28nm Mobile SoC Copper Pillar Probing Study

Jose Horas (Intel Mobile Communications)
Amy Leong (MicroProbe)
Darko Hulic (Nikad)

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Overview

- **Introduction to IMC**
- **Copper Pillar Implementation at IMC**
- **Low-force Vertical Probing Qualification**
  - Probe mark characterization
  - Contact resistance stability
  - Test reproducibility
  - Probing - Packaging interaction (coplanarity)
- **Future Work**
  - Probing - Silicon interaction (PoAA)
  - Hardware lifetime
- **Conclusion**

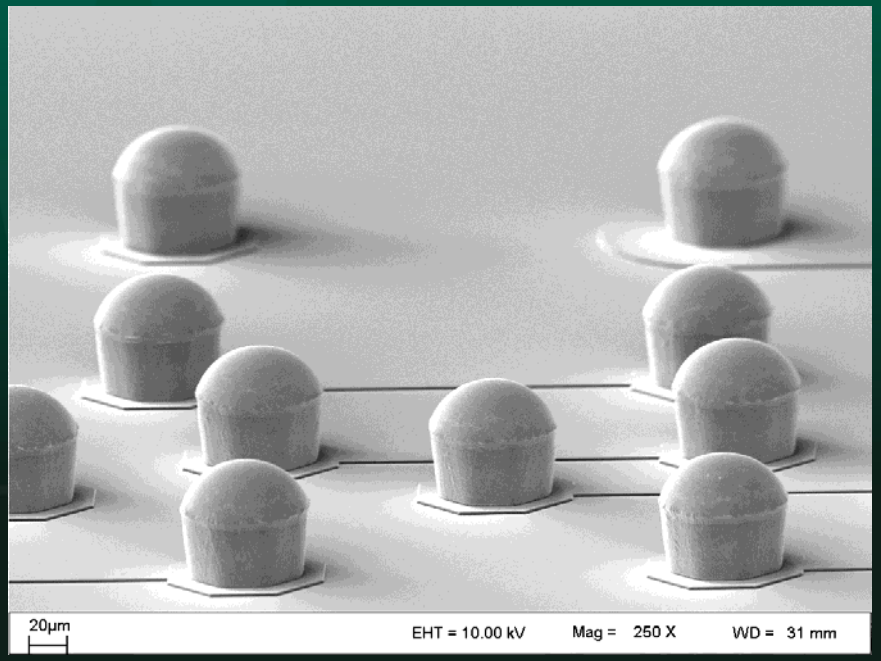
Introduction to IMC

- **Intel Mobile Communications (within Intel MCG) develops products and solutions for mobile communications**
  - 2G/3G single-chip, 3G and 4G slim modem and RF solutions
- **4000 employees worldwide, 1700 work in Germany**

Copper Pillar (CuP) Advantages

- **IMC roadmap includes Cu pillar bumps with lead-free SnAg caps**
- **CuP delivers several advantages compared to SnAg bumps:**
  - Lower than 150 µm pitch
  - Lower substrate costs due to relaxed design rules and no solder-on-pad
  - Lower packaging cost thanks to easier Molded Underfill process
  - Better current carrying capacity
  - Better thermal performance
- **Allows analogous probing and assembly processes as SnAg bumps**

Typical Value	**CuP w/ SnAg caps**	**SnAg Solder bumps**
Pitch	120 µm	150 µm
Diameter	70 µm	100 - 110 µm
Height	75 µm	75 - 80 µm

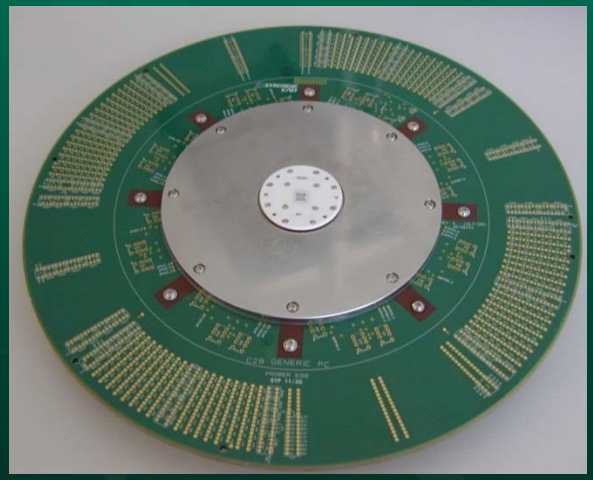


* B. Ebersberger, C. Lee, "Cu Pillar Bumps as a Lead-Free Drop-in Replacement for Solder-Bumped, Flip-Chip Interconnects", *Proc 58th Electronic Components and Technology Conf.*, Lake Buena Vista, FL, May 27 – May 30, 2008, pp. 59-66.

CuP Probing Solution Qualification Test Set-up

- **Objective**
  - Characterize low-force vertical probe technology for fine-pitch full grid-array CuP application

- **IMC Device**
  - 28nm Mobile SoC Test Chip
  - Copper pillars with SnAg caps
  - Minimum pitch of 120um



MicroProbe Low-force Apollo™ Card

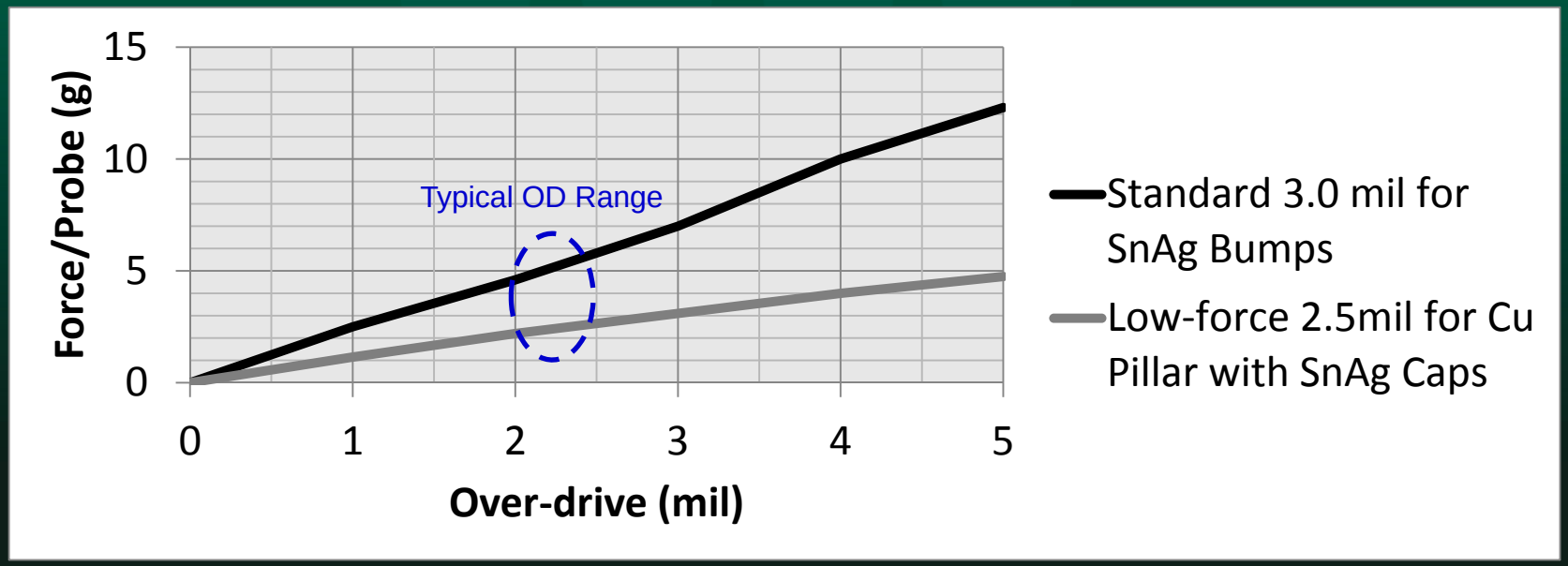
- **MicroProbe Probe Card**
  - Apollo™ product
  - 2.5mil vertical probe
  - Low-force optimized: 2.5-4 gram/probe @ production OD

Low-force Apollo™ Probe Card Key Evaluation Criteria

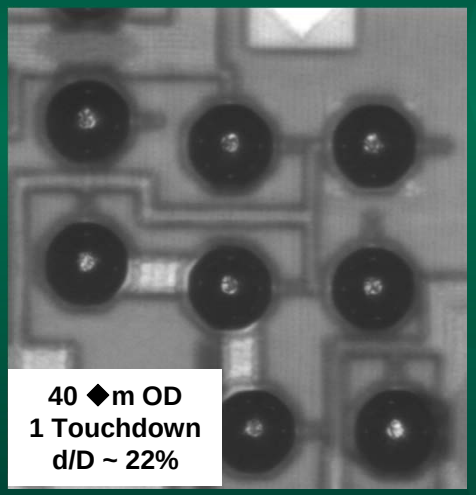
- **Key Evaluation Criteria**
  - Mechanical
    - Probe force vs. overtravel
    - Probe mark quality vs. overtravel
    - Probing over Active Area (PoAA) reliability
    - Production life-time study
  - Electrical
    - Contact resistance (Cres) stability
    - On-line cleaning recipe
    - Test (binning) reproducibility
  - Probe-Packaging Interaction
    - Pillars co-planarity

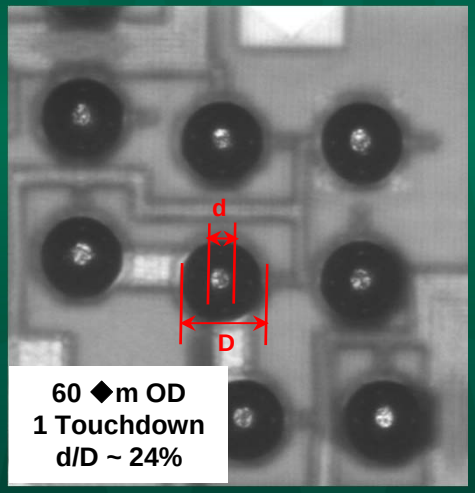
Probe Force: Low-force Vertical Probes for Thin SnAg Caps

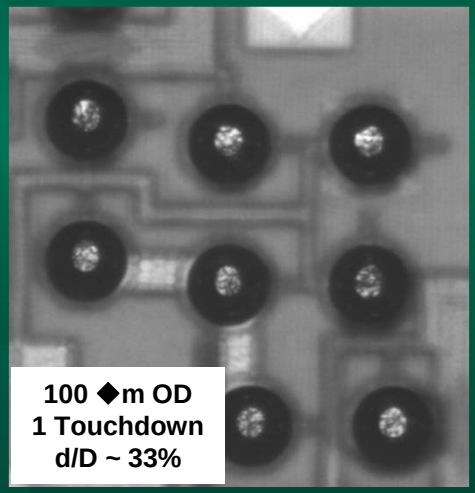
- Apollo™ low-force probes were used to minimize probe damage to thin SnAg caps on Cu Pillar
- At an over-drive of 2 mil, low-force 2.5mil probe offers 50% probe force reduction compared to a 3.0mil probe typically used for SnAg bumps



Probe Mark: Low-force Probes Satisfy Probe Mark Quality Requirement

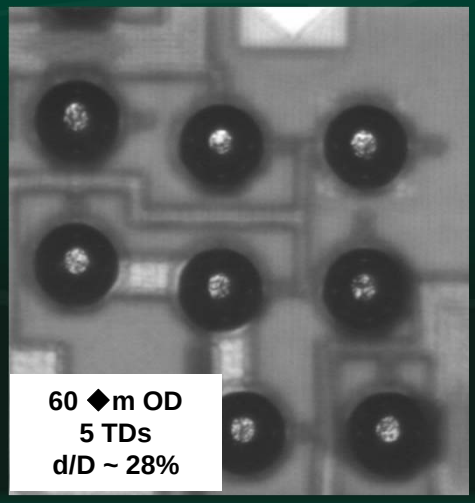






Probe Mark Guideline

d/D <50% to ensure packaging reliability

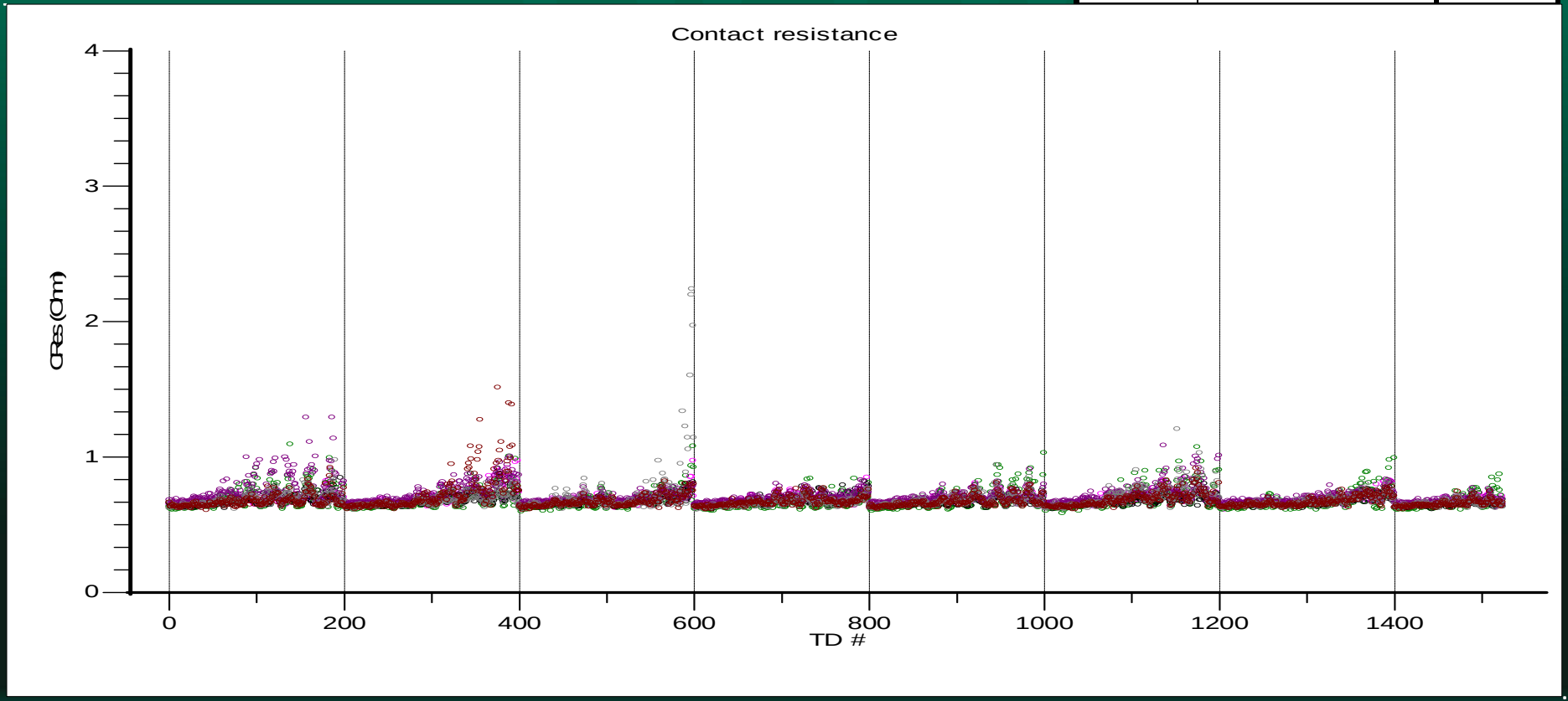


- Low-force probes provide acceptable probe mark at various OD conditions
- 50-60um overdrive is sufficient for CuP production set-up

Contact Resistence (Cres) Stability

- **Demonstrated stable contact resistence of < 2 Ω**
  - No bin failures because of good Cres
  - Cres criteria for bin fails > 10 Ω
- **On-line cleaning every 200TDs with 3um lapping film**

Cleaning parameters		
Test OD		50 µm
Cleaning	OD	50 µm
	Octagon movement	50 µm
	# of octagons	5
	Interval	200 TDs

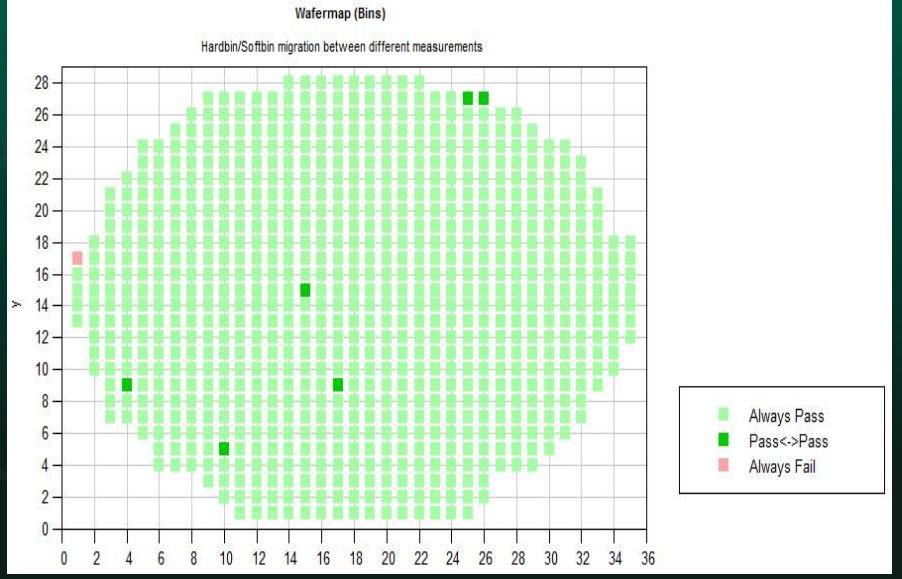


Test Reproducibility: Acceptable Result of >99%

- **Same wafer was measured two times to calculate test reproducibility**
- **Test results from 80 test structures on test chips are used for binning**
  - Leakage and resistance measurement with current forcing
  - 10 Ω spec range in most restrictive test structures
- **Bin-flips occurred on soft bins**
  - 5 bin flips on tests with spec range k Ω
  - 1 bin flip on test with spec range 10 Ω
  - → one flip possibly due to probecard condition
- **Acceptable reproducibility of over 99%**

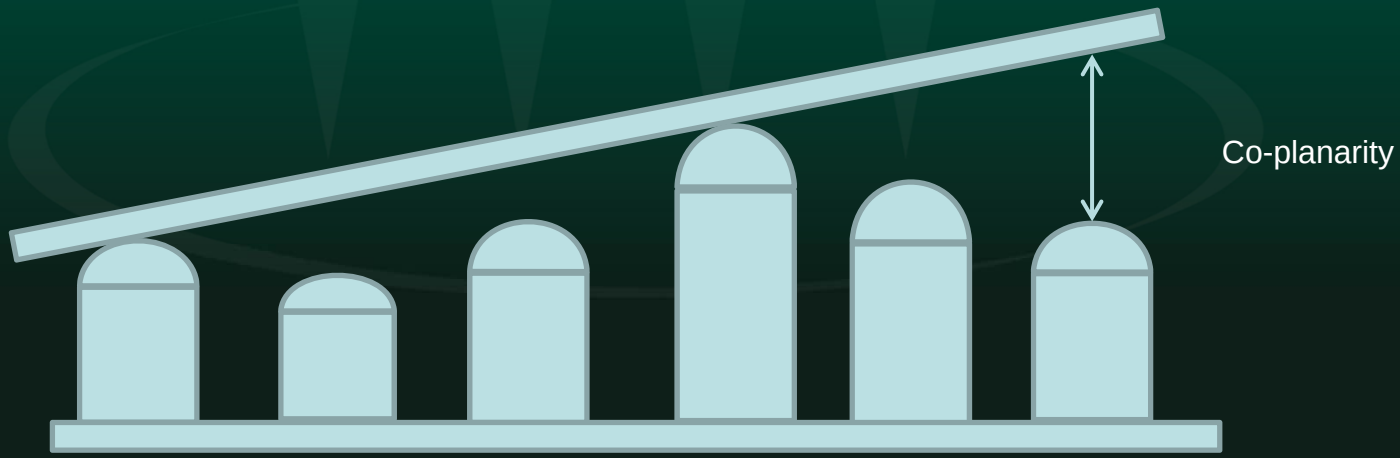
Retest-Quality: 99.2 %

# systems	%	Category
767	99.1	Always same PASS
1	0.1	Always same FAIL
0	0.0	Change **PASS** <-> **FAIL**
0	0.0	Changing **FAIL** bins
6	0.8	Changing **PASS** bins
0	0.0	No Hardbin-Information provided



Co-planarity: Cu Pillars Requirement

- Co-planarity is an established outgoing quality check criteria from bumping houses to ensure packaging reliability
- It is defined as maximum distance from a bump/pillar to the seating plane
- Maximum spec is typically 20 µm or better
- Packaging fails (non-wet) seen for > 25 µm on SnAg bumps

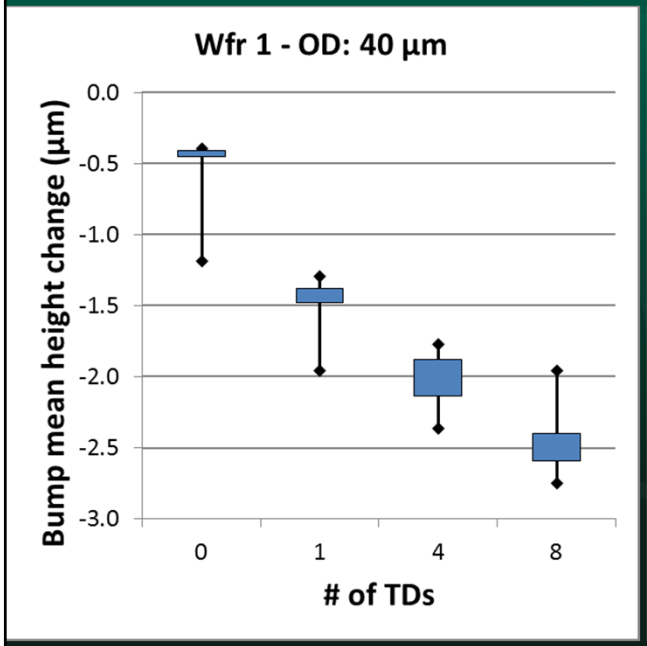


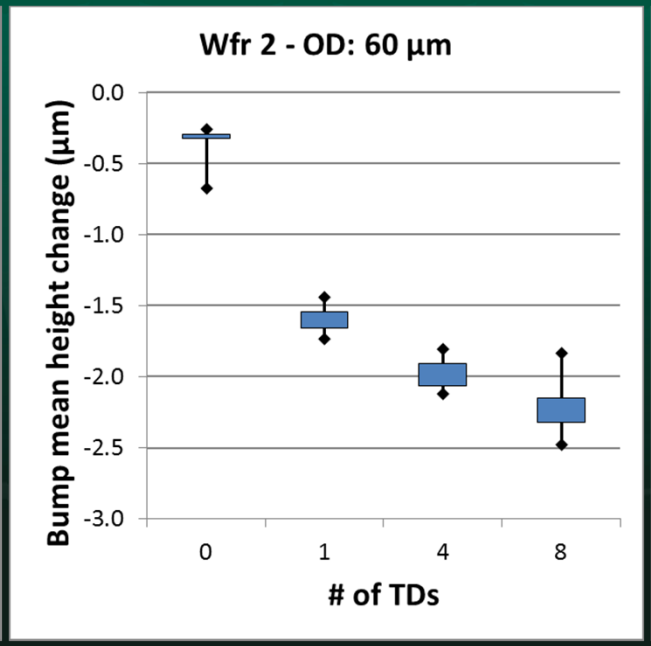
Co-planarity: Probe Conditions to Validate Co-planarity Before & After Probing

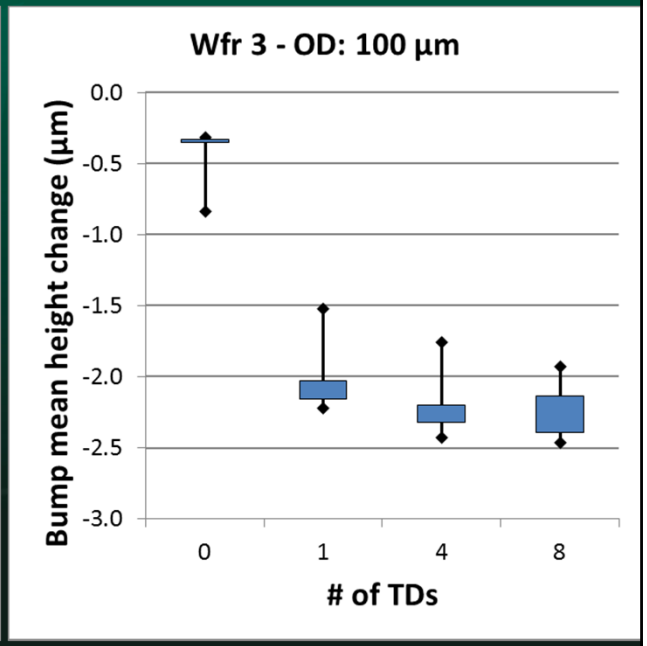
- **Coplanarity was measured on three wafers before and after probing**
- **Automated 100% 3D inspection (laser triangulation)**
- **Probing conditions:**
  - Wafer 1: OD 40µm, TDs: 0, 1, 4, 8
  - Wafer 2: OD 60µm, TDs: 0, 1, 4, 8
  - Wafer 3: OD 100µm, TDs: 0, 1, 4, 8

Coplanarity: Bump Height Reduces With An Increase in Probing Touchdowns

- Bump height reduces < 3 µm (< 10% SnAg cap height) with 8 probing touch downs
- No noticeable SnAg material reduction

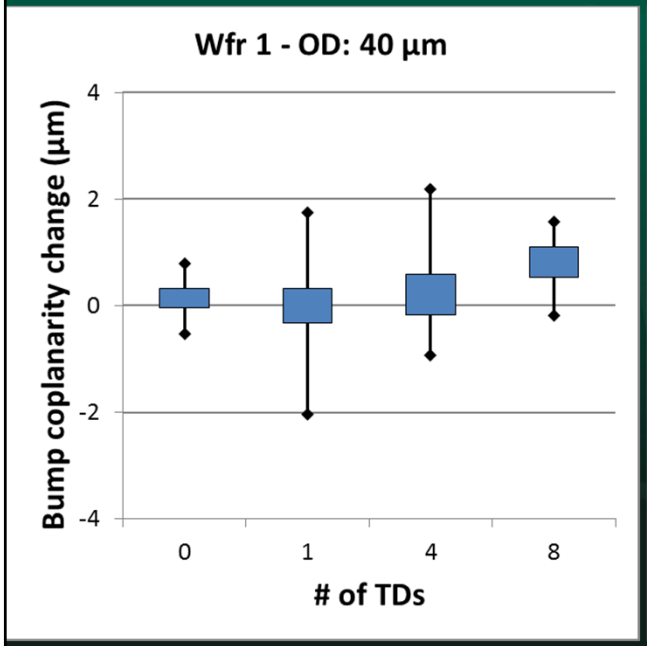


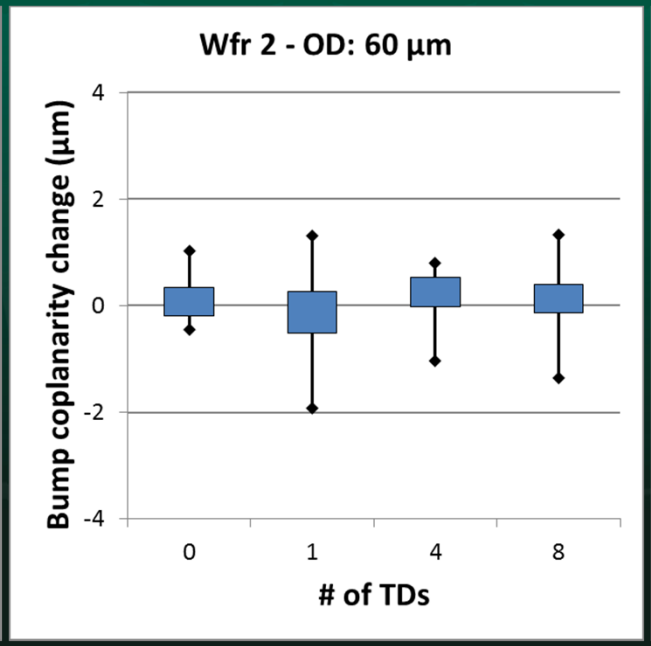


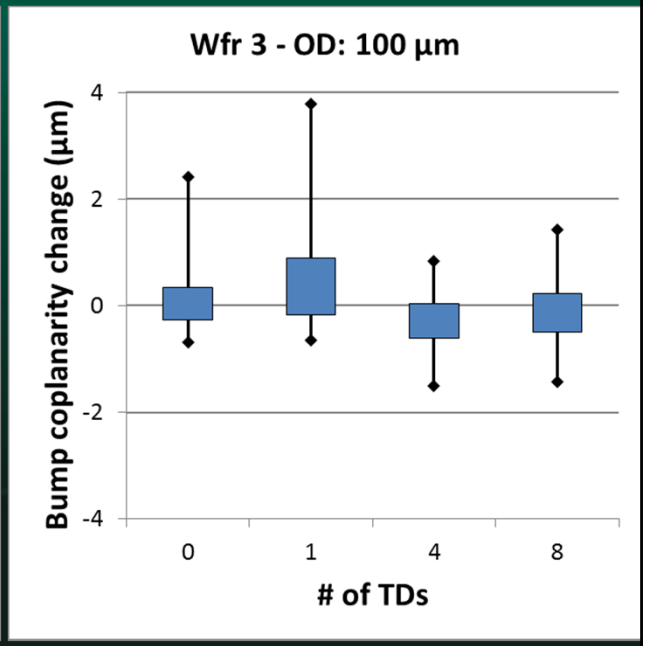


Co-planarity: No Substantial Co-planarity Change Post Probing

- **Co-planarity change before and after probing is minimal**

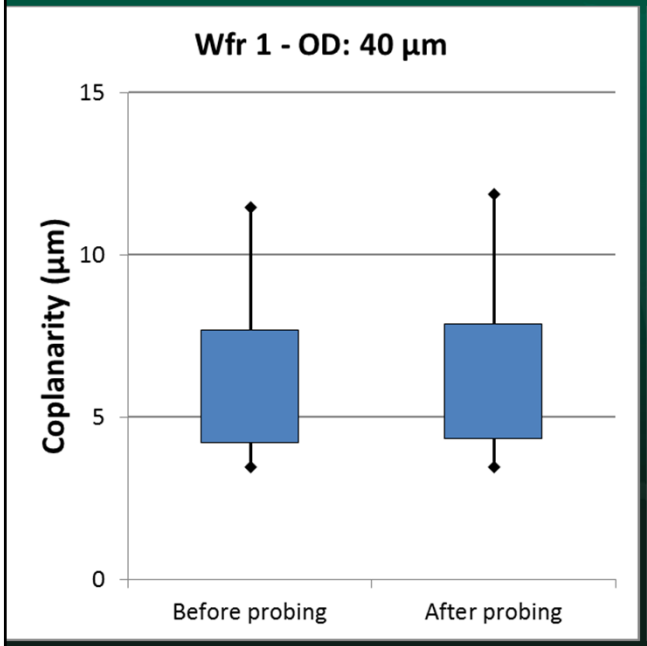


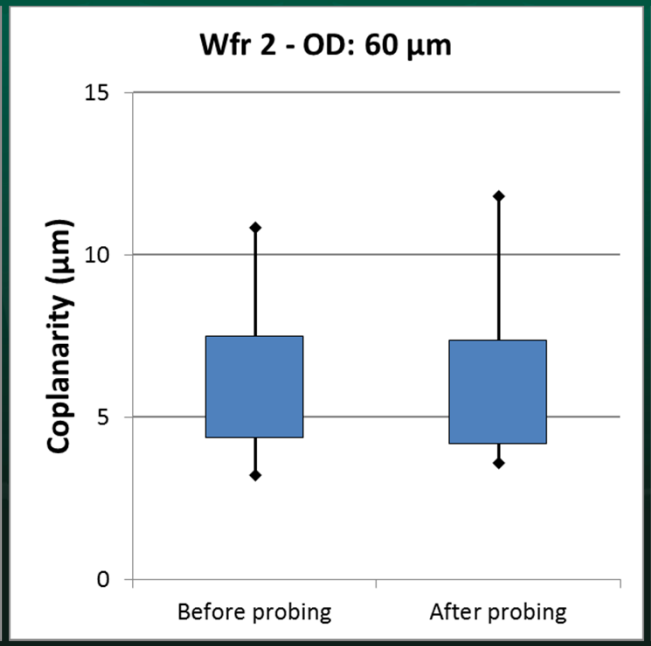


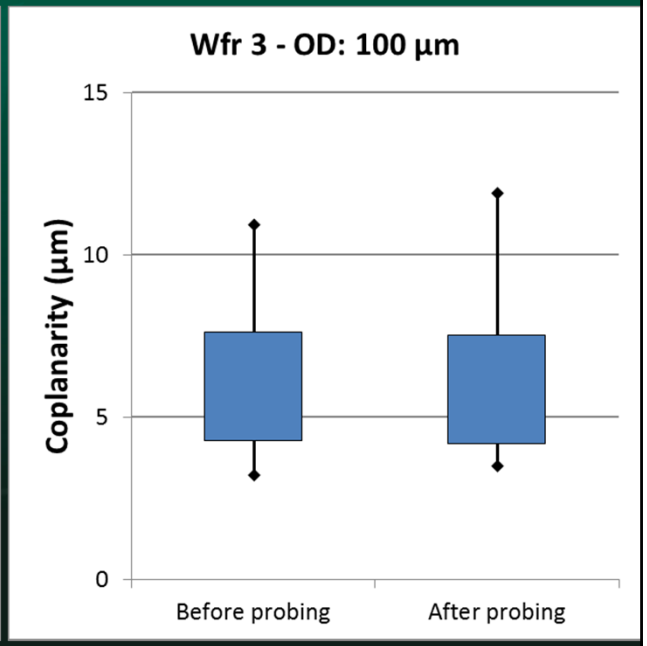


Coplanarity: Overall Co-planarity Meet Bump House Reliability Check

- Probing process, with up to 8 touch downs, did not change pillar co-planarity signficantly
- Wafers showed comparable final co-planarity range of <10 um as the initial pillar condition before probing

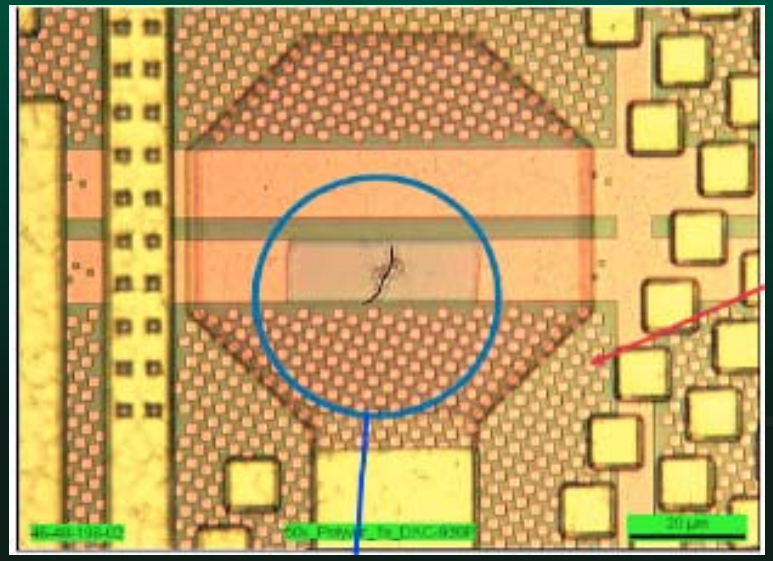






Future work

- Investigation on under-pads crack generation after worst case probing, PoAA reliallility characterization
- Monitoring in production environment to ensure lifetime requirement (>1M TDs)



Previous example of an under-pad crack observed on 65nm Mobile SoC

Conclusion

- **Implementation of Cu pillar with SnAg caps allows vertical probe card as used to probe on SnAg bumps**
  - MicroProbe low-force Apollo™ vertical product is a qualified solution
  - 2.5 mil probe geometry is a prefered configuration for 120um pitch
- **Low-force Apollo™ product has demonstrated robust performance on fine-pitch grid-array Cu pillar for:**
  - Contact stability
  - Test reproducibility
  - Bump damage
- **Future work**
  - Confirm PoAA reliability
  - Optimize production probecard lifetime