Innovative Approach to MEMS Contactor

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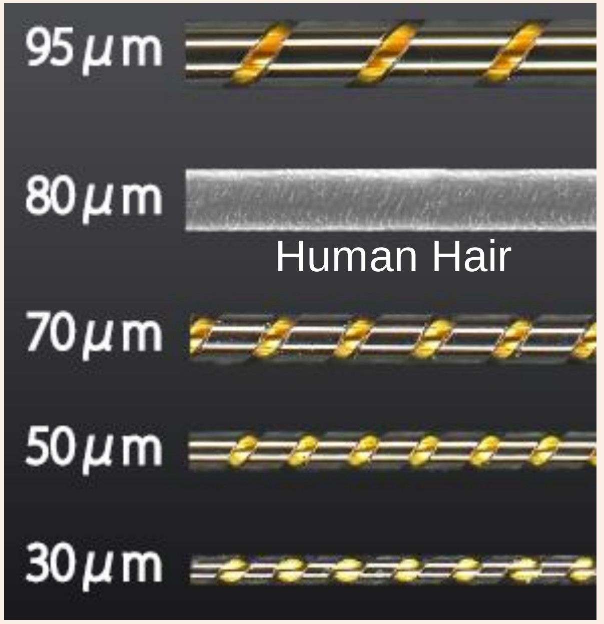
BiTS Workshop
March 4 - 7, 2018

Overview

- Background
- MEMS Spring Probe Definition
- Manufacturing Process Detail
- Design Process Detail
- Advanced Features
- Performance Data
- Technology Road Map
- Conclusions

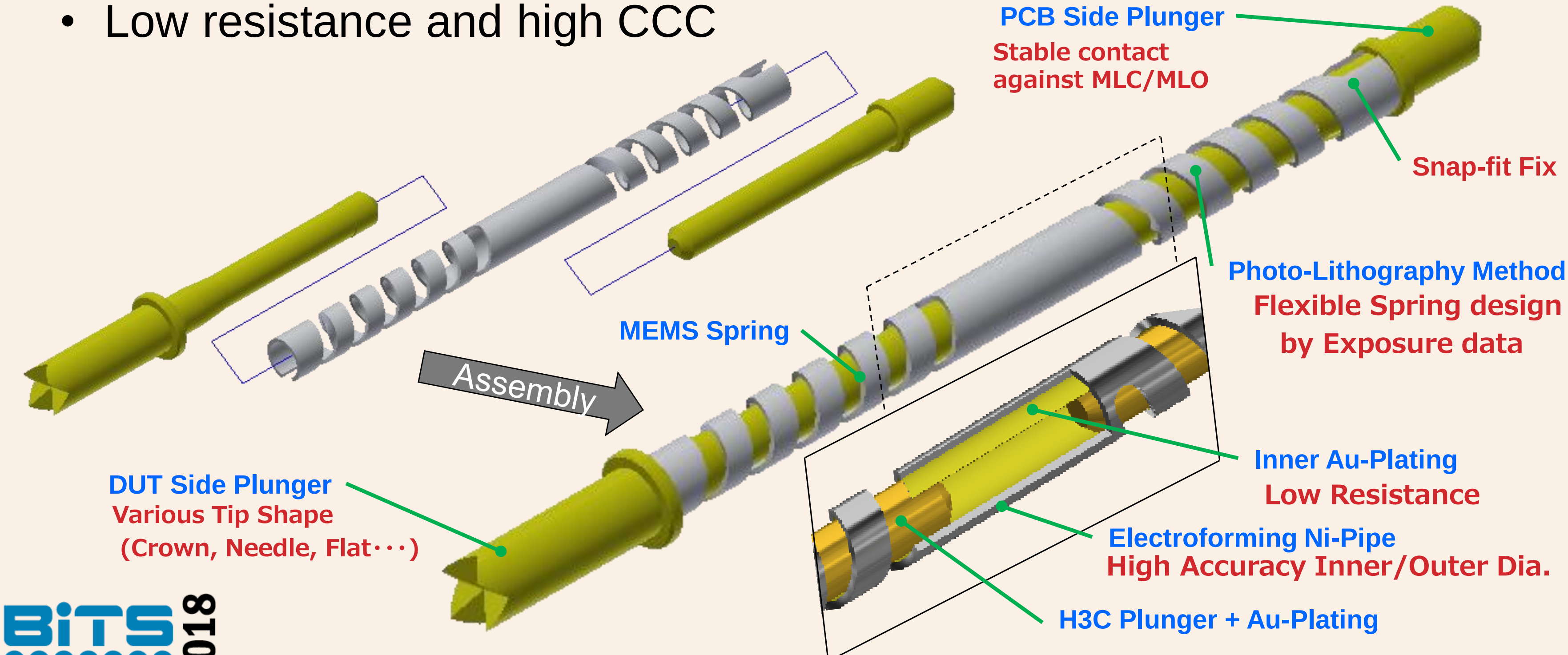


Background

- Advanced packaging technologies driving requirements for innovation in the contactor space
- Fan-out WLCSP (FOWLP) and copper pillar interconnects are pushing requirements for low-cost, flexible probe technologies
- The confluence of applications and packaging requires more than a “one size fits all” approach
- A MEMS spring pin developed for IC substrate contact test fixtures is finding new applications in WLCSP, socket, and flip chip probe applications

MEMS Spring Pin Probe Definition

- Simple structure with spring and snap-fixed two plungers
- Low resistance and high CCC



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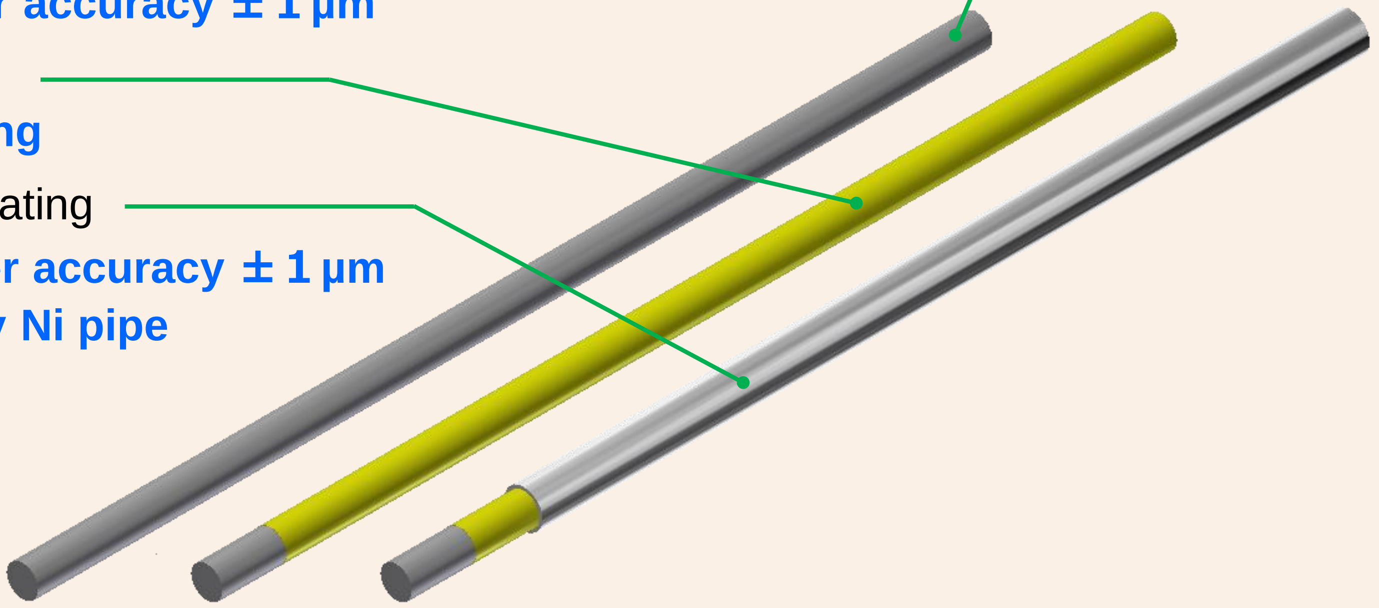
Manufacturing Process – Electroformed Pipe

- Automated continuous process

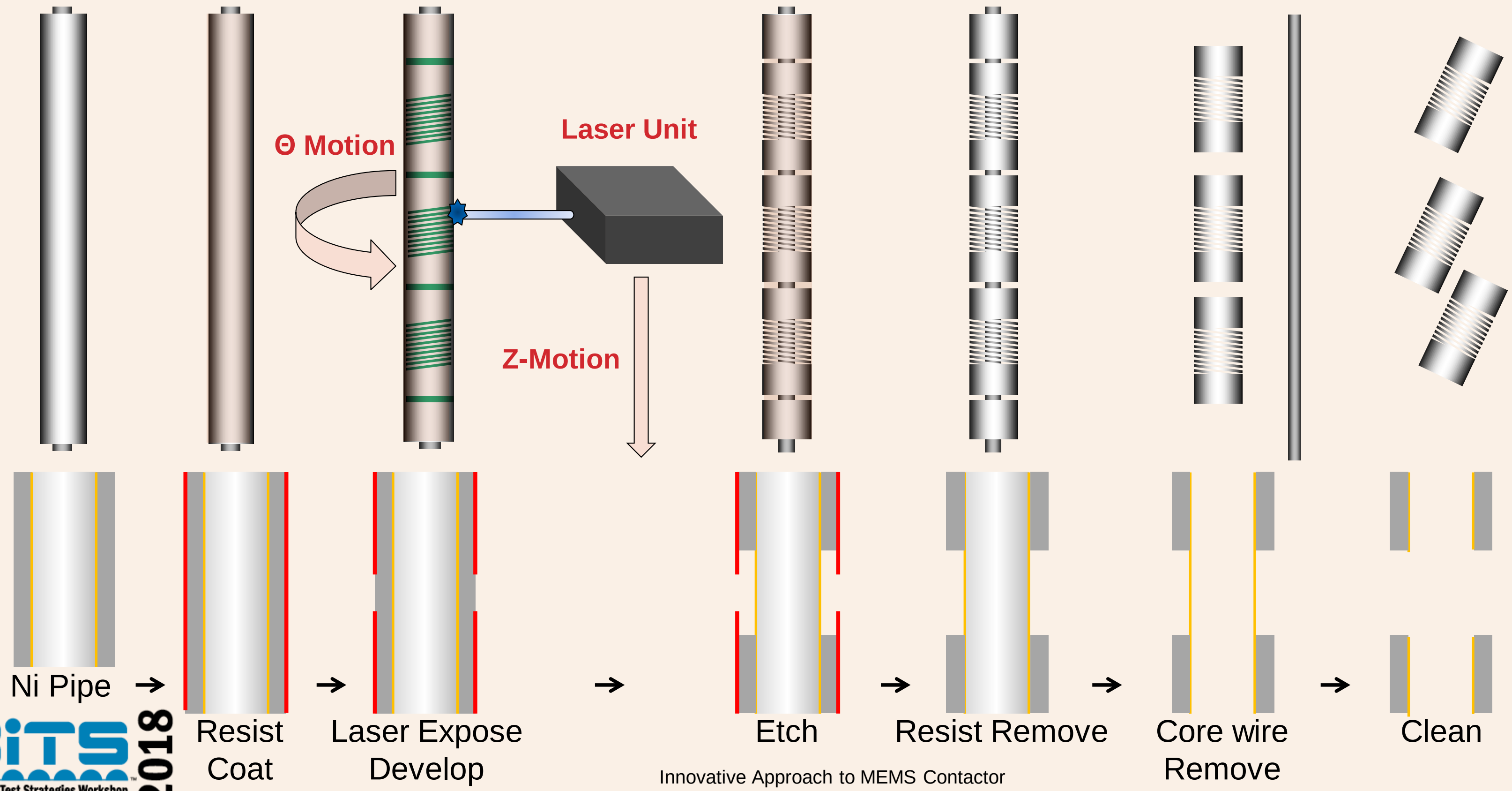
Step 1 - Stainless wire acts as mandrel for electroforming process
Inner diameter accuracy ± 1 μm

Step 2 – Au Plating
Inner Au Plating

Step 3 – Ni Alloy plating
Outer diameter accuracy ± 1 μm
High accuracy Ni pipe



Manufacturing Process – Photolithography



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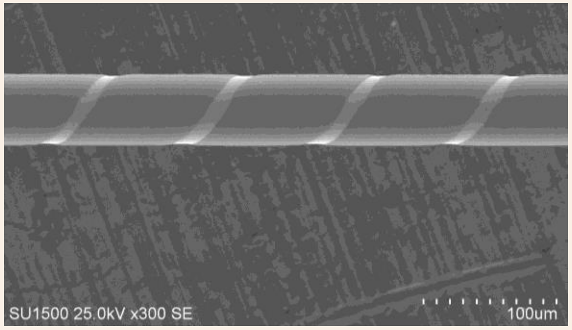
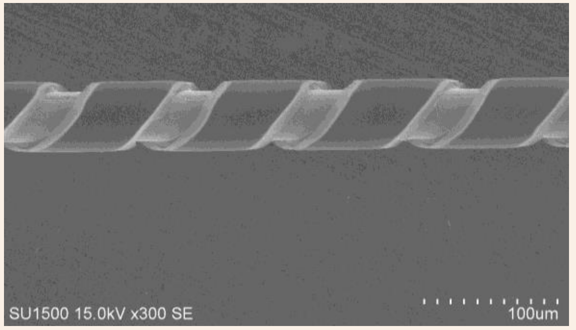
Manufacturing Process – Photolithography

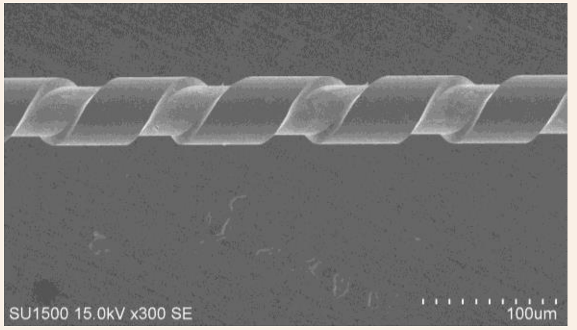
After Resist Coat/ Laser Expose/Develop



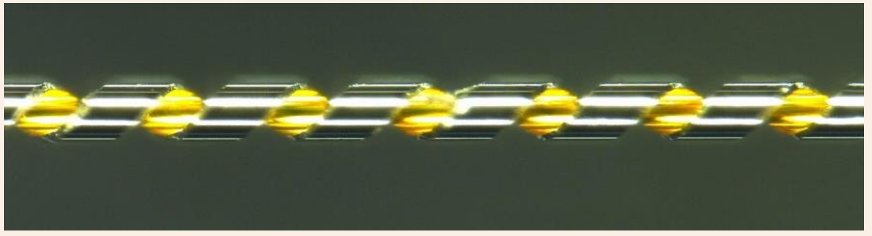
After Etch



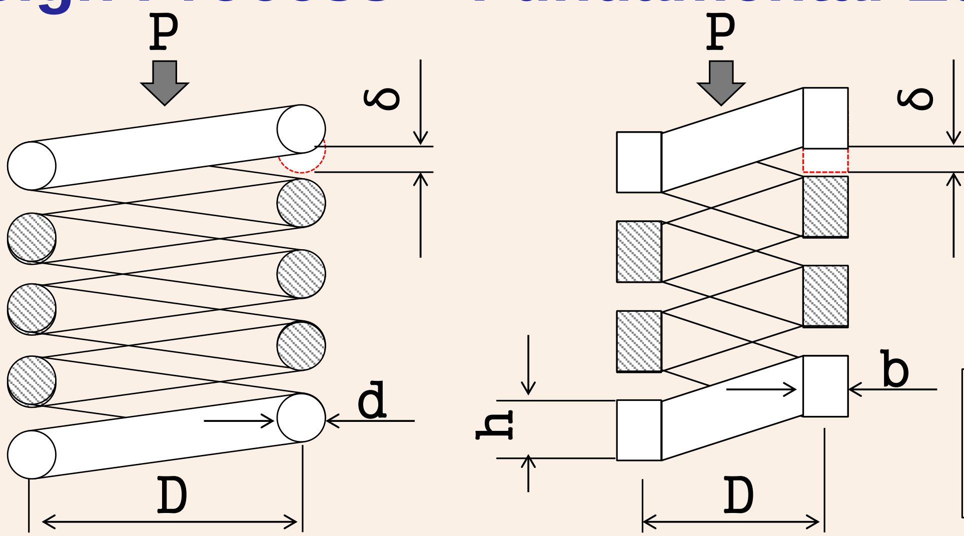
After Resist Removal



After Core Wire Removal



Design Process – Fundamental Equations



Adapt fundamental coil spring equations to account for thin rectangular cross section of MEMS spring

Na= number of turns
G = Modulus of transverse elasticity

$$\delta = \frac{8NaD^3P}{Gd^4}$$

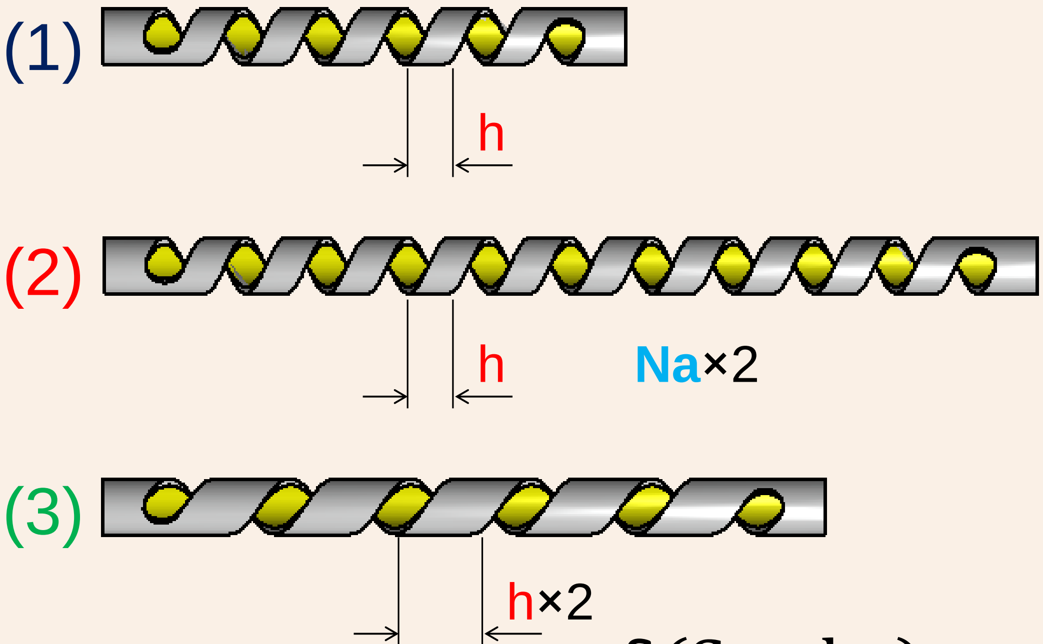
$$\delta = \frac{0.9\pi NaD^3P(b^2+h^2)}{Gb^3h^3}$$

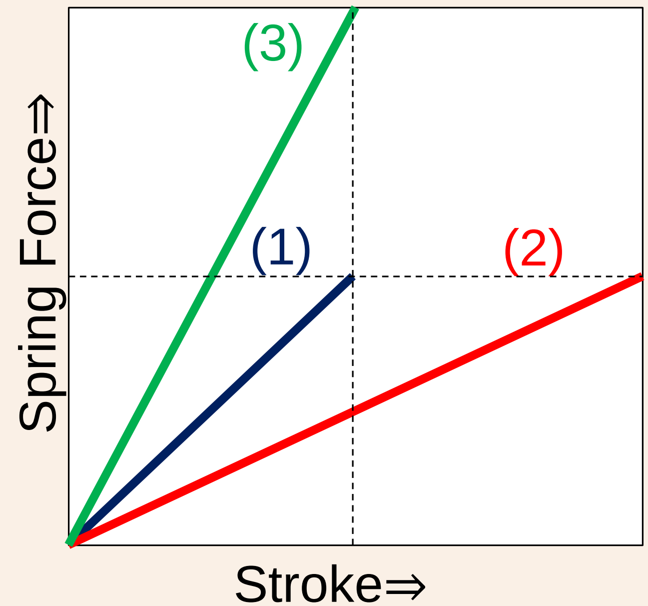
$$\tau = \frac{8DP}{\pi d^3}$$

$$\tau = \frac{0.8DP\,(2\times b+h)}{b^2\times h^2}$$

Design Process

Effect of Design Parameters on Spring Force and Stroke

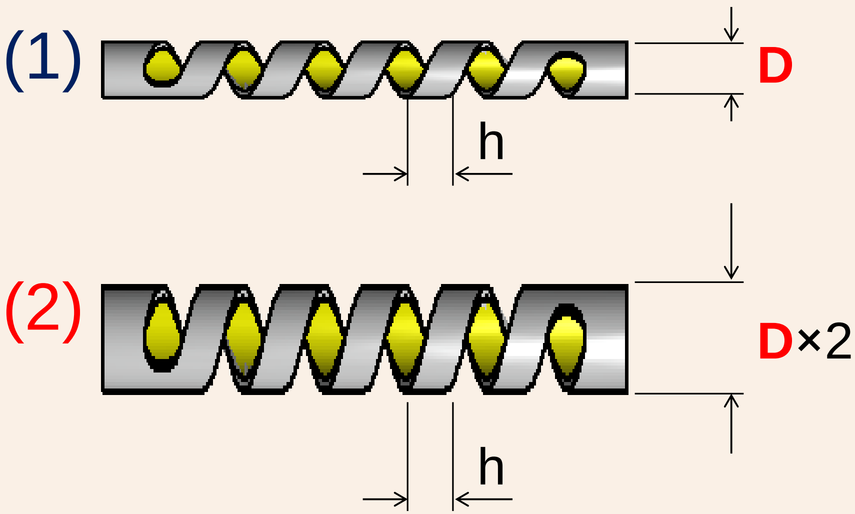


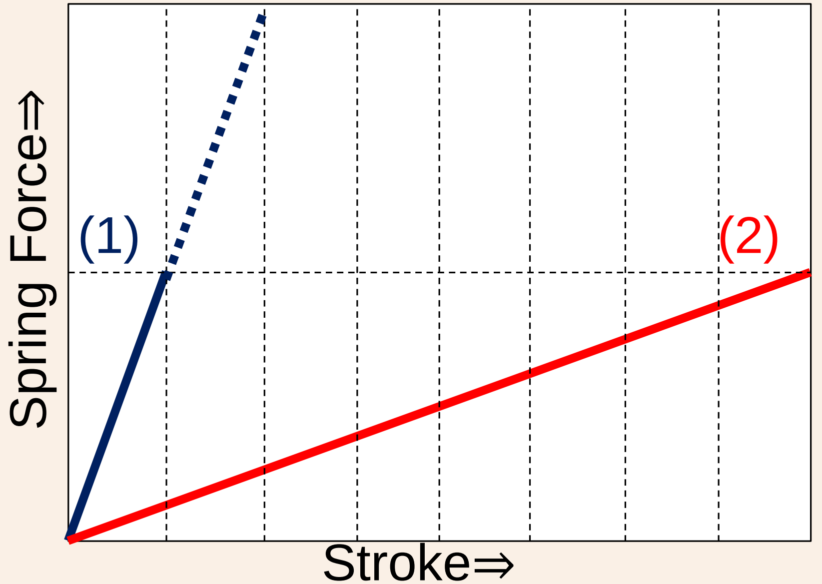


$$\delta(\text{Stroke}) = \frac{0.9\pi N a D^3 P(b^2+h^2)}{G b^3 h^3}$$

Design Process

Effect of Design Parameters on Spring Force and Stroke



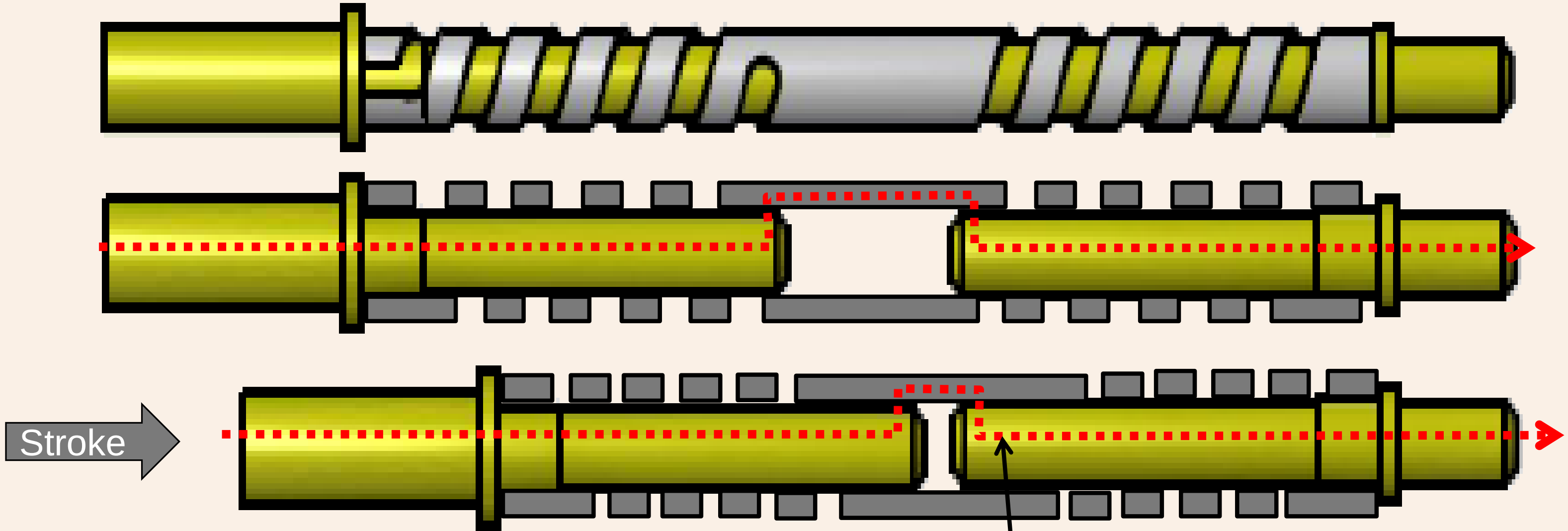


$$\delta(\text{Stroke}) = \frac{0.9\pi N a D^3 P(b^2+h^2)}{G b^3 h^3}$$

Advanced Features

- Current Path ・・・ Low resistance and high CCC

Primary current path is through the low-resistance plunger and center barrel section



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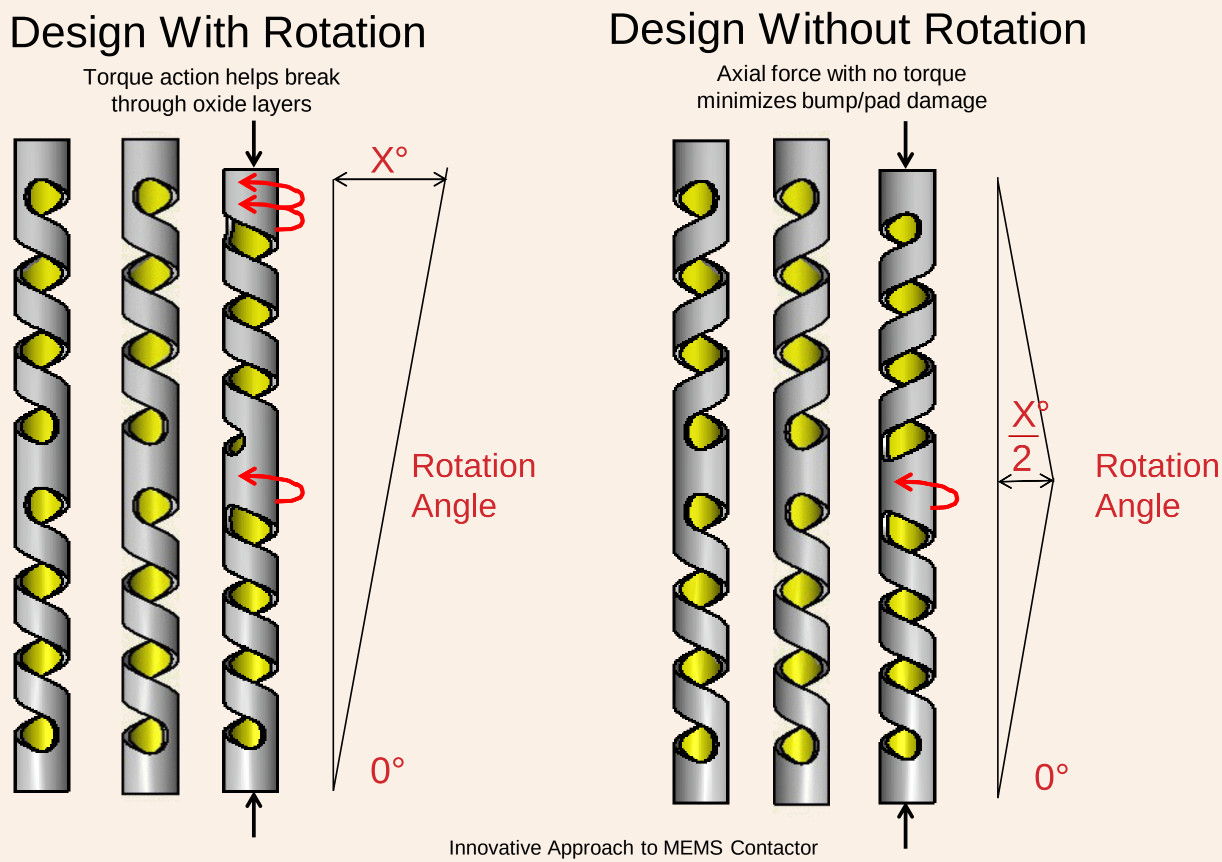
Advanced Features – Spring Rotation



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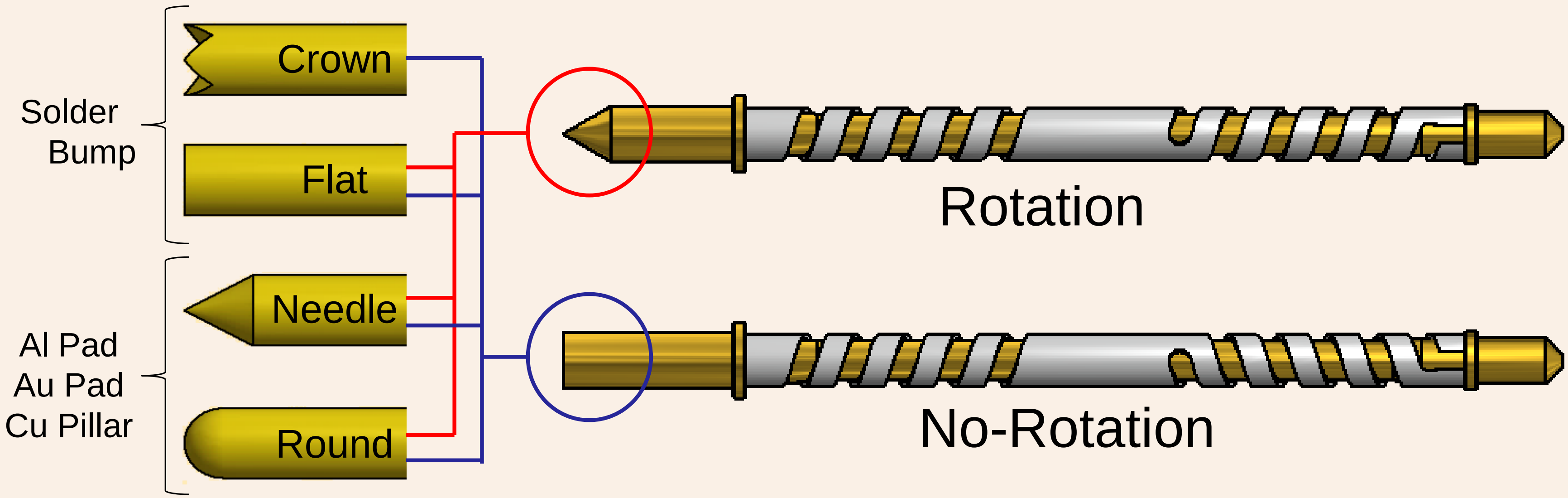
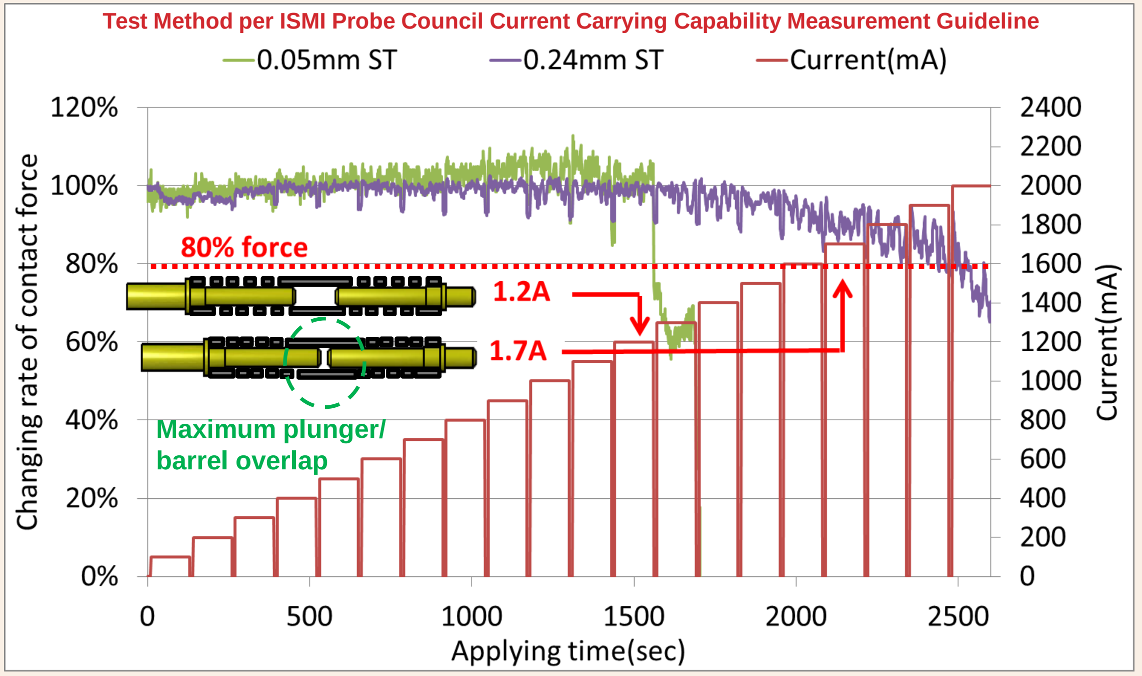
Advanced Features – Plunger Tip Shape

- Select tip shape appropriate for the application

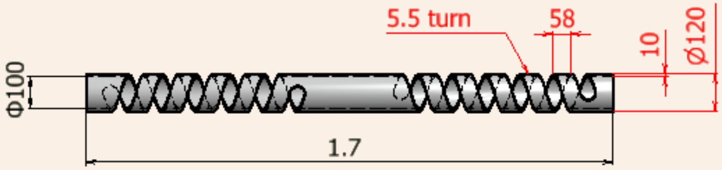


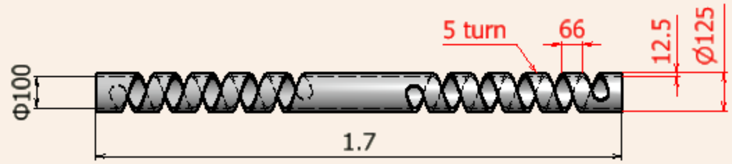
Performance Data – Current Carrying Capability

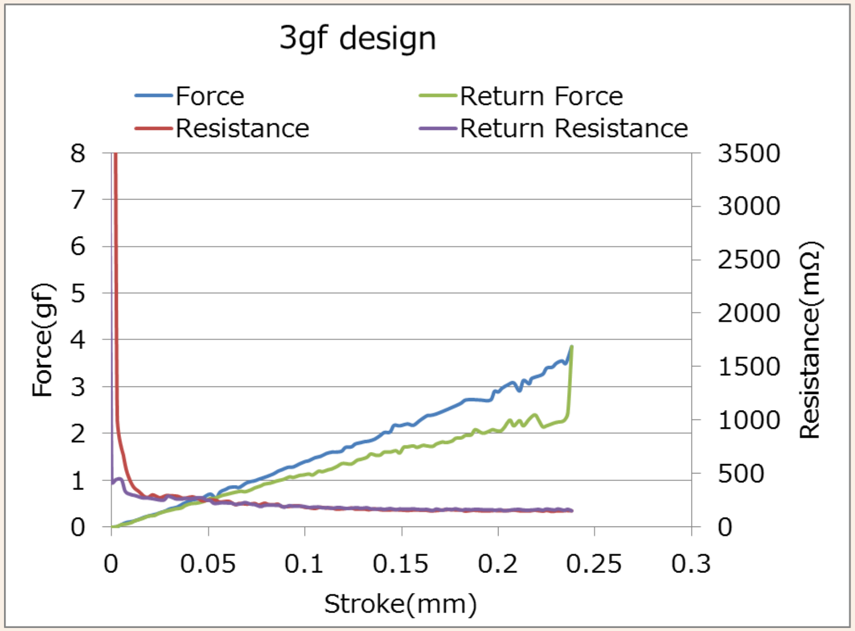


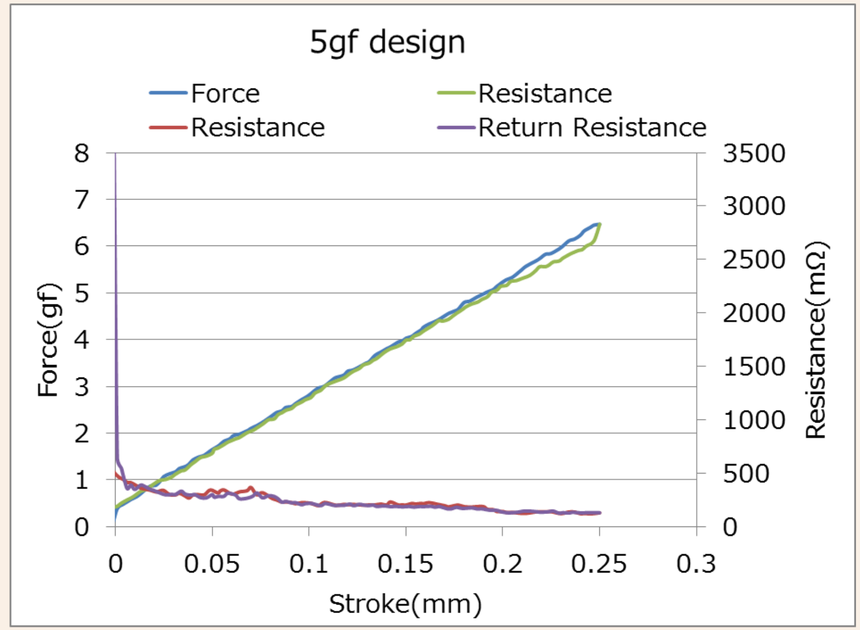
CCC performance is maximized at full design stroke

Performance Data – Custom Spring Force by Design

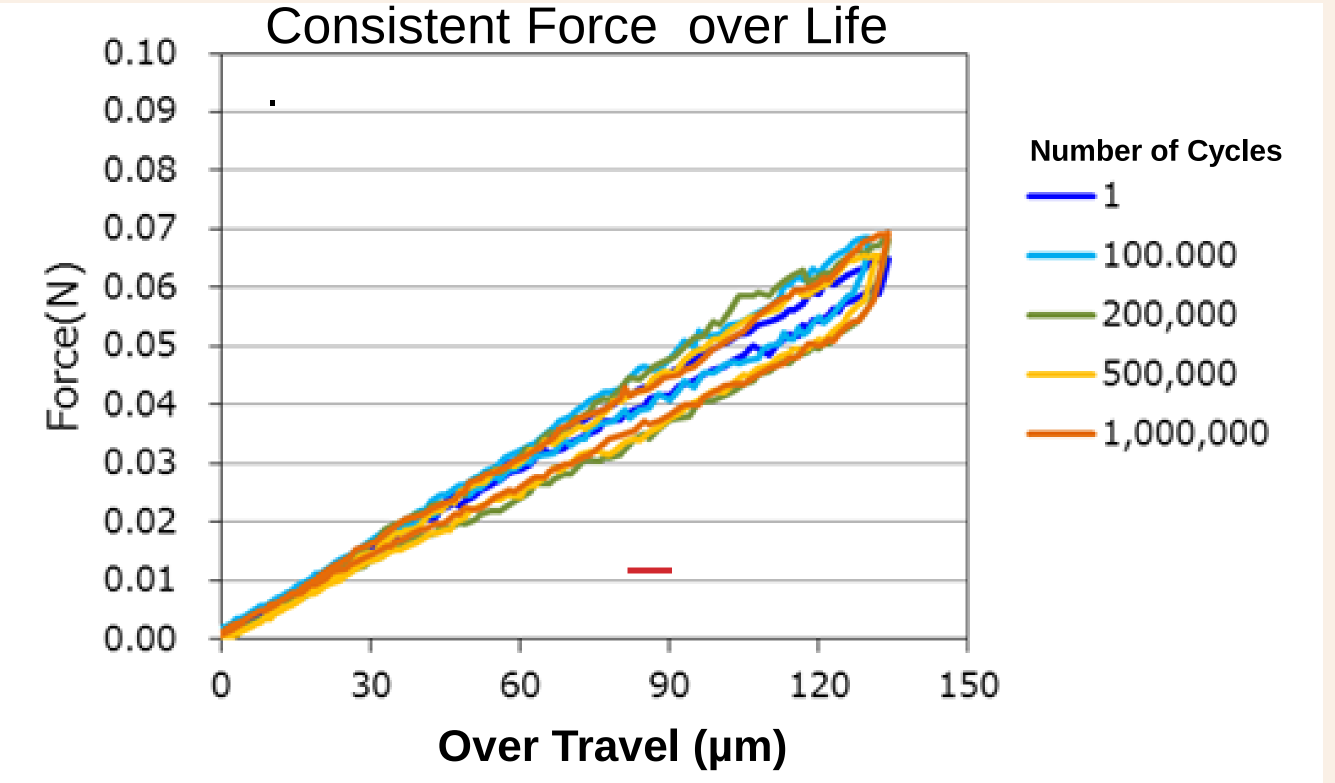




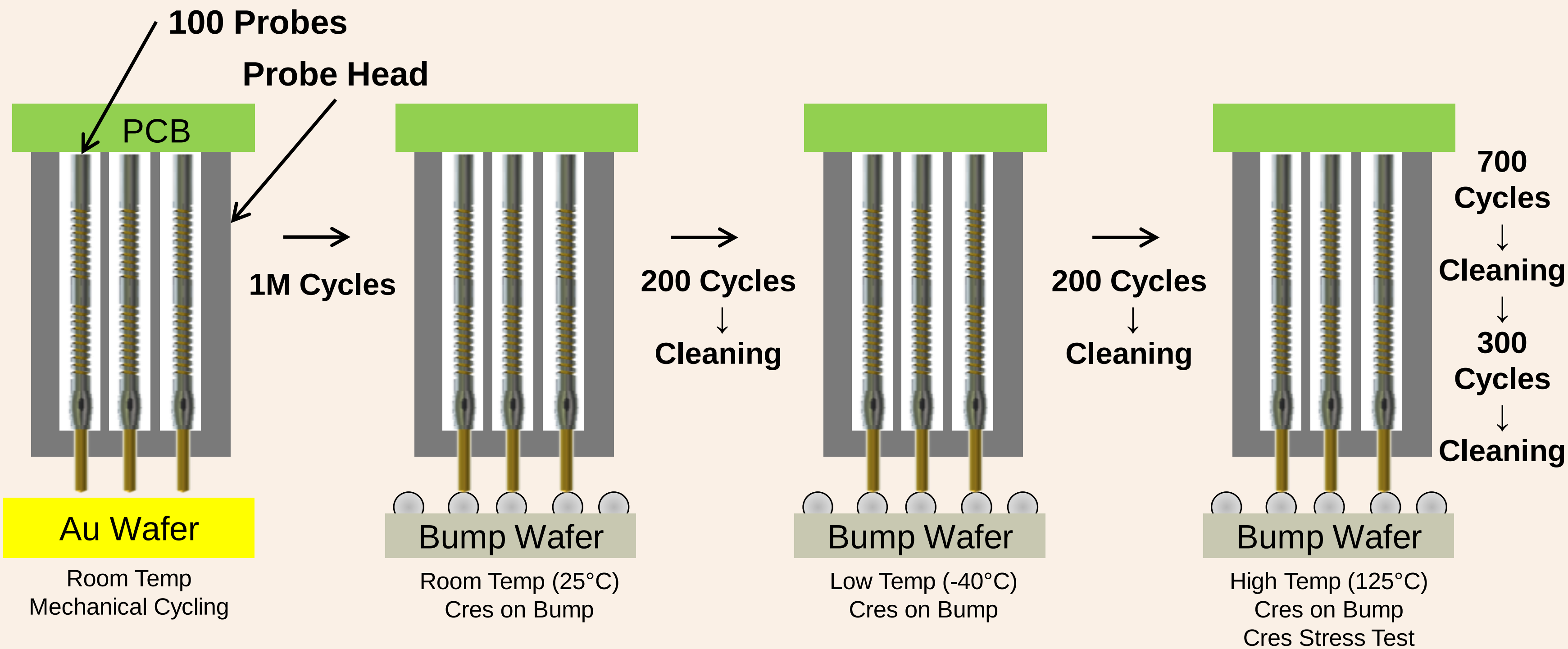




Performance Data – Durability Test



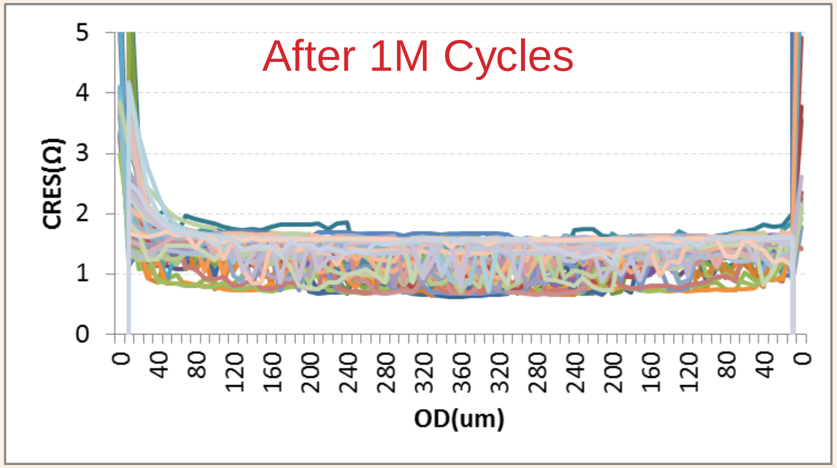
Performance Data – Durability Test Diagram



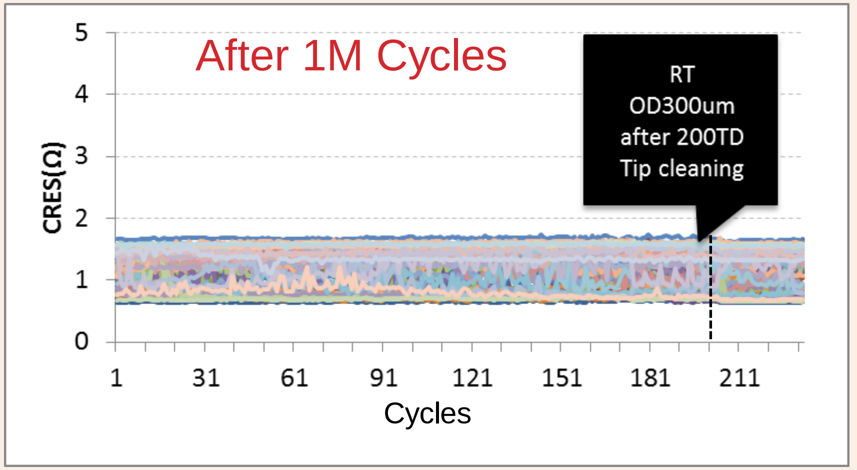
Performance Data – Durability Test

25°C Bump Contact Performance

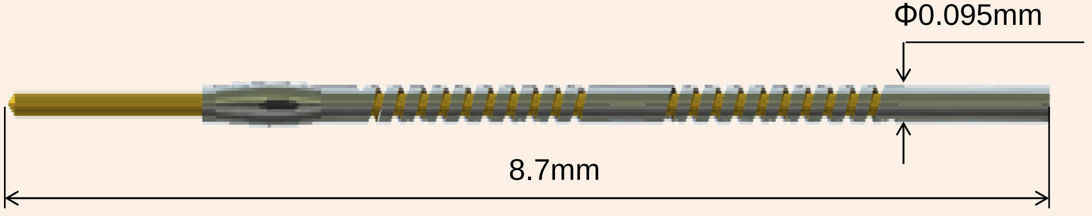
OD vs Cres @ Room Temp



200TD @ OD300µm

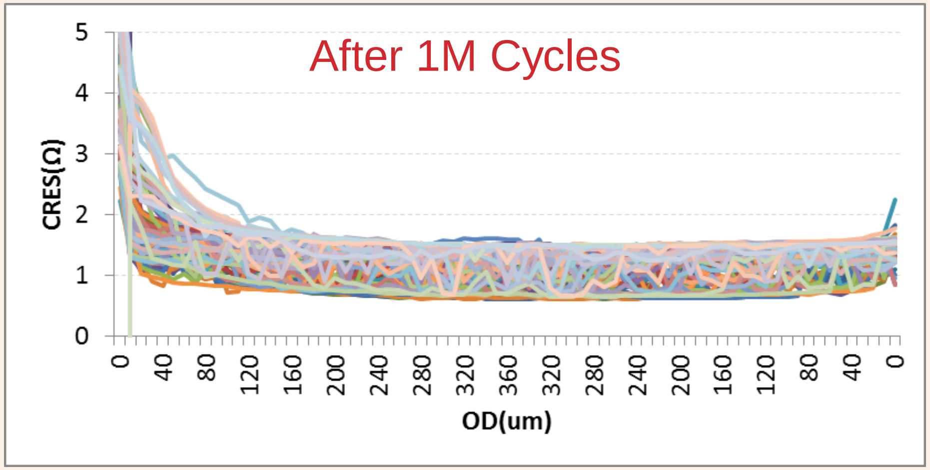


- N = 100 probes
- Stable Cres < 2Ω

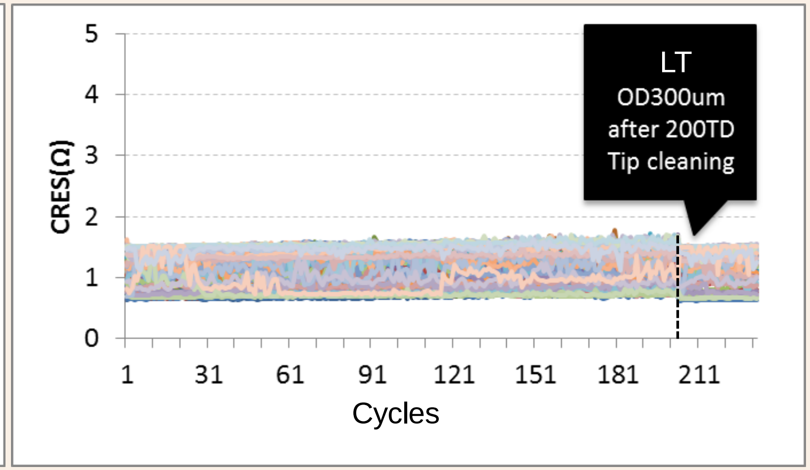


Performance Data – Durability Test
- 40°C Bump Contact Performance

OD vs Cres at Cold Temp



200TD (OD300µm)

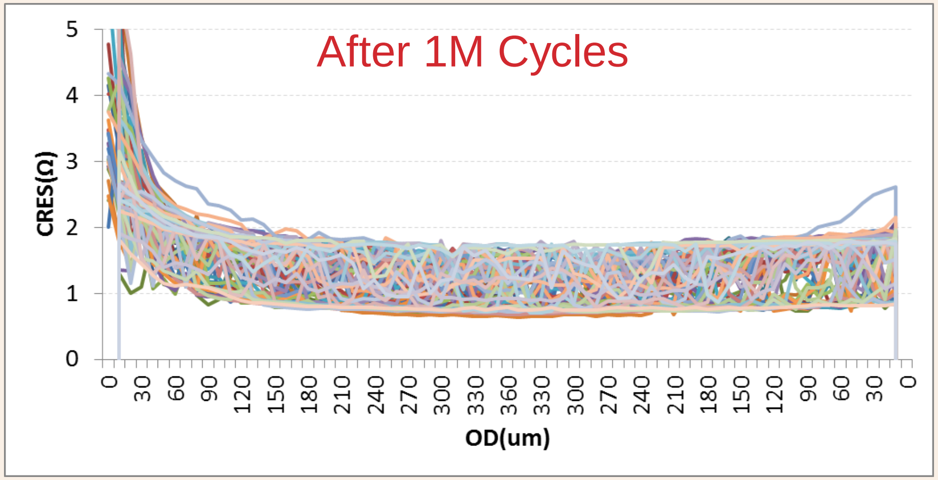


- Low temperature performance generally consistent with room temp.
- Cres improvement after cleaning more pronounced

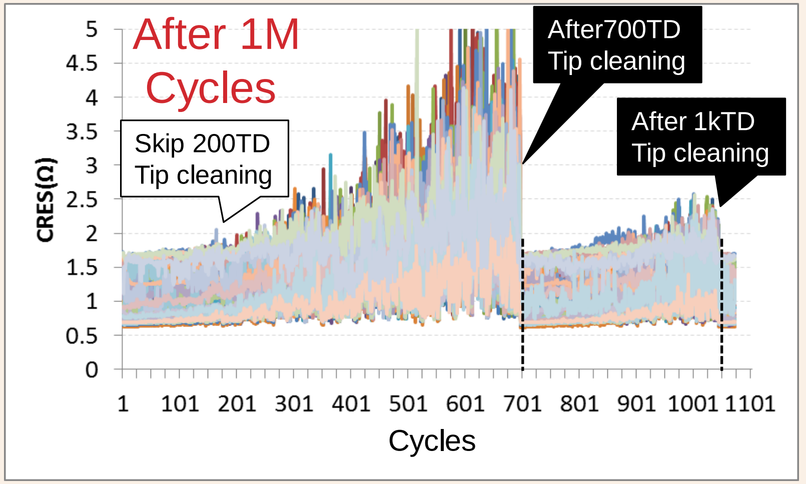
Performance Data – Durability Test

125°C Bump Contact Performance

OD vs Cres at Cold Temp



700+300TD (OD300μm)



- High temperature performance remains <2Ω up to 200 cycles
- Cres Stress Test shows significant degradation 200-700 cycles
- Cres performance stabilizes after cleaning

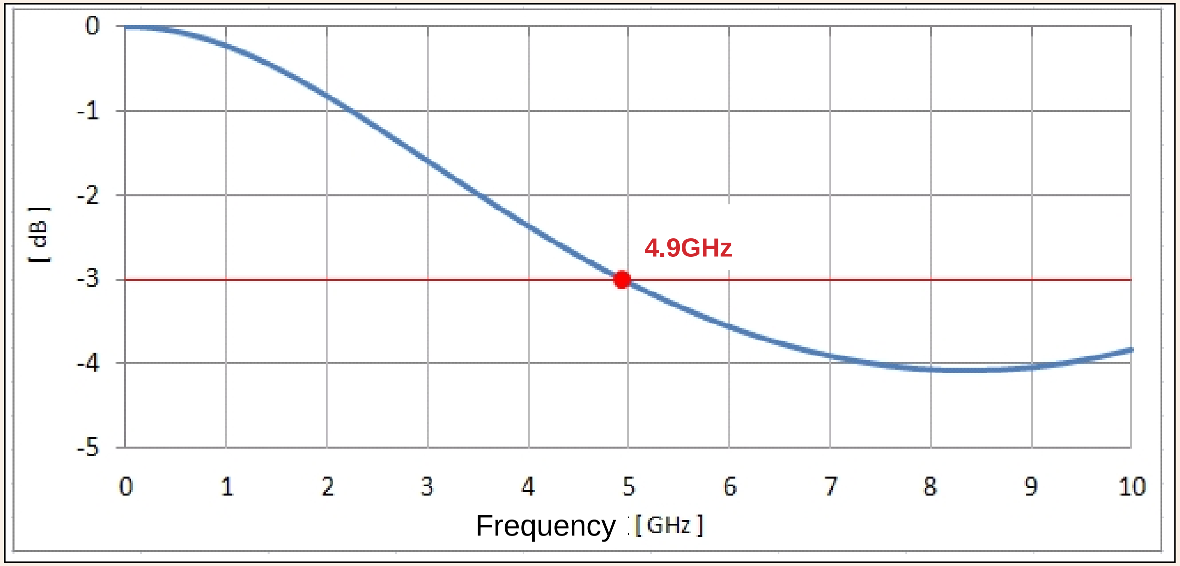
Performance Data – Frequency

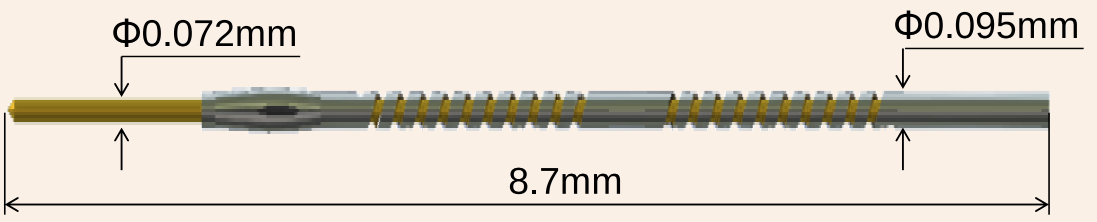
Test Condition

- S-G 160um
- SPICE simulation application
- Probe only simulation

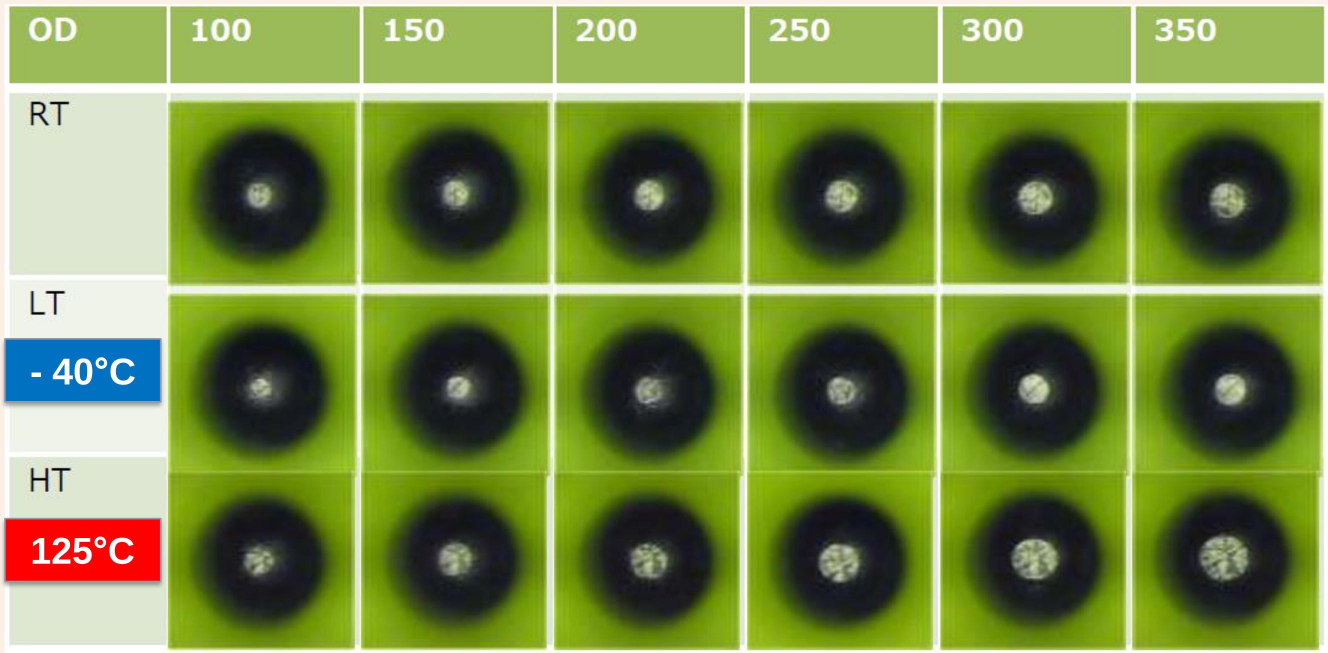
Test Result

- S21 (-3db, rectangular wave)
- 1.6GHz (=4.9GHz/3)





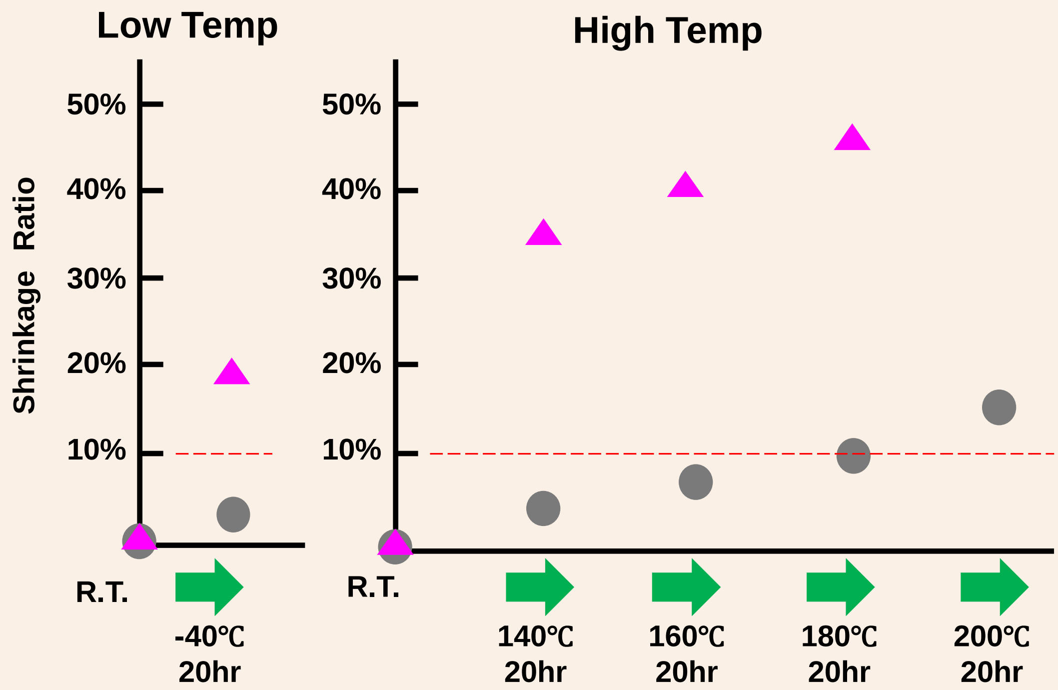
Performance Data – Probe Mark Bump Damage

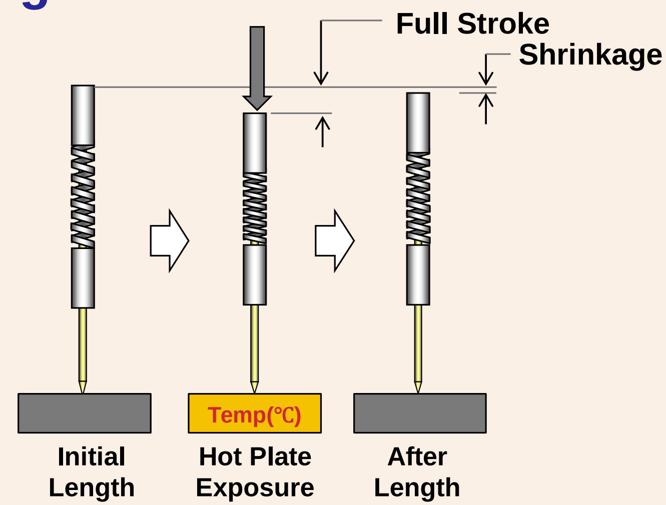


- Probe mark is smaller @ low temp but Cres remains stable
- Probe mark becomes larger @ high temp

Performance Data

Heat Resistant Ni Alloy Spring Material





▲ Standard Alloy
● High Temp Alloy

$$\text{Shrinkage Ratio} = \frac{\text{Shrinkage}}{\text{Full Stroke}}$$

**High Temp Alloy used for all data in this presentation*

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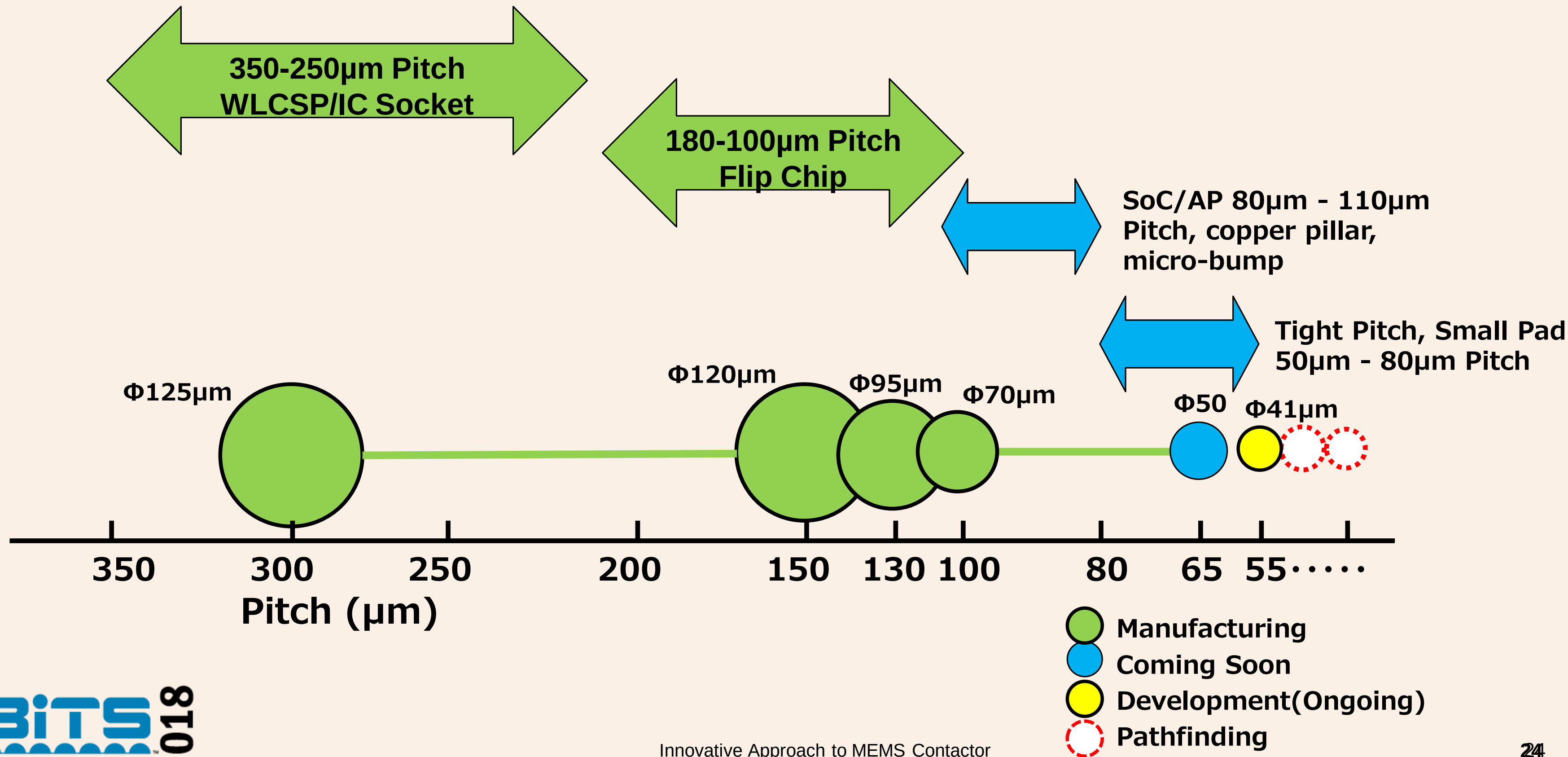
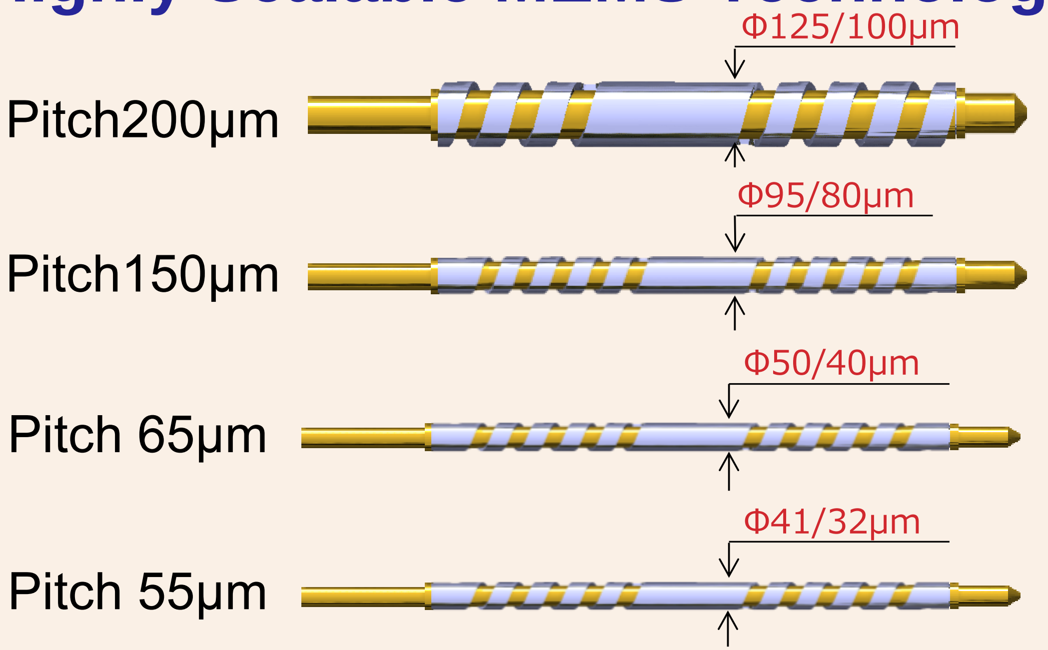
Technology Road Map



Technology Road Map
Highly Scalable MEMS Technology



With the same basic probe structure, it is easy to adapt design from wide pitch to narrow pitch

Conclusions

- The MEMS SPRING PROBE technology can easily provide small diameter probes that can not be realized with conventional coil springs
- Simple structure realizes high CCC and low CRES which is stable over life and temperature
- Minimize Bump damage by Rotation control and free tip shape
- Alloy material Spring can be used under high temperature
- Roadmap to 55 µm pitch
- Wide variety of pin specs achievable using common manufacturing process and no hard tooling