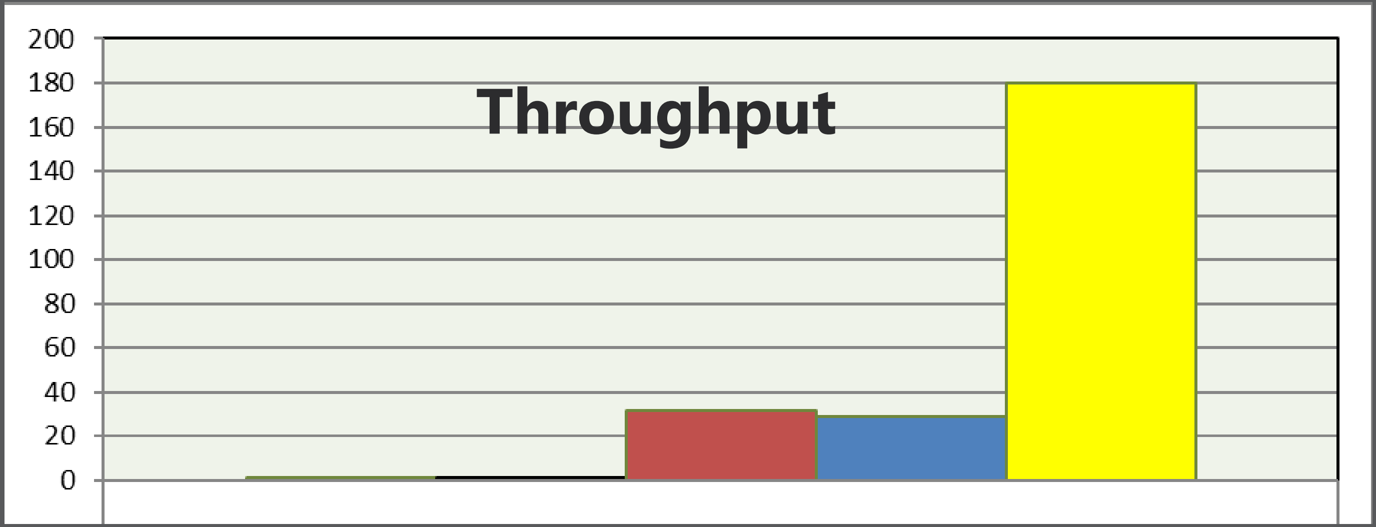
- **Lower force lower stress. Increase tip size lower stress.**

Baseline: 100um OD , 0.1g/um probe force. 1um X and 1um Y ≈ 0.02 g/um force

SCRUB METROLOGY TOOL DOE RESULTS

- **5 tools evaluated**
- **1 tool met most criteria (*)**
  - Evaluated at slow speed
  - Extensive recipe tuning needed
    - Area
    - Depth

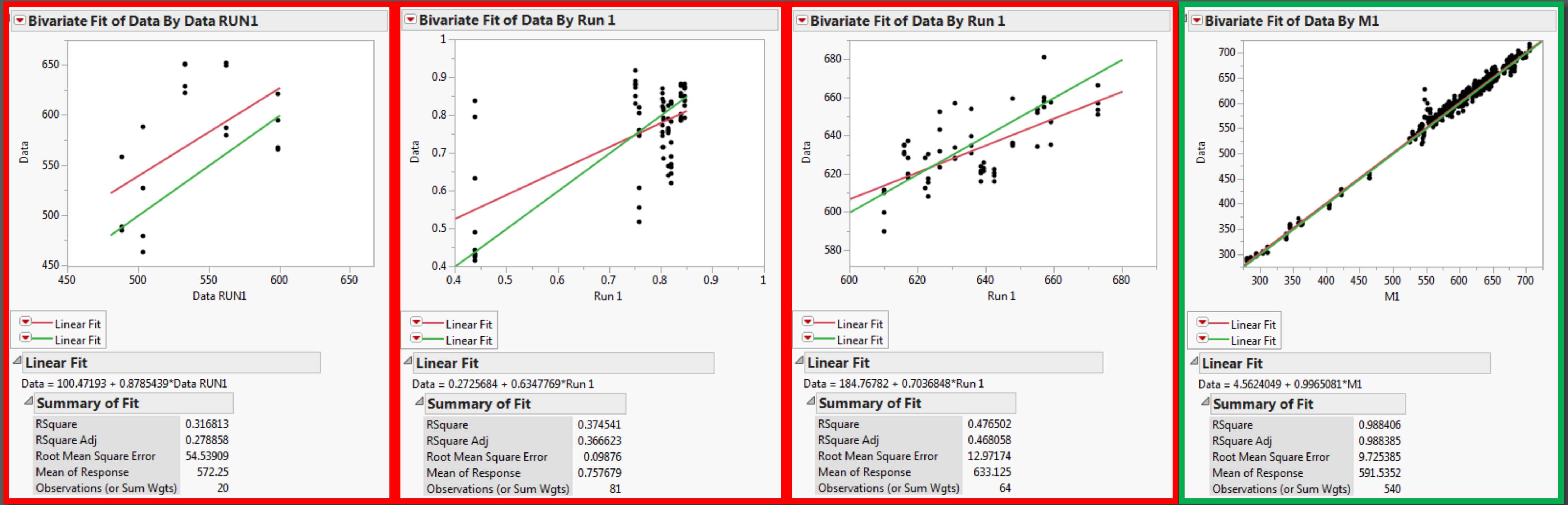




Bar Legend

Tool 1
Tool 2 *
Tool 3
Tool 4
Tool 5

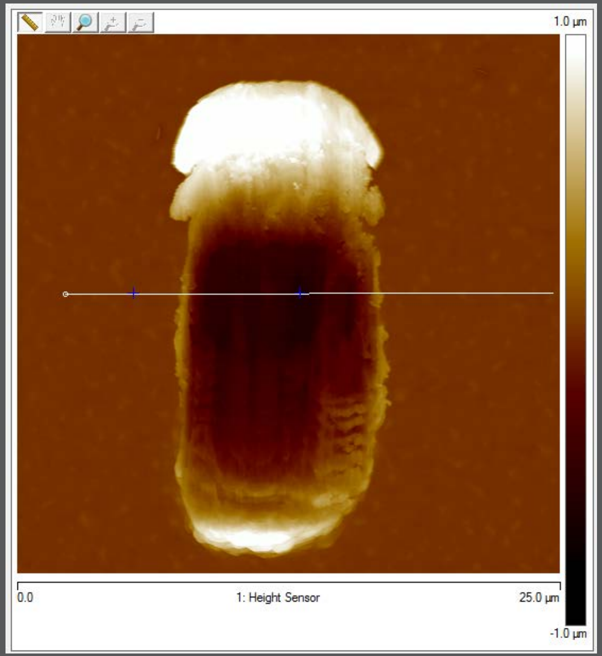
METROLOGY TOOL DOE REPEATABILITY

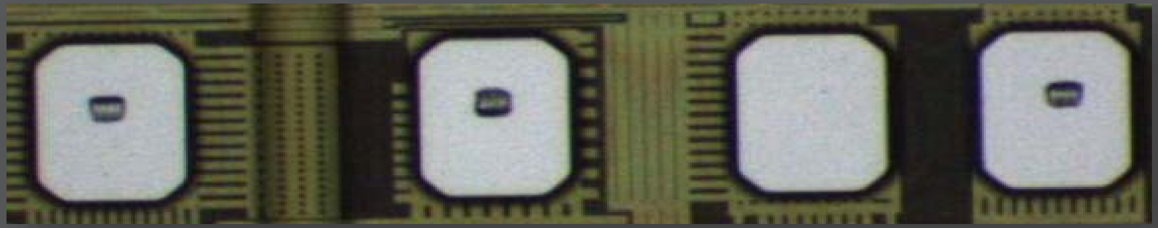


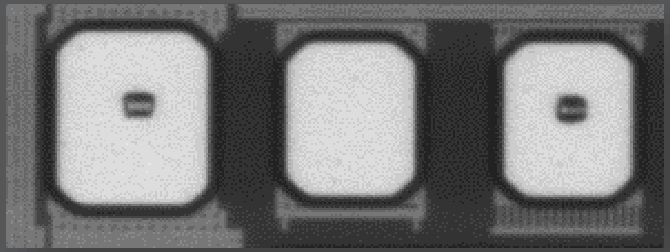
- **Repeatability unacceptable (0.32 < R^2 < 0.48)**
- **Repeatability acceptable on 1 tool (after extensive recipe tuning)**

3D METROLOGY SUMMARY

Solution	Pros	Cons
AFM	Very accurate	Very slow; low volume
Other 3D Tools	Higher volume	Unreliable depth data





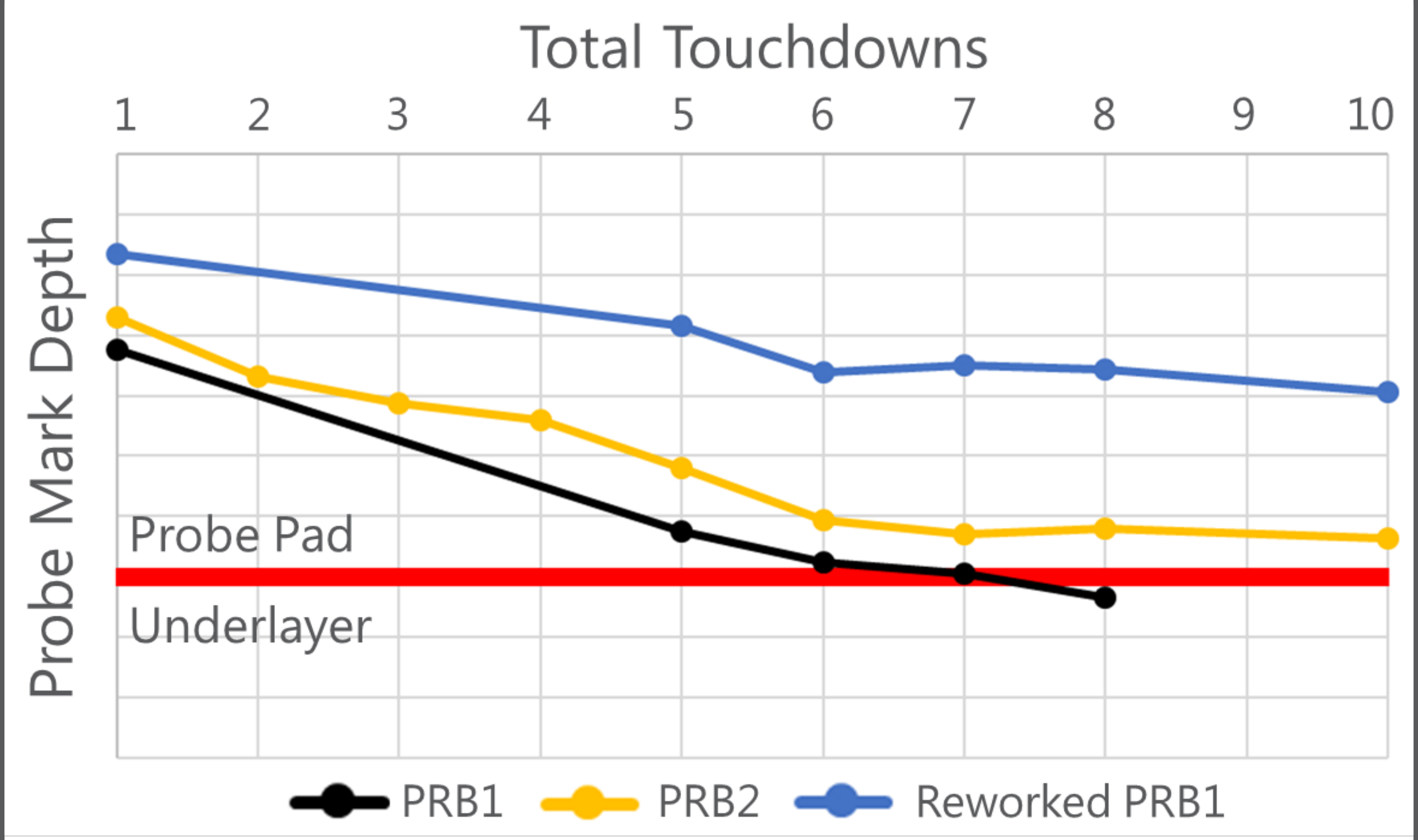


Not necessarily a reflection of Micron probe pads

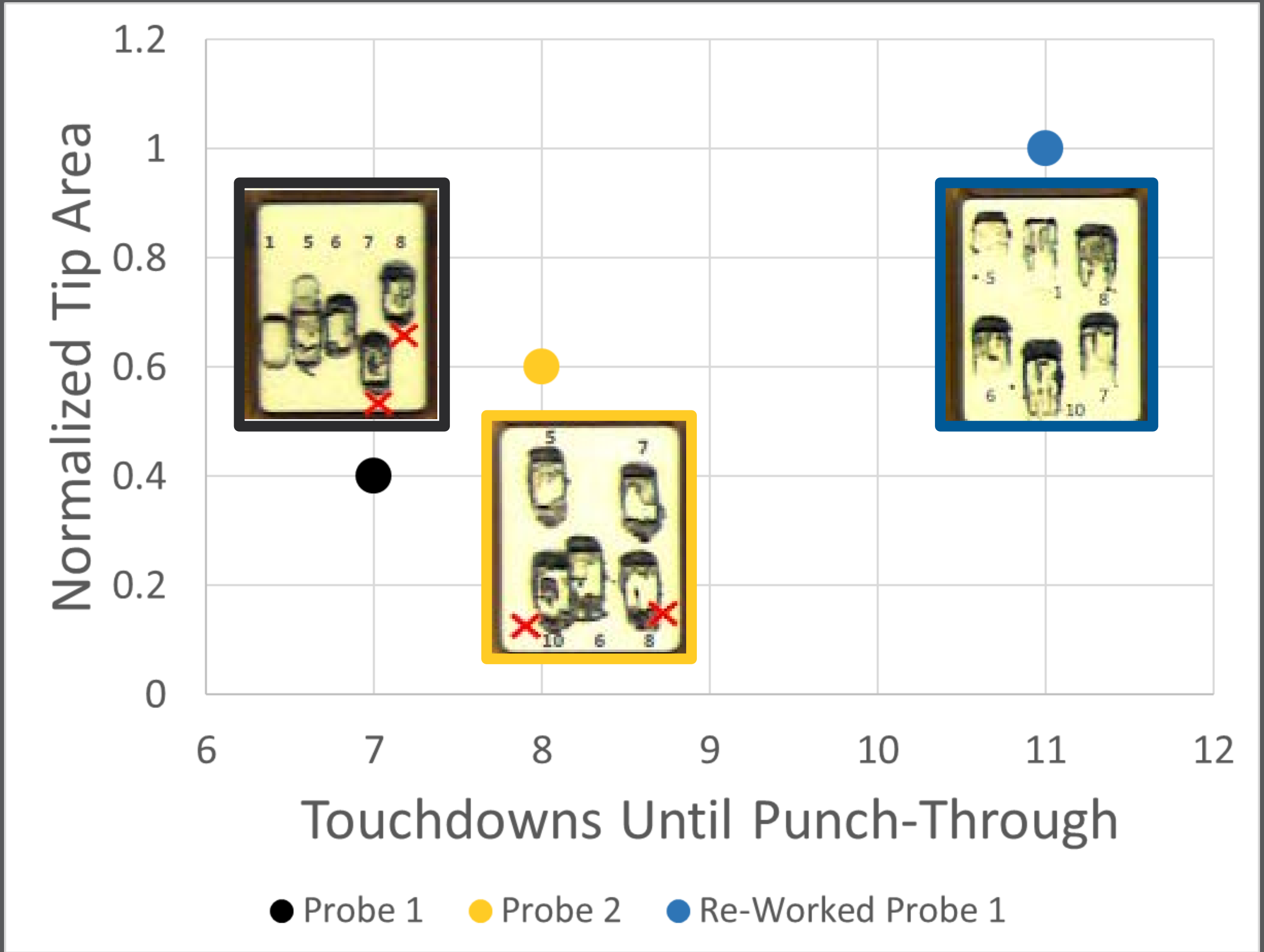
Short-Term Solutions

SCRUB DEPTH DOE RESULTS

- **Increased tip size to distribute probe stress**
- **Larger probe tips minimize scrub depth/pile height**
  - **PSC**
  - **EOL**
  - **Correlation/cleaning**
- **Improves confidence in bonding after multiple TDs**



SCRUB DEPTH DOE RESULTS



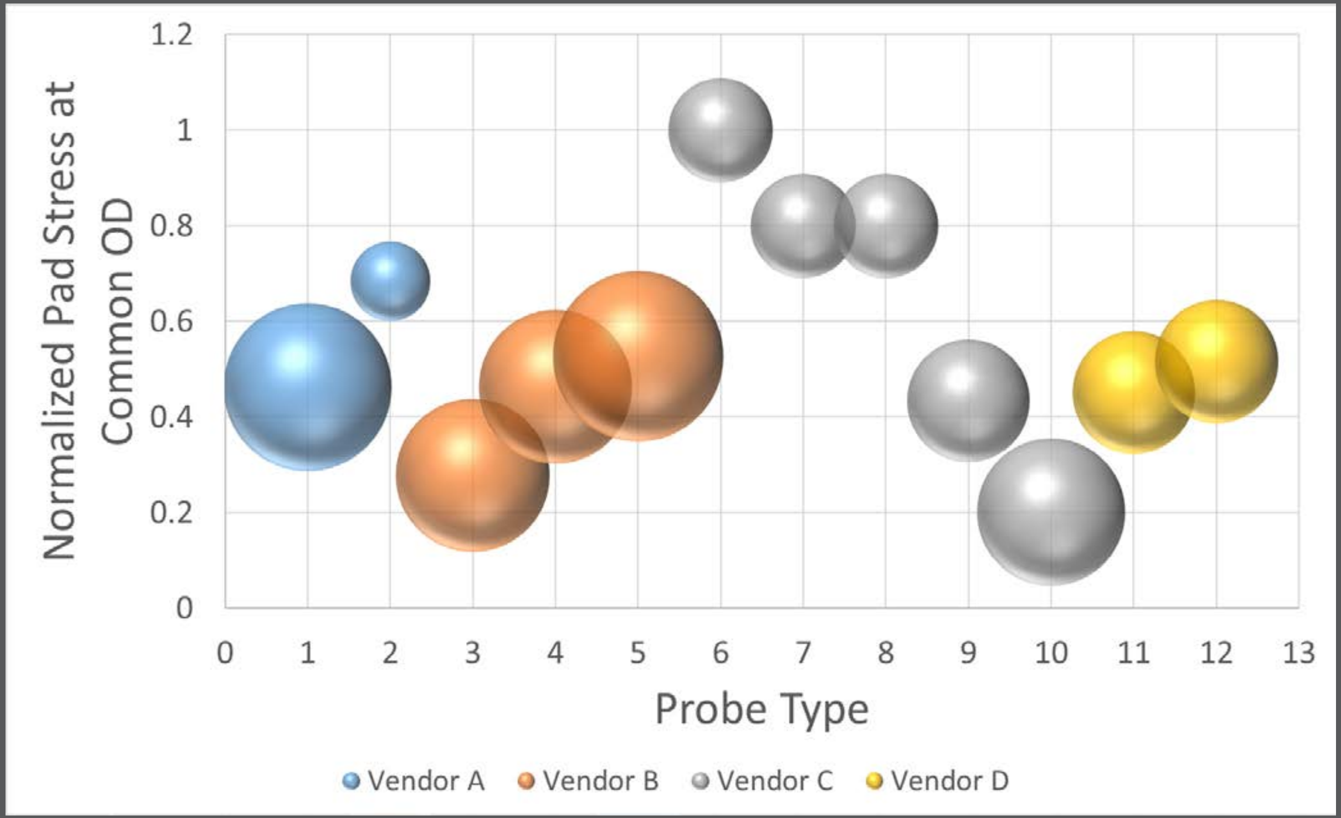
- **Tip conditioning is a high maintenance & un-optimized temporary solution**

What We Need

PROBE TECHNOLOGY REQUIREMENTS

We Need

- Low-force, high-current probes
- Low-scrub/material displacement
- Tolerance to multiple TDs
- Extended temp range
- Higher frequencies



PMI METROLOGY TOOL REQUIREMENTS

We Need

- **HVM-capable in-line 3D scrub depth measurement**
  - High-accuracy
  - High-throughput
  - Repeatable

Category	Target	Minimum	Unacceptable
Precision-to-Total Variation Ratio	<10%	10% < x <30%	>30%
Precision-to-Tolerance Ratio	<10%	10% < x <30%	>30%
Number of Distinct Categories	≥5	NA	<5
Discrimination Ratio	≥4	NA	<4

ACKNOWLEDGEMENTS

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