EIGHTEENTH ANNUAL

BiTS™
Burn-in & Test Strategies Workshop

March 5 - 8, 2017

Hilton Phoenix / Mesa Hotel
Mesa, Arizona

Archive – Session 6

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Session 6

Jason Mroczkowski
Session Chair

BiTS Workshop 2017 Schedule

Frontier Day

Tuesday March 7 - 1:30 pm

Making Contact

"High Current Final Test Contactor Development"

Thiha Shwe, Hisashi Ata – Texas Instruments

Kenichi Sato – Yokowo

"Customers Are the New Team Member for Board to Board Connectors"

Derek Biggs – Plastronics

"WLCSP Contacting Technologies for 0.2 mm Pitch and Below"

Valts Treibergs - Xcerra Corporation

"Coming to terms with Burn-In sockets"

James Tong - Texas Instruments

WLCSP Contacting Technologies for 0.2 mm Pitch and Below

Valts Treibergs
Xcerra Corporation

BiTS Workshop
March 5 - 8, 2017

Agenda

- ATE Socket vs. Wafer Probe Head
- WLCSP at BiTS
- Spring Pins in WLCSP – BiTS History
- WLCSP Technologies
  - Barrel & Plunger Spring Probes
  - Open Coil Spring Probes
  - MEMS Coil Spring Probes
  - Cantilever Technology
  - New Concept – Monolithic MEMS Compliant Probe
- Space Transformers

ATE Contactor and Wafer Probe Head Quick Comparison

Test Socket/Contactor	Wafer Probe
•High compliance •High power •Tri-temp testing •0.3mm pitch and above •Reliable in very dirty environments - handlers	•Planar wafer – minimal compliance •Controlled scrub •Very fine pitch – spread out signals with space transformers or by design

Wafer Level Chip Scale Packaging (WLCSP)

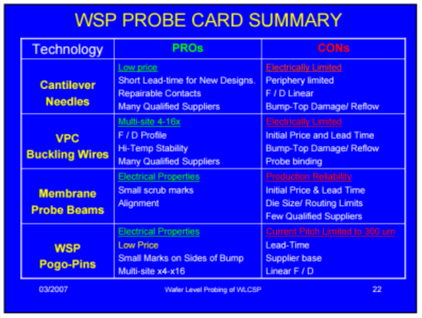
- More compliance needed vs. wafer probe because of redistribution layer and larger bumps/flatness tolerances
- Electrical performance requirements of ATE sockets
- Space transformers generally required except for low I/O devices

Socket and Wafer Probe – Merging Technologies

A New Probe Card Approach for Wafer Level Chip Scale Package Testing

2007 Burn-in and Test Socket Workshop
March 11 - 14, 2007

Norman J. Armendariz, PhD



WSP PROBE CARD SUMMARY

Technology	PROs	CONs
Cantilever Needles	Low price Short Lead-time for New Designs. Repairable Contacts Many Qualified Suppliers	Electrically Limited Periphery limited F / D Linear Bump-Top Damage/ Reflow
VPC Buckling Wires	Multi-site 4-16x F / D Profile Hi-Temp Stability Many Qualified Suppliers	Electrically Limited Initial Price and Lead Time Bump-Top Damage/ Reflow Probe binding
Membrane Probe Beams	Electrical Properties Small scrub marks Alignment	Production Reliability Initial Price & Lead Time Die Size/ Routing Limits Few Qualified Suppliers
WSP Pogo-Pins	Electrical Properties Low Price Small Marks on Sides of Bump Multi-site x4-x16	Current Pitch Limited to 300 um Lead-Time Supplier base Linear F / D

03/2007 Wafer Level Probing of WLCSP 22

Test Socket/Contactor

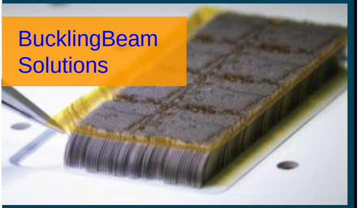
- Spring probes
- BeCu cantilevers
- Elastomers / rigid elements
- PCB preload

Wafer Probe

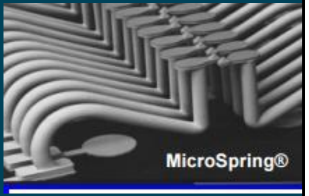
- Cantilever needles
- Buckling contacts
- MEMS compliant structures
- Membrane

WLCSP

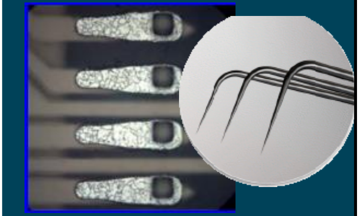
- Mainly spring probes
- Wafer probe technologies often first tried because of familiarity



BucklingBeam Solutions



FormFactor Inc



WLCSP Contacting Technologies for 0.2 mm Pitch and Below

WLCSP Basics – Well Covered at BiTS

- Probe components
- Space transformer concerns
- Technology of fine pitch probing

Advances in WSP- Wafer Socket Pogo-Pin Probing

Norman Armendariz
James Tong

2010 BiTS Workshop
March 7 - 10, 2010

Electroformed Barrels for Fine Pitch Test Probes

Larre Nelson
John Winter
Rika Denshi America

2011 BiTS Workshop
March 6 - 9, 2011

Wall Thickness

Thin walls with concentric ID and OD. (OD: 0.3 mm)

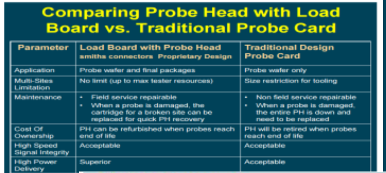
Gold plating on the ID. (Au: 1.5 µm, Ni: 13.5 µm)

3/2011 Electroformed Barrels for Fine Pitch Test Probes 14

Space Transformer PCB For Testing 200 µm WLCSP

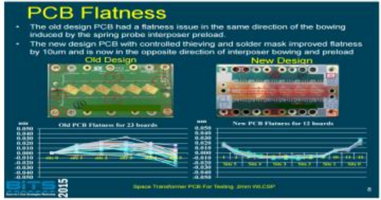
Khaled Elmadbouly
Smiths Connectors

2015 BiTS Workshop
March 15 - 18, 2015



Comparing Probe Head with Load Board vs. Traditional Probe Card

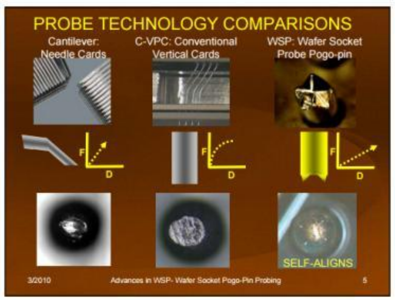
Parameter	Load Board with Probe Head smiths connectors Proprietary Design	Traditional Design Probe Card
Application	Probe wafer and final packages	Probe wafer only
Multi-Sites Limitation	No limit (up to max tester resources)	Size restriction for tooling
Maintenance	• Field service repairable • When a probe is damaged, the cartridge for a broken site can be replaced for quick PH recovery	• Non field service repairable • When a probe is damaged, the entire PH is down and need to be replaced
Cost Of Ownership	PH can be refurbished when probes reach end of life	PH will be retired when probes reach end of life
High Speed Signal Integrity	Acceptable	Acceptable
High Power Delivery	Superior	Acceptable



PCB Flatness

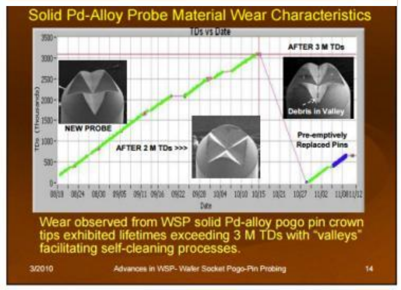
- The old design PCB had a flatness issue in the same direction of the bowing induced by the spring probe interposer preload.
- The new design PCB with controlled thieving and solder mask improved flatness by 10um and is now in the opposite direction of interposer bowing and preload

Space Transformer PCB For Testing .2mm WLCSP



PROBE TECHNOLOGY COMPARISONS

3/2010 Advances in WSP- Wafer Socket Pogo-Pin Probing 5



Solid Pd-Alloy Probe Material Wear Characteristics

Wear observed from WSP solid Pd-alloy pogo pin crown tips exhibited lifetimes exceeding 3 M TDs with "valleys" facilitating self-cleaning processes.

3/2010 Advances in WSP- Wafer Socket Pogo-Pin Probing 14

Spring Probes in WLCSP

- Spring probe have proven performance in WLCSP real-world applications


BiTS 2015 LEENO

Kelvin Contact Solution for WLCSP

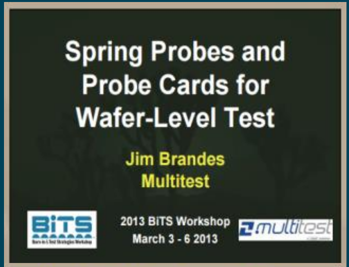
Jay Kim, Daniel Shin
LEENO Industrial Inc.

Test Set Up #1: (Ball Contact)

- Mount General Kelvin and Improved Kelvin Probes into respective sockets
- Contact both probes onto balls
- Measure distance and capture images of ball marks

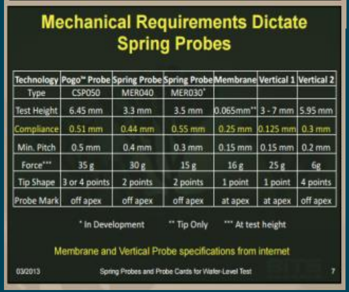
Test Results:

- Probe marks
- Mark distance


Spring Probes and Probe Cards for Wafer-Level Test

Jim Brandes
Multitest

2013 BiTS Workshop
March 3 - 6 2013


Mechanical Requirements Dictate Spring Probes

Technology	Pogo™ Probe	Spring Probe	Spring Probe	Membrane	Vertical 1	Vertical 2
Type	CSP050	MER040	MER030*			
Test Height	6.45 mm	3.3 mm	3.5 mm	0.065mm**	3 - 7 mm	5.95 mm
Compliance	0.51 mm	0.44 mm	0.55 mm	0.25 mm	0.125 mm	0.3 mm
Min. Pitch	0.5 mm	0.4 mm	0.3 mm	0.15 mm	0.15 mm	0.2 mm
Force***	35 g	30 g	15 g	16 g	25 g	6g
Tip Shape	3 or 4 points	2 points	2 points	1 point	1 point	4 points
Probe Mark	off apex	off apex	off apex	at apex	at apex	off apex

* In Development ** Tip Only *** At test height

Membrane and Vertical Probe specifications from internet

03/2013 Spring Probes and Probe Cards for Wafer-Level Test 7


A Comparison of Probe Solutions for an RF WLCSP Product

James Migliaccio
RF Micro Devices

2013 BiTS Workshop
March 3 - 6, 2013


Witness Marks on Solder Balls


Spring Pin Pros/Cons

Pros:
- Pins will bottom out in the housing
- Each pin can move independently – overhang allowed
- Higher contact pressure possible
- Spring pins have greater usable contact range

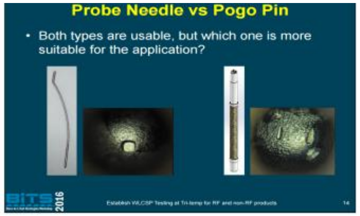
Cons:
- Prober alignment for different spring tip geometry can be a challenge
- Cleaning regiment not as clear
- Will need more downtime for rework
- Not a clear cut cost advantage

03/2013 A Comparison of Probe Solutions for an RF WLCSP Product 20


Establish WLCSP Testing at Tri-temp for RF and non-RF products

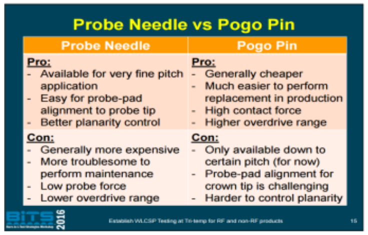
Tan Jin Sheng
Intel Technology Asia Pte Ltd
Edwin Valderama
Intel Value Engineering/Technology

2016 BiTS Workshop
March 6 - 9, 2016


Probe Needle vs Pogo Pin

- Both types are usable, but which one is more suitable for the application?

Establish WLCSP Testing at Tri-temp for RF and non-RF products 14


Probe Needle vs Pogo Pin

Probe Needle	Pogo Pin
Pro: - Available for very fine pitch application - Easy for probe-pad alignment to probe tip - Better planarity control	**Pro:** - Generally cheaper - Much easier to perform replacement in production - High contact force - Higher overdrive range
Con: - Generally more expensive - More troublesome to perform maintenance - Low probe force - Lower overdrive range	**Con:** - Only available down to certain pitch (for now) - Probe-pad alignment for crown tip is challenging - Harder to control planarity

Establish WLCSP Testing at Tri-temp for RF and non-RF products 15

Spring Probe Technology vs. Planarity

- Package test requires spring probe preload
- Preload causes socket bowing – tip planarity across grid
- Analysis must be done to optimize

PCB Pad Wear Analysis at 0.4mm Pitch

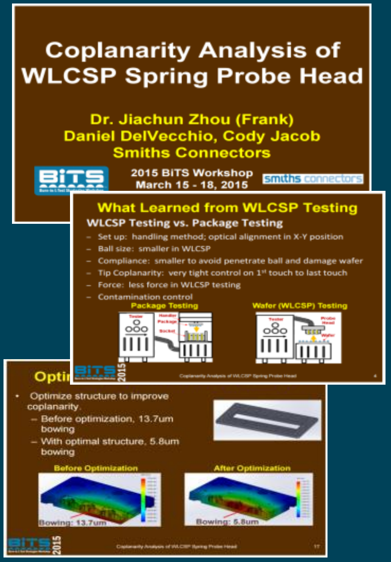
- the story continues...

Valts Treibergs & Chris Cuda
Multitest

2011 BiTS Workshop
March 6- 9, 2011

Probe Tip Marks – 7.5µm Ni, 0.5µm Au

03/2011 PCB Pad Wear Analysis at 0.4mm Pitch 10



Coplanarity Analysis of WLCSP Spring Probe Head

Dr. Jiachun Zhou (Frank)
Daniel DelVecchio, Cody Jacob
Smiths Connectors

2015 BiTS Workshop
March 15 - 18, 2015

What Learned from WLCSP Testing

WLCSP Testing vs. Package Testing

- Set up: handling method; optical alignment in X-Y position
- Ball size: smaller in WLCSP
- Compliance: smaller to avoid penetrate ball and damage wafer
- Tip Coplanarity: very tight control on 1st touch to last touch
- Force: less force in WLCSP testing
- Contamination control

Coplanarity Analysis of WLCSP Spring Probe Head 4

Opti

- Optimize structure to improve coplanarity.
  - Before optimization, 13.7um bowing
  - With optimal structure, 5.8um bowing

Coplanarity Analysis of WLCSP Spring Probe Head 17

Pushing the Envelope in DFM (Design for Manufacturing) for 0.2mm Pitch WLCSP Socket

Paul Gunn, Muhammad Syafiq, Takuto Yoshida
Test Tooling Solutions Group

2015 BiTS Workshop
March 15 - 18, 2015

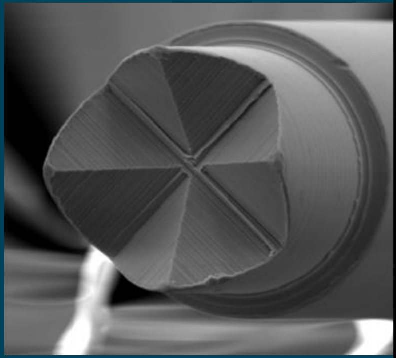
Improved Socket 2 Simulation

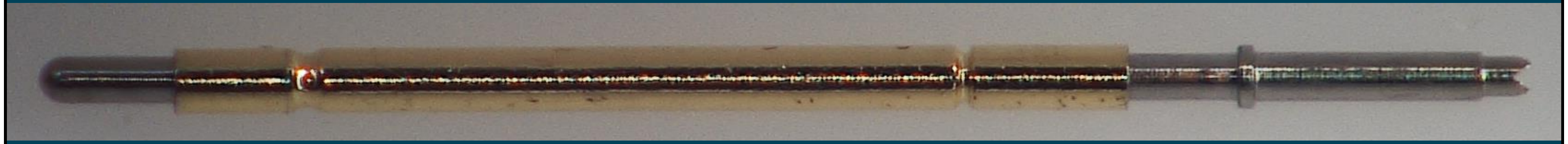
- Max. 0.116mm coplanarity from improved simulation
- Max. 0.125mm coplanarity from measurement

Pushing the Envelope in DFM (Design for Manufacturing) for 0.2mm Pitch WLCSP Socket 11

WLCSP – Barrel/Plunger Spring Probes

- The most commonly available probe technologies available from a variety of suppliers
- 3 or 4 piece design
- Barrel can be machined, drawn or e-formed
- Plungers plated or monolithic alloy



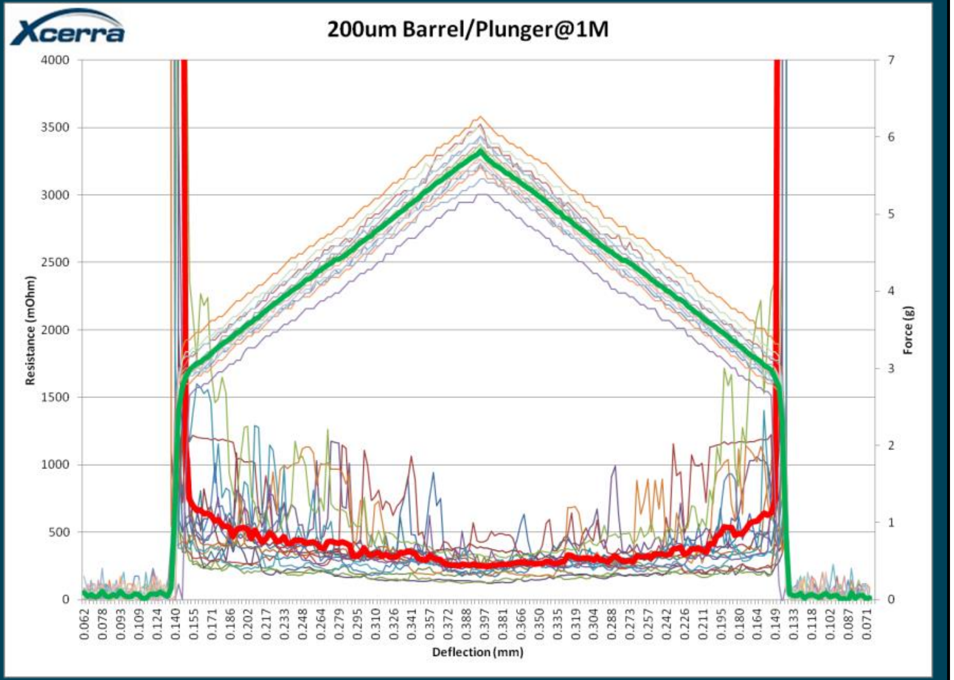


WLCSP – Barrel/Plunger Spring Probes

- Since springs are contained within the barrel inner diameter (ID), their diameter is very small and must be very long
- Little to no controlled plunger/barrel biasing possible

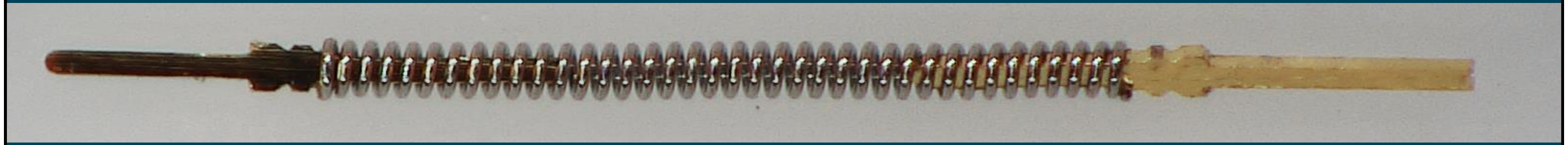
Example Barrel/Plunger Spring Probe

- 5.7 g average force to 1M cycles
- $R_{contact} < 500\ m\Omega$
- 1.3 A Current Carrying Capacity (International SEMATECH Manufacturing Initiative)
- RF: >40 GHz @ -1dB



WLCSP – Open Coil Spring Probes

- Available from several suppliers
- 2 or 3 piece design – spring could act as PCB side contact
- Coil spring acts as probe barrel
- Plungers plated or utilize monolithic alloy

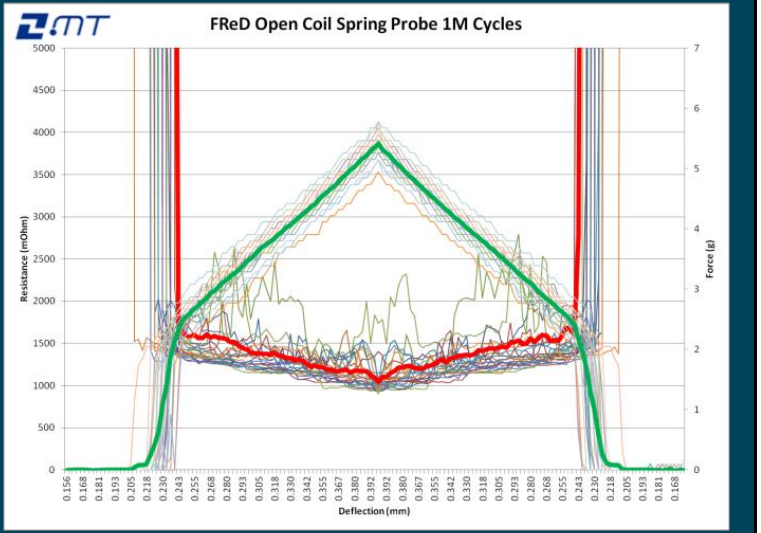


WLCSP – Open Coil Spring Probes

- Springs are maximum diameter within the housing hole – best force and deflection possible
- Plungers permanently attached to springs – may have protrusions into spring
- Springs often incorporate ‘dead’ coils
- Plunger rotation from spring compression – drilling effect

Example – Open Coil Spring Probe

- Force 5 g through millions of touchdowns
- $R_{contact}$ >1 Ω
- RF poor <1 GHz -1 dB (open coil design)
- RF good (closed and shorted coils – design optimized)

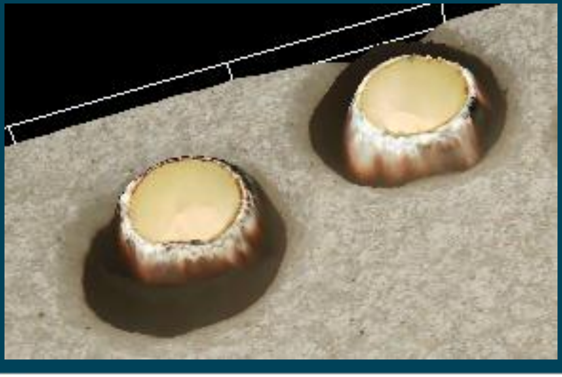


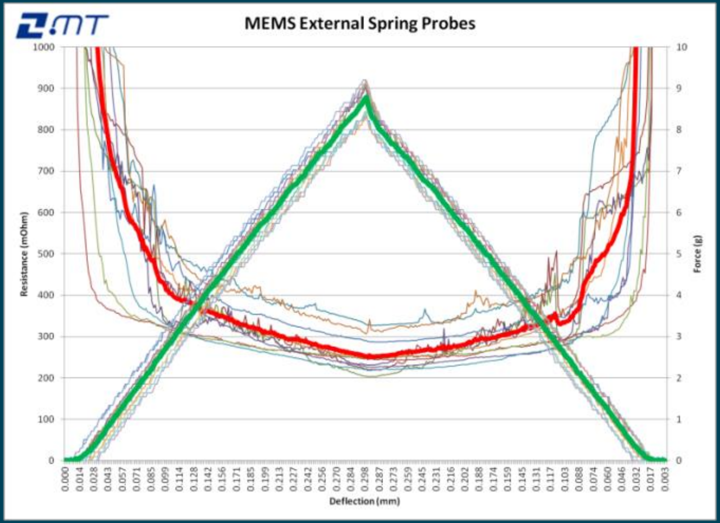
WLCSP – MEMS Spring Probes

- Spring is manufactured from e-formed tubes and precision cut with controlled spiral structure
- Homogeneous alloy plunger
- Rotation or designed no-rotation possible
- Plunger permanently attached to spring

WLCSP – MEMS Spring Probes

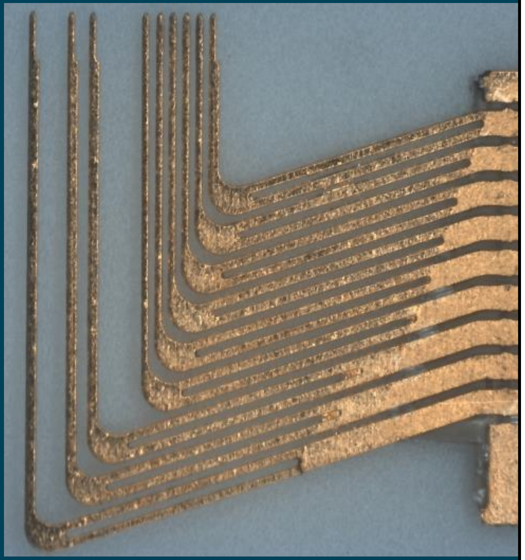
- Good probe normal force for probe size
- PCB interconnect side is metal tube – not ideal contact – very fragile
- $R_{contact}$ <400 mΩ
- RF: >30 GHz @ -1dB





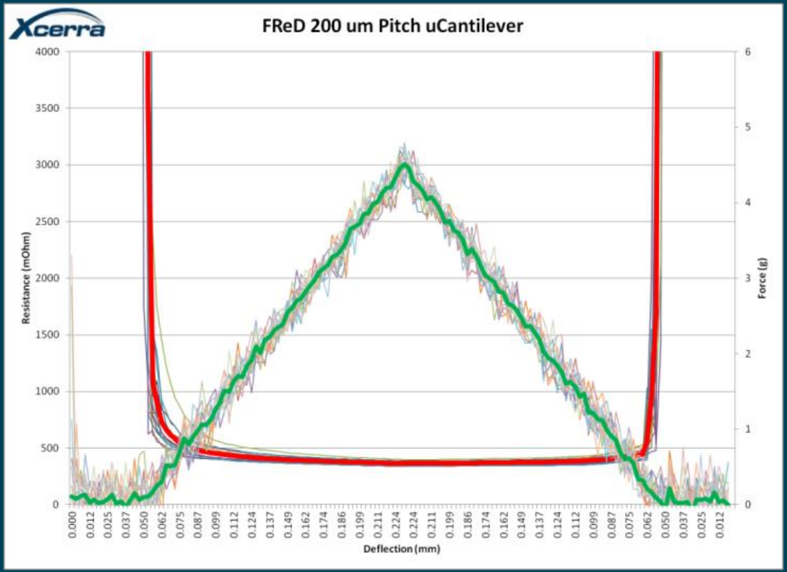
WLCSP – Cantilever Technology

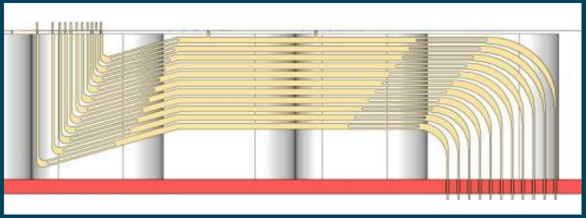
- Proven technology in wafer probe – redesigned to offer high compliance
- Single metal component PCB to DUT – no moving parts – 2 point contact
- PCB side compliance independent of DUT compliance
- Benefit of embedded space transformer/fan-out

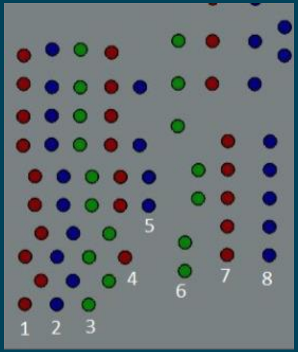


WLCSP – Cantilever Technology

- Applicable to a limited number of applications – challenging on non-regular grids
- $R_{contact}$ <400 mΩ - little variance
- RF: not measured – assumed poor unless impedance controlled







Comparison of WLCSP Test Attributes

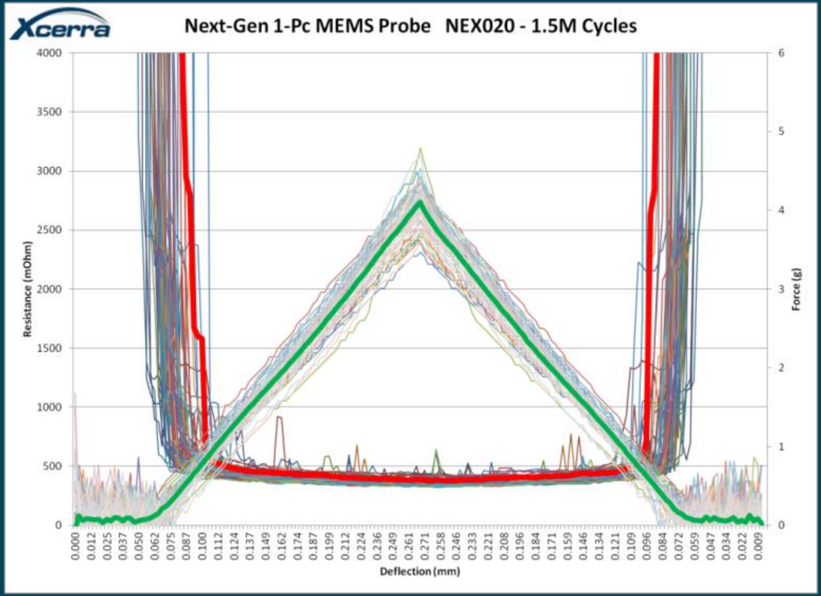
Contacting Technology	**Ease of Application**	**DC Electrical**	**RF Electrical**	**COST**
Barrel/Plunger Spring Probe	**Easy**	**Good**	**Good**	**$$**
Open Coil Spring Probe	**Easy**	**OK**	**Poor/Good**	**$$**
MEMS Spring Probe	**Challenging**	**Good**	**Good**	**$$$**
Cantilever	**Challenging**	**Good**	**Poor**	**$$$**
⬇	⬇	⬇	⬇	⬇
Sweet Spot	**Easy**	**Good**	**Good**	**$**

New Monolithic Vertical MEMS Probe

- Design high-compliance/low stress volumetric spring
- Built with MEMS manufacturing technology
- One metal component – 2 point contact
- No elastomers or springs
- Optional gold plating – all surfaces are external

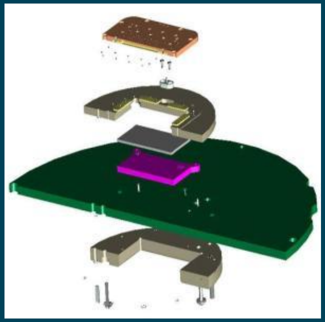
Monolithic Vertical MEMS Probe - Nexus

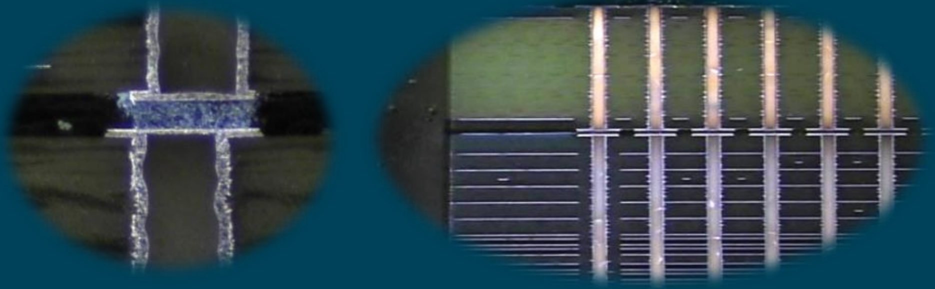
- Lab test results through 1.5M touchdowns
  - Force: 4.5 g
  - $R_{contact}$ <400 mΩ
  - ISMI current 400 mA
  - RF: 24.9 GHz (-1 dB-GSG .2 mm pitch)



PCB-Like Space Transformers

- Fine-pitch fan-out PCBs spread signals to the ATE interface board
- Multilayer Organic (MLO) / Multilayer Ceramic (MLC) boards available – product using package substrate technology becoming available in lower volumes
- Extreme care must be taken in design for signal and power integrity – simulation and measurement essential
- Space transformers sit on intermediate board-board ‘tower’ or are direct bonded to ATE main board

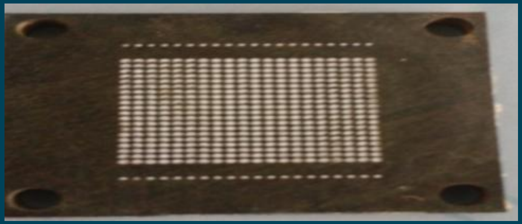




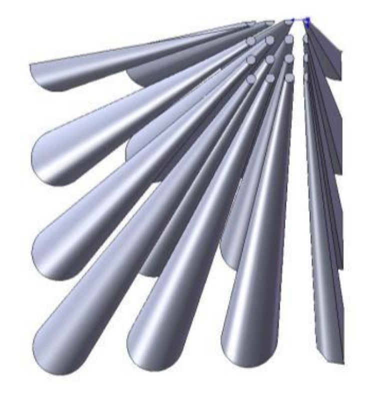
ViaBond process from Harbor Electronics

Non-PCB Space Transformer Option

- Directly connecting input to output via copper wires without planar stacked PCB structures and vias
- Full grid array with capability of 45 um pitch DUT side
- Impedance control possible for critical nets
- Shortest possible path



Direct Space Transformation technology from ThinkMEMS



Summary

- A variety of WLCSP contacting technologies are available today
- Depending on application, some solutions will work better than others
- Next-generation solutions allow for scaling 0.2 mm and below and are becoming more and more cost-effective