



**SW Test Workshop**  
Semiconductor Wafer Test Workshop

# **Katana RFX: A New Technology for Testing High Speed RF Applications Within TI**



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# Overview

- **Introduction**
- **Objectives**
- **Procedures**
- **Results**
- **Summary**
- **Follow-On Work**

# Introduction

- **High Speed testing has been a specialized area that not every probe card supplier is able to play in. There is much to be studied and understood in both design of board and also repeatability of measurements due to sensitivity of application for high volume, large site count probing.**
- **Cascade Microtech's membrane-based Pyramid Probe card has long been one of the leading probe card technologies in the RF space. With the recent purchase of Cascade Microtech by FormFactor, there is now the opportunity to evaluate some of FormFactor's technologies for high speed.**

# Objectives

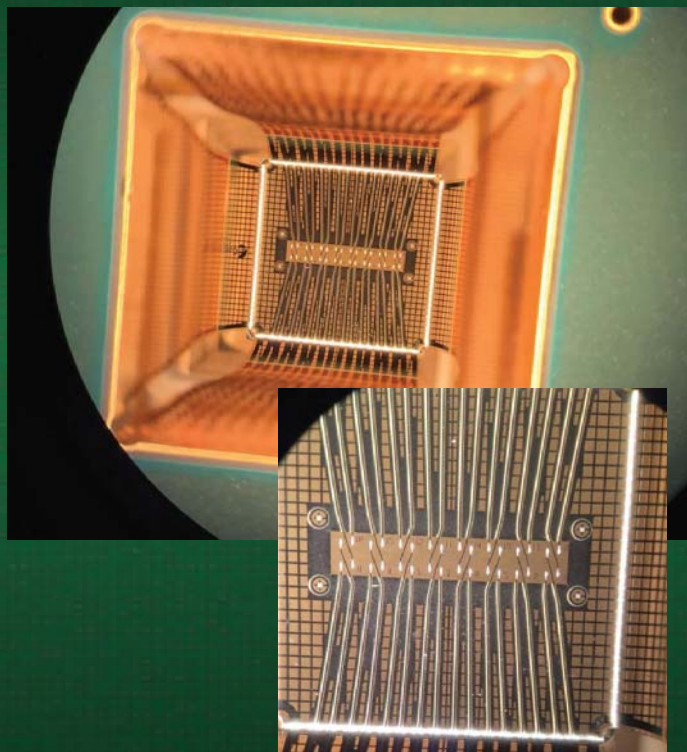
- **This paper will look to compare and contrast the performance of FFI's Katana RFX technology to the Pyramid Probe results. This paper will compare and contrast the two technologies on the same device and look to provide another option for RF testing using the Katana RFX pin.**
- **Key Parameters to look at:**
  - Electrical Performance
  - Mechanical Performance
    - Planarity
    - Probe Mark Damage
    - Needle Alignment
    - Reparability
    - Lifetime
    - Cleaning Settings

# Procedures

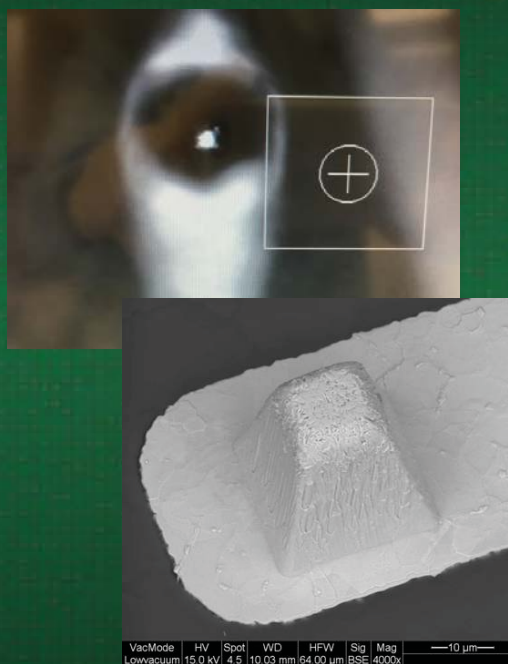
- **The evaluation started with an existing RF device that was utilizing the Pyramid Probe as a baseline for RF performance.**
- **Wafers were probed with the Pyramid Probe probe card and then compared with wafers probed with FFI Katana RFX probe card to compare results with the FFI Katana RFX**

# Probe Card Overview – Pyramid Probe

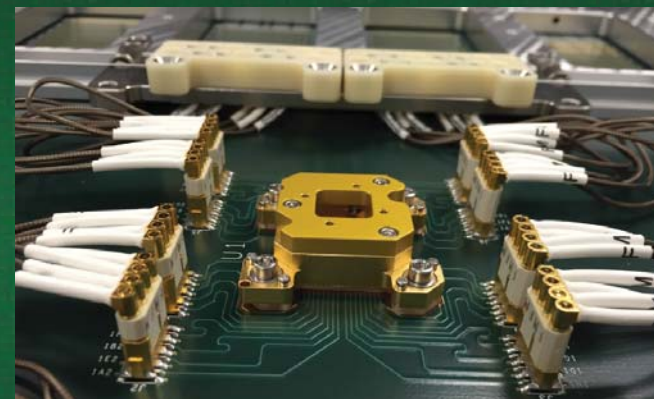
Wafer Side



Probes



Tester Side



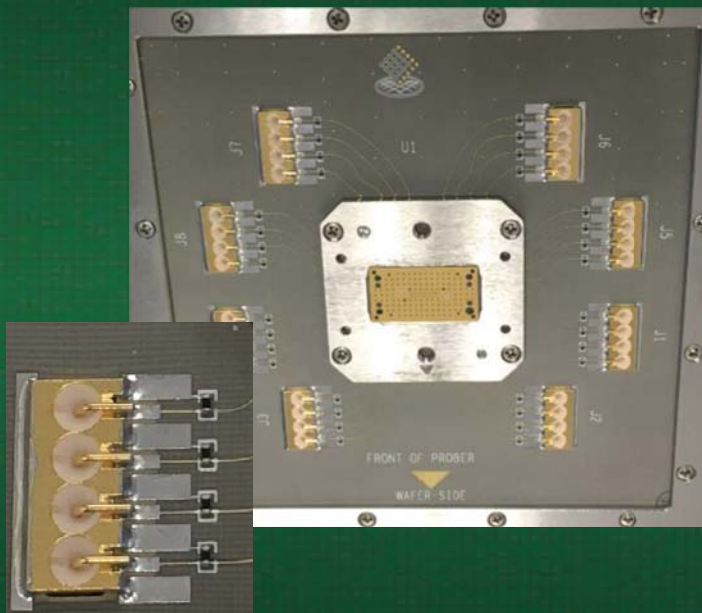
# Pyramid Probe Pin Specifications

Probe Options	Pads	Solder Balls
Probe Technology	Membrane	Membrane
Probe Tip Shape	Flat	Flat
Minimum Pitch [ $\mu\text{m}$ ]	50 Inline Single Row	57 Inline Single Row
	150 Square Grid	150 Square Grid
Flat Tip Size ( $\mu\text{m}$ )	12 x 12	18 x 18
Probe Force at OT	10 g @ 150 $\mu\text{m}$	10 g @ 150 $\mu\text{m}$
Max OT [ $\mu\text{m}$ ]	250	250
Tip CCC [A] *	0.2 – 1.0	0.2 – 1.0
Probe Length [mm] *	0.025 – 0.050	0.030 – 0.058
Operating Temperature	-50~125C	-50~125C
Ground Inductance	0.04 nH	0.04 nH
Reparability	Field replaceable probe head	Field replaceable probe head

\* Design dependent

# Probe Card Overview – Katana RFX

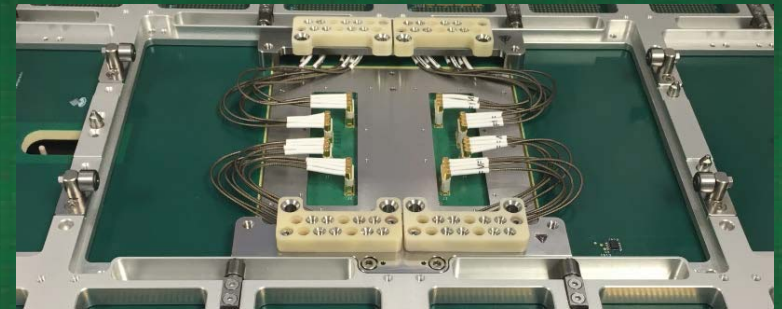
Wafer Side



Probes



Tester Side



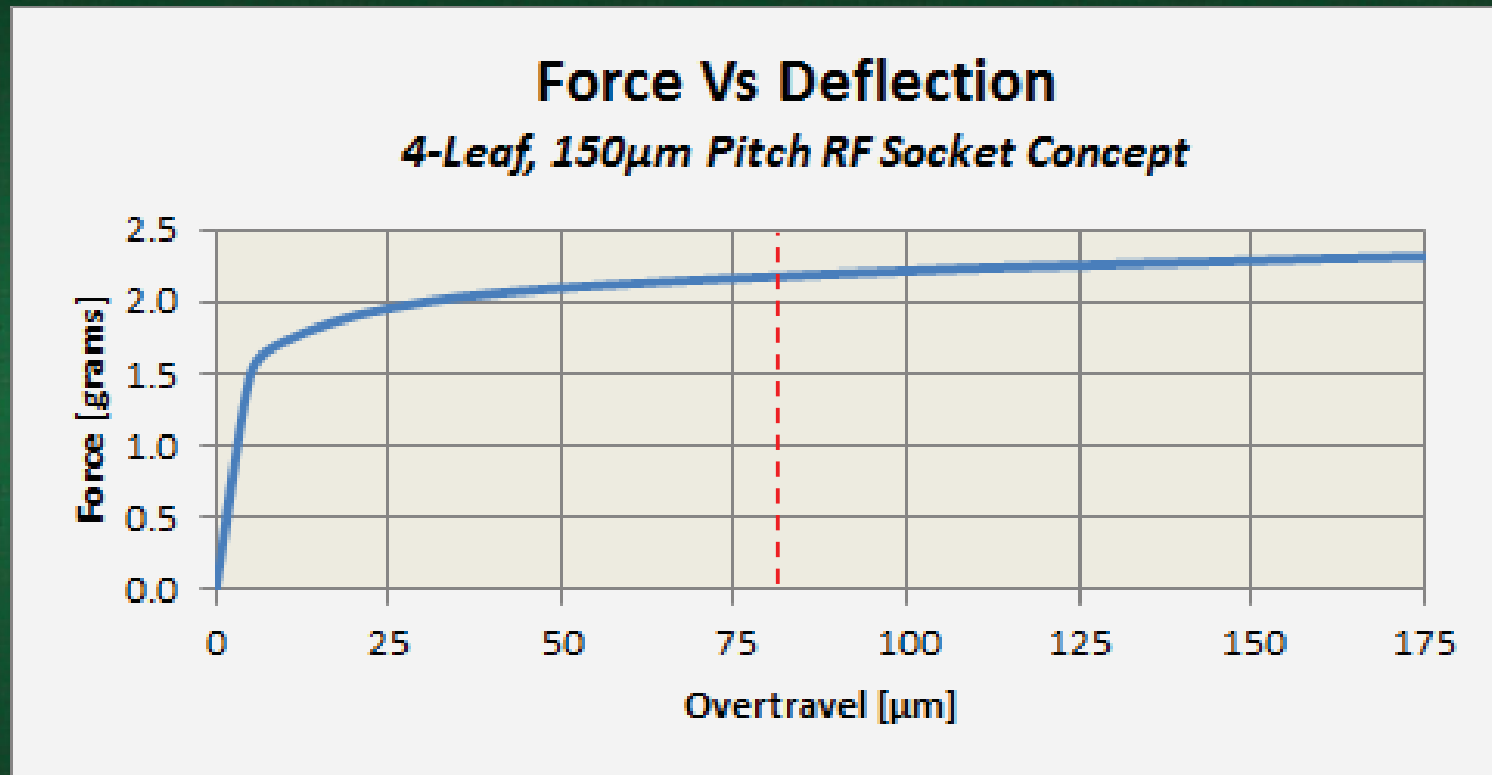
- RF connectors extend coax to the wafer side of the PCB



# Katana RFX Pin Specifications

Probe Options	K400	K150	K80
Probe Technology	Vertical MEMS	Vertical MEMS	Vertical MEMS
Available Probe Tip Shape	Flat	Flat, <b>Pointed</b>	Flat, Pointed
Minimum Pitch [ $\mu\text{m}$ ]	100 Inline Single Row	74 Inline Single Row	74 Inline Multi-Row
	200 Square Grid	106 Square Grid	80 Square Grid
	250 anywhere	150 anywhere	90 anywhere
Flat Tip Size ( $\mu\text{m}$ )	80 x 200	55 x 75, 12 x 12	50 x 60, 12 x 12
Probe Force at Production OT(g)	5~6	2.1~2.3	1.9~2.1
Max OT [ $\mu\text{m}$ ]	350	175	125
CCC [A]	1.5	1.1	0.8
Probe Length [mm]	2.9	2.7	2.7
Operating Temperature	-40~160C	-40~160C	-40~140C
Loop Inductance @ Assembly Minimum Pitch	0.6-1.2 nH GSG	0.4 nH GSG	0.4 nH GSG
	1.0-1.8 nH GS	0.75 nH GS	0.75 nH GS
Reparability	Probe Head and Single Probe Replaceable	Probe Head and Single Probe Replaceable	Probe Head and Single Probe Replaceable

# Katana RFX Pin Specifications



- **Large production overdrive window at desired probe force**

# Cleaning Recipes

	Pyramid Probe	FFI Katana RFX
Probing Overtravel (um)	FT+125	RT+80
Cleaning Overtravel (um)	FT+125	FT+80
Cleaning Interval (Td)	175	175
Cleaning TDs (Td)	16	25
Cleaning Media	Probe Lap (1um)	Probe Lap (1um)

- **Standard cleaning recipes for technologies above.**

- Cascade recommended cleaning settings

- Probing OT: FT + 125um
- Cleaning OT: FT + 35 to 75um

# Qual Plan

- Standard Qualification Plan developed for TI
- This qualification had to deviate slightly because of the RF measurements.
- We do not have the ability to make Cres measurement because no DC path on the test instruments.

Incoming Inspection of Probe Card On Analyzer <small>*(If not available, than must rely on Outgoing Vendor Data)</small>	Planarity Check	Planarity of +/- 15um range: 30um
	Alignment Check (x/y)	Alignment of: Vertical +/- 12.5um
Visual Inspection		Correct wiring/solder points/residues on probe card. Place photos in "Photos" tab.
Outgoing Analyzer Results from Vendor		Pass / Fail
Device Characterization	Prober Device File Setup	Needle Alignment Settings defined.
	Bin to Bin Correlation	98% bin to bin from baseline card to new probe technology or LBE/PDE acceptance.
	Cres Over Time	Limit of 3 Ohms Standard deviation on 100k TD and a minimum 100 wafers probed. Confirm cleaning optimized to keep Cres consistent.
	Life time study	100k TD and a minimum 100 wafers Probed in production or accelerated probing and cleaning wear study to show the TD vs. Tip length as it relates to probe card end of life. (life expected must be >500k)
	Thermal Agility	X, Y, Z correction across a wafer must be less the 30um min to max without dramatic swings not including stops to the prober with in a wafer once the card gets to temps
	Cleaning Optimization	Optimize on cleaning OD / Recipe. (Record recipe in Probe & Cleaning Recipe Tab)
Quality	MSDS Sheet	New materials require MSDS sheet. No polyethylene allowed, high temp transfer study is needed.
	AVI Fail Rate	Fail rate must be less the 0.25% across 20 EWR lots at all temperatures.
	Bump Damage (FC or WCSP)	Damage must meet all packaging requirements.
Dielectric Cracking Study (if needed)	Max TD Test	Dielectric cracking study Automotive requirement 9x TD in the same location and max production probing OT) –Note weakest dielectric stack up is C027 Pass TD in the same location 6x TD
	Punch Through	No under layer metal exposure on automotive products QSS states for AI technologies "shall not expose underlying passivation or underlying metal equal to or greater than 25% of the pad width adjacent to the edge of the pad or exceeds 1.0mil2 near the center of the bond pad.

# FFI Katana-RF Acceptance Criteria:

- **Electrical performance**
  - All parameters <5% error at 30°C
  - Frequency
    - Die 100x repeatability < 0.5ppm at 30°C.
    - Wafer 3x repeatability < 2.0ppm at 30°C.
- **Mechanical Performance**
  - Planarity
    - First to last touch < 40um (expect better than membrane).
  - Probe Mark Damage
  - Needle Alignment
    - Alignment Algorithm to account for offset needle tip of Katana
  - Reparability
  - Lifetime
    - Wear out test to ensure Katana can achieve expected lifetime (~1MTds?)
  - Min Pitch
  - Cleaning Settings
    - Optimize cleaning and probing settings for RF application.

# Results – Electrical Performance

- **All parameters <5% error at 30°C**

- Less than 3%
  - Output power delta to Pyramid Probe = 0.13dB

- **Frequency**

- Die 100x repeatability < 0.5ppm at 30°C.
  - $\sigma \pm 0.534\text{ppm}$
- Wafer 3x repeatability < 2.0ppm at 30°C.
  - $\sigma \pm 0.835\text{ppm}$  with new Auto-Z.
- Temperature delta to Pyramid Probe < 5.0ppm (-40°C to 125°C)

- **Inherent Parasitic Delta Between Technologies**

- Known delta between the Pyramid Probe and Katana RFX in parasitic parameters due to design / structure of the pins (probe tip capacitance and inductance)
- Even with this delta, data within each technology was repeatable w/ small std deviation

# Results – Mechanical Performance

- **Planarity**

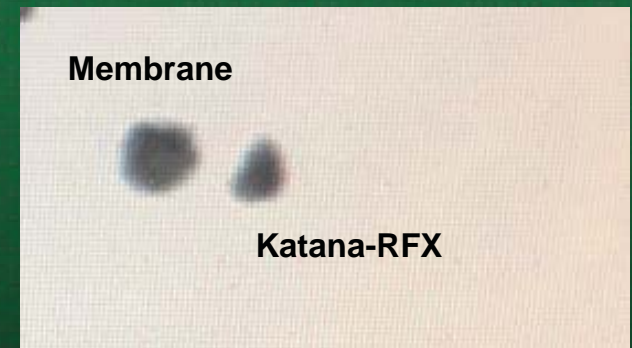
- Auto-Z Planarity

- Cascade Membrane: ~40um
- Katana RFX: ~10um

- **Probe Mark Damage**

- Pyramid Probe slightly bigger mark than Katana RFX
- Even after multiple insertions, both Pyramid Probe and Katana RFX show small total area of mark on pad
- Probe mark shift due to temperature smaller with Katana RFX than Pyramid Probe

	All Touch – Average (um)	All Touch – StDev (um)	All Touch – Max (um)
FFI Katana RFX	9.605	5.408	31
Pyramid Probe	40.907	12.902	75



# Results – Mechanical Performance

- **Needle Alignment**

- Prober must shift offset for camera to account for offset of tip
- There were some issues with needle alignment
- Sometimes the prober could not focus on correct part of tip for Katana
- Need to continue to work this to improve so that probes stay aligned to same position each insertion



- **Reparability**

- Any time a Pyramid Probe card hits end of life or is damaged, the entire Pyramid Probe core must be replaced onsite or sent back to factory to be lapped
- FFI Katana RFX has the ability to replace single pins on site.
  - This helps to keep card running
  - Also minimizes lead time for repair or rebuild as can just replace the pins instead of entire core
  - Could also provide cost savings as just replacing single pins versus an entire core



# Results – Mechanical Performance

## • Lifetime

– Goal to achieve at least 1MTds

### • Pyramid Probe

- Head 1: 563kTD (Card was crashed before EOL)
- Head 2: 2.23MTD (EOL)
- Head 3: 2.33MTD (EOL)
- Head 4: 1.80MTD (Running)

### • FFI Katana RFX (Lifetime Study ongoing)

- Head 1: 140kTD (Running)
- Head 2: 236kTD (Running)

## Cleaning Media Comparison – Wear Rates

Continuous TDs on cleaning media; no TD on AI wafer

Media	Useful Tip Length (um)	Wear (um)/1000 Cleaning TD	Cleaning TDs to EOL	OD (um)	Cleaning TDs/Cycle	Cleaning Interval	Projected TDs to EOL
PL-1AH (POR)	20	3.17	6,309	80	6	35	36,803
PL-0.5AH	20	0.4013	49,838	80	6	35	290,722
PL-1AG/50%	20	0.2859	69,955	80	6	35	408,068
Formula:	$\text{Tip Length} / \text{Wear Rate} \times 1000 / \text{Cleaning TDs per Cycle} \times \text{Cleaning Interval}$						

# Summary

	Pyramid Probe	FFI Katana RFX
Electrical Performance up to 3GHz	Comparable	Comparable
Needle Alignment	Aligns ok	Needs work
Upfront Cost	Comparable	Comparable
Rebuild cost	High	Low
Reparability	Rebuild only	Single pin reparable
Lifetime	>1.5Mil	Ongoing
Planarity	<50um	<20um
Array Pitch	>150um	>100um

- **Pyramid Probe has long been the leader in RF High Speed probing, but there have recently been some solutions offered that can provide some comparable performance.**
- **A Katana RFX head was built on an existing RF device to compare performance to the Pyramid Probe.**
- **The Katana RFX showed comparable electrical performance for up to 3GHz with the Pyramid Probe.**
- **There were some benefits also seen for the Katana RFX in terms of mechanical robustness and reparability.**
- **The initial results give us a path moving forward for RF Testing with Katana RFX, but some optimization is still necessary for Lifetime , Cleaning Recipe, and Pin Tip recognition.**

# Future Work

- **As mentioned in the summary, the Katana RFX looks promising but there still is some optimization we need to continue to work on.**
  - We need to evaluate the Katana RFX with different cleaning medias and recipes to try to help optimize the lifetime.
  - When moving to the RFX pin from Standard Katana there are some slight differences in how prober can see pin tip that need to be optimized for alignment
    - FFI working with TEL / Accretech on probe tip recognition
  - Evaluate Katana RFX testing above 3GHz and on bumped devices within TI

# Questions



# Thank You!

- **TI**
  - Trevor Tarsi
  - ATD
- **FFI / Cascade**
  - Ben Eldridge
  - Jeff Arasmith
  - Frank Meza
  - Doug Shuey
  - Cameron Harker