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# Kelvin Contactors for Wafer-Level Test


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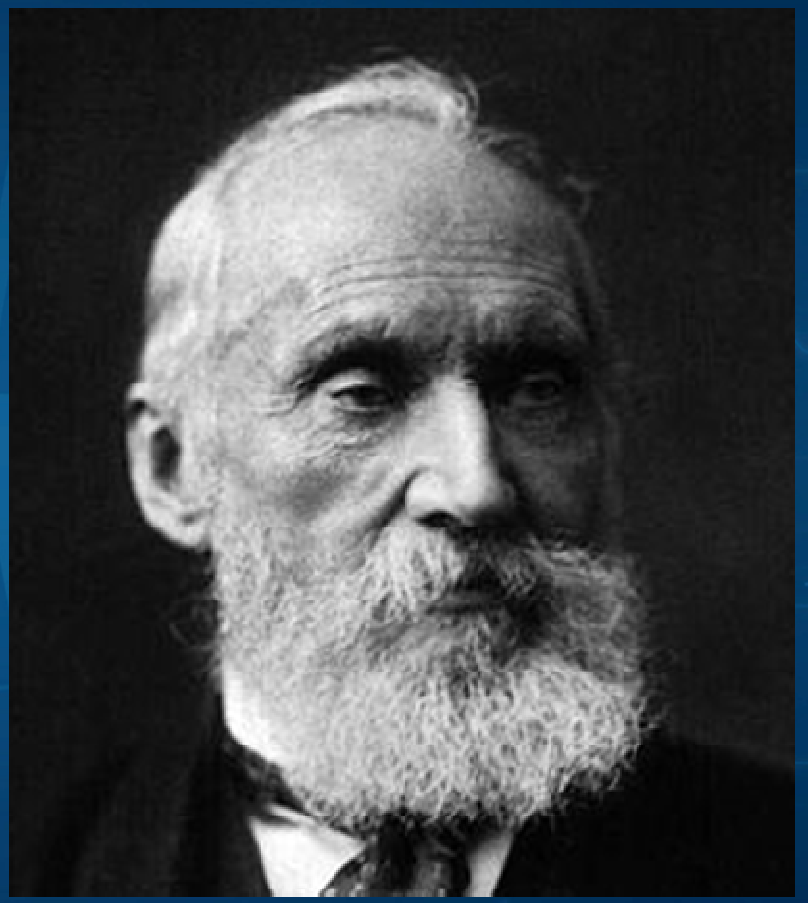
# Kelvin Method over 150 Years Old

- Created by William Thompson (Lord Kelvin)
- Also Calculated Absolute Zero
- Kelvin temperature scale named for him



# Industry Standard

- Kelvin is recognized as the best way to perform $R_C$-sensitive measurements
- Without a Kelvin connection:
  - Yields suffer
  - Probes require frequent cleaning
  - Probes require frequent replacement

# Kelvin is a Mechanical Challenge

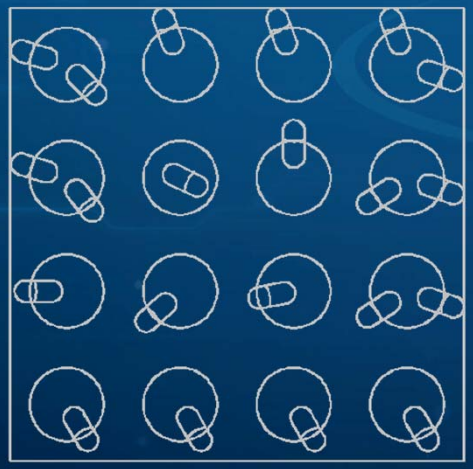
- Electrical contact points are small
- Landing a single probe tip is a challenge
- Landing two doubles the challenge
  - Especially in area arrays (BGAs, e.g.)
- Challenge increases as pitches shrink

# 0.4 mm Pitch Kelvin

- Introduced in 2008 - Very successful
  - Hundreds of designs
  - Thousands of contactors
  - Millions of probes
- Main limitation has been pitch
  - Capable of 0.4 mm pitch in-line
  - Capable of full arrays at 0.65 mm pitch
  - Capable of partial arrays at 0.5 mm pitch
  - Capable of partial arrays (peripheral) at 0.4 mm pitch

# Need for Kelvin at WL Test

- **Wafer-Level test has always been an important application for Kelvin**
  - **Many devices include power management**
- **Mainline pitch has been 0.4 mm**
  - **0.4 mm probe used despite array limitations at 0.4**



*Contactor for WL test using 0.4 mm pitch probe*

# Spring Probes for WL Test

- **Spring probes good choice for WL test**
  - **WL test is final test**
  - **More capability required than wafer probe**

| Technology | Pogo™ Probe | Spring Probe | Spring Probe | Membrane | Vertical 1 |
|---|---|---|---|---|---|
| Type | CSP050 | 0.4 Kelvin | 0.3 Kelvin | | |
| Inductance | 1.22 nH | 1.1 nH | 1.8 nH | 0.2 nH** | N/A |
| DC Current | 1.7 A | 1.8 A | 1.5 A | 200 mA*** | 0.5 A |
| Resistance | 100 mΩ typ. | 75 mΩ typ. | 100 mΩ typ. | < 200 mΩ | < 2 Ω |
| Bandwidth | 5.7 GHz | 16 GHz | 17 GHz | 20 - 33 GHz | 1.3 GHz |
| | | | ** Tip Only | *** On Solder | |

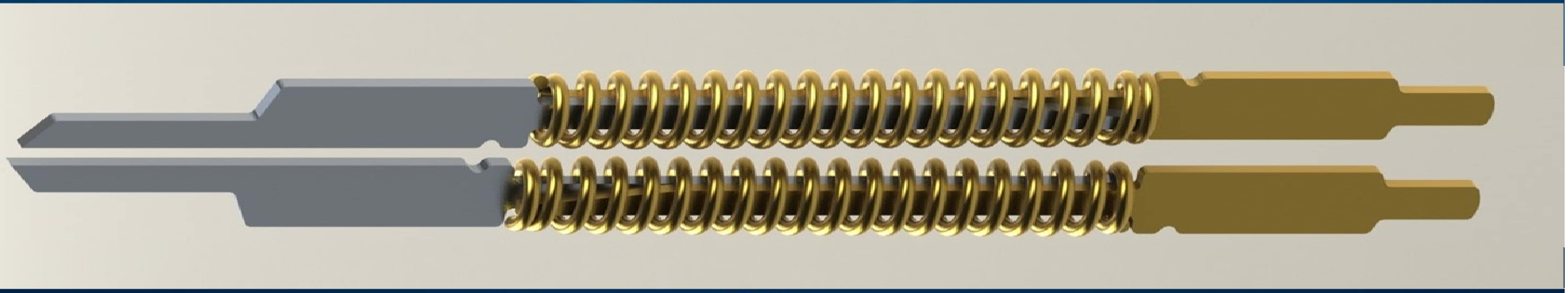
Membrane and Vertical Probe specifications from internet

# First Attempt at 0.3 mm Probe Failed

- First Attempt at finer pitch simple shrink of 0.4 mm Kelvin probe
- QuadTech architecture results in geometries that are too fragile
- Development shelved for several years

# More-Recent Release of 0.3 mm Probe

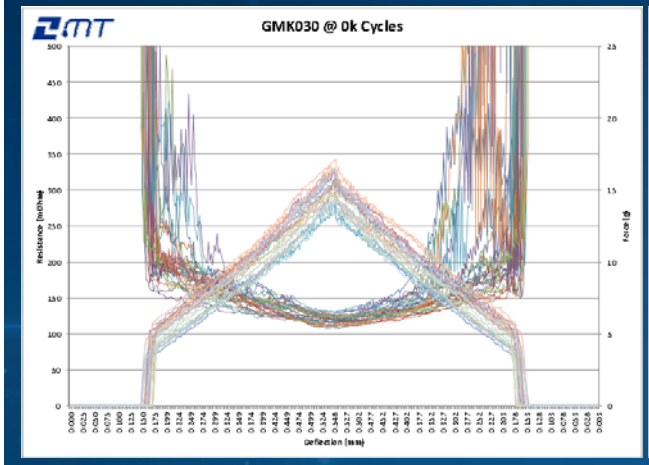
- Development restarted in 2012
- Different approach taken
- Internal contact simple flat-on-flat
- Latching mechanism is different
- A patent has been applied for, based on the latch feature

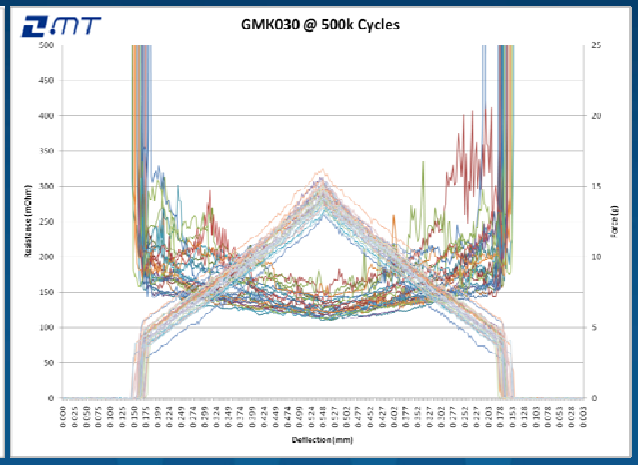


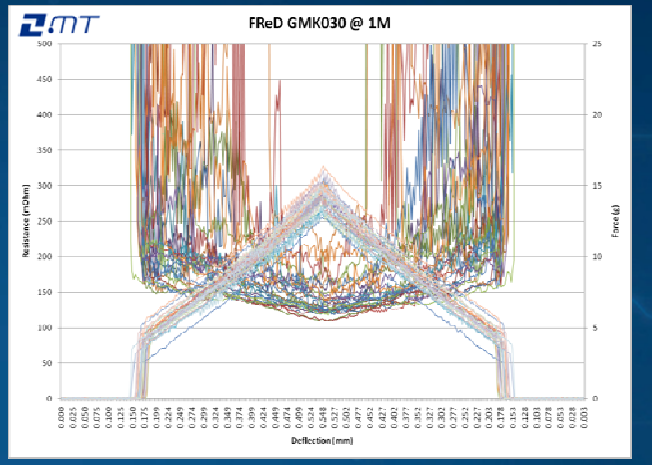
# 0.3 mm Probe Basic Specifications

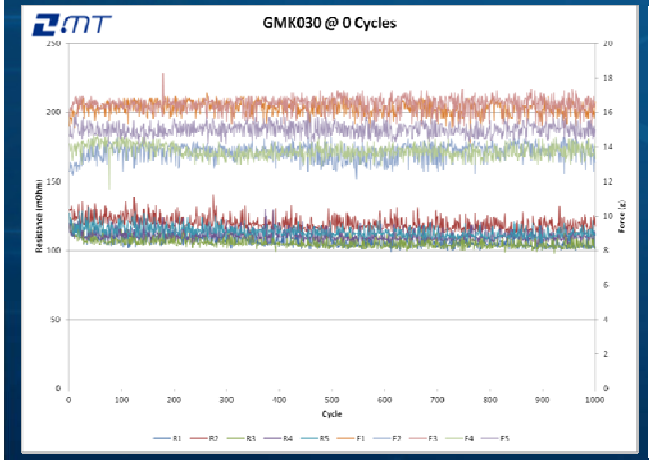
| | |
|---|---|
| Conductance @ 20° C rise | 1.5 A |
| Maximum Resistance (New Probe) | 150 mΩ |
| Bandwidth @ -1dB (Dual-Probe, GSG) | 17 GHz |
| Inductance (Loop, Dual-Probe, GSG) | 1.01 nH |
| Tip Options | K & D now, B later |
| Minimum Kelvin Tip Spacing | 83 µm |
| Test Height | 3.46 mm |
| Total Compliance | 552 µm |
| DUT-Side Compliance | 412 µm |
| Force at test height | 15 g |
| Material | H.P. Alloy |
| Plating (Board Side Only) | Hard Gold |

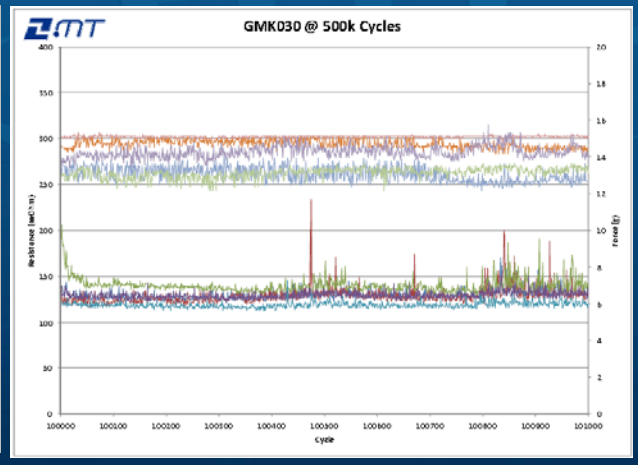
# GMK030 Characterization: Life Test

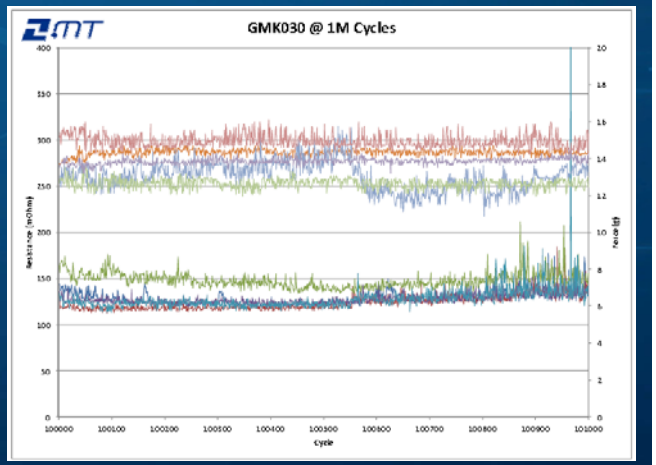


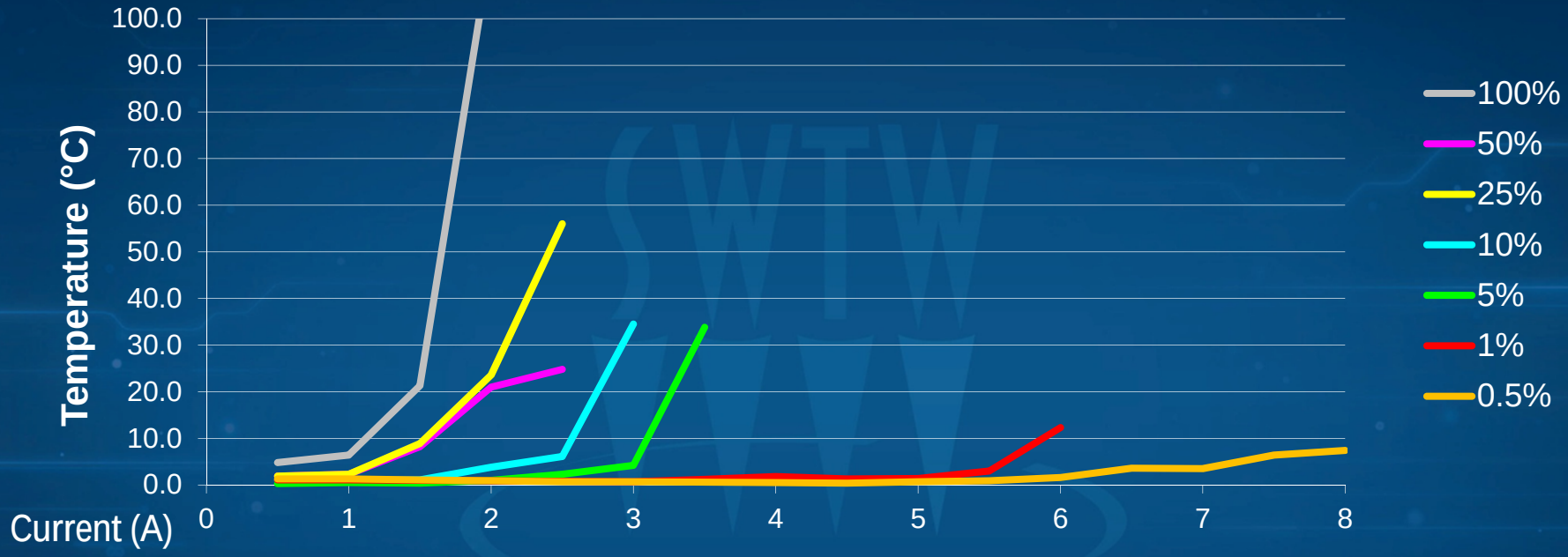



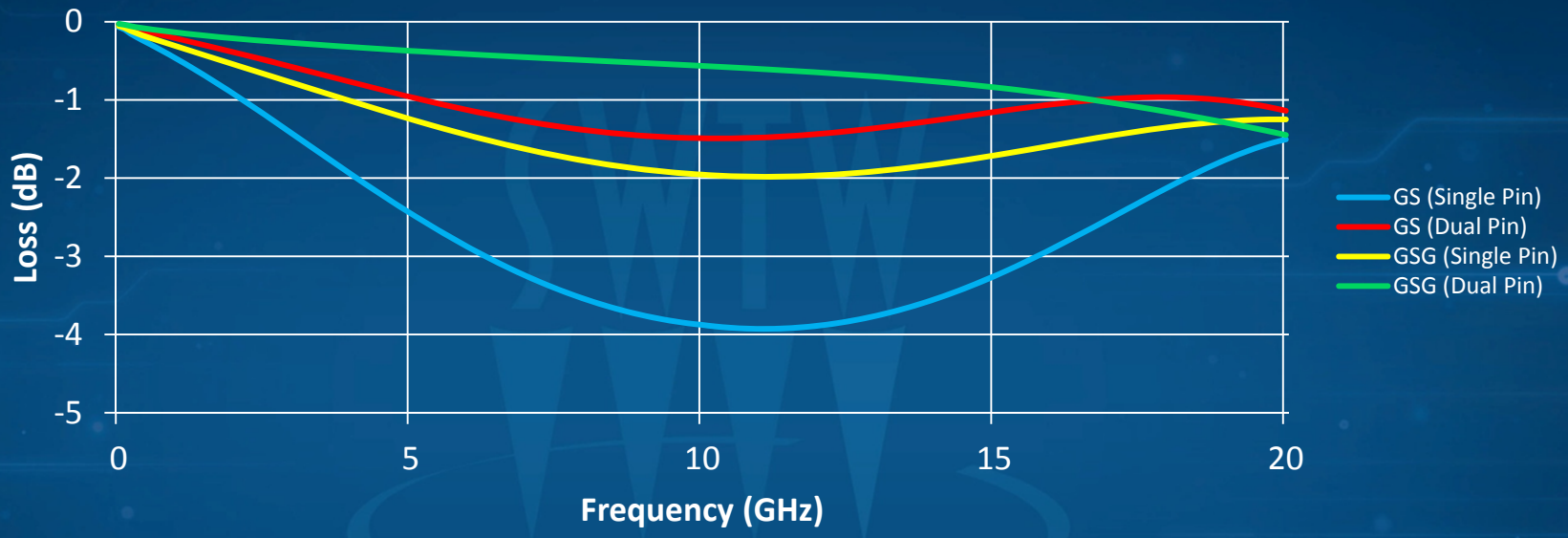



# 0.3 mm probe Characterization: High Current Test



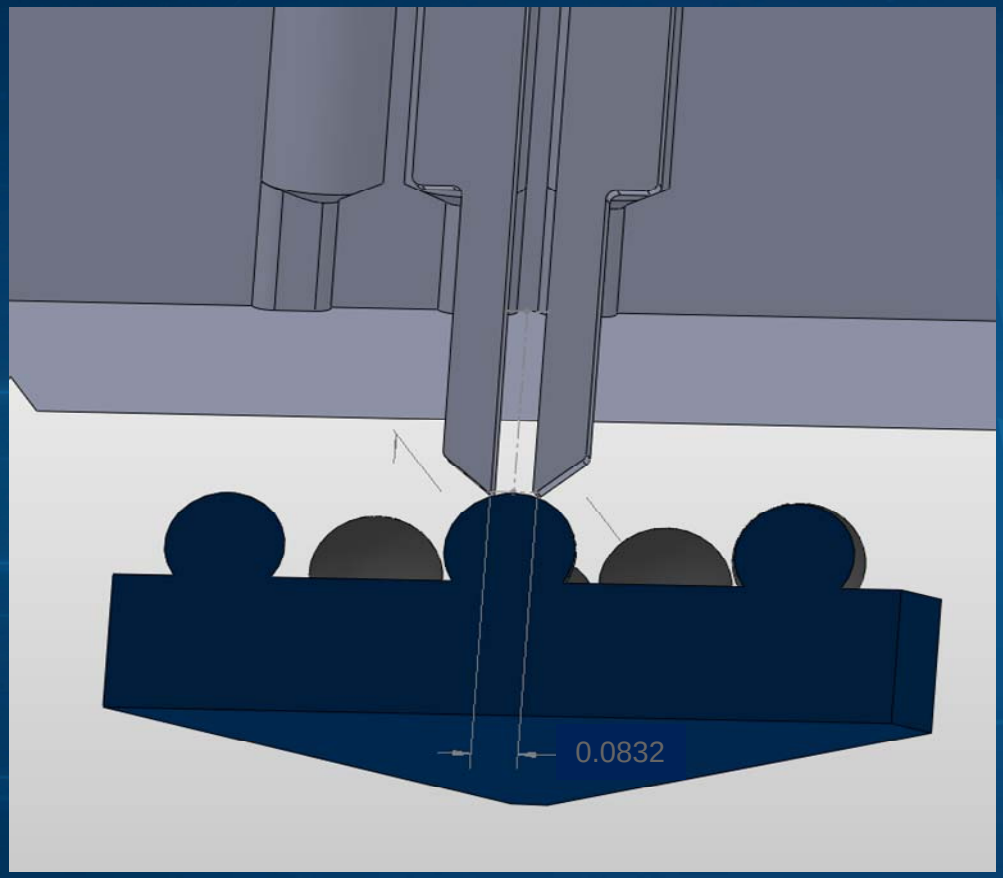

| Gemini Kelvin 030 | |
|---|---|
| 20° C Temperature Rise | 1.5 A |
| 40° C Temperature Rise | 1.6 A |
| 60° C Temperature Rise | 1.7 A |
| 1% duty cycle | 5.0 A |

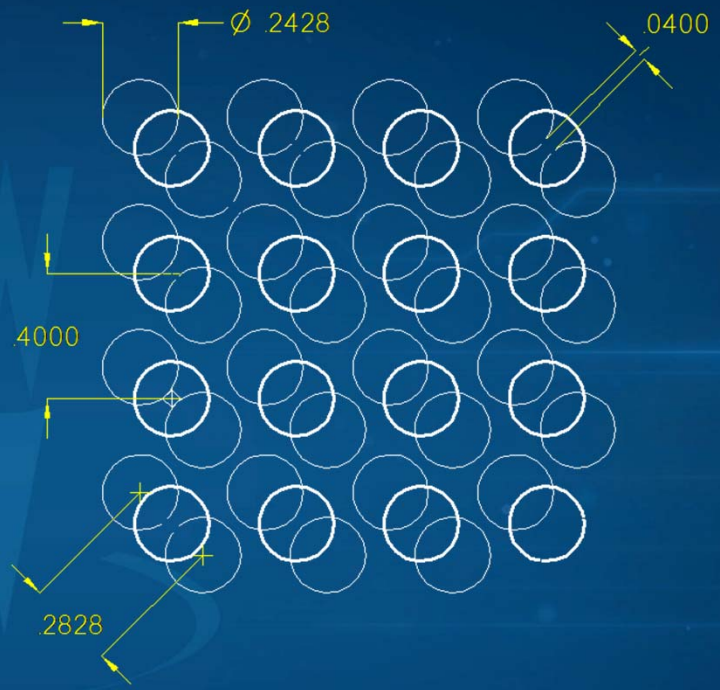
# 0.3 mm Probe Characterization: RF Simulation




| GMK030 -1dB Bandwidth | | GMK030 Loop Inductance | |
|---|---|---|---|
| Single-Probe GS | 2.1 GHz | Single Probe | 1.77 nH |
| Dual-Probe GS | 5.2 GHz | Dual Probe | 1.01 nH |
| Single-Probe GSG | 3.9 GHz | inductance values are GSG | |
| Dual-Probe GSG | 16.7 GHz | all values at 0.3 mm pitch | |

# Board Fabrication Challenging

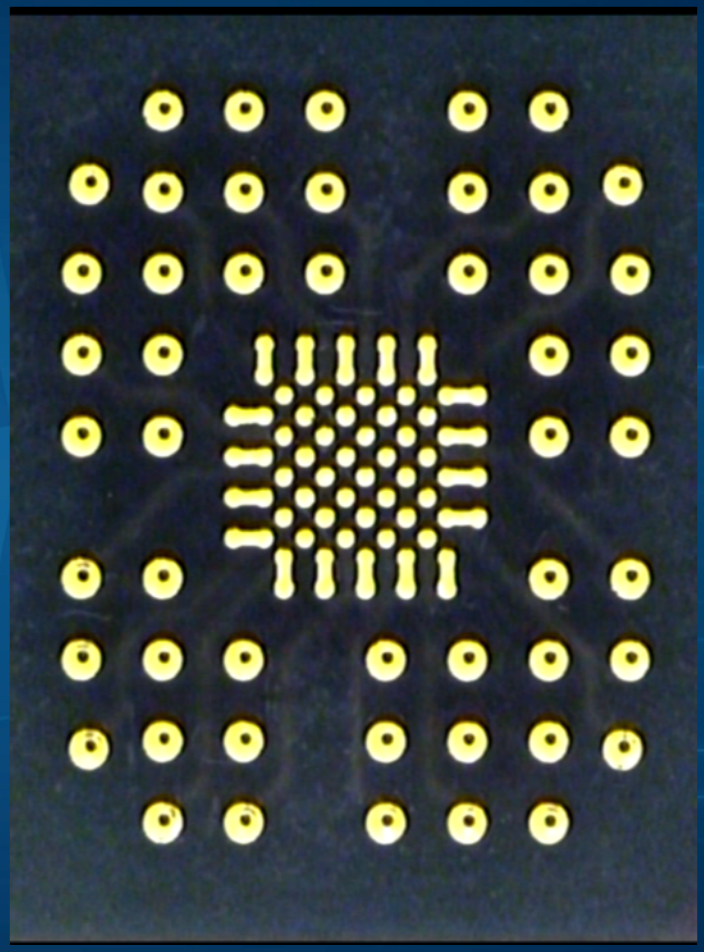



*Equally distributing the probes to make contact to a 0.4 mm pitch device results in a probe pitch of 283 µm and a probe tip spacing of 83 µm*

# Board Fabrication Challenging

- Space Transformer Board
  - May be used for full Kelvin @ 0.4 mm
  - Fans 283 µm pitch to something larger
- Full Performance Board
  - Full Kelvin may be possible @ 0.4 mm
  - Depending on probe and site count
- Few Shops are Capable

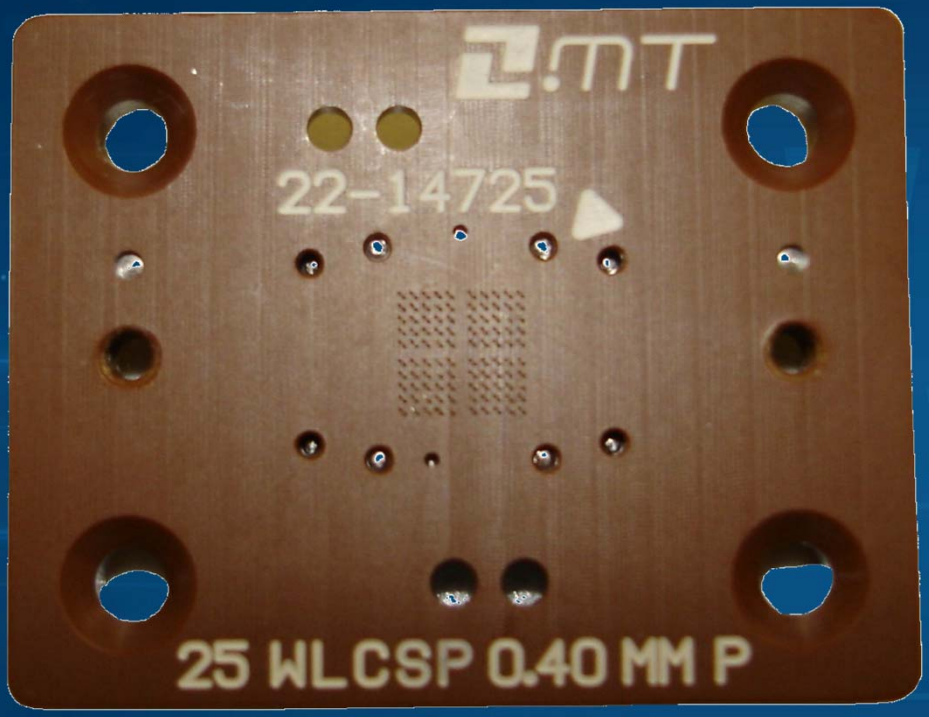


*Space Transformer Board*

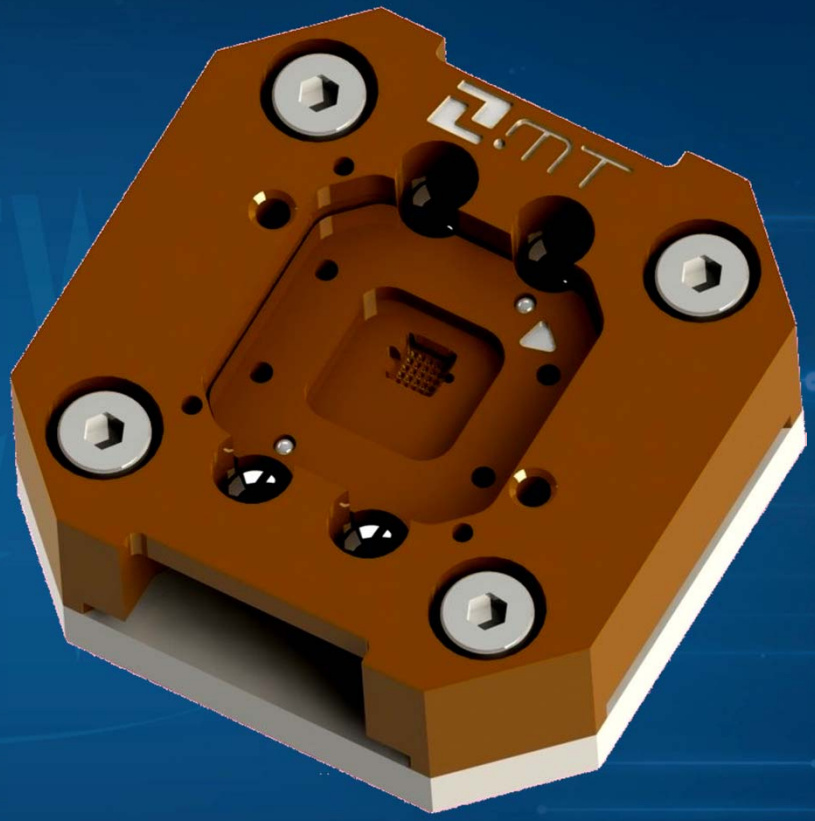
# Beta Site History #1

- First beta-site contactors shipped Feb 2013
  - 25-ball device
  - WL test and manual test contactors
  - Only used for engineering work
- Each contactor has only a few thousand uses
  - Insufficient to conclude beta site
- User excited – has acquired several more
  - Six quad-site (25-ball device)
  - Six quad-site (12-ball device)

# First Beta-Site Contactors



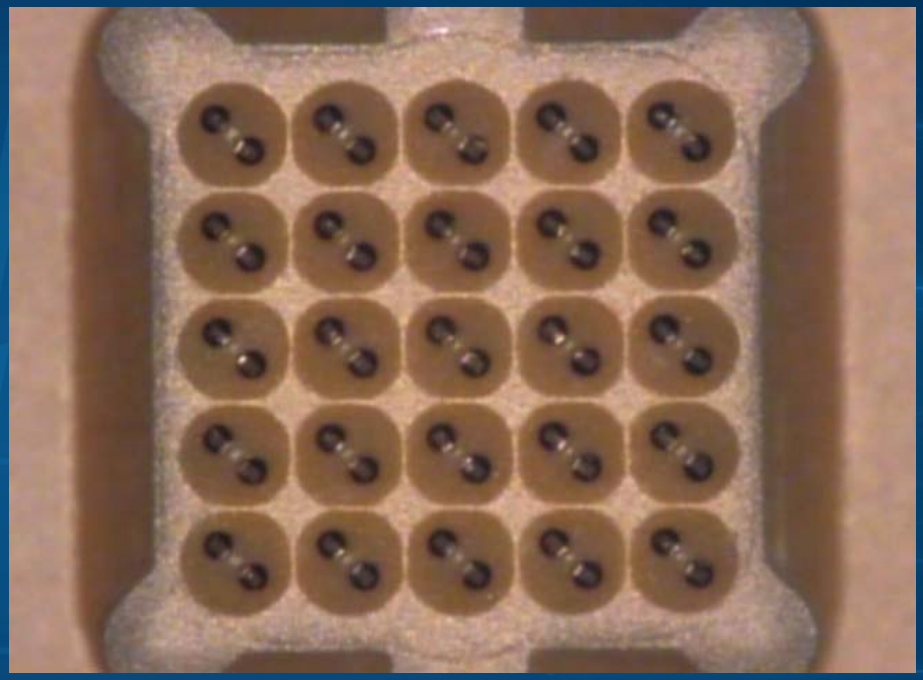

*Quad-site HVP contactor*



*Drawing of single-site hand-test contactor*

# Contactors for Singulated Devices

- Probe designed to support a FAP
- Necessary for singulated devices
- Wafer-level or other packaging

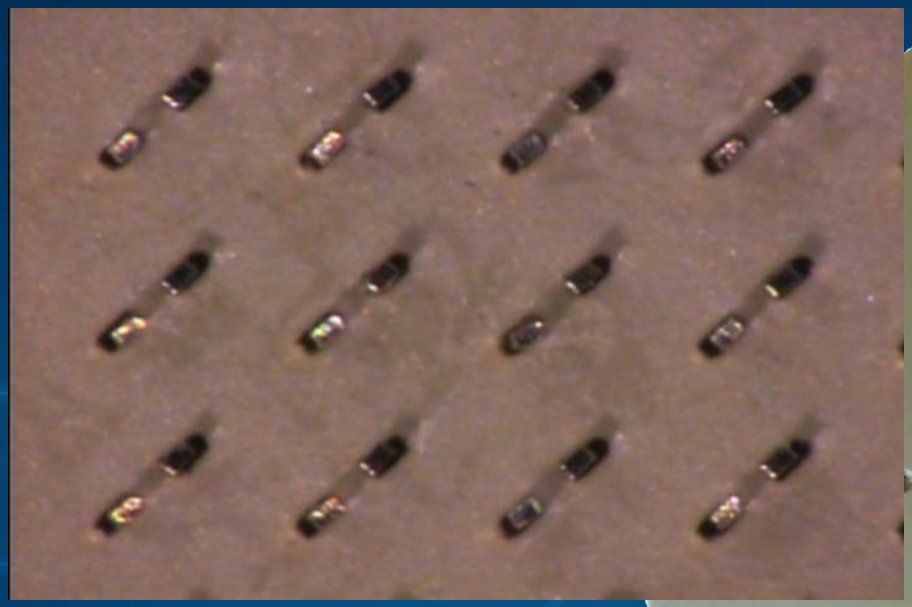


*DUT pocket of contactor for singulated 25 BGA*

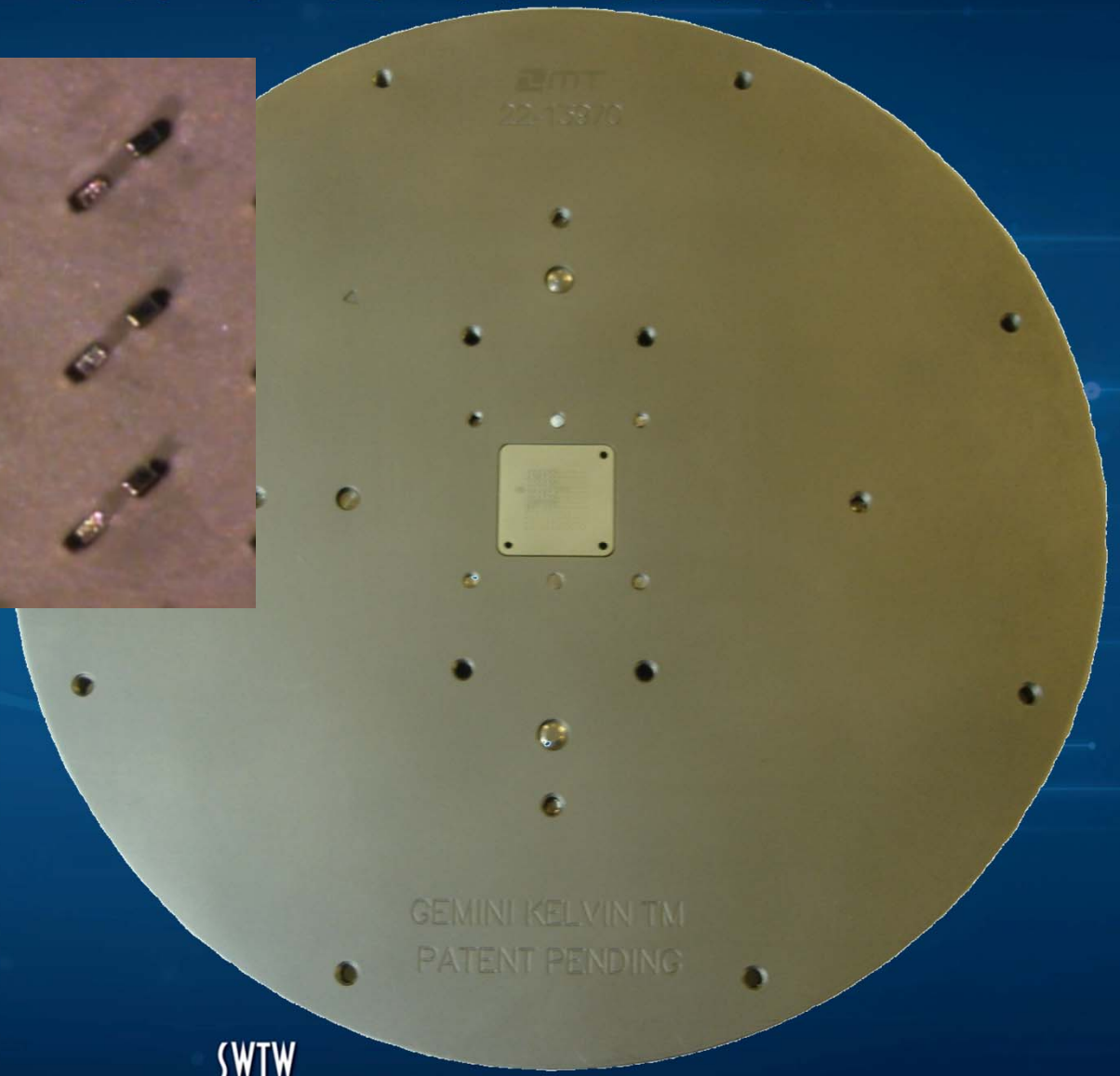
# Beta Site History #2

- Second beta-site contactor shipped March 2013
  - "Universal" WL contactor – 0.5 mm pitch
  - 12 X 12 array, partially populated
- It took a visit in July to get them to start using
- After first 100 k touchdowns
  - Life and yield far exceeded incumbent
  - Insufficient to conclude beta site
- User excited enough to acquire more

# Second Beta-Site Contactor



*Close-up of probes in the populated area of the "universal" contactor*



# Beta Site History #2

- Additional Shipments:
  - One “universal” (12 X 12), 0.4 mm pitch
    - August 2013
  - Second universal 0.5 mm pitch
    - August 2013
  - Eight quad-site HVP contactors, 46-ball, 0.4 mm pitch
    - Three in December 2013, five in May 2014
  - Spare probes
- One contactor has reached 850 k touchdowns
  - Almost enough high-volume production data to conclude beta site

# Beta Site History #3

- After browbeating, 0.3 mm pitch probe offered to a third user, on an evaluation basis
- Two contactors for singulated devices
  - 32-ball device – July 2013
- Two 20-site HVP contactors
  - 6-ball device – October 2013
- Five quad-site HVP contactors
  - 12-ball device – February 2014
- Spare probes
- Still not enough high-volume production data

# Summary

- Sixteen months later . . .
- With 41 contactors in the field . . .
- Of fifteen separate designs . . .
- The beta site stage is *almost* complete
- (That's the way it goes sometimes)
- **Questions?**