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

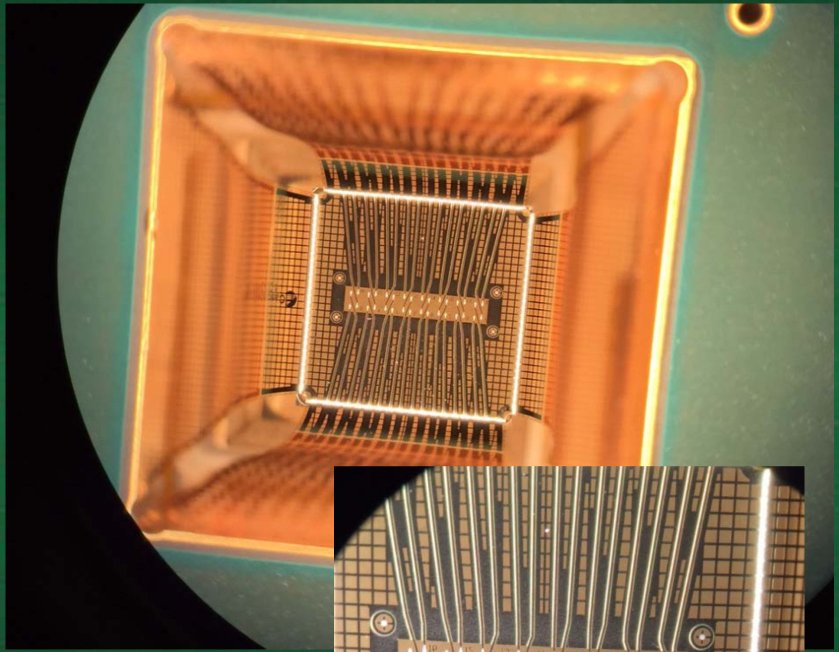
- **This paper will look to compare and contrast the performance of FFI's Katana RFX technology to the Pyramid Probe results. This paper will compare and contrast  the two technologies on the same device and look to provide another option for RF testing using the Katana RFX pin.**
- **Key Parameters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

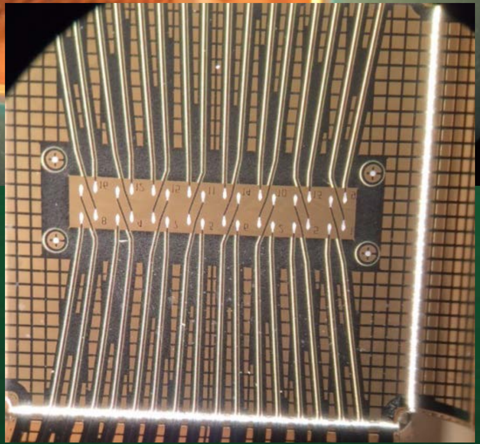
# Procedures

- 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

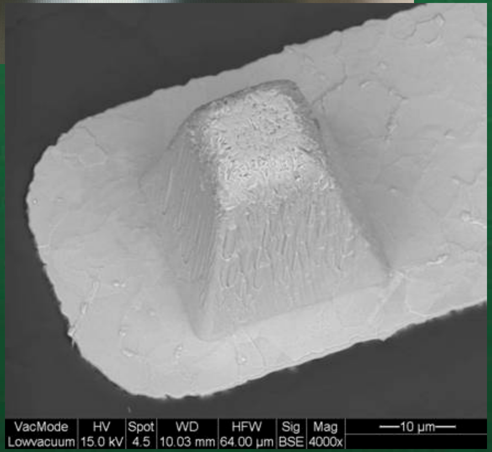
# Probe Card Overview – Pyramid Probe

### Wafer Side

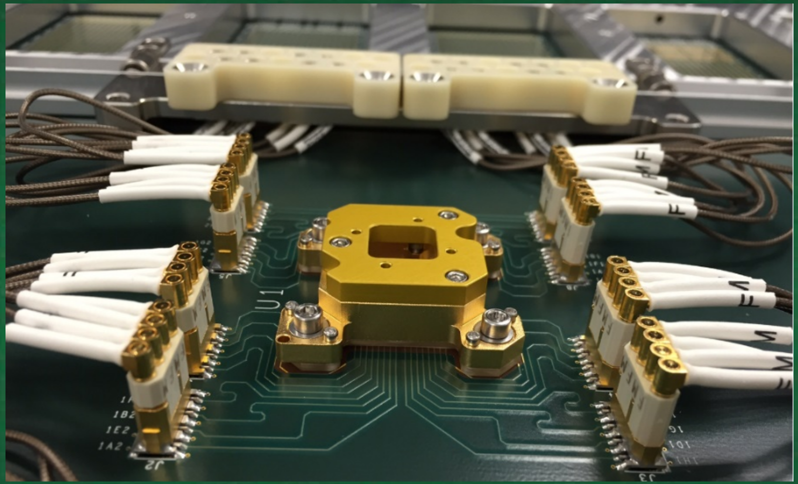




### Probes




### Tester Side



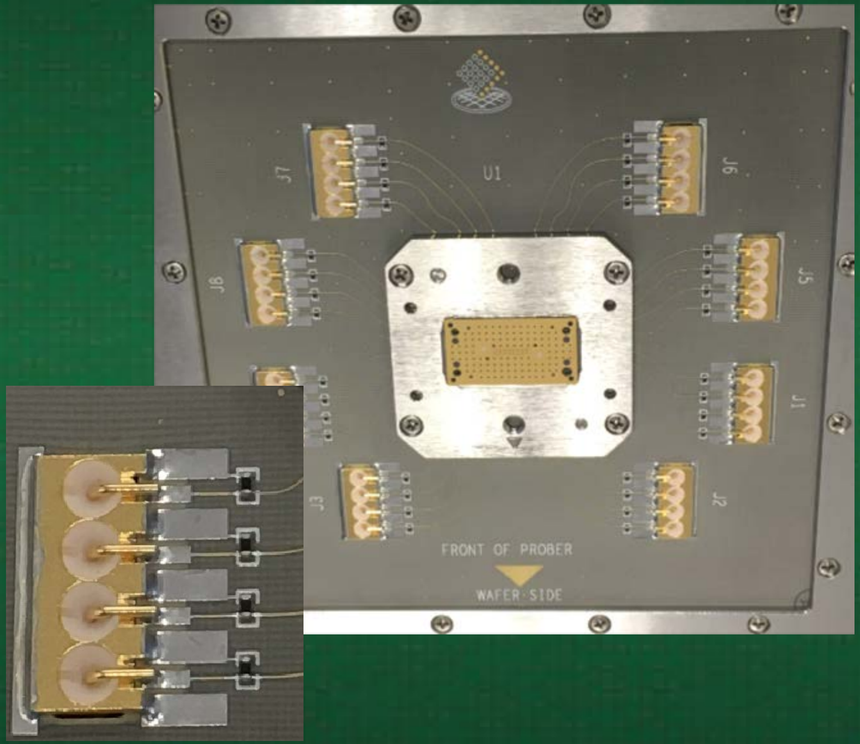
# Pyramid Probe Pin Specifications

| Probe Options | Pads | Solder Balls |
|---|---|---|
| Probe Technology | Membrane | Membrane |
| Probe Tip Shape | Flat | Flat |
| Minimum Pitch [µm] | 50 Inline Single Row | 57 Inline Single Row |
| | 150 Square Grid | 150 Square Grid |
| Flat Tip Size (um) | 12 x 12 | 18 x 18 |
| Probe Force at OT | 10 g @ 150 µm | 10 g @ 150 µm |
| Max OT [um] | 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 |

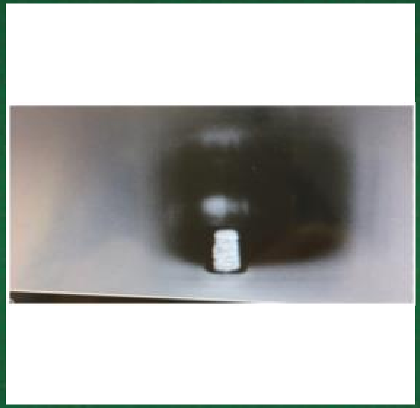
* Design dependent

# Probe Card Overview – Katana RFX

**Wafer Side**




**Probes**



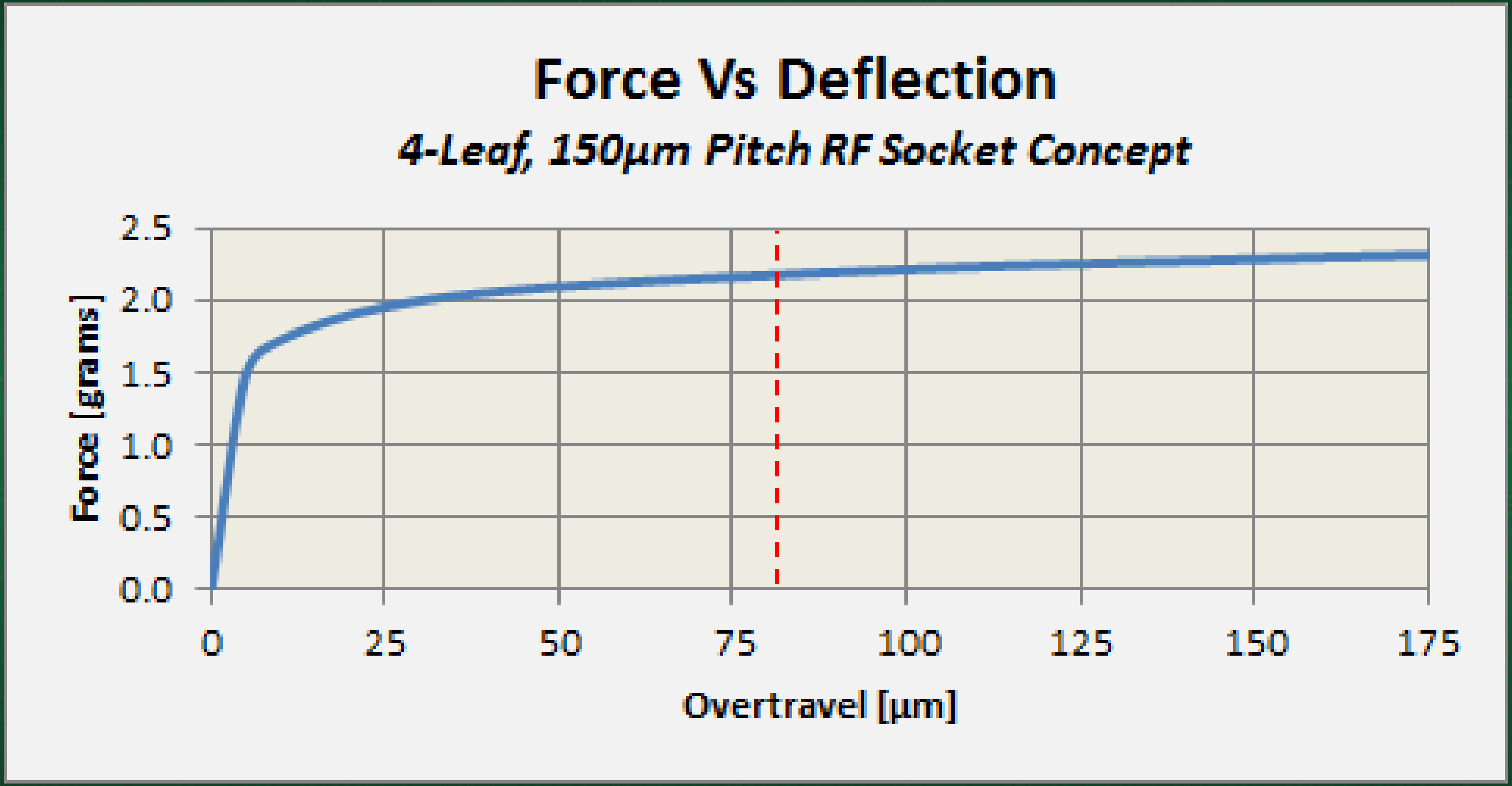
**Tester Side**

- 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, Pointed | Flat, Pointed |
| Minimum Pitch [µm] | 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 (um) | 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 [um] | 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 *(If not available, then must rely on Outgoing Vendor Data) | Planarity Check | Planarity of +/- 15um<br>range: 30um |
| | Alignment Check (x/y) | Alignment of:<br>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.<br>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 lest 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 Al 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

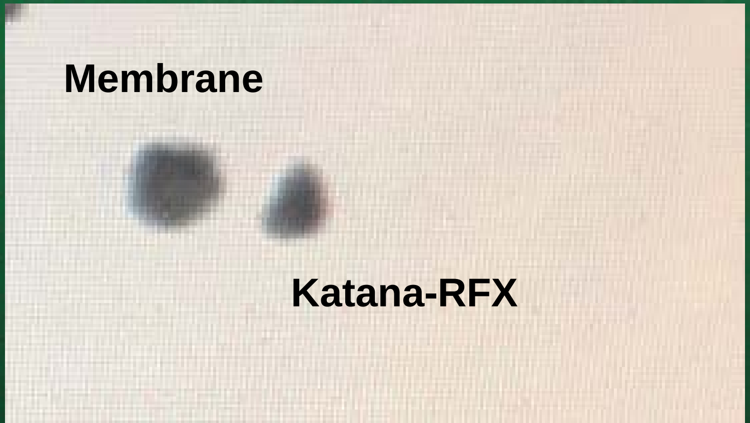
- **All parameters <5% error at 30˚C**
  - Less than 3%
    - Output power delta to Pyramid Probe = 0.13dB
- **Frequency**
  - Die 100x repeatability < 0.5ppm at 30˚C.
    - σ ± 0.534ppm
  - Wafer 3x repeatability < 2.0ppm at 30˚C.
    - σ ± 0.835ppm with new Auto-Z.
  - Temperature delta to Pyramid 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

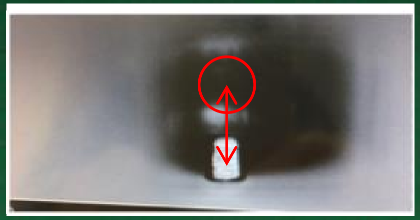
- **Planarity**
  - Auto-Z Planarity
    - Cascade Membrane: ~40um
    - Katana RFX: ~10um

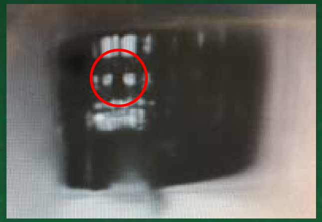
| | All Touch – Average (um) | All Touch – StDev (um) | All Touch – Max (um) |
|---|---|---|---|
| FFI Katana RFX | 9.605 | 5.408 | 31 |
| Pyramid Probe | 40.907 | 12.902 | 75 |

- **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



# 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 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 medial; no TD on Al 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: | Tip Length / Wear Rate x 1000 / Cleaning TDs per Cycle x 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