IEEE SW Test Workshop
Semiconductor Wafer Test Workshop

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Contacting various metal compositions using ViProbe® Vertical Technology

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- ViProbe® Vertical Probe Technology.
- CRES Measurement setup.
- Evaluation Results Al, Au, Cu Pad.
- ViProbe® Temperature Probe @ 200'C.
- ViProbe® ADC Testing in Probe to Data Sheet specifications.
- Conclusions.
- Future Work.

Motivation.

ViProbe® Vertical Probe Technology.

CRES Measurement setup.

Evaluation Results Al, Au, Cu Pad.

ViProbe® Temperature Probe @ 200'C.

ViProbe® ADC Testing in Probe to Data Sheet specifications.

Conclusions.

Future Work.

Motivation

- **Minimum pad deformation post sort required for,**
  - Die shipping direct to customer (automotive).
  - FCOL (Flip Chip on Lead) Bumping process.
  - OPM (Over Pad Metallisation) Assembly process.
- **Multiple 'contact pad' metal compositions,**
  - Al, Au, Cu.
- **Multi-site Sort >8 sites / Grid Array Pattern.**
  - EWLP (Embedded Wafer Level Package).
    - WLCSP (Minus bump).

Motivation (Cont.)

- **Temperature Sort of products used in,**
  - Automotive,
  - Industrial applications.
- **KGD (Data Sheet Specifications) with any combinations of the above.**
- **Increased requirement for Vertical Probe Technologies.**
  - Minimum pad deformation, Stable CRES.

Motivation.

ViProbe® Vertical Probe Technology.

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ViProbe® Temperature Probe @ 200'C.

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ViProbe® Vertical Probe Technology.

ViProbe® Wired Connector

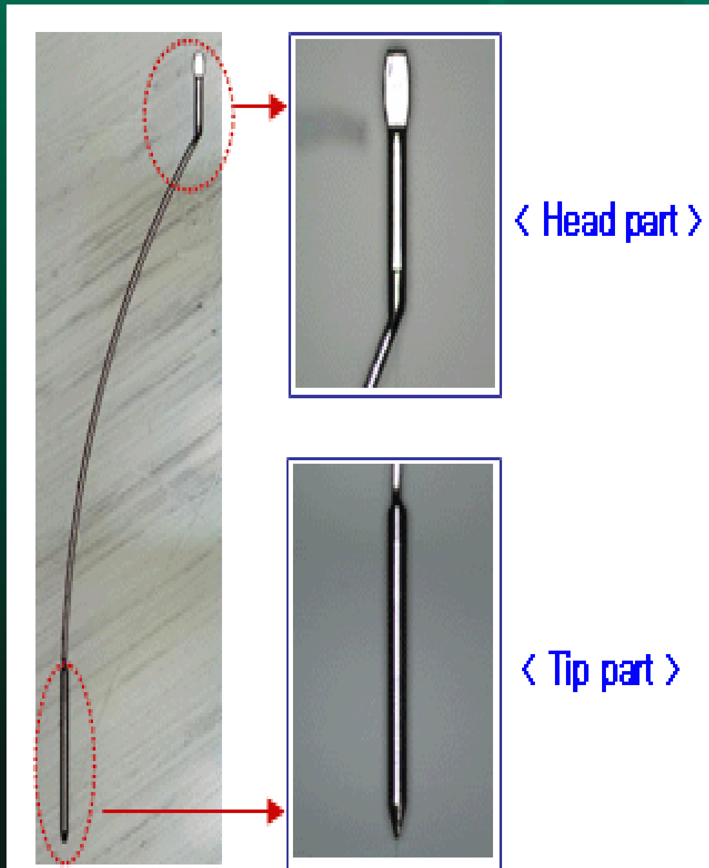
PCB

ViProbe® Head

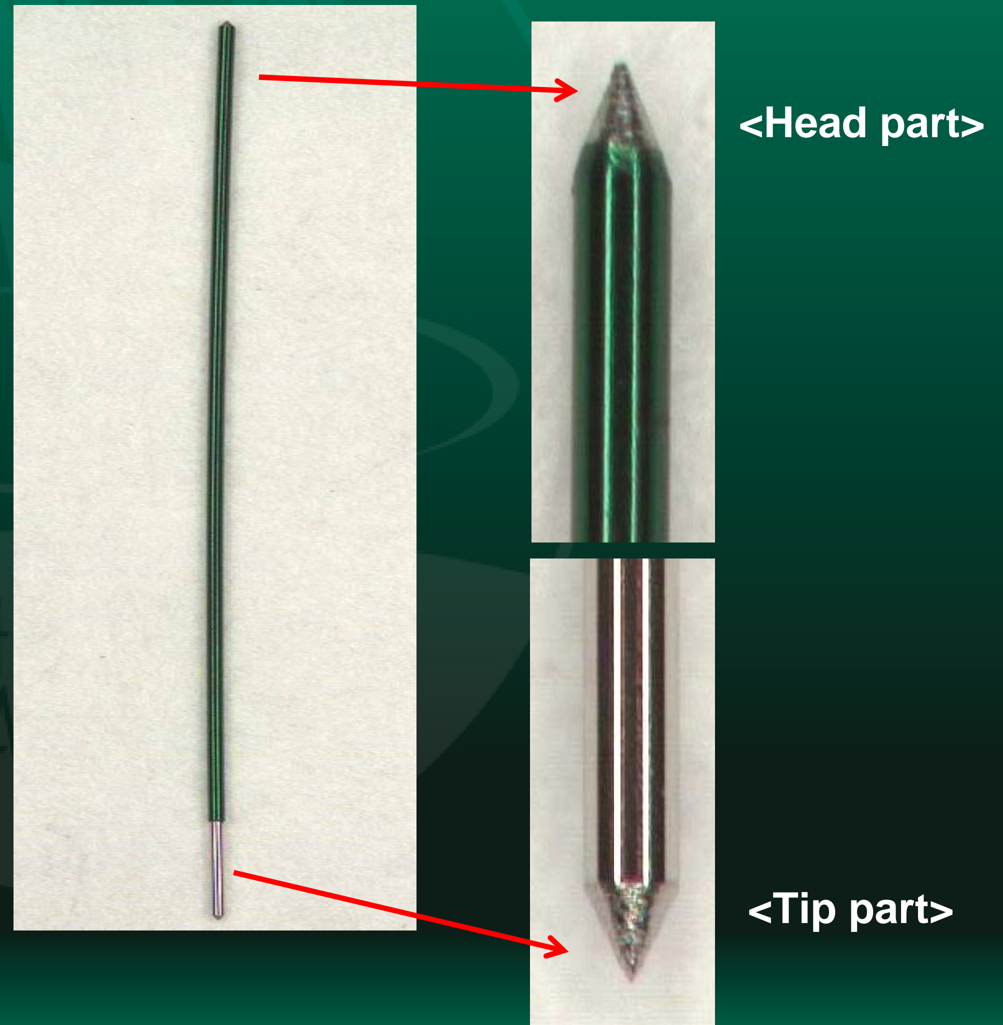
- **Feinmetall ViProbe® Wired Series**
- Same construction / needle tip for WLCSP, Al, Au, Cu Pad.

ViProbe® Vertical Probe Technology.

‘Cobra’ style Needle



‘ViProbe® Beam



ViProbe® Vertical Probe Technology.

Prüftechnik für Elektronik

Feinmetall ViProbe® versus Cobra/Cantilever

force in cN

Cantilever / Cobra (linear)

ViProbe®

(not linear)

Overtravel in µm

Ch. Gers / S. Allgaier

FEINMETALL | 1 | 15.04.2010

- ViProbe® a safer technology than Cantilever where probe mark area and scrub depth need to be controlled.

ViProbe® Advantages

- Mechanically robust and reliable.
- Consistent probe mark signature across full array.
- Easily repaired, minimum downtime.
- Same ViProbe® Beam used for contacting WLCSP Solder bump, Al / Au / Cu Pad.
- ViProbe® improvements (innovation development from Feinmetall) keeping pace with customer requirements.

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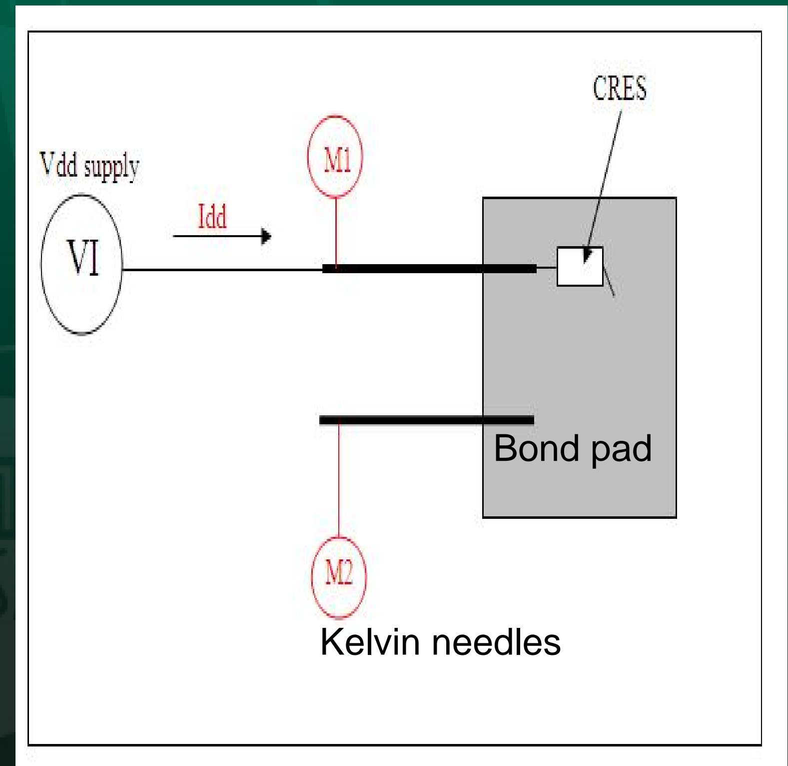
CRES Measurement Setup.

- **Method 1: Measure CRES as part of Production Sort.**

Requirements

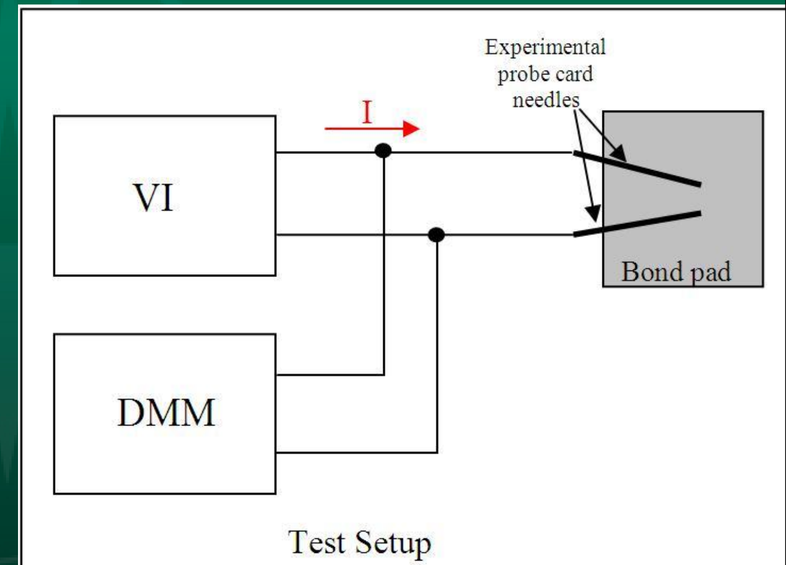
- – A pad large enough for a Kelvin contact (Force & Sense).
- – Preferably a supply pin.
- – PIB board design must include CRES measurement capability.
- – CRES = (Vm1 – Vm2) / Idd

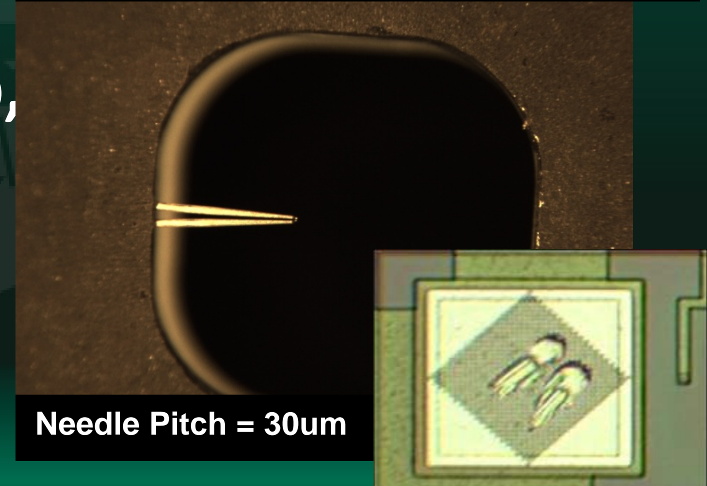


CRES Measurement Setup.

Method 2: "CRES Test Jig"

- **Offline CRES measurement.**
- **"CRES Test Jig"**
  - A 2 Needle Probe Card.
  - CRES PIB connected to DMM & VI.
- **Enables CRES experiments and capability to optimize Sort setup, debug yield hits.**





CRES Measurement Setup.

HF HS DMM LF LS

V / I

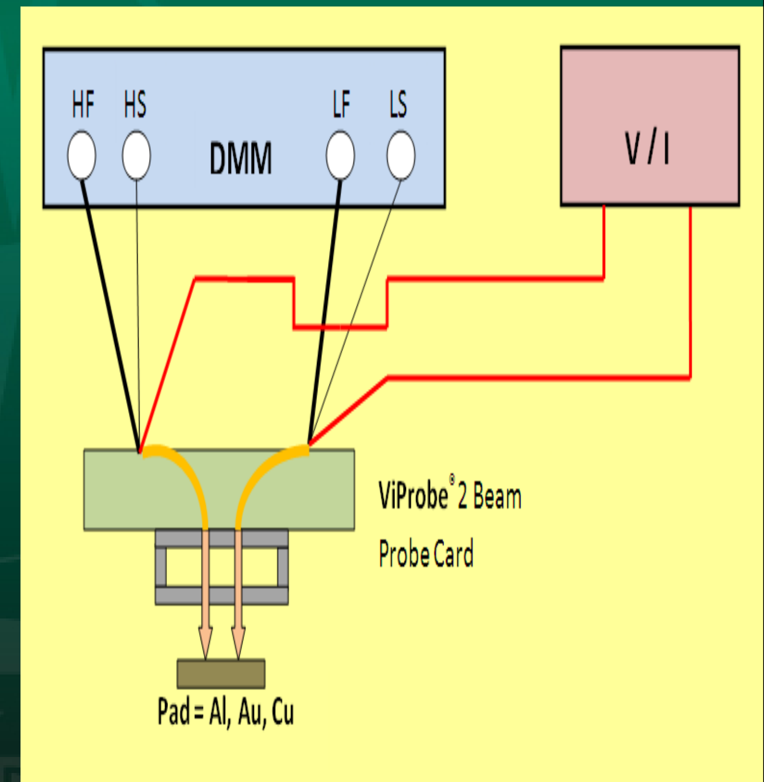
ViProbe® 2 Beam Probe Card

Pad = Al, Au, Cu

- **CRES Test Jig (ViProbe®** 2 Beam Probe Card)
  - **2 Mil Beams (Trivar HC® pointed tip),**
  - **75µM Pitch.**

CRES Measurement Setup.

- Experiment Steps (CRES Test Jig),
  1. Touchdown on Pad 1 on Die 1,
  2. Measure CRES with DMM (1mA),
  3. Force current (i = 30mA),
  4. Measure CRES with DMM (1mA),
  5. Index to Pad 1 next die,



- Probe Pad 1 all Die,
- Re-probe at Pad 1 with X,Y, offset,

Or change to Pad 2

- Motivation.
- ViProbe® Vertical Probe Technology.
- CRES Measurement setup.
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Evaluation Results Al, Au, Cu Pad.

- **Post Sort with ViProbe® Vertical Technology,**

  Measurements / Analysis from,

  (1) 2D Probe Mark inspection (Leica Microscope),

  (2) 2D Probe Mark inspection (NSX 105),

  (3) 3D Probe Mark inspection (Zygo Profilometer),

  (4) CRES.

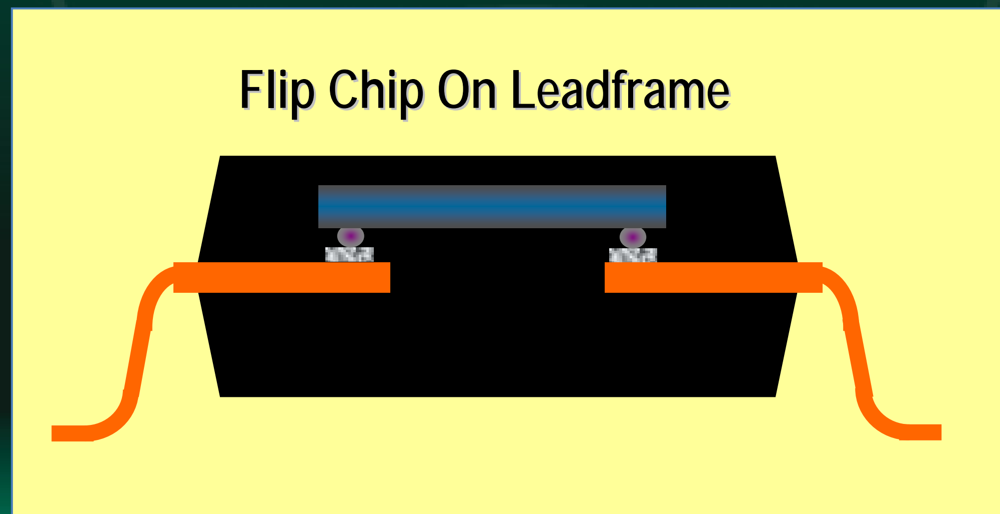
  NOTE:

  (1) to (3) above PMI measurements taken after Sort with full ViProbe® Production Probe Cards.

  (4) Using CRES JIG using ViProbe® 2 Beam Probe Card.

ViProbe® on Al Pad.

- **Flip Chip on Lead (FCOL) requires Sort before bumping.**
  - Electroplated bump process requires smallest possible probe mark.
  - ViProbe® was qualified to probe Al Pad (FCOL parts) before electroplated bump process.

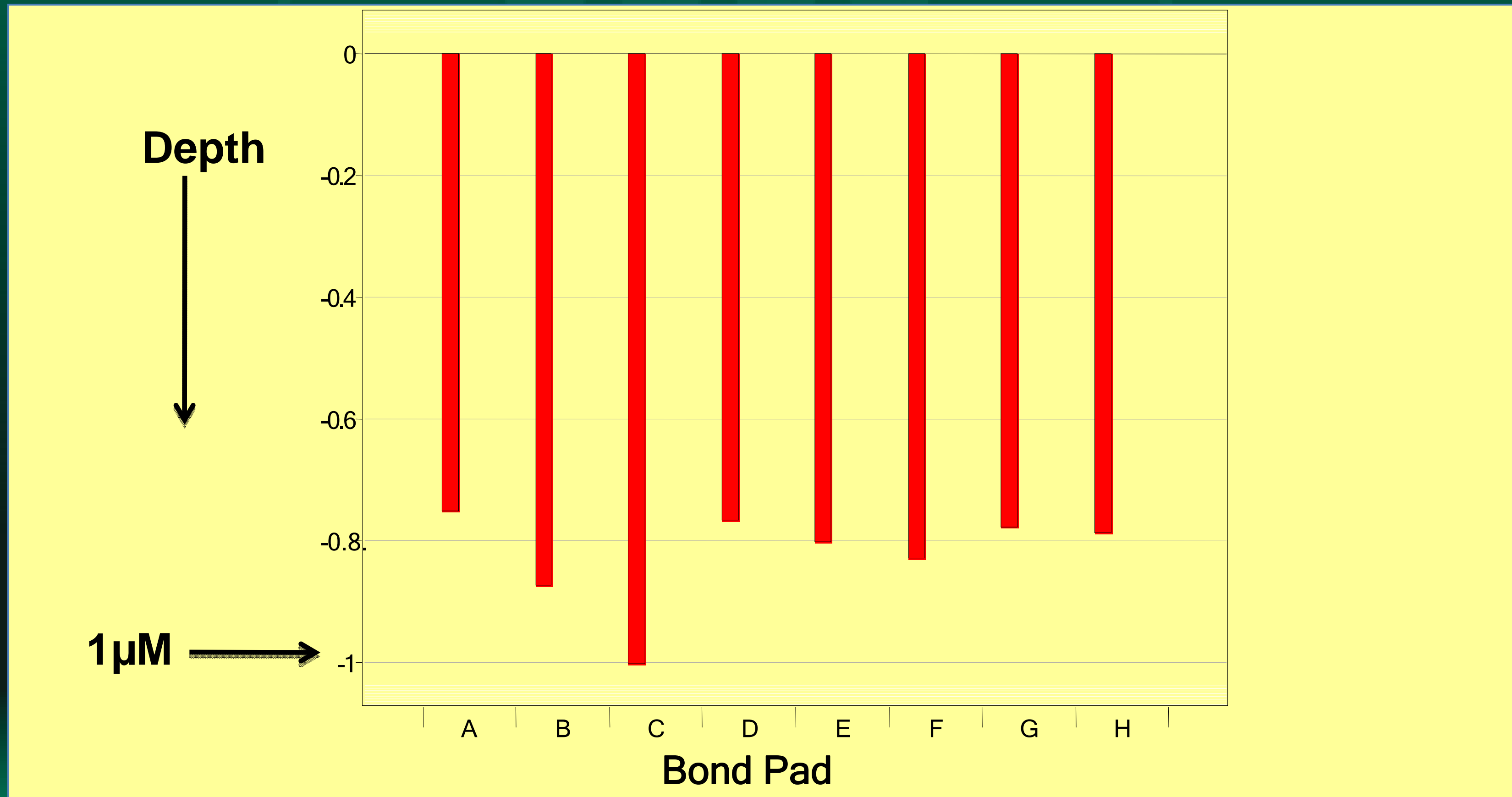


ViProbe® on Al Pad.

- **Automotive KGD, 3 Temperature pass (Ambient, -40’C, +160’C).**
- **Critical Quality parameters,**
  - Probe Mark Size,
  - No Pad edge incursions.

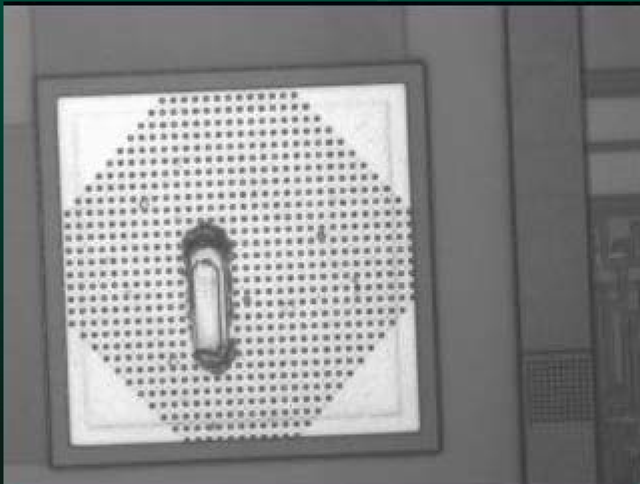
ViProbe® on Al Pad.

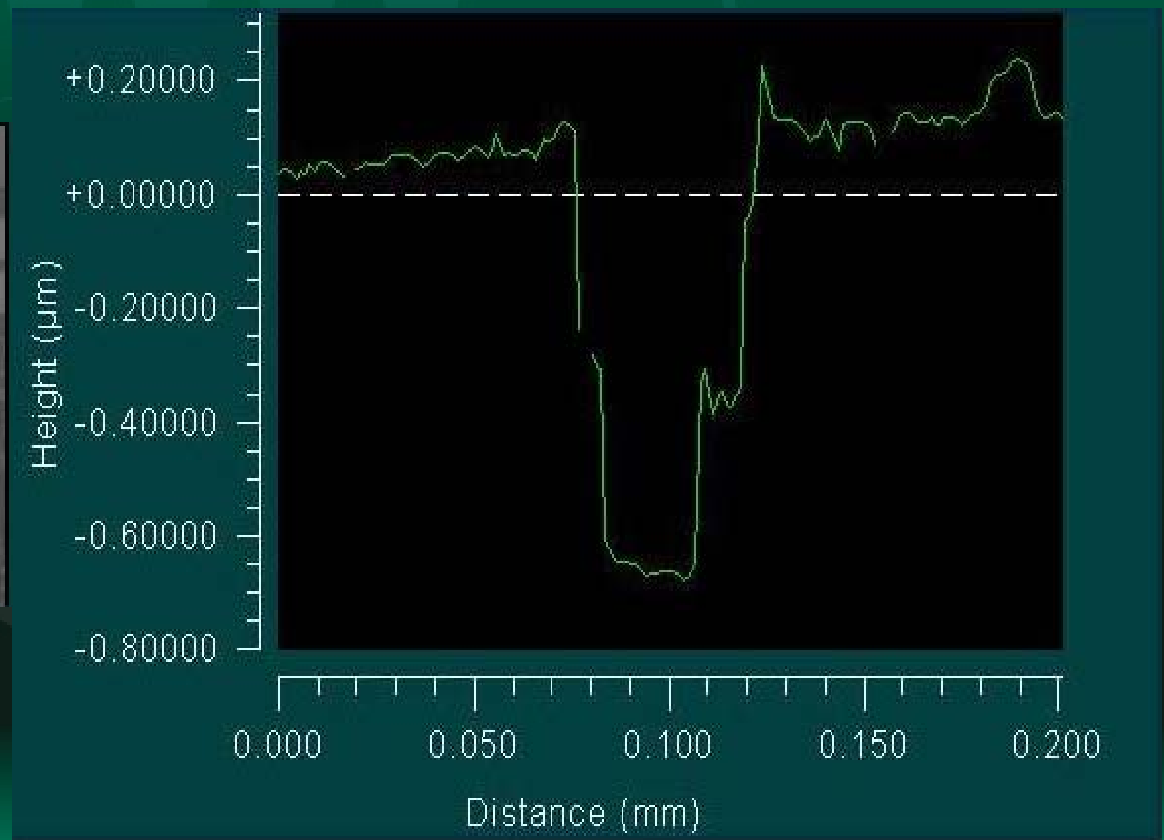
- Al Pad deformation post Cantilever Sort.
  - Zygo Profilometer (2007 Data).
  - Typical Scrub depth 0.8µM.



ViProbe® on Al Pad.

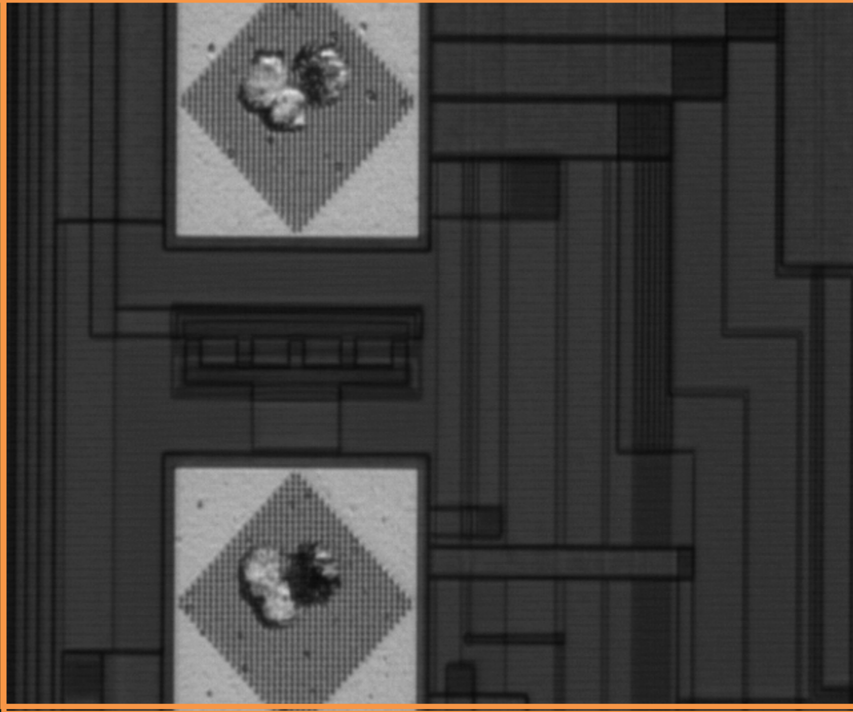
- **Zygo Profilometer.**
- **Depth of <u>Cantilever</u> on Al Pad = 0.7μM.**





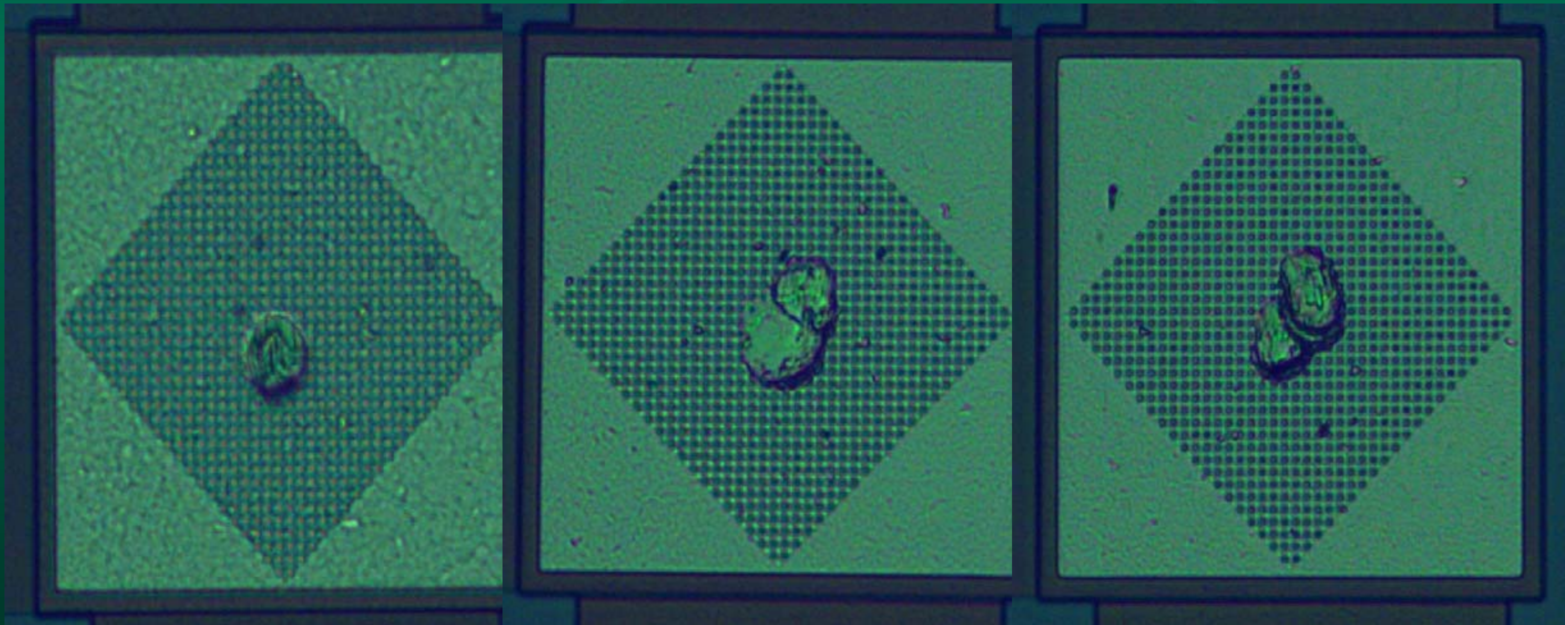
ViProbe® on Al Pad.

ViProbe® Probe Marks post 3 pass Sort.



3 Cantilever Probe Scrubs breaking Pad Edge

ViProbe® on Al Pad.

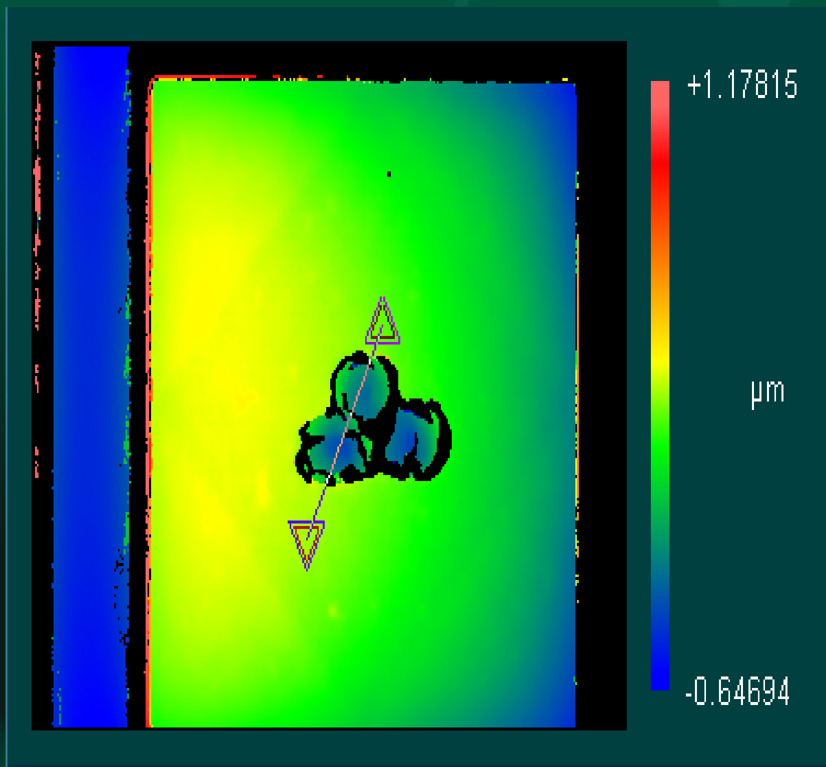


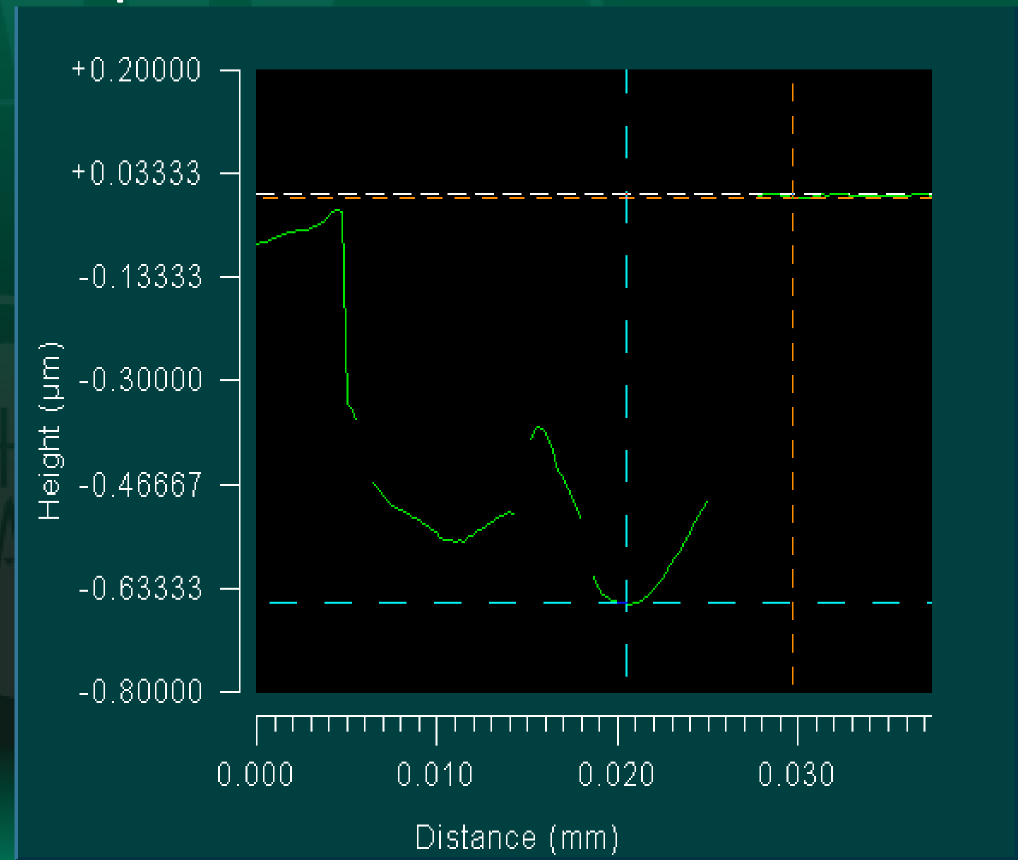
Pass 1   Pass 2   Pass 3

- **NSX 105 post <u>Pass 3</u>**
  - Probe Mark Area = 546μM²,
  - Probe Mark % of Pad = 3.8%
  - Pad Edge Proximity = 35μM.

ViProbe® on Al Pad.

- **Zygo Profilometer.**
- **Depth of ViProbe® Scrub on Al Pad post <u>Pass 3</u>,**
  - Probe Mark Depth = 0.6µM





ViProbe® on Al Pad.

- CRES baseline 0.6 Ohm, CRES stable over temperature

Raw Data (Active)

File Options Help

2 TEST_cres

TEST_cres

Mean: 0.655586
SD: 0.0587618

Mean: 0.690062
SD: 0.0421267

150'C CRES = 0.83 (Mean + 3 σ)

25'C CRES = 0.81 (Mean + 3 σ)

Resistance (ohms)

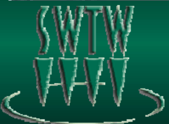
3.5
3
2.5
2
1.5
1
0.5
-0

-0 1000 2000 3000 4000 5000 6000

Count

Samples

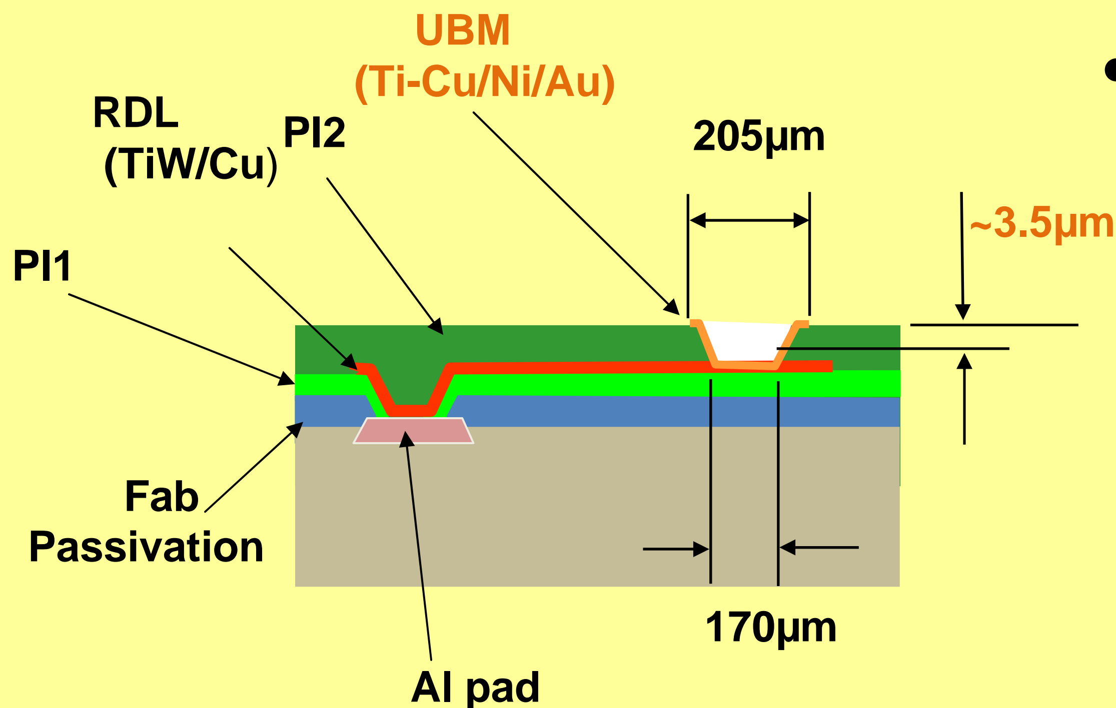
D52395_1_1_5_cts5040_psunq15_120208_150.stdf (TEST_cres)
D52395_1_1_5_cts5040_psunq15_120208_25.stdf (TEST_cres)



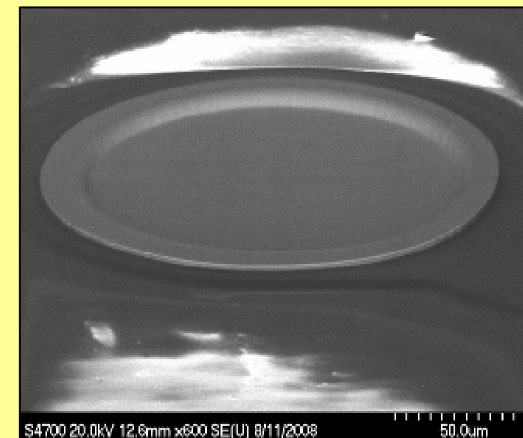
ViProbe® on Au Pad.

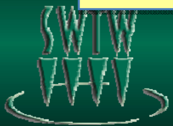
- **EWLP – Embedded Wafer Level Package.**

  - WLCSP (Minus Bump)



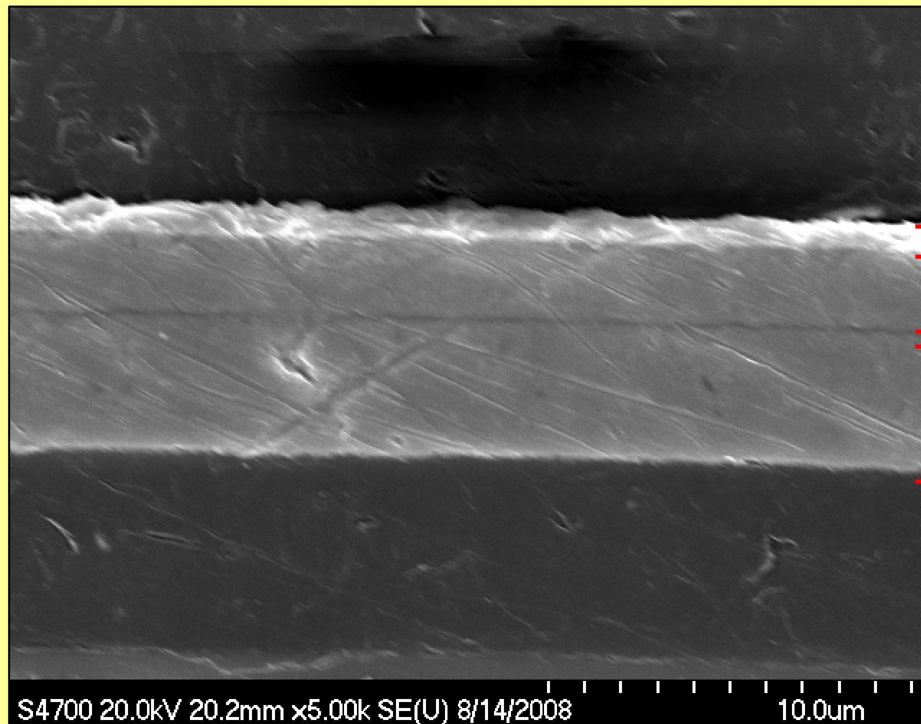
  - SEM of UBM Pad





ViProbe® on Au Pad.

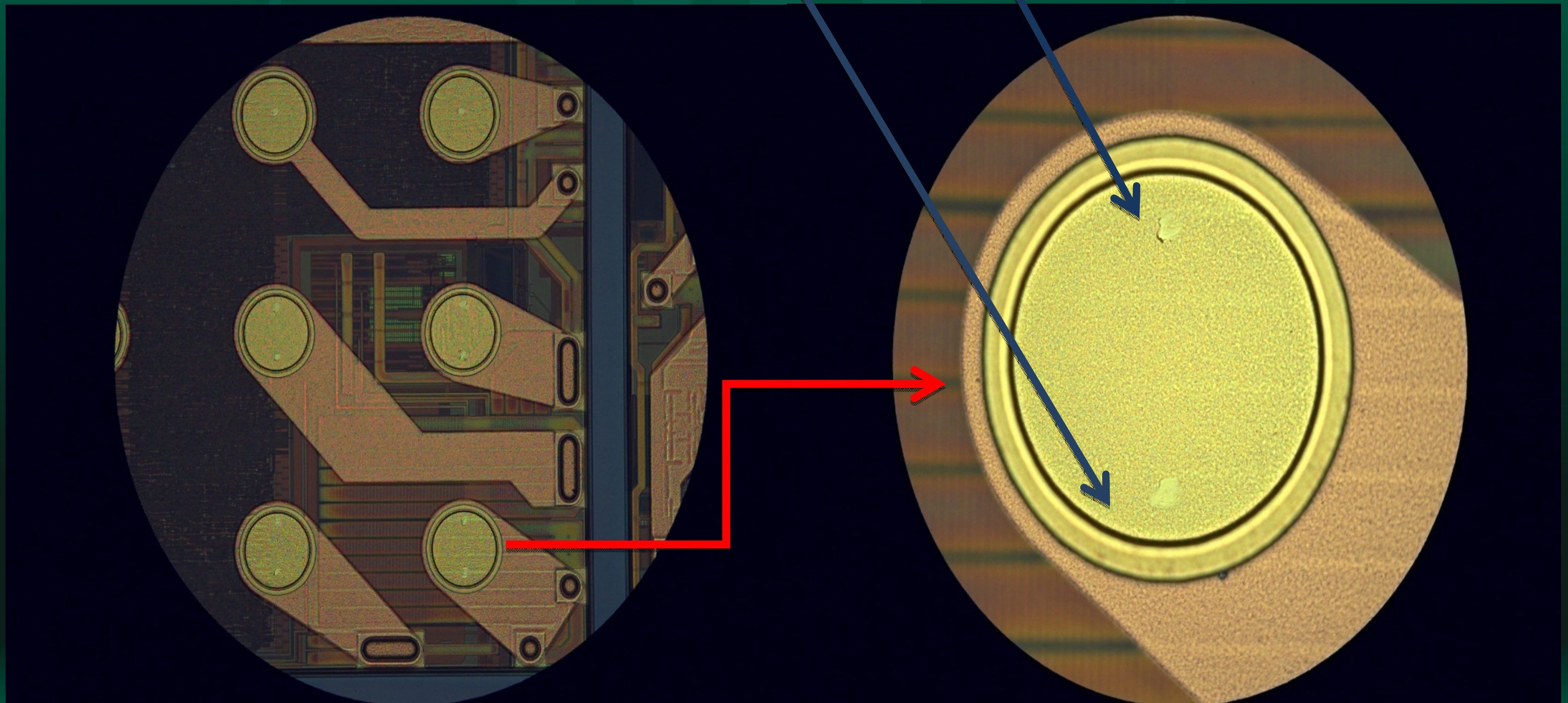
- EWLP – Au Pad of ~1μM Au Flash,
- Post Sort Requirement: No Punch Thru.



~1μm layer of Gold
Nickel
Titanium
Copper

ViProbe® on Au Pad.

- 2D PMI (Leica microscope),
- Scrub Mark area ~400µM^2.
  - ViProbe® Kelvin at 86µM pitch.



ViProbe® on Au Pad.

- 3D PMI (Zygo Profilometer).
- Depth of ViProbe® Scrub on Au Pad = 0.185µM

zygo Surface Map

+0.37085
µm
-0.35641

PV	0.727	µm
rms	0.146	µm
Ra	0.122	µm
Size X	0.07	mm
Size Y	0.05	mm

Removed: Plane
Trimmed: 0
Filter High Wavelen:
Filter Low Wavelen:

zygo 3D Model

zygo Surface Profile

+0.10000
+0.02500
-0.05000
-0.12500
-0.20000
Height (µm)
0.0 10.0 20.0 30.0
Distance (µm)

PV	0.341	µm
rms	0.095	µm

Ra 0.080 µm
Profile Stats

zygo Intensity Map
Profile Plot

yMax:		µm
yMin:		µm
xMax:		µm
xMin:		µm
yDst:	0.185362	µm
xDst:	9.66	µm
angle:	1.09921	degs

Update | Inspector 2
Reset | Prof PV
Set | Trace
Spline BG

ViProbe® on Au Pad.

- CRES at 125'C, No Online Clean required.

Raw Data (Active)

File Options Help

ViProbe® on Cu Pad.

- Cu RDL + Cu Pad.
- Concern was oxidation and the resulting difficulty of making good electrical contact.

~3um Cu RDL

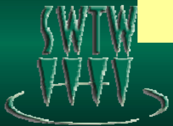
Bare Copper Pad
7.5um Min thicknes

Copper RDL

Passivation

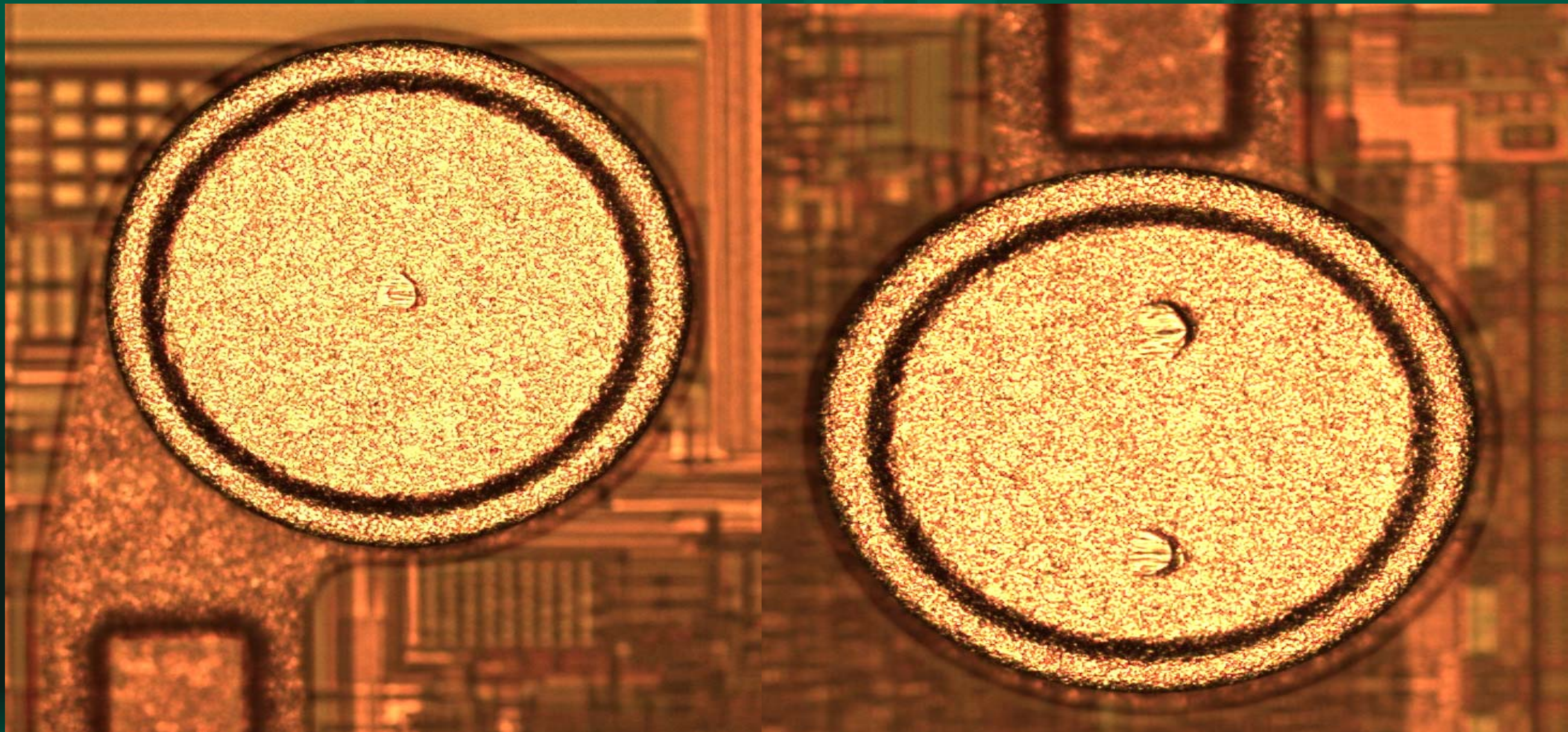
Bond Pad

Silicon



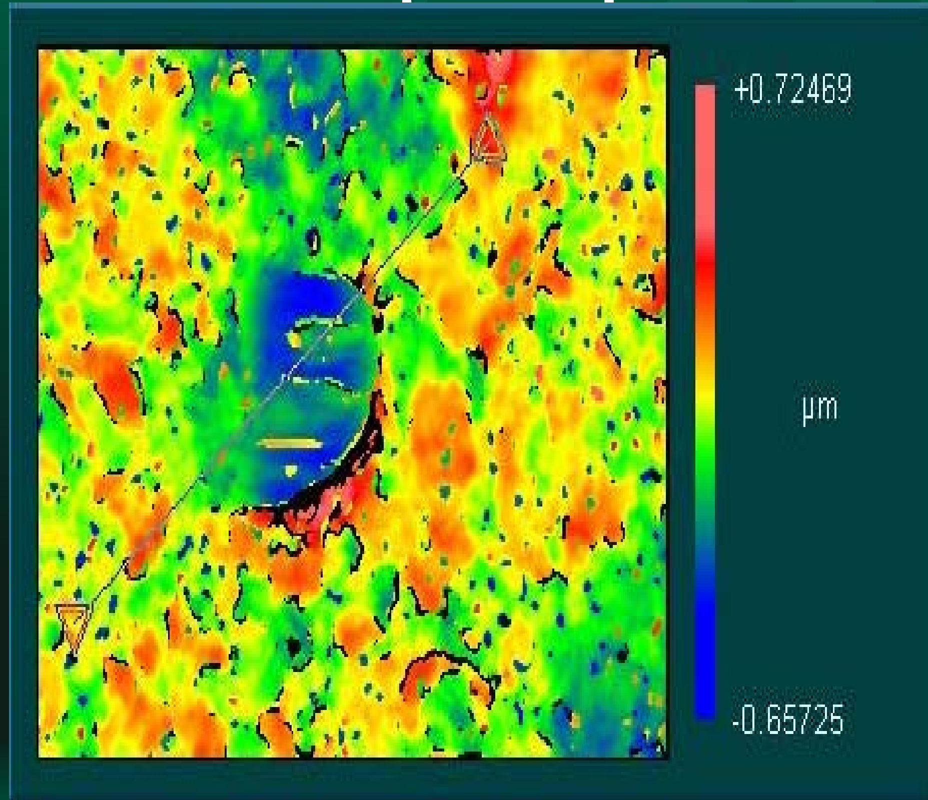
ViProbe® on Cu Pad.

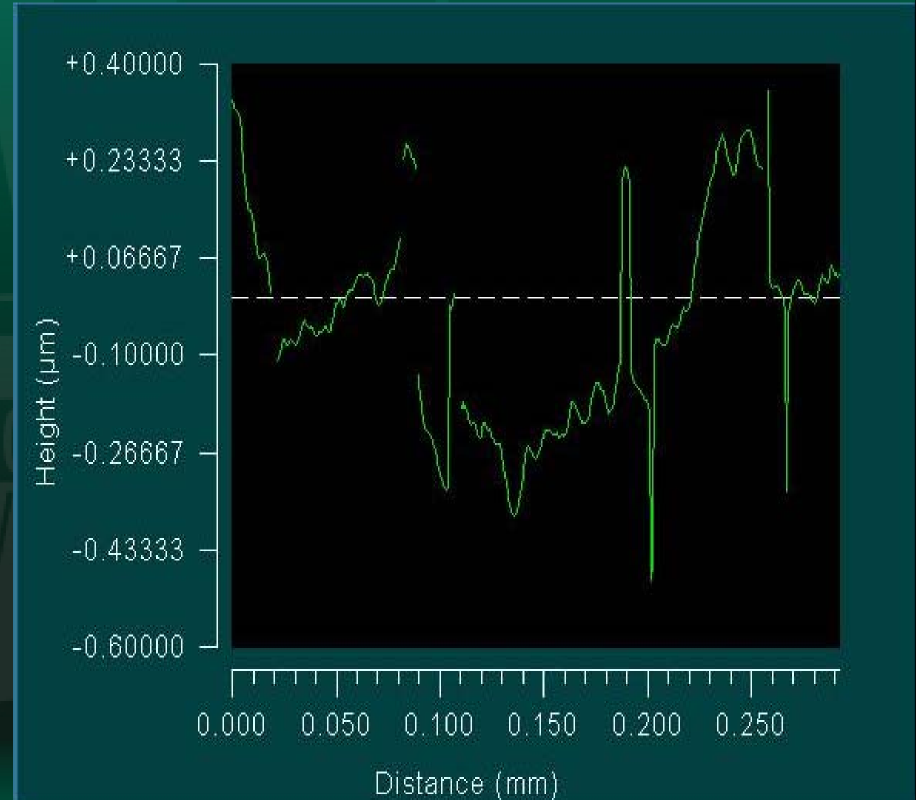
- **2D PMI (Leica microscope).**
  - **Single and Kelvin Probe Marks.**



ViProbe® on Cu Pad.

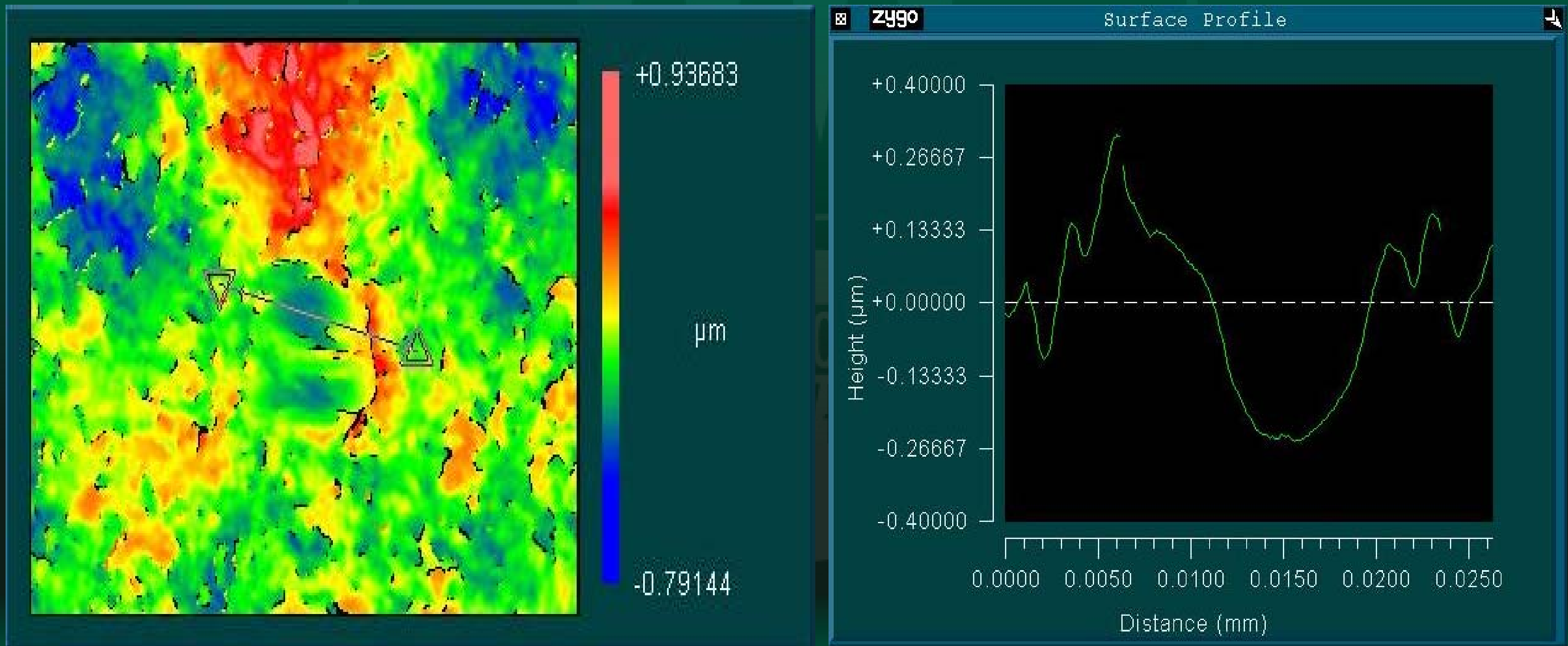
- **3D PMI (Zygo Profilometer).**
  - **Noisy result for a single touchdown,**
  - **~0.360µM depth.**





ViProbe® on Cu Pad.

- **3D PMI (Zygo Profilometer).**
  - **x10 touchdown (flattening effect from re-probe),**
  - **0.266µM depth.**



ViProbe® on Cu Pad.

- **Measure CRES, Force 30mA, Measure CRES.**
  - **Fritting has a slight improvement on unstable CRES.**

Raw Data (Active)

File Options Help

2 TEST_cres 6 TEST_cres

TEST_cres TEST_cres

Mean: 0.640937
SD: 0.235671
Min: 0.51867 Max: 3.48612

Mean: 0.612746
SD: 0.173738
Min: 0.519171 Max: 3.50912

Count

V70232_V70232_11E4_cts5340_psunq3_050510_184109.stdf.gz (TEST_cres)
V70232_V70232_11E4_cts5340_psunq3_050510_184109.stdf.gz (TEST_cres)

ViProbe® on Cu Pad.

- **Online Clean (ITS Probe Polish, every 1K Tds).**
  - **Stable CRES to 9,000 Tds, Need to improve?**

Raw Data (Active)

File Options Help

2. TEST_cres

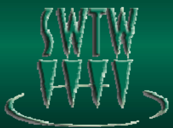
TEST_cres

12
10
8
6
4
2
-0

-0 3000 6000 9000 12000 15000 18000

Count

V70232_V70232_11E4_cts5340_psunq3_050610_155911.stdf.gz (TEST_cres)



ViProbe® on Cu Pad.

- **Online Clean (ITS Probe Polish, every 1K Tds).**
  - **Cu CRES = 0.53 (Mean + 3 σ) to 9K Tds.**

Raw Data (Active)

File Options Help

2 TEST_cres

TEST_cres

Mean: 0.517384
SD: 0.0037209
Min: 0.510987 Max: 0.546534

1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
-0

-0 2000 4000 6000 8000

Count

V70232_V70232_11E4_cts5340_psunq3_050610_155911.stdf.gz (TEST_cres)

ViProbe® on Cu Pad.

- Cu at 125’C (setup verification at Ambient to 1K Tds).
  - Cu CRES unstable from ~3K Tds at temperature.

Raw Data (Active)

File Options Help

2 TEST_cres 6 TEST_cres

TEST_cres TEST_cres

Mean: 2.10082
SD: 3.48995
Min: 0.515717 Max: 59.4919

Mean: 1.57181
SD: 1.20927
Min: 0.515498 Max: 12.416

60 50 40 30 20 10 -0

-0 3000 6000 9000 12000 15000

Count

V70232_V70232_12D7_cts5340_psunq3_051210_192113.stdf.gz (TEST_cres)
V70232_V70232_12D7_cts5340_psunq3_051210_192113.stdf.gz (TEST_cres)

ViProbe® on Cu Pad.

- **Cu CRES Summary:**
  - At ambient temperature, CRES stable to 9K Tds,
    - But online Clean needed.
  - Many hours on Sort floor trying to extend CRES stability above 9K Tds,
    - No definite solution
      - ViProbe® Technology good, Cu Challenging.
  - Long Term solution is to work with ITS and Feinmetall to find optimum online Clean recipe.

Motivation.

ViProbe® Vertical Probe Technology.

CRES Measurement setup.

Evaluation Results Al, Au, Cu Pad.

ViProbe® Temperature Probe @ 200'C.

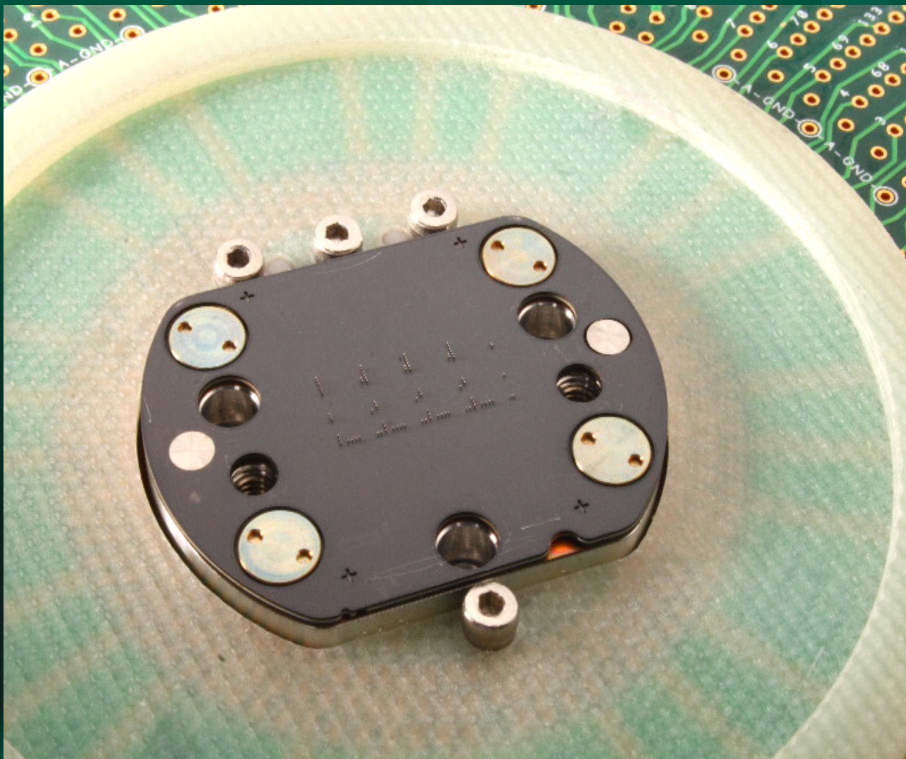
ViProbe® ADC Testing in Probe to Data Sheet specifications.

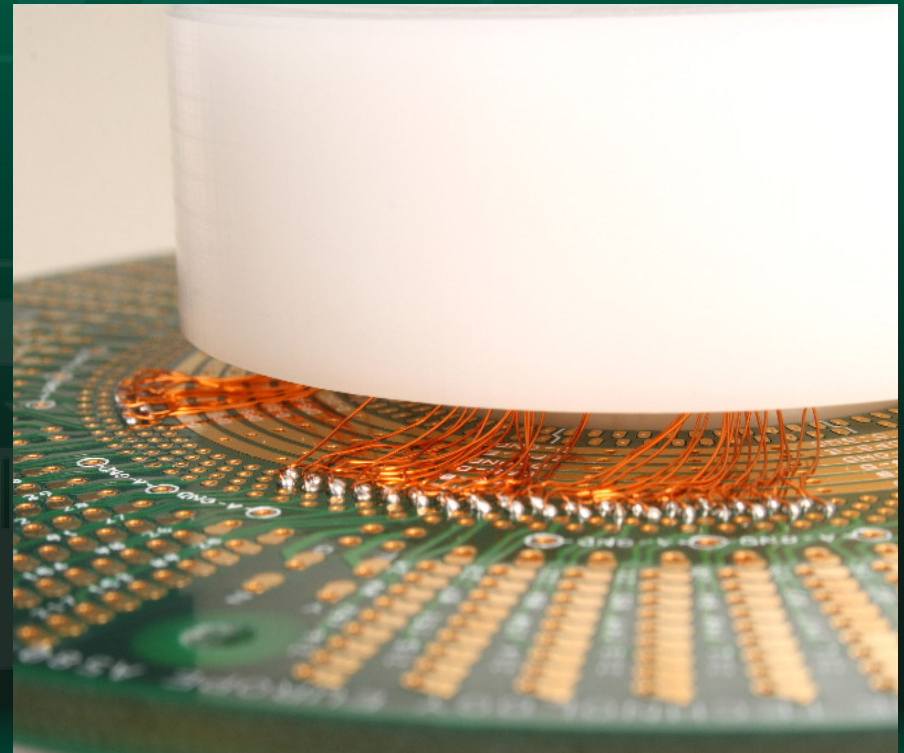
Conclusions.

Future Work.

ViProbe® Temperature Probe 160'C.

- 3 Pass Automotive Probe Card.
- Feinmetall specification 150'C, used at 160'C.
- ADI requirement for >160'C capability.





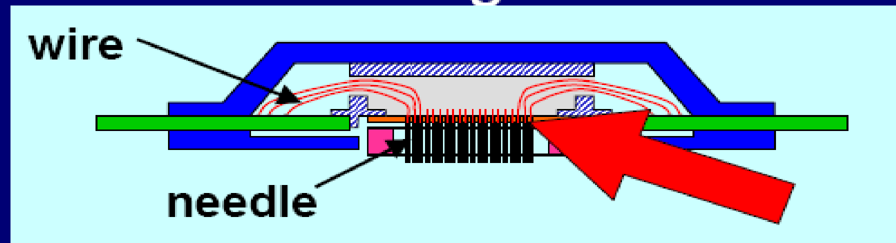
ViProbe® Temperature Probe 200‘C.

- Use existing automotive solution as test vehicle for measuring Max temperature capability.
- Evaluation involved testing product with +5’C increments in temperature.
- Existing solution worked to 170’C, at 175’C open circuit failures,
  - But Probe Marks still centre of Pad?

ViProbe® Temperature Probe 200‘C.

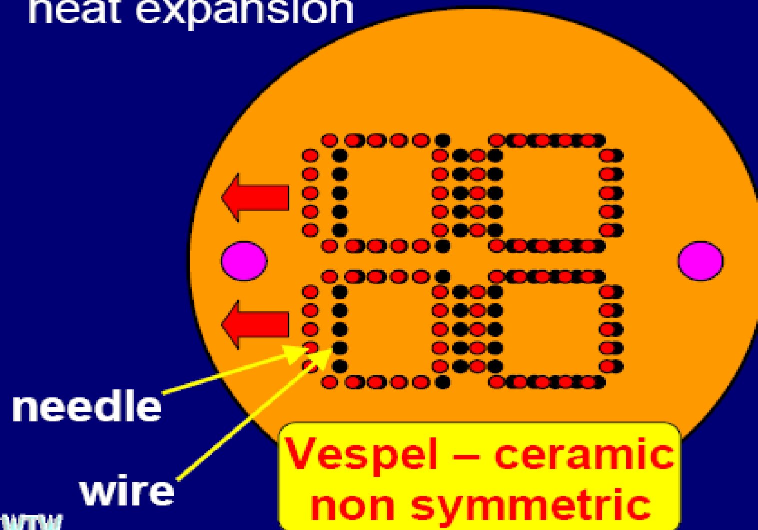
- SchaeferBoehm et al SWTW paper 2009.
  - Probe Head to Connector contact point issue.

3. Needle – Connector Alignment

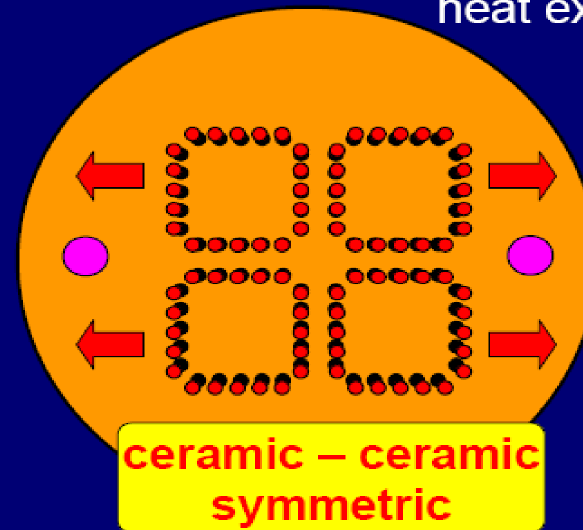


old style
heat expansion

new design
heat expansion



Vespel – ceramic
non symmetric

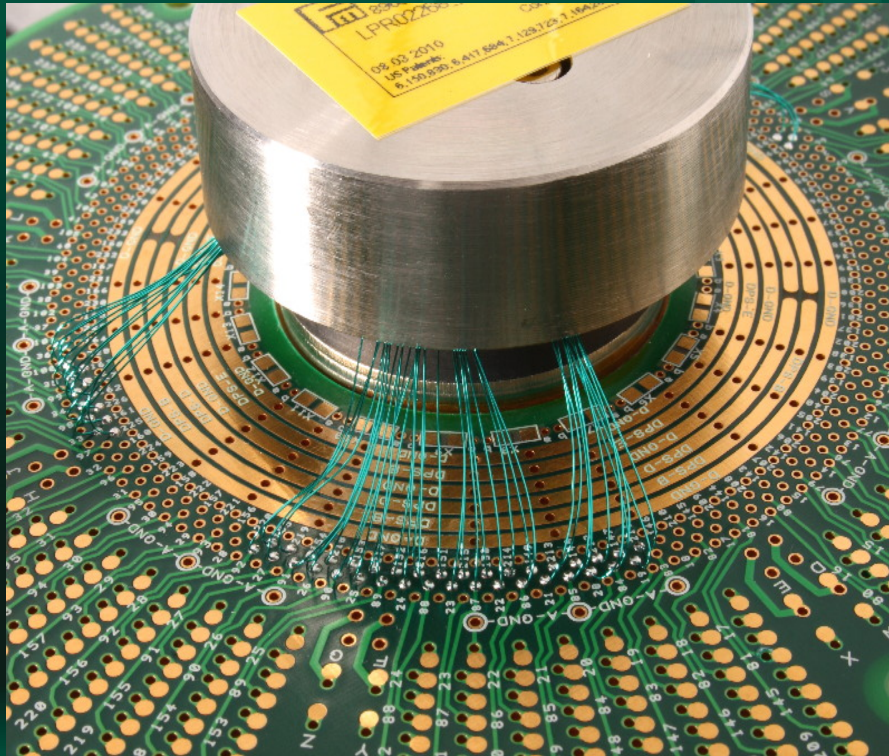


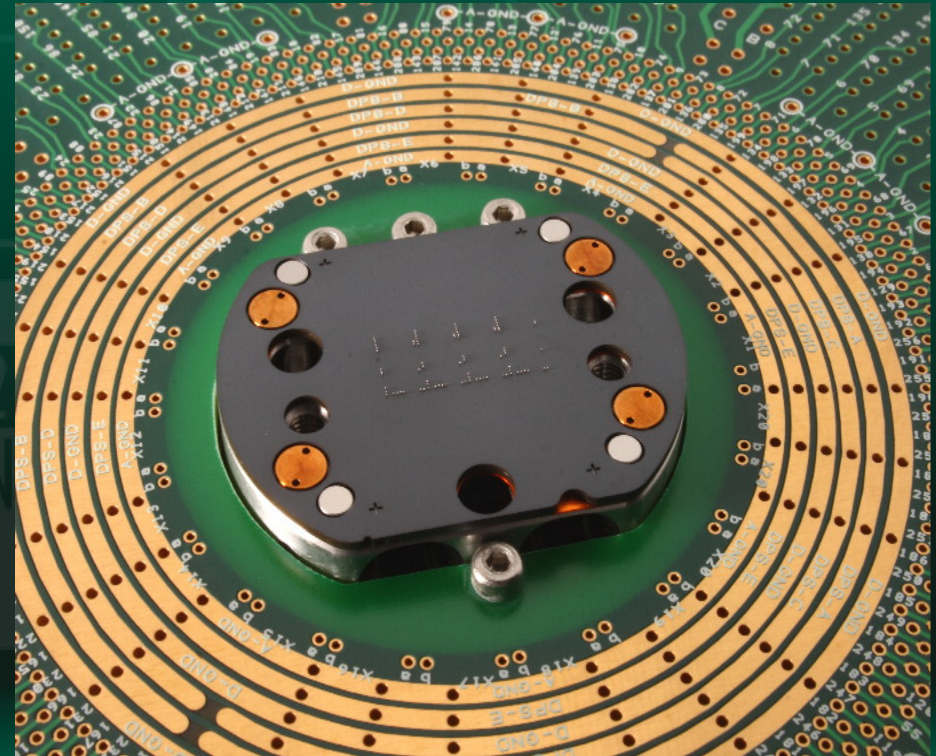
ceramic – ceramic
symmetric

June 2009 FEINMETALL GmbH, Dr. W. Schaefer / G. Boehm 10

ViProbe® Temperature Probe 200‘C.

- 200’C W41 ViProbe® Probe Card (No O/C Fails).
  - Using higher temperature specification materials.
  - >200’C possible with ‘Heat Shield’ and higher T_g PCB.





Motivation.

ViProbe® Vertical Probe Technology.

CRES Measurement setup.

Evaluation Results Al, Au, Cu Pad.

ViProbe® Temperature Probe @ 200’C.

ViProbe® ADC Testing in Probe to Data Sheet specifications.

Conclusions.

Future Work.

ViProbe® ADC Testing in Probe to Data Sheet Specifications.

- **<u>Objective:</u> Can KGD be provided at Probe for a 210MSPS ADC (Product A) and similar high speed converters.**
- **Use Product A performance results (**INL/DNL, and SNR**) as an indication of the influences of the 'Probe Card' on the signal paths and decoupling.**
  - Existing KGD High Performance Cantilever solutions already available.
  - Need a Vertical Technology KGD capability.

ViProbe® ADC Testing in Probe to Data Sheet Specifications.

- Low Inductance decoupling.
- 50 Ohm impedance as close to DUT as possible.

TESTER
PIB BOARD
POGO TOWER
10MHz latch signal
DC Supplies
Signal conditioning
Signal conditioning
Ain
Clk
PRODUCT A
Data Out
Latch
LVDS/CMOS Receivers
= 50ohm impedance lines
= Low inductance
Probe Card

ViProbe® ADC Testing in Probe to Data Sheet Specifications.

- **ViProbe® Solution.**
  - Direct Attach ViProbe® Probe Card with custom PCB (all signal conditioning components on PCB).
  - PCB layout based on working Cantilever solutions.
  - ADI supplied PCB, Direct Attach ViProbe® Head from Feinmetall.
- **Results:** Are for INL/DNL, SNR (10.3 & 70MHz) for
  - Data sheet spec,
  - A Final test part tested on the same tester,
  - ViProbe® Direct Attach solution.

ViProbe® ADC Testing in Probe to Data Sheet Specifications.

- **INL Results.**
- **Final test program limit:**
  - INLn: -1.5lsb to 0.0lsb
  - INLp: 0.0lsb to 1.5lsb
  - No missing codes

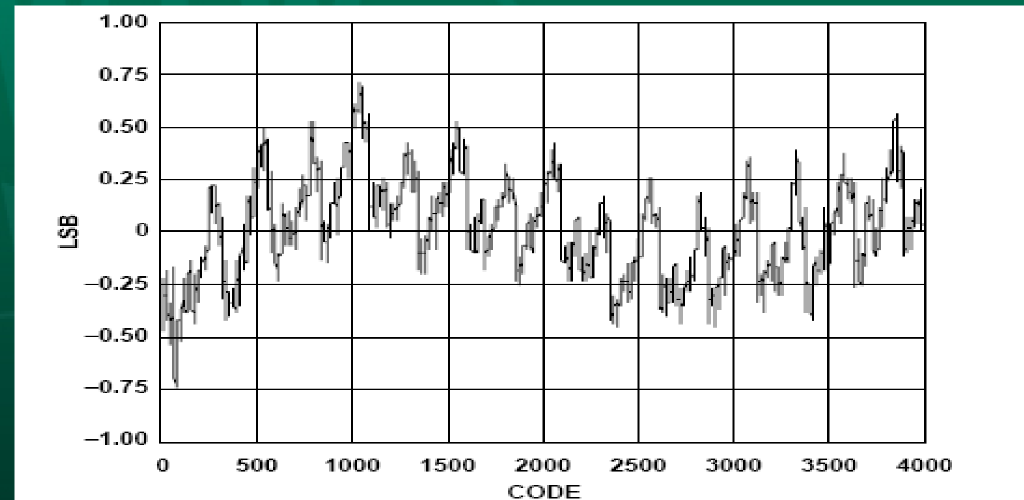
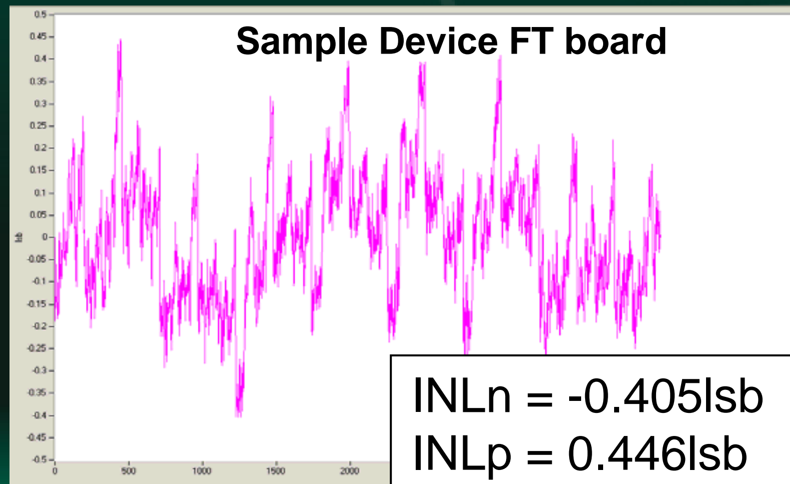
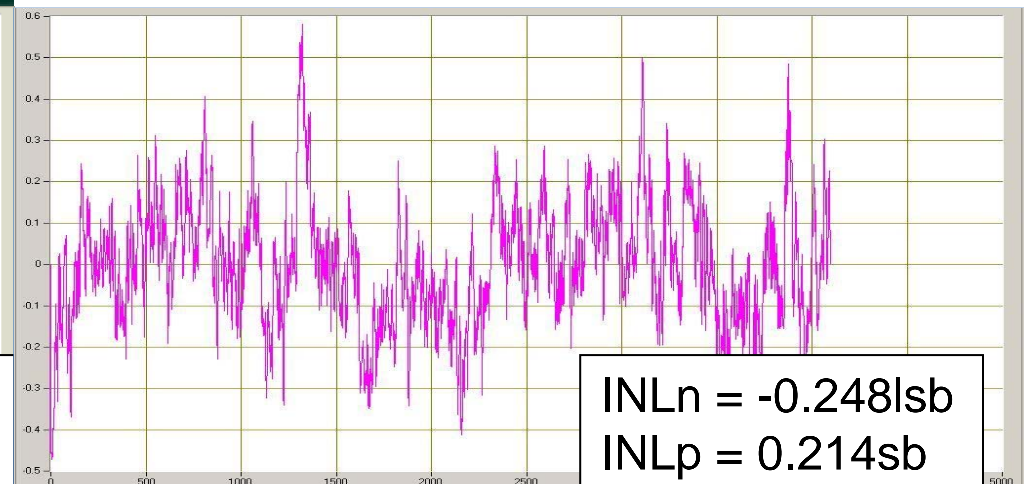
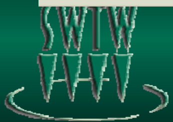


Figure 39. Typical INL Plot (AIN = 10.3 MHz @ −0.5 dBFS, 170 MSPS, LVDS)







ViProbe® ADC Testing in Probe to Data Sheet Specifications.

- **DNL Results.**
- **Final test program limit:**
  - DNLn: -0.850lsb to 0.0lsb
  - DNLp: 0.0lsb to 0.850lsb

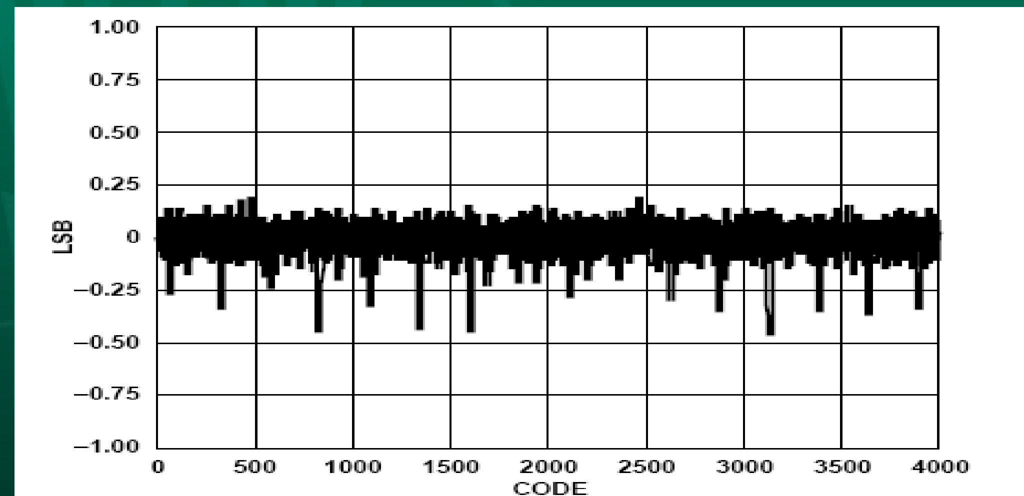
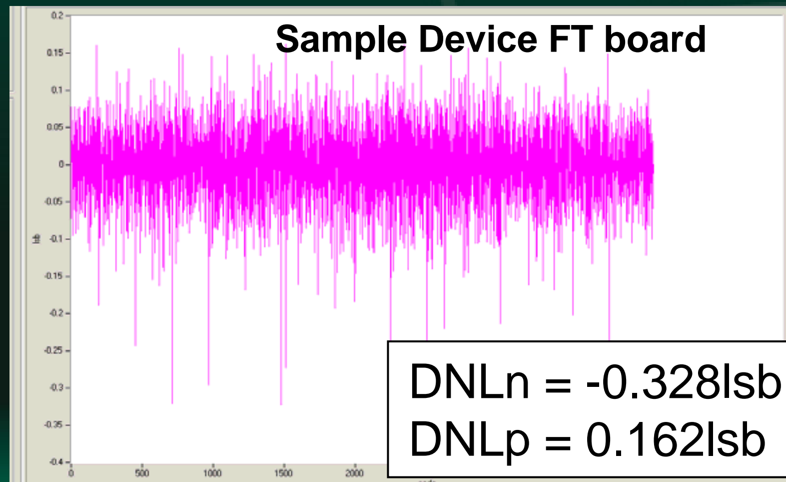
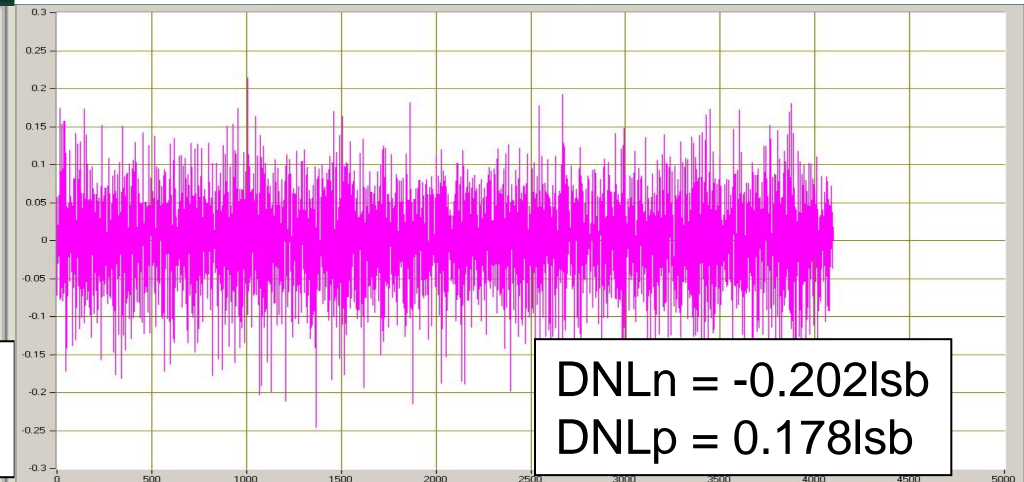
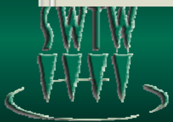


Figure 40. Typical DNL Plot (A_{IN} = 10.3 MHz @ −0.5 dBFS)







ViProbe® ADC Testing in Probe to Data Sheet Specifications.

- **SNR / SINAD Results.**
- **Final test limit (Fin = 10.3 MHz):**
  - SNR: 62.9dB
  - SINAD: 62.9dB
  - H2: -75dB
  - H3: -75dB

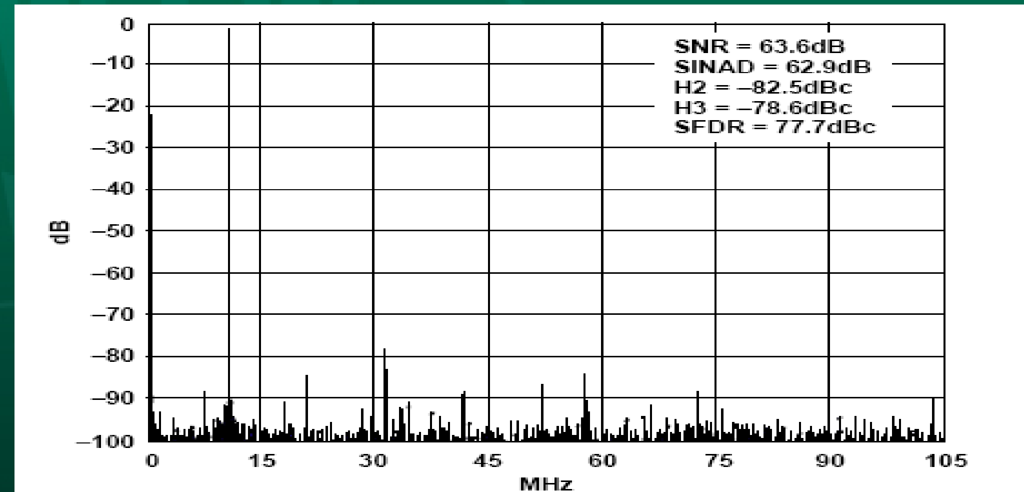
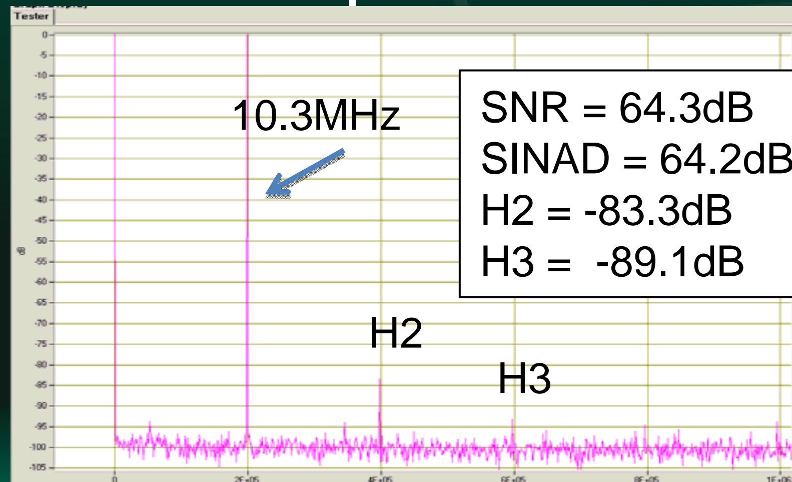
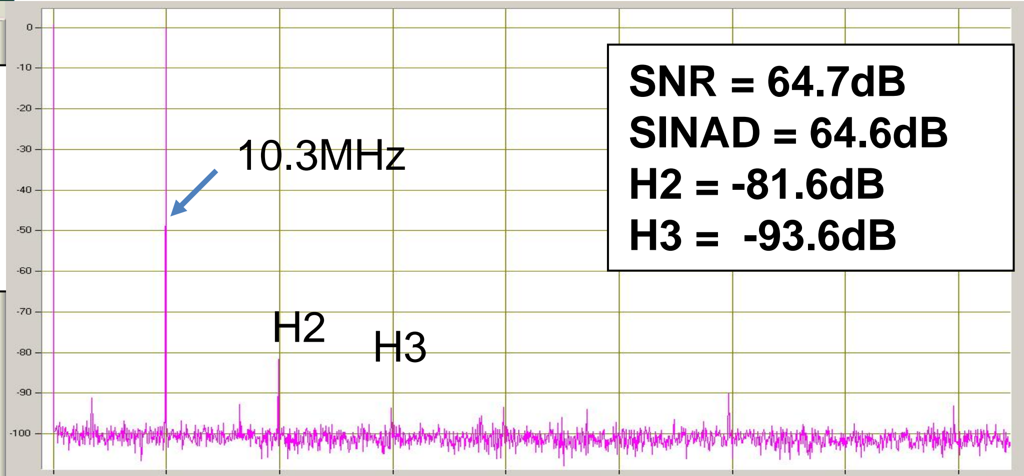
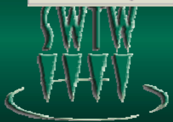


Figure 16. FFT: f_S = 210 MSPS, A_{IN} = 10.3 MHZ @ –0.5 dBFS, LVDS Mode

Sample Device FT board







ViProbe® ADC Testing in Probe to Data Sheet Specifications.

- **SNR / SINAD Results.**
- **Final test limit (Fin = 70 MHz):**
  - SNR: 62.9dB
  - SINAD: 62.9dB
  - H2: -75dB
  - H3: -75dB

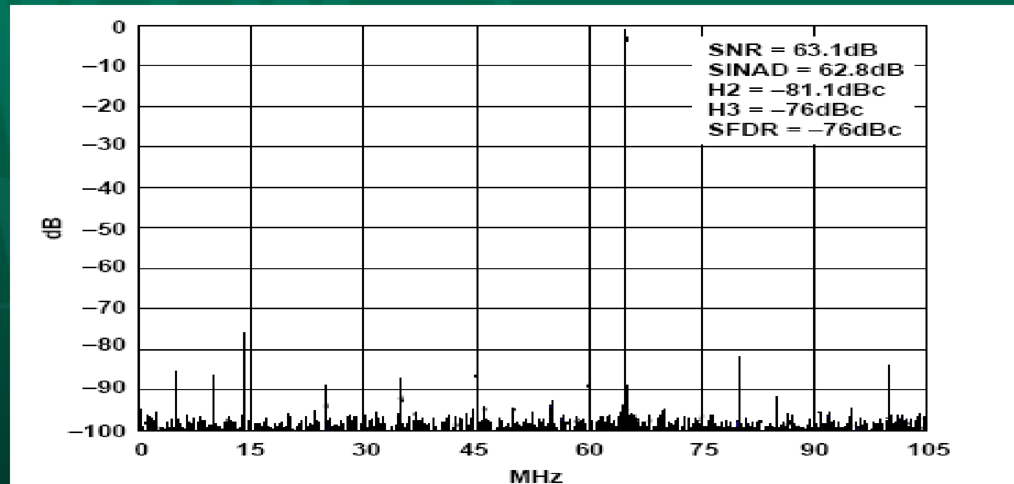
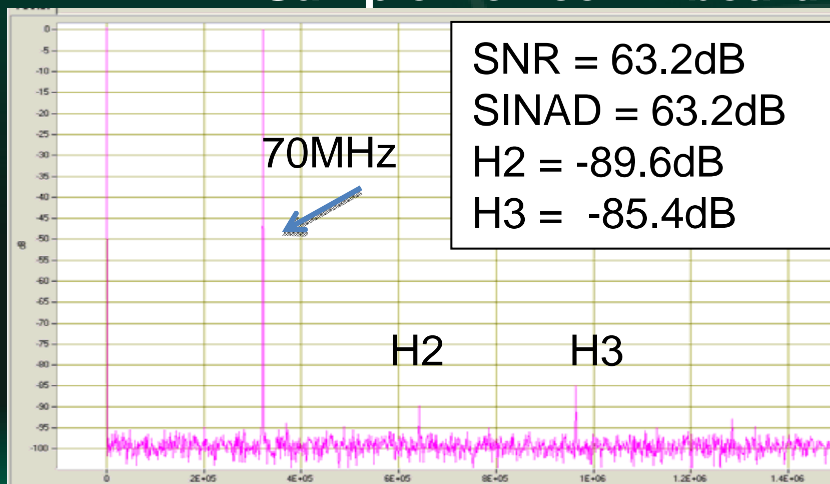
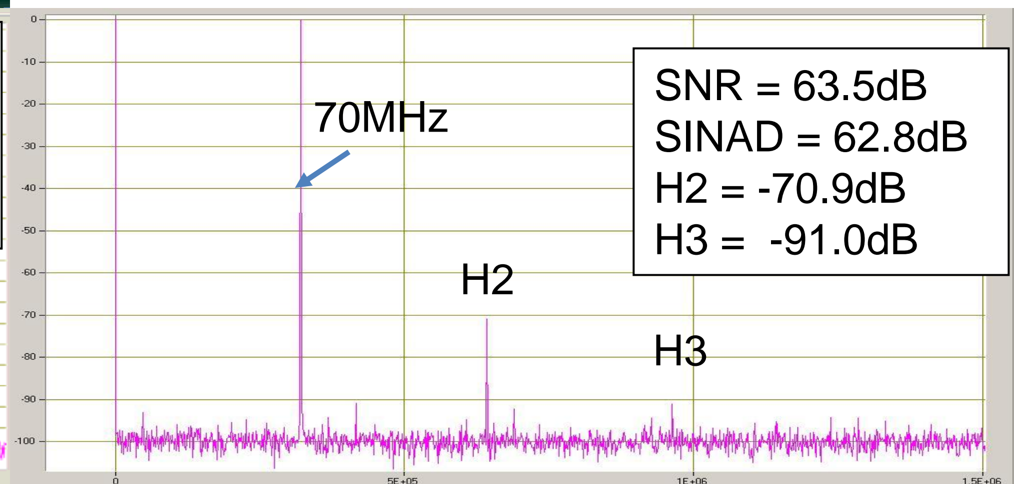


Figure 17. FFT: f_s = 210 MSPS, A_{IN} = 65 MHz @ −0.5 dBFS, CMOS Mode

Sample Device FT board





Conclusions.

- **ViProbe® used successfully to Sort multiple Pad Compositions Al, Au, and Cu.**
- **Presented Post ViProbe® data for Al, Au, and Cu.**
  - Meets required minimum pad deformation,
  - Meets stringent automotive quality requirements.
  - Technology suitable for Au flash OPM applications.
  - Stable CRES (Online Clean needed for Cu).
- **W41 ViProbe® enables >200'C Sort.**
- **KGD High Speed Converter testing (at Sort) is possible using ViProbe® Direct Attach.**

Future Work.

- **Work with ITS and Feinmetall to find optimum online clean recipe (Required for Cu Pad).**
- **Evaluate bandwidth capabilities of ViProbe® Direct Attach.**
- **Investigate high temperature >200'C and influence of prober limitations.**
- **Further Over Pad Metallization (OPM) evaluations Au flash < 1µM.**

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Thank You.

Questions?