SWTEST

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2022 CONFERENCE

Introduction of New Probe, VPT (Vertical Probe Transformed)

Probe Innovation

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Outline of Presentation

1. Background and Goals
2. What VPT is. (VPT = Vertical Probe Transformed)
3. Grand Plan of VPT Development
4. Result of Study & Test
   4.1. Process Test and Data
   (Process Simulation, Process Data, BCF, CRes, CCC)
   4.2. Design Plan of "Smart Jig" to simplify VPT Process
   4.3. Data and Prospect of Automated Pins Inserting Test
5. Discussion/Development subject left
6. Summary

1. Background and Goals

(1) Background:

Innovative Concept "VPT" (Vertical Probe Transformed)

Born from several years of study on all kind of probes

Turned out to be the ultimate solution as High Performance, Long Probe life, and High Productivity are expected.

(2) Goals of development:

Verify following performances by data one by one and step by step

- Low CRes
- High CCC
- Good BCF
- Long Probe life
- High Productivity

2. What VPT is (Vertical Probe Transformed).

(1) Innovation in Concept

Straight pins are transformed
to curved probes inside jig
by simple buckling compression

Advantageous in
Full Array Fine Pitch

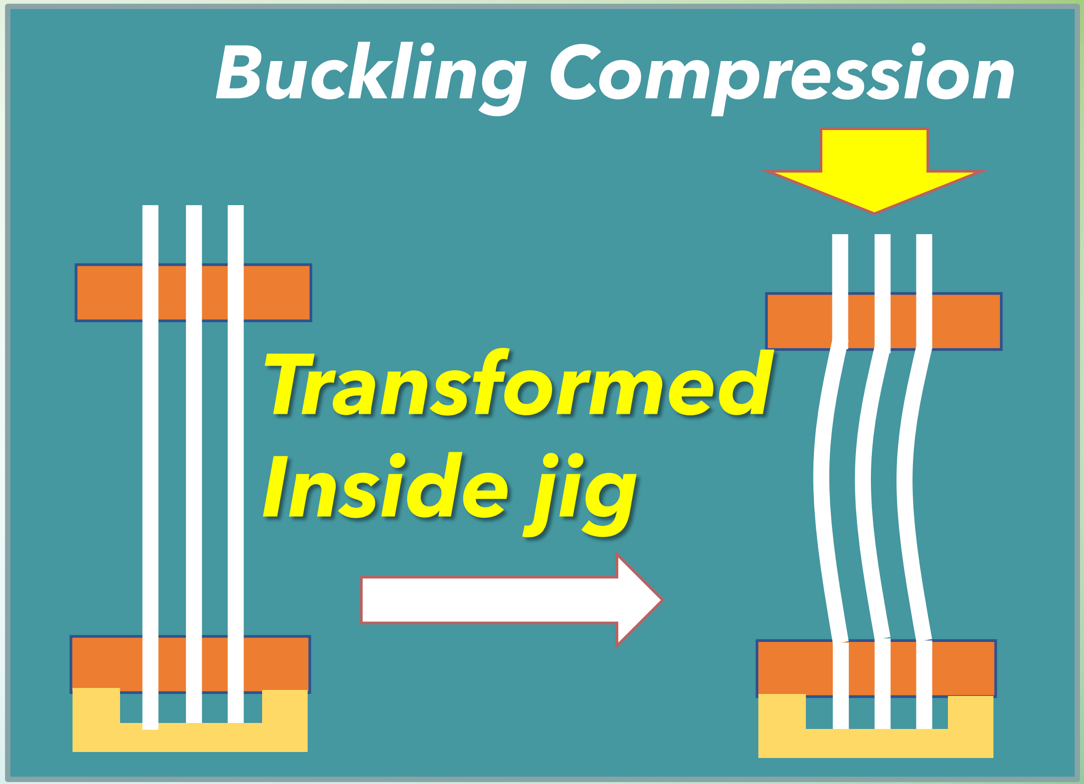


Figure 2-1 Concept Innovation

(2) Process Principle of VPT

USA patent proclamation finished

(1) Automated inserting of Straight Pins	(2) Shift of Lower Aperture Plate	(3) Buckling Compression	(4) Stress Release

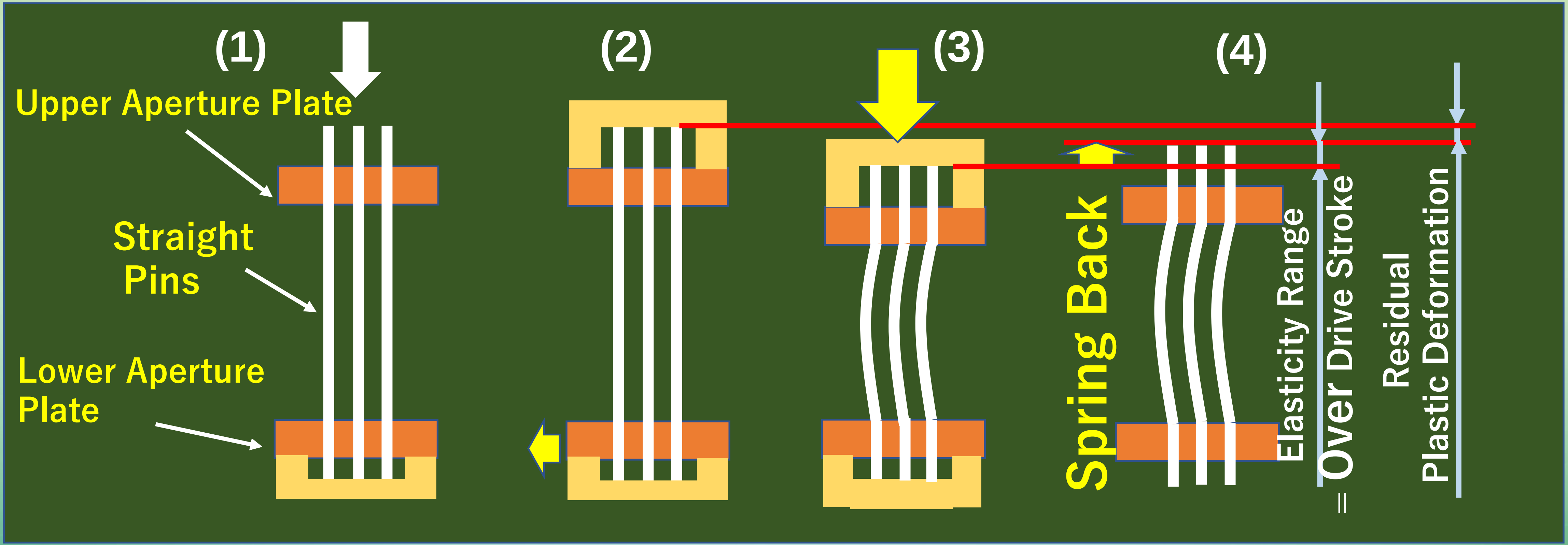


Figure 2-2 Principle of VPT Process

(3) Innovation in Probe Performance by VPT and Iridium

In VPT, Iridium is adopted as probe material.
Iridium is the best material which has excellent properties shown below.
Functional probe shape created by VPT Process and performance of Iridium bring innovative probe performance.

Properties of Iridium as probe material

① High CCC
② Low CRes
--- Sample data are shown in this presentation

③ Low affinity with probe material and Low cleaning frequency --- Basic data of affinity are shown in this presentation

④ High Elasticity, High Hardness, Low Resistivity --- Well known.

Why VPT is the only vertical probe to which Iridium is available?

Probe Type	Availability of Iridium
Cobra	**Unavailable** as micro-crack is caused in Iridium wire during press forming.
Wire Probe (Buckling Beam)	**Unavailable** as it has low flexibility in elastic deformation. Wire Probe has straight shape and Elasticity of Iridium is very high. So, wire probe made of Iridium has very high contact force unless it has long length.
MEMS	**Unavailable** as material loss of Iridium is very large in MEMS process.
Canti-lever probe	***Available.*** Canti-lever probe made of Iridium has achievements of long probe life such as 4 million T/D.
VPT	***Available.*** VPT has curved shapes made by bucking compression, and it has high flexibility in elastic deformation.

(4) Innovation in Probe Life

VPT will bring remarkable Probe Life.

1) Conventional probe materials have high affinity with lead-free solder. These materials require frequent tip cleaning using abrasive cleaning gel, which reduces probe life.

⇒ High Frequency of Tip Cleaning
⇒ Abrasive Cleaning Gel

Short Probe Life

2) Iridium has very low affinity with bump materials such as Copper or Lead-free Solder.

⇒ Low Frequency of Tip Cleaning
⇒ Non-Abrasive cleaning gel

Long Probe Life

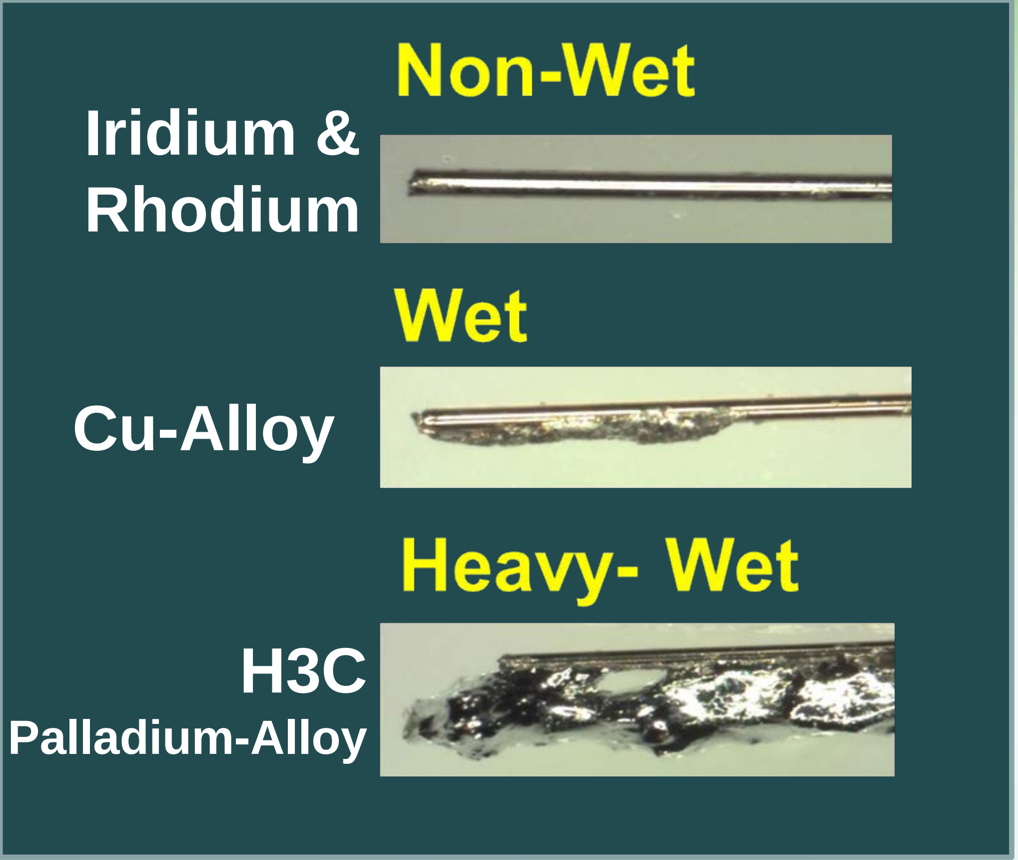


Figure 2-3 Solder Rubbing Test
Comparison Test Results of Affinity with lead-free solder

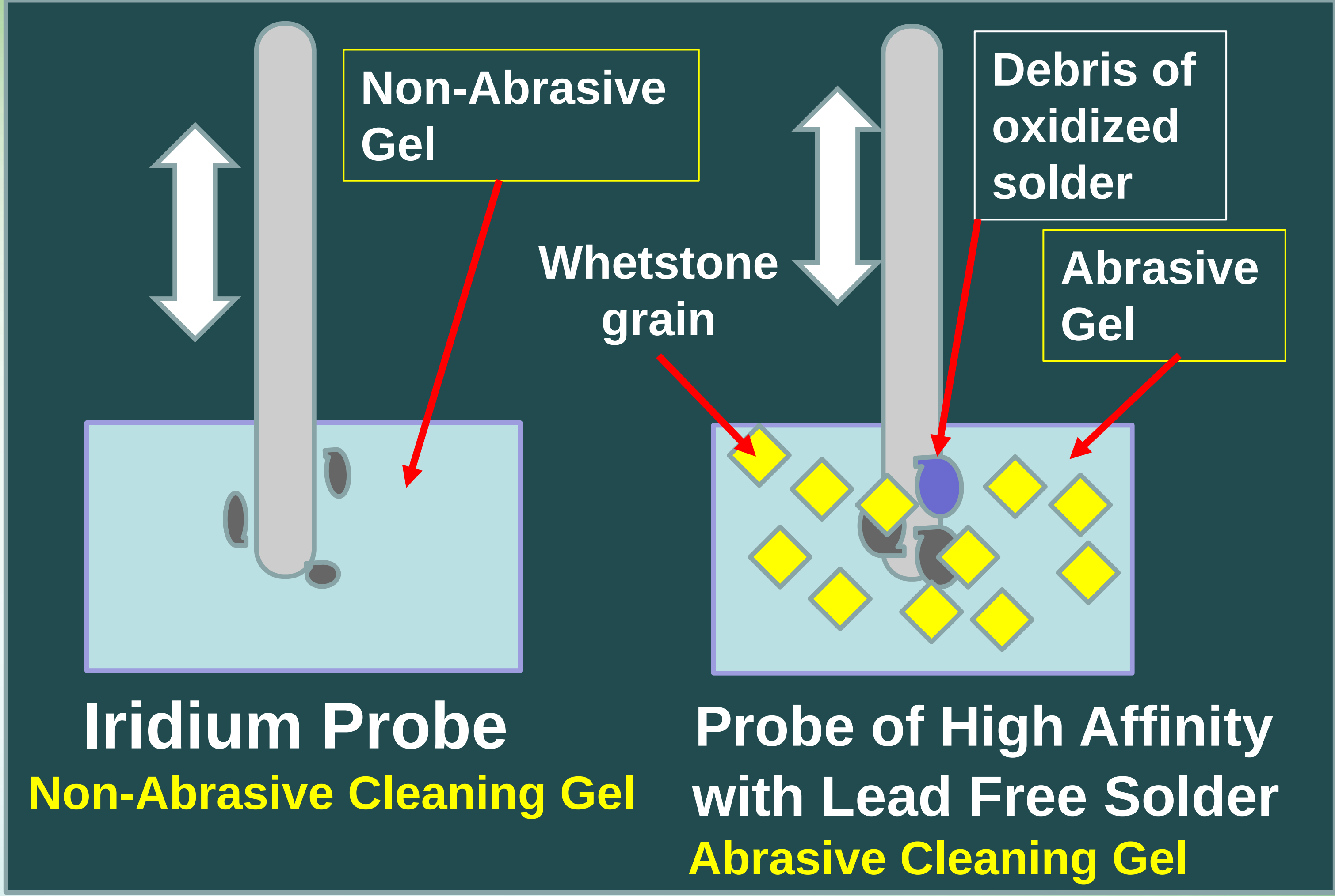


Figure 2-4 Illustration to explain Difference of Cleaning Gel depending on Affinity Level with Lead Free Solder

(5) Innovation in Productivity

VPT will bring two Innovation in Productivity.

① Assembly Innovation ⇒ ***Automated Pins Inserting*** to Aperture Jig

② Facility Innovation ⇒ VPT Process has been simplified by ***Smart Jig***

In VPT manufacturing, no need for expensive facility!

Two Innovations in Productivity are shown from next page:

① Assembly Innovation ⇒ ***Automated Pins Inserting*** to Aperture Jig

Here outline of Automated Inserting is explained.
Test result is shown later.

(1) Straight pins are inserted in the multiple guide holes and vertical vibration is given to straight pins.
(2) Pins are inserted to upper aperture and lower aperture by vertical vibration.

Figure 2-5 shows the principle of automated pins inserting.

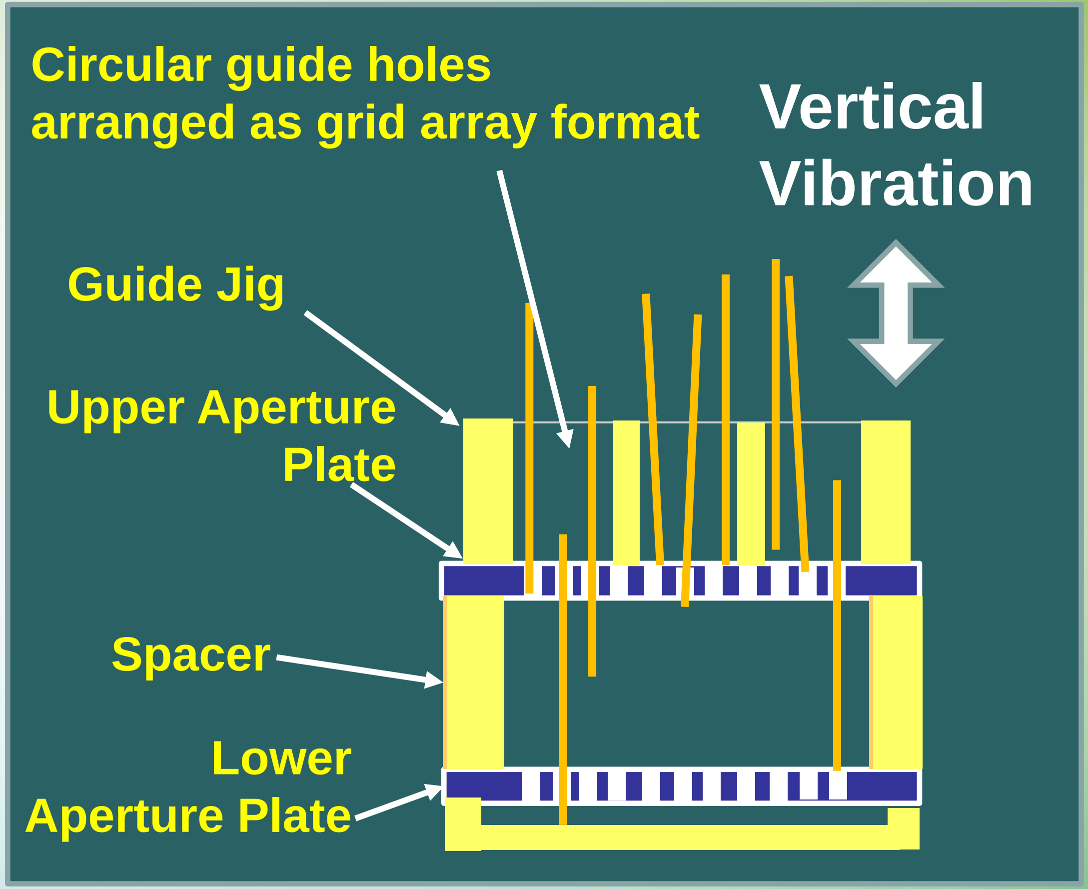


Figure 2-5 Principle of Automated Pins Inserting

As guide for pins, Grid Array of Guide Holes has blind spots to cover all apertures.

To cover blind spots, as re-trial, grid array is moved, and pins inserting is repeated.

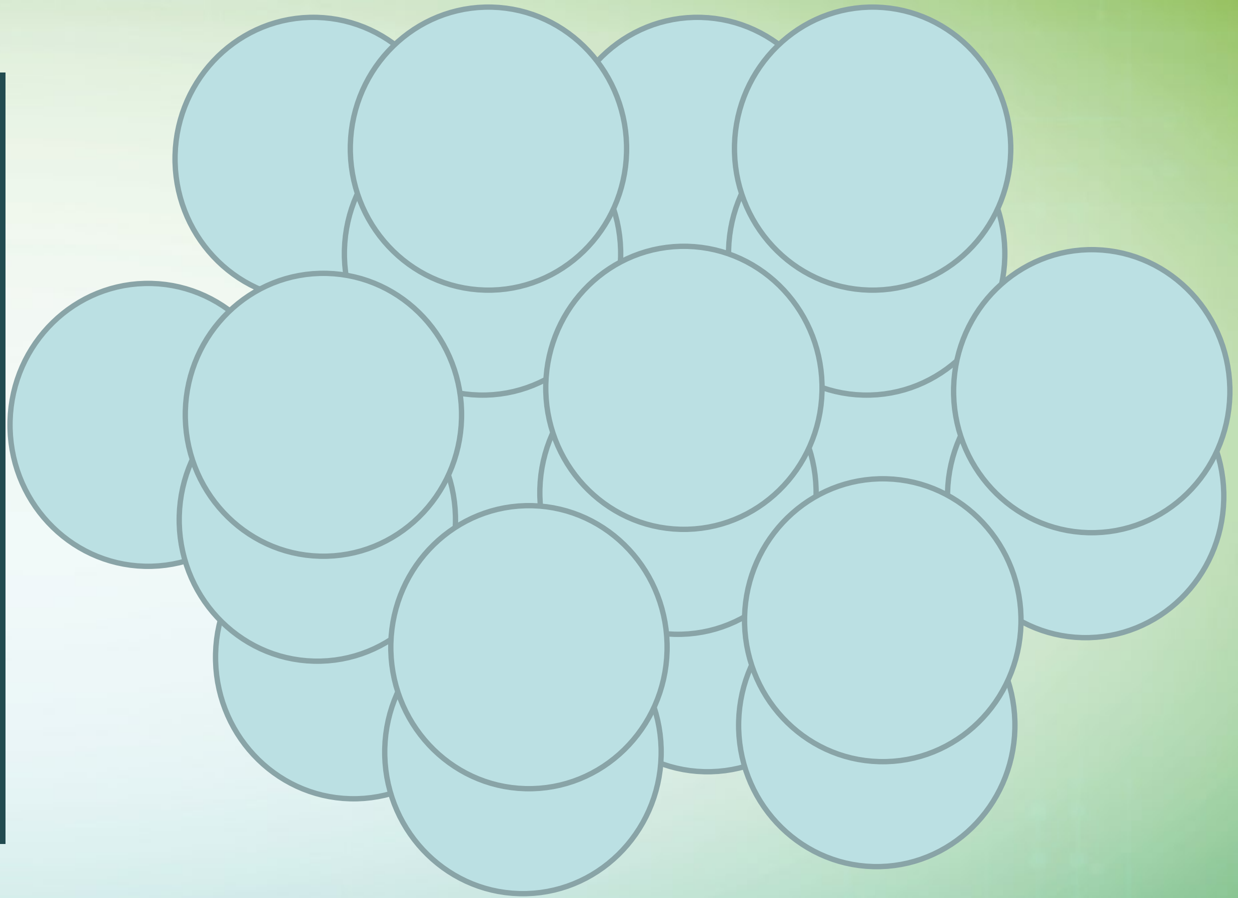


Figure 2-6 Retrials of Pins Inserting

② Facility Innovation ⇒ VPT Process has been simplified by *Smart Jig*

Patent application finished

Figure 2-7 shows upper view of Smart Jig.

In Figure 2-7, only one chip area is shown. But Smart Jig is available to multiple chips inspection by expanding chip area.

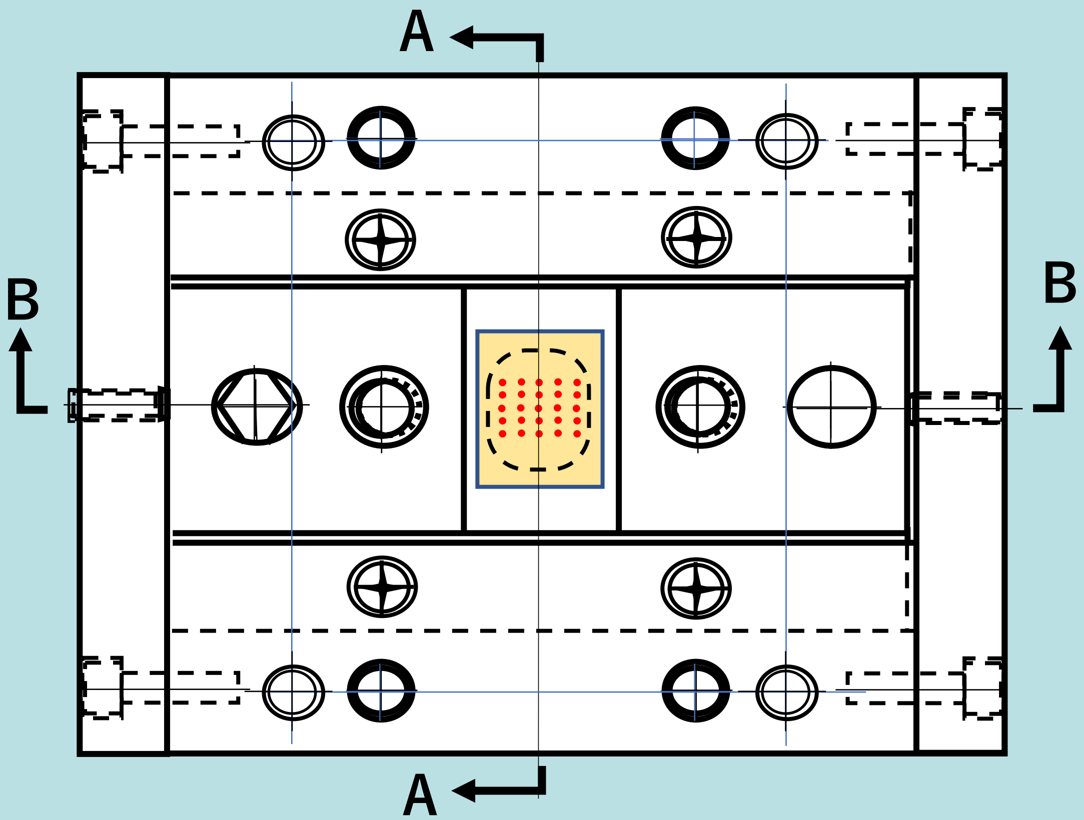


Figure 2-7 Upper View of Smart Jig

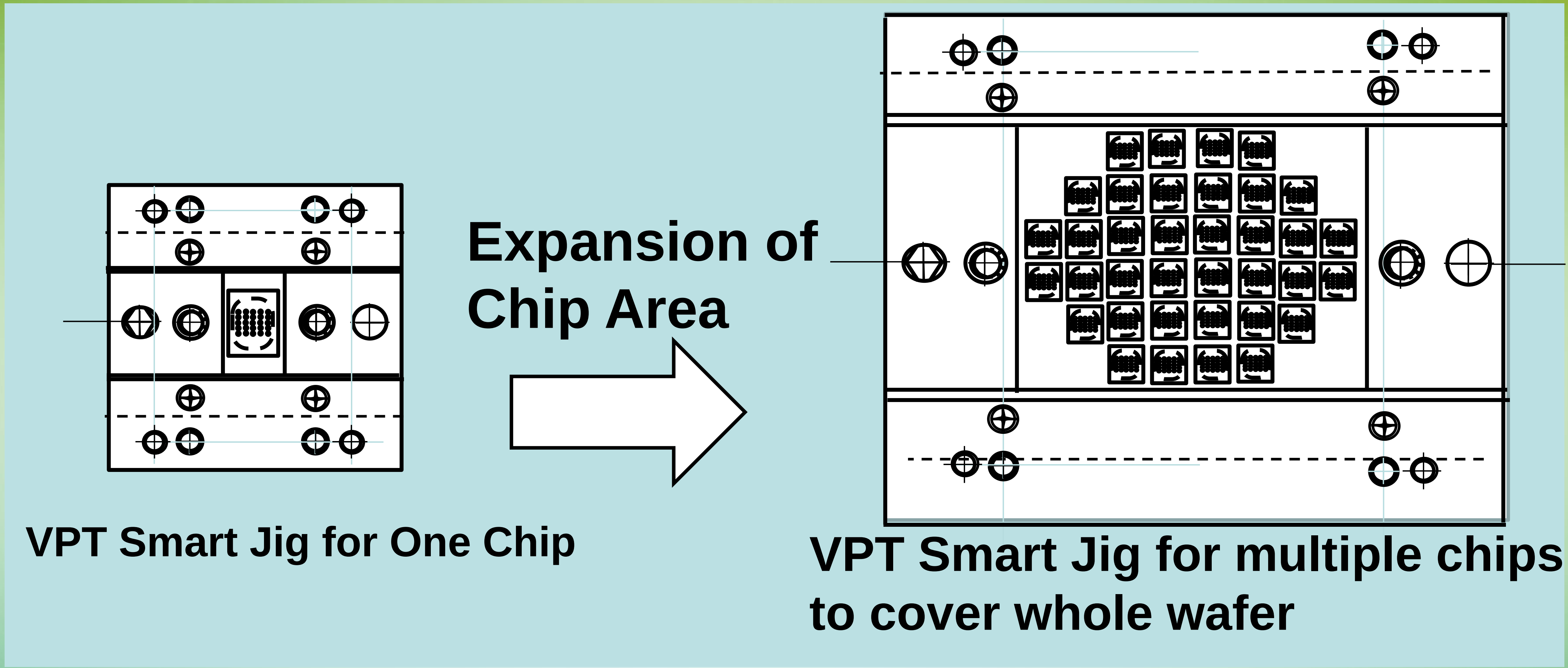


Figure 2-8 Expandability of VPT Smart Jig in Chip Area

As the start of VPT Process in Smart Jig, Figure 2-9 shows the process of positioning of both upper and lower Smart Jig.

Locating Pins are inserted and pierce upper and lower apertures.

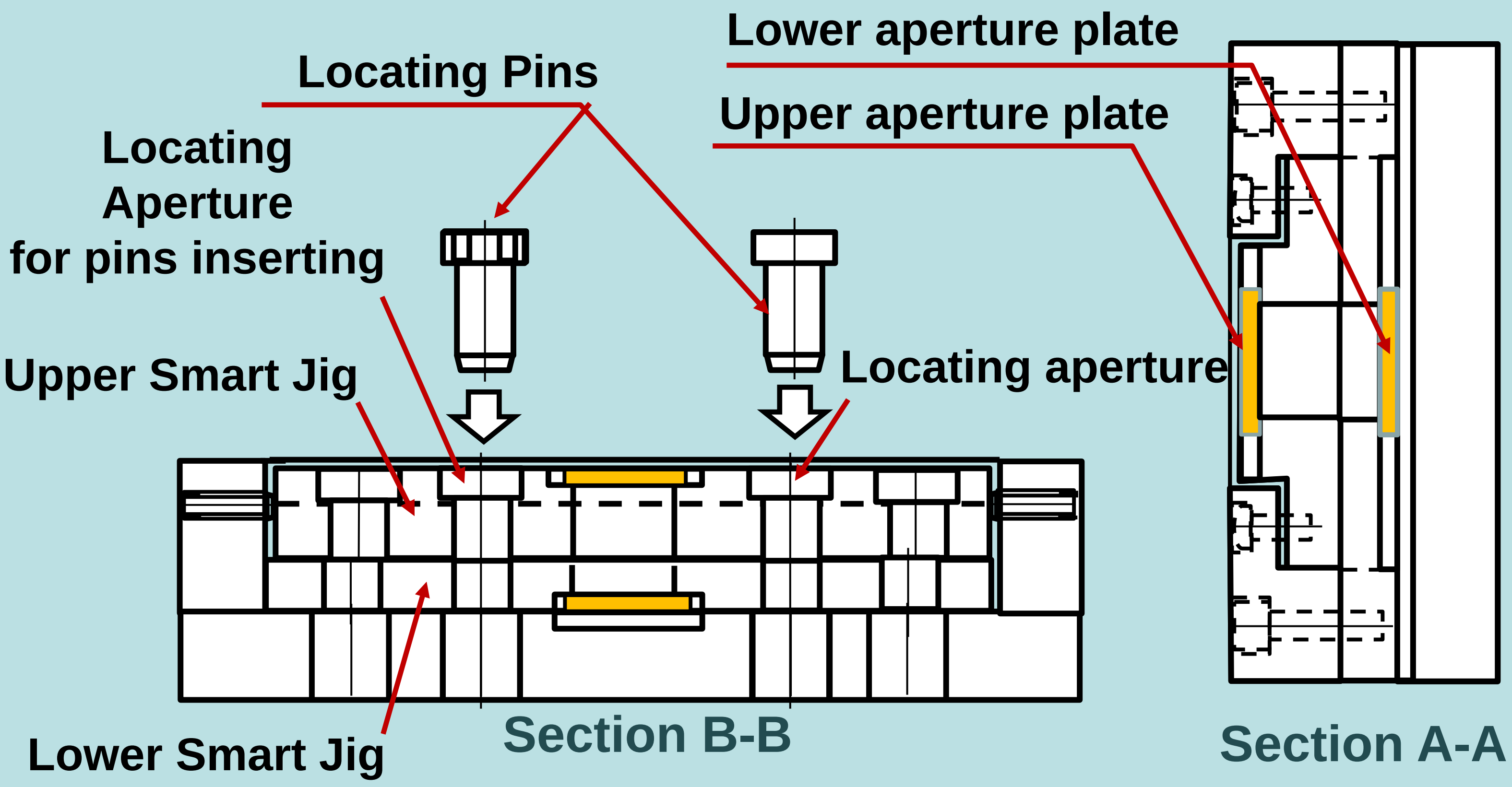


Figure 2-9 VPT Process by Smart Jig (Inserting Locating Pins)

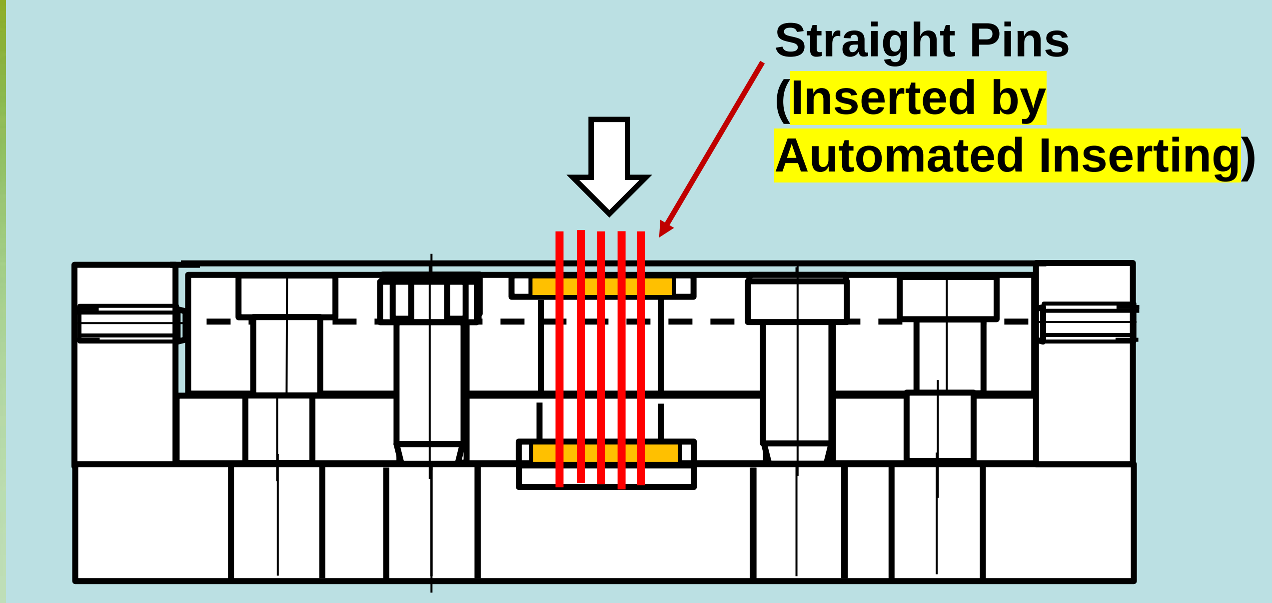


Figure 2-10 VPT Process by Smart Jig
(Inserting Straight Pins)

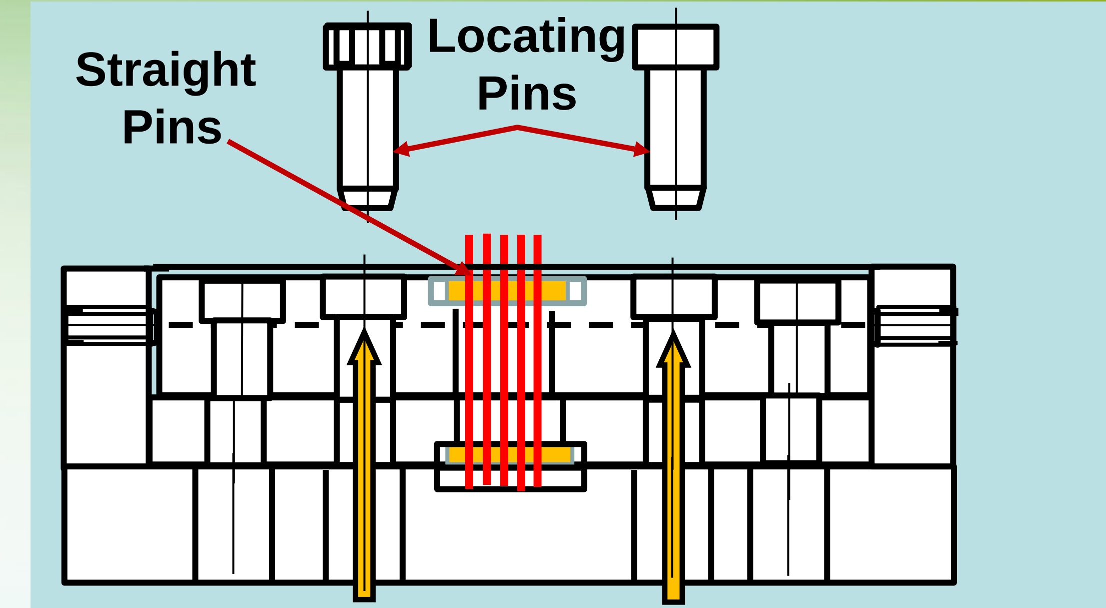


Figure 2-11 VPT Process by Smart Jig
(Locating Pins are picked out.)

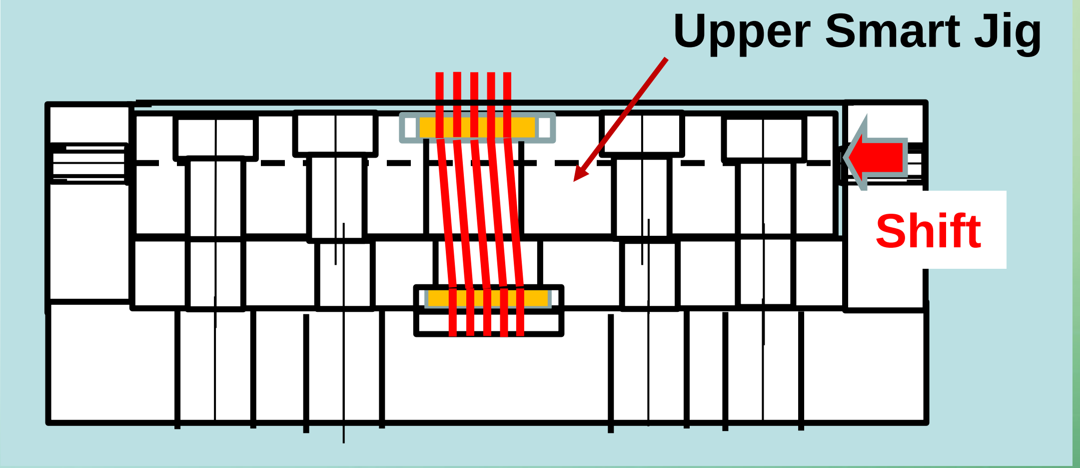


Figure 2-12 VPT Process by Smart Jig
(Upper Smart Jig is shifted.)

In Figure 2-10, straight pins are inserted to Smart Jig.

In Figure 2-11, after inserting straight pins, locating pins are pushed out.

In Figure 2-12, upper Smart Jig is shifted to the direction of red arrow.

In Figure 2-13, locating pins are inserted to Smart Jig to position the upper and lower Smart Jig.

In Figure 2-14, straight pins are given Buckling Compression.

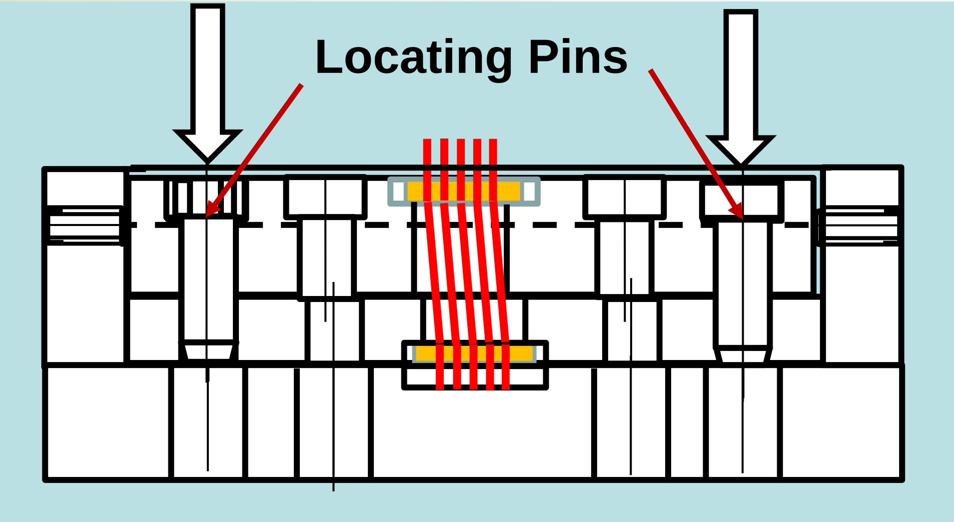


Figure 2-13 VPT Process by Smart Jig
(Locating Pins are inserted for final location.)

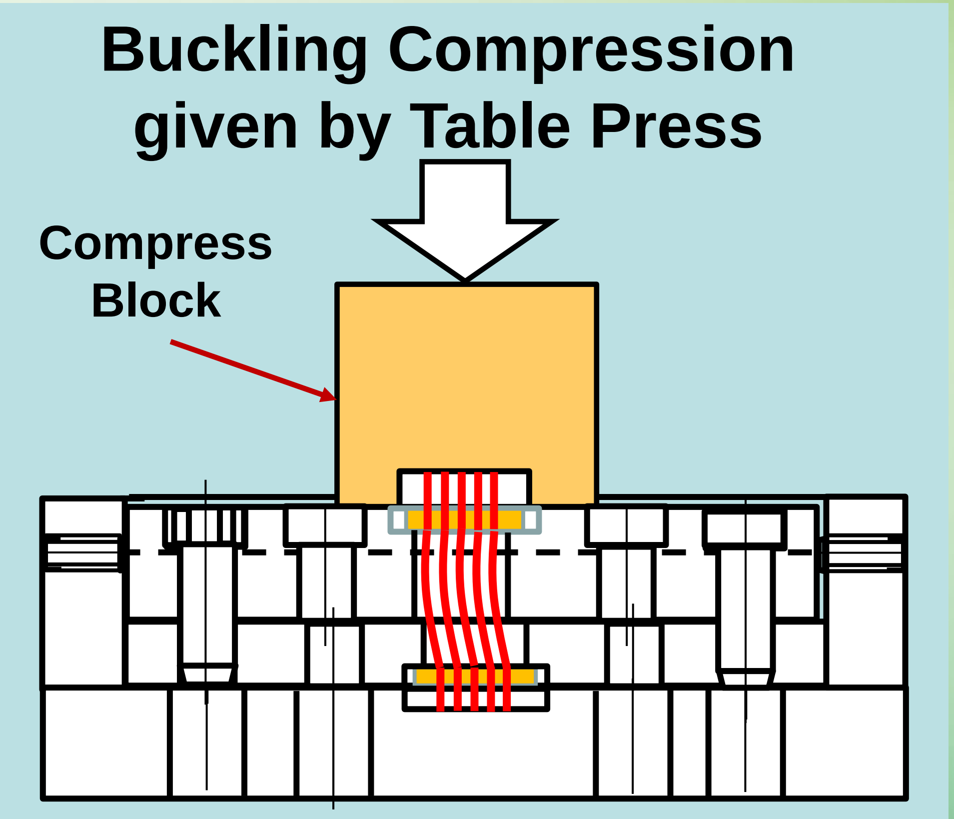
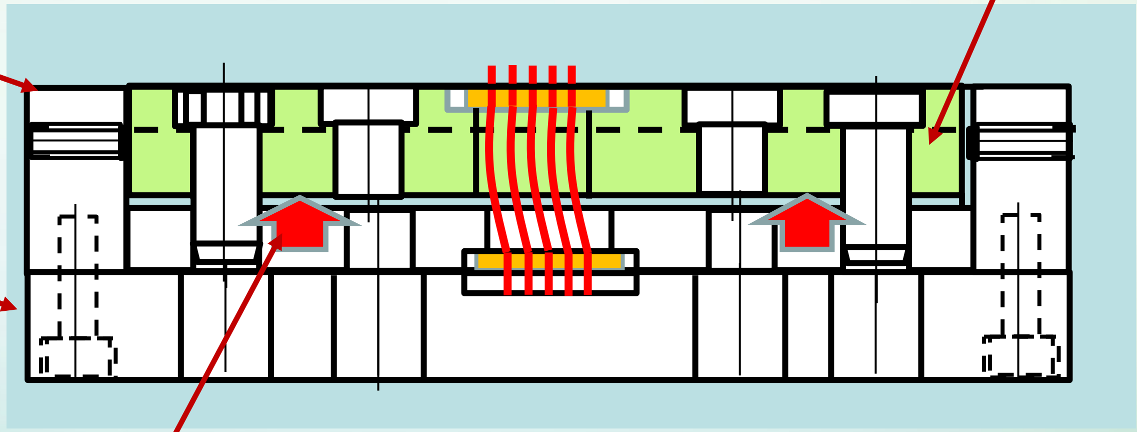
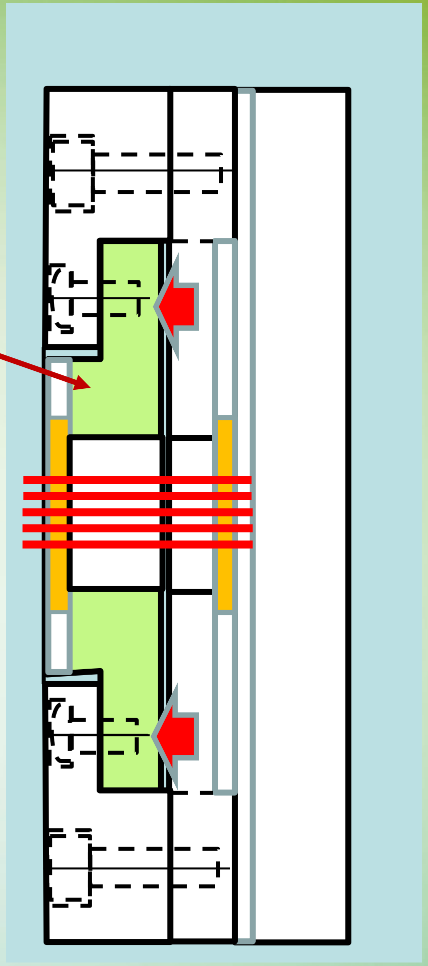


Figure 2-14 VPT Process by Smart Jig
(Buckling Compression is given to straight pins.)

In Figure 2-15, Upper Smart Jig is lifted, and elastic strain in VPT probes are released.





Upper Smart Jig is lifted, and elastic strain in VPT probes are released.

Figure 2-15 VPT Process by Smart Jig
(Residual Elastic Strain is released by Spring Back.)

3. Grand Plan of VPT Development

1st Step (at present)

- (1) VPT Process Test by Φ30μ pins
- (2) Automated Pins Inserting Test by Φ30μ pins
- (3) Insulating Coating Test (Parylene Coating to pins)

2nd Step (～2022/10)

- (4) Durability Test by jig of pitch 50μ x Φ30μ x 10x10=100 pins

3rd Step (～2023/2)

- (5) Durability Test by jig of pitch 40μ x Φ20μ x 10x10=100 pins
- (6) Development of Repair Equipment (Manually Operated)
- (7) Sales Start of Probe Head Jig <5,000 pins

4th Step (2023/9～2025/9) Applying Japanese government subsidy system

- (8) Development of Probe Head of large pin number (>20,000)
- (9) Development of Repair Equipment (Semi Automated Type)
- (10) Probe Life Comparison Test (by Joint Study with university)

4. Test and Result in 1st Step

4.1. Process Test and Data (VPT Process, BCF, CRes, CCC)

Photo 4-1 shows Appearance of VPT Process Test Equipment.

① One Iridium pin is inserted through upper- and lower-aperture plate.
② Lower-aperture plate is shifted by X-axis.
③ Buckling compression and release of load is given by Z1-axis.
④ In BCF measurement, Contact Force is given by Z2 Axis and detected by Load Cell.

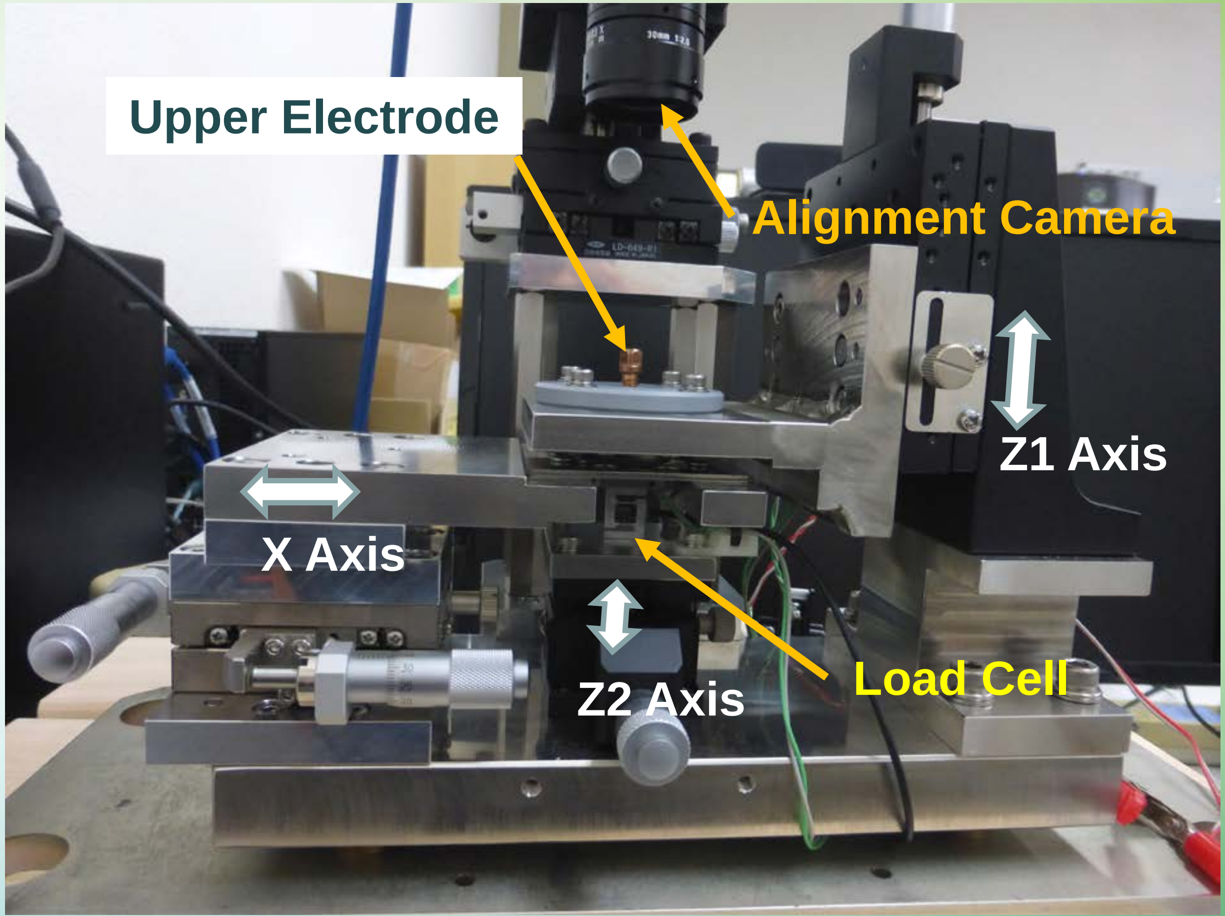


Photo 4-1 Appearance of VPT Process Test Equipment

(1) Process Test and Data: Process Simulation

In advance of VPT Process Test, computer simulations were required to estimate the test conditions such as Contact force/Over Drive.

In computer simulation model, there are two kind of model, Linear Model and Non-Linear Model. If precise analysis is required, Non-Linear Model is better including plastic deformation, but additional data is necessary.

This time, we adopted Linear Model.

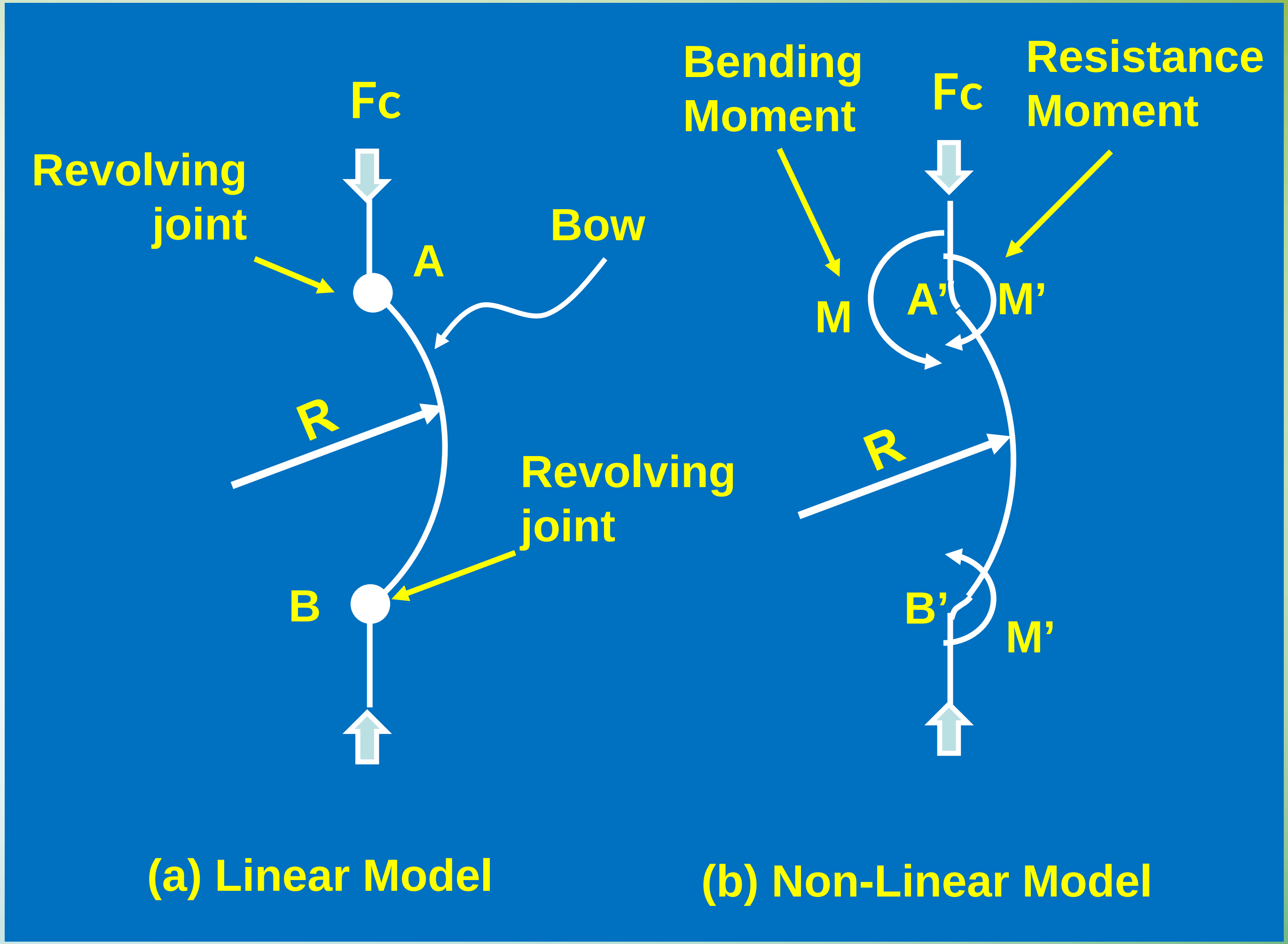
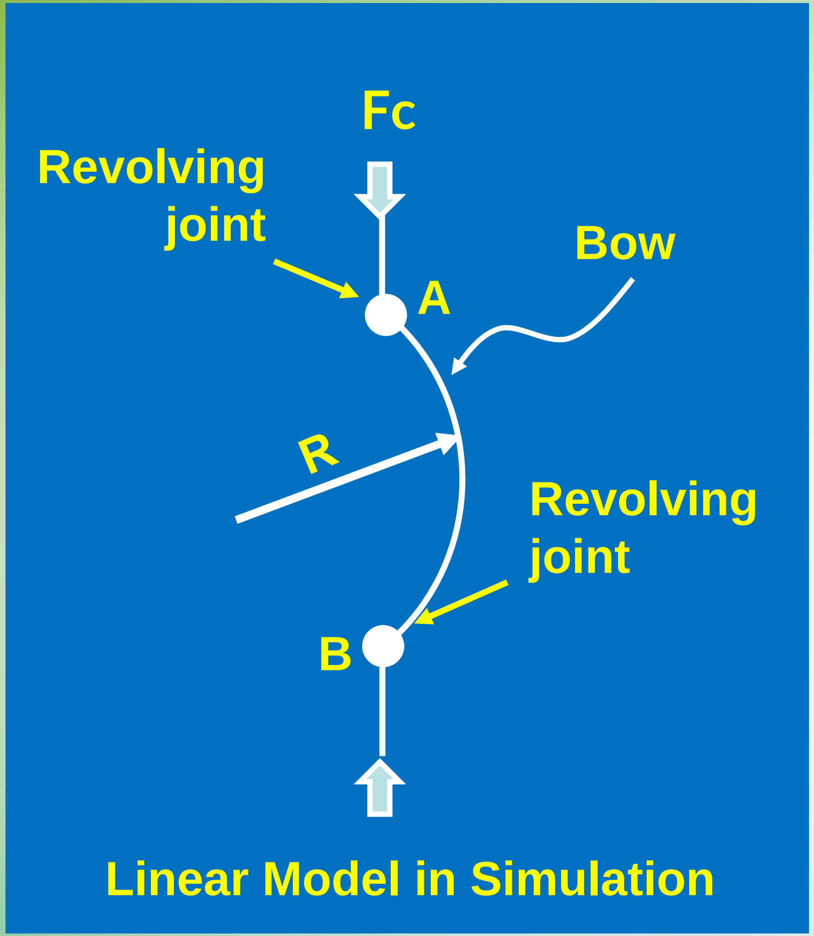


Figure 4-1 Linear and Non-Linear Model of VPT Process Simulation



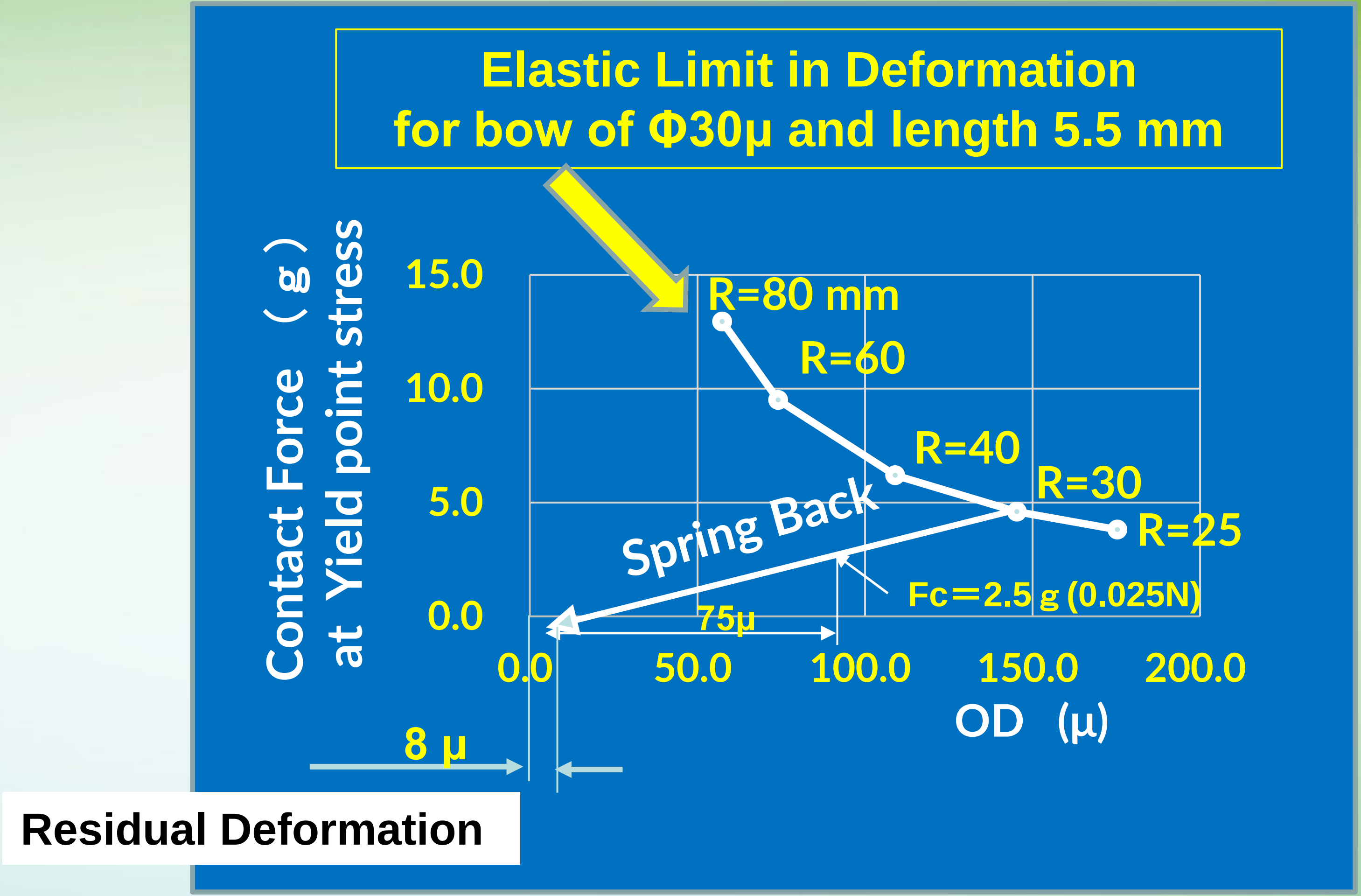


Figure 4-2 Simulation Result by Linear Model

(2) Process Test and Data: Process Data and BCF

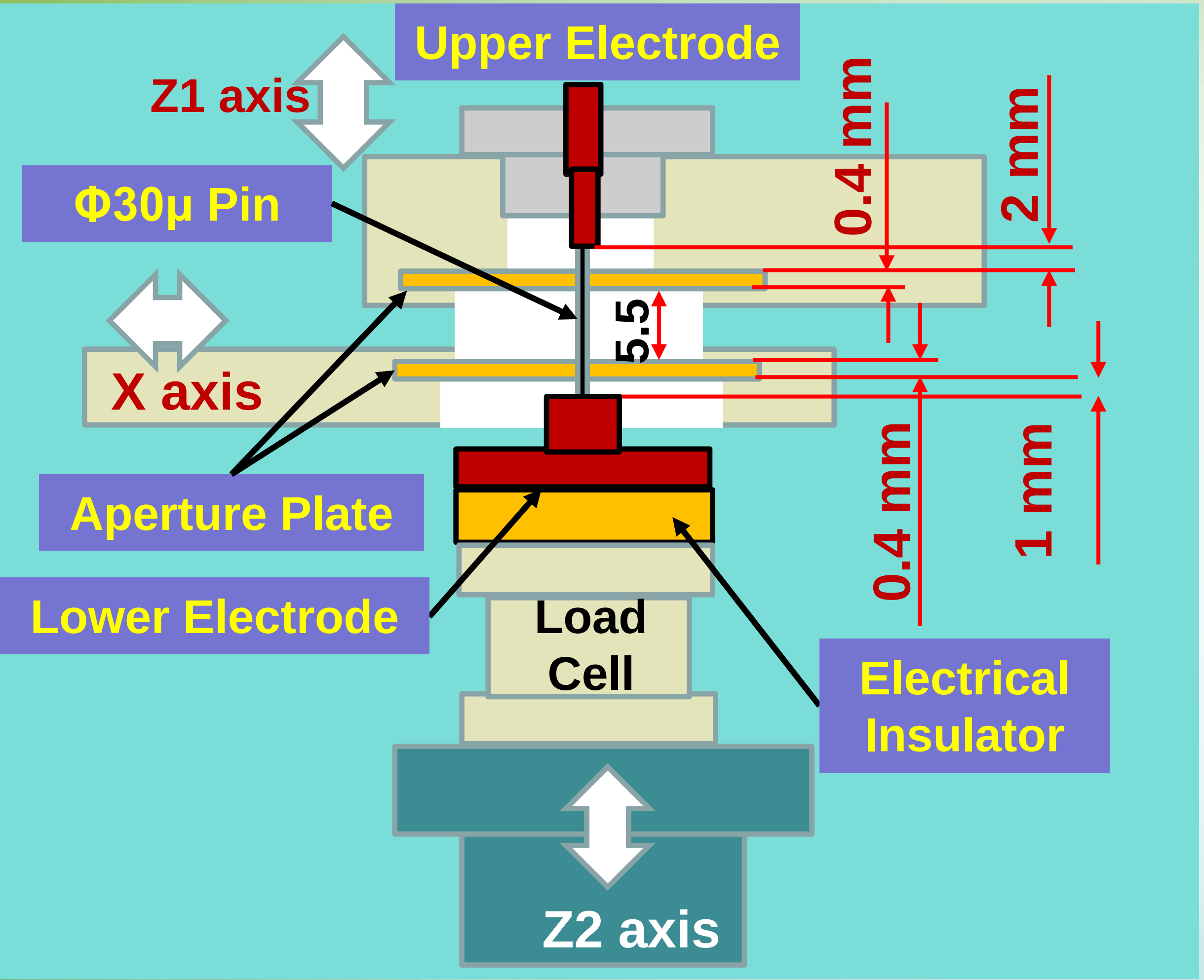


Figure 4-3 Composition of the VPT Process Test device

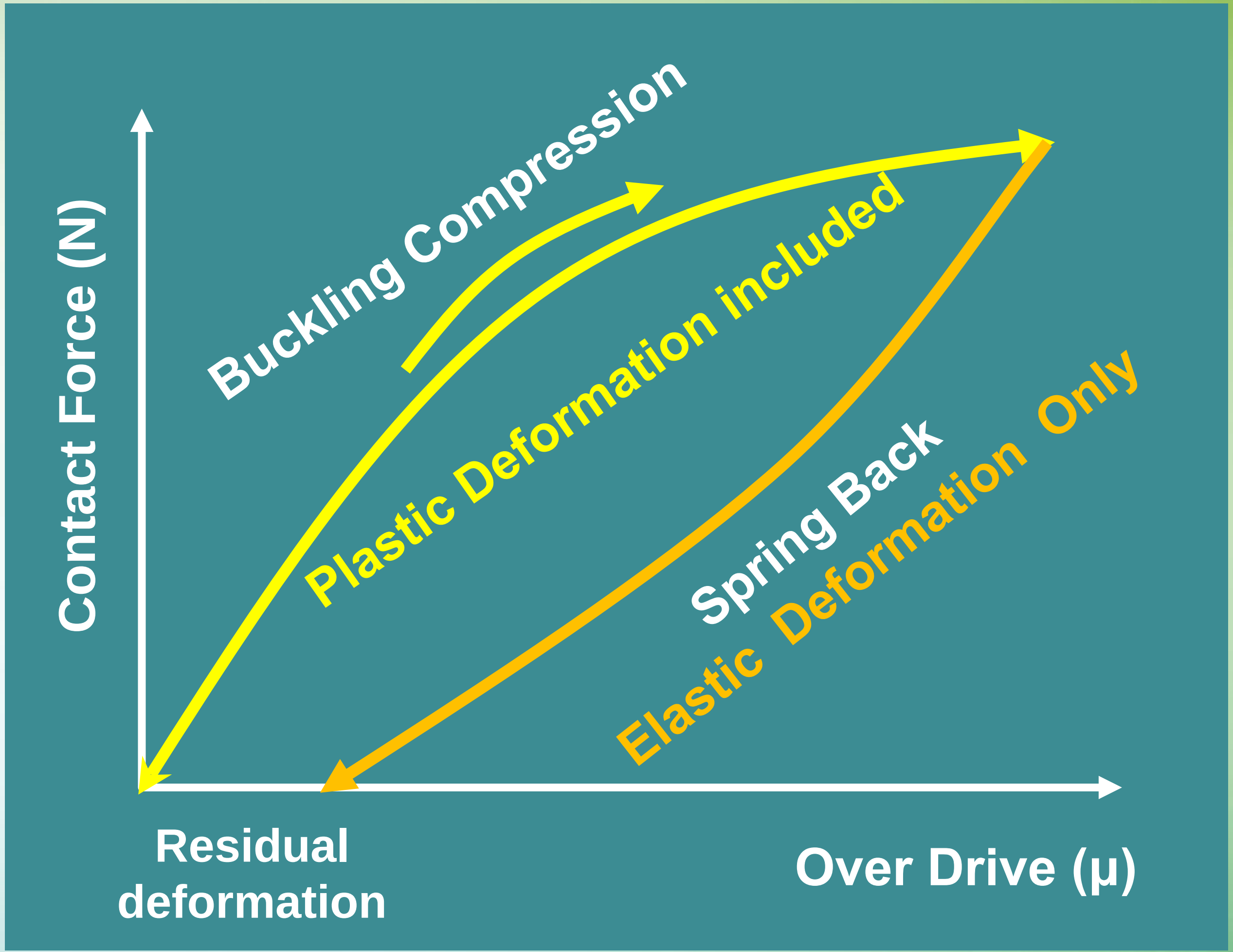


Figure 4-4 Typical Pattern of Contact Force/Over Drive During VPT Process

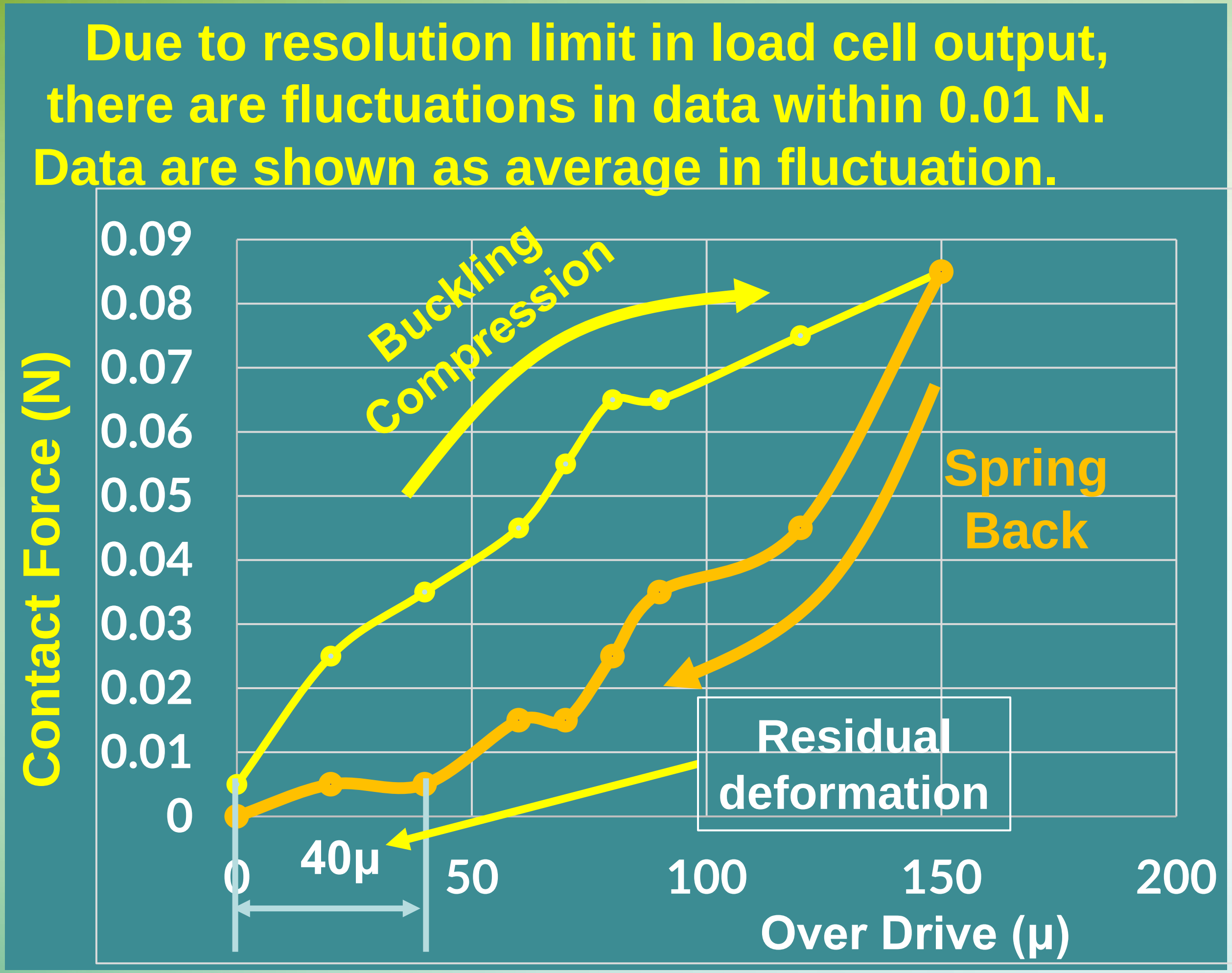


Figure 4-5 Round Trip Raw Data of Contact Force/Over Drive During VPT Process

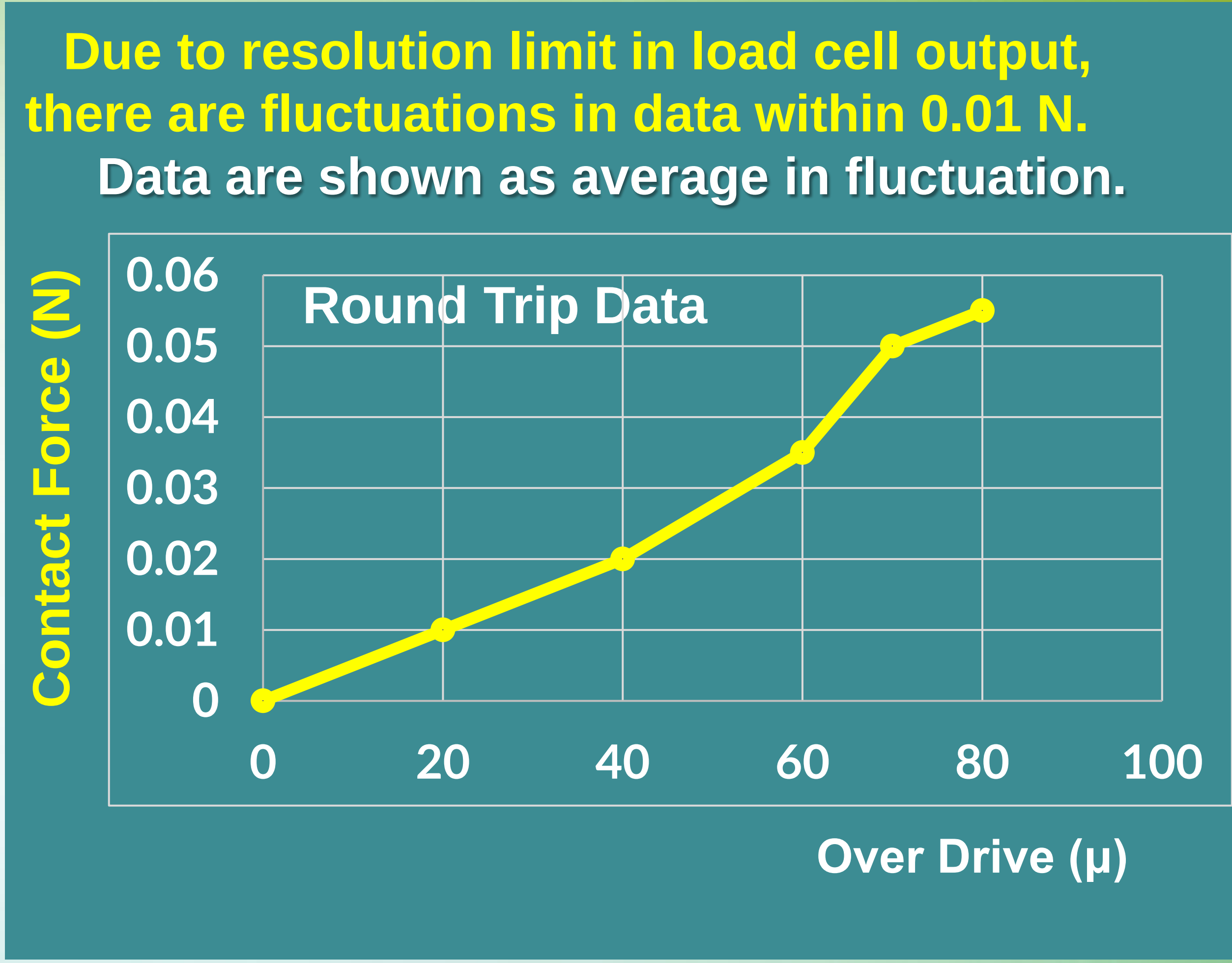


Figure 4-6 Typical BCF Data

(3) Process Test and Data: CRes (Contact Resistance)

Contact resistance of two points, upper electrode and lower electrode

Pin Material	Circuit Resistance R=V/I (Ω)	Resistance (Ω) of wire Φ30μ x 9.2mm at Room 21.2℃	CRes (Ω)
Iridium	0.21V/ 0.099A =2.12 Ω	0.680	1.44
Rhenium Tungsten	0.12V/ 0.051A =2.35Ω	1.25	1.1

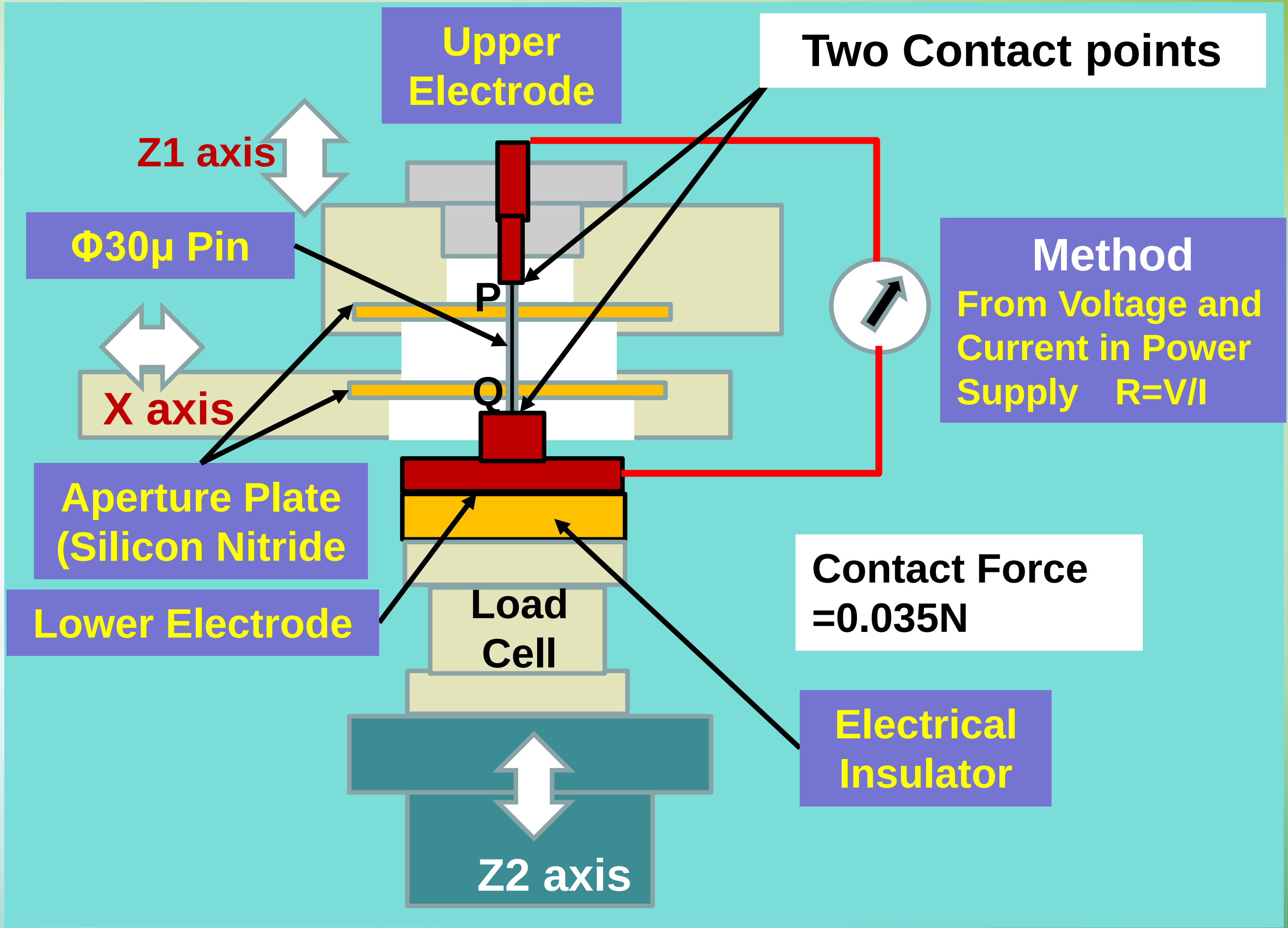
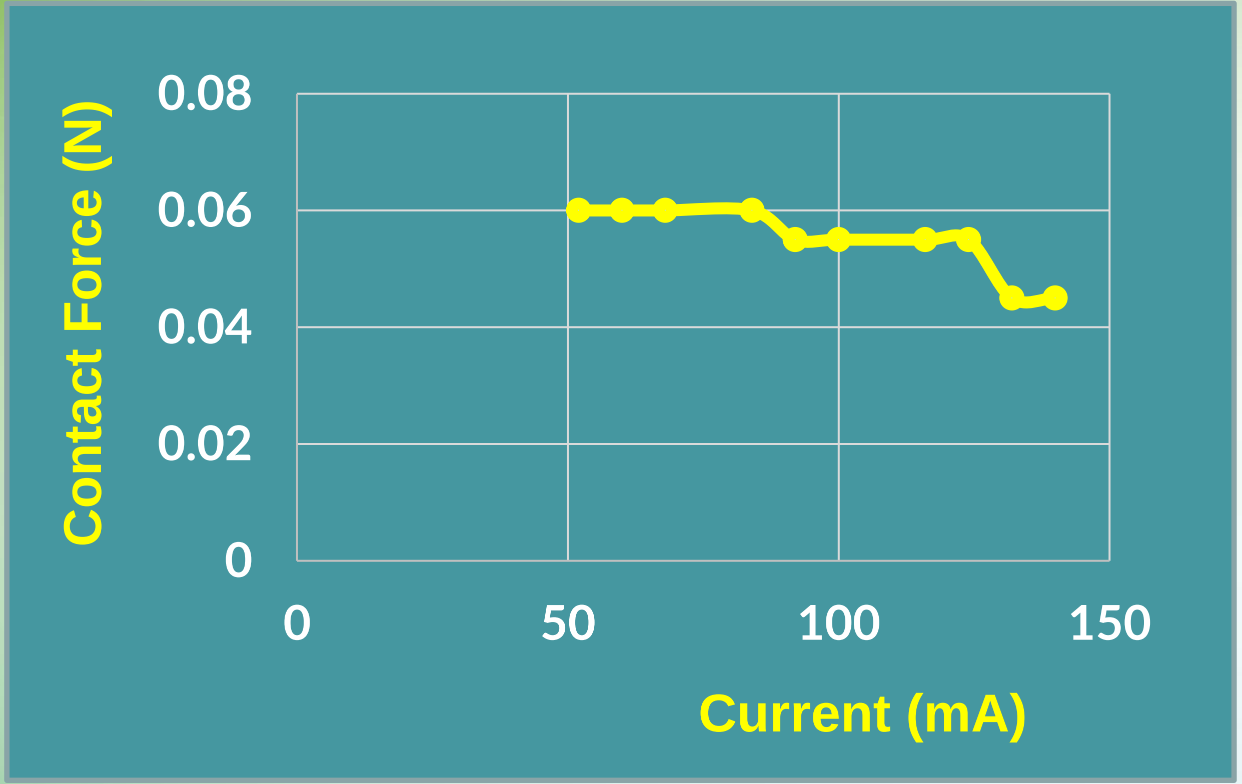


Figure 4-7 Method to get Data of Typical CRes

(4) Process Test and Data: CCC (Current Carrying Capability)



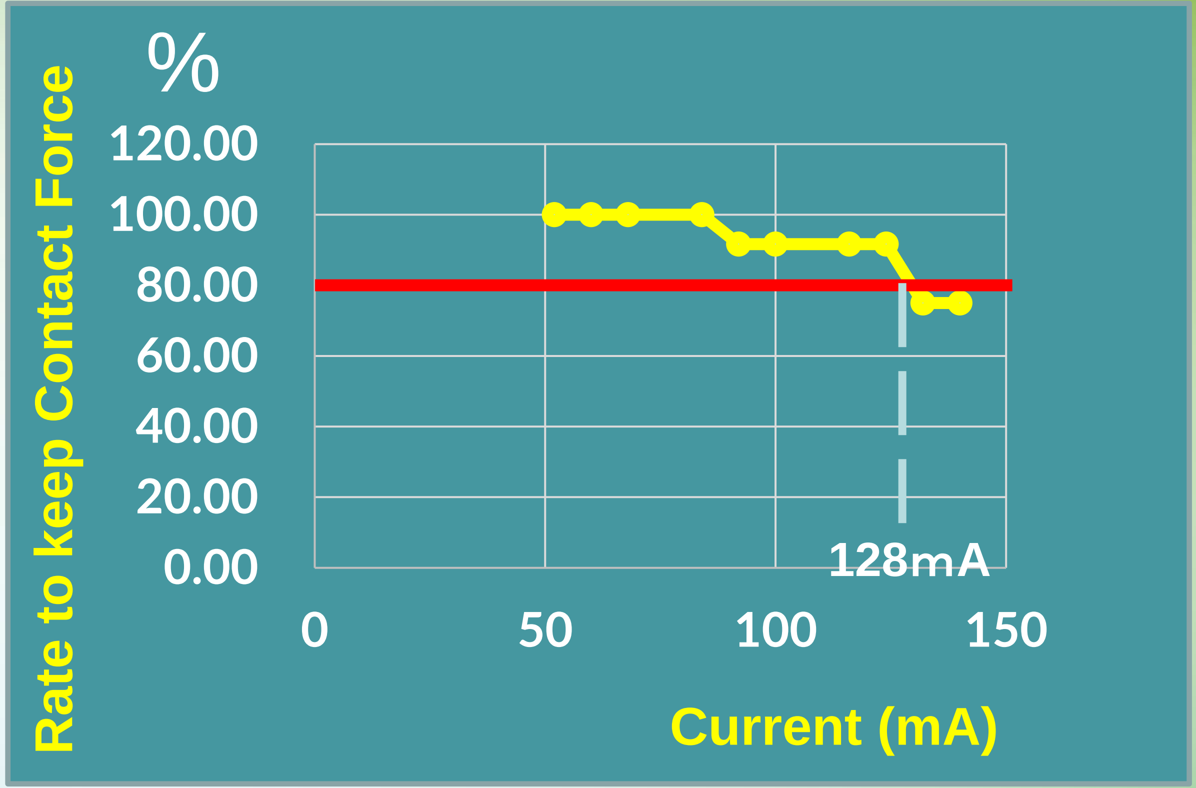


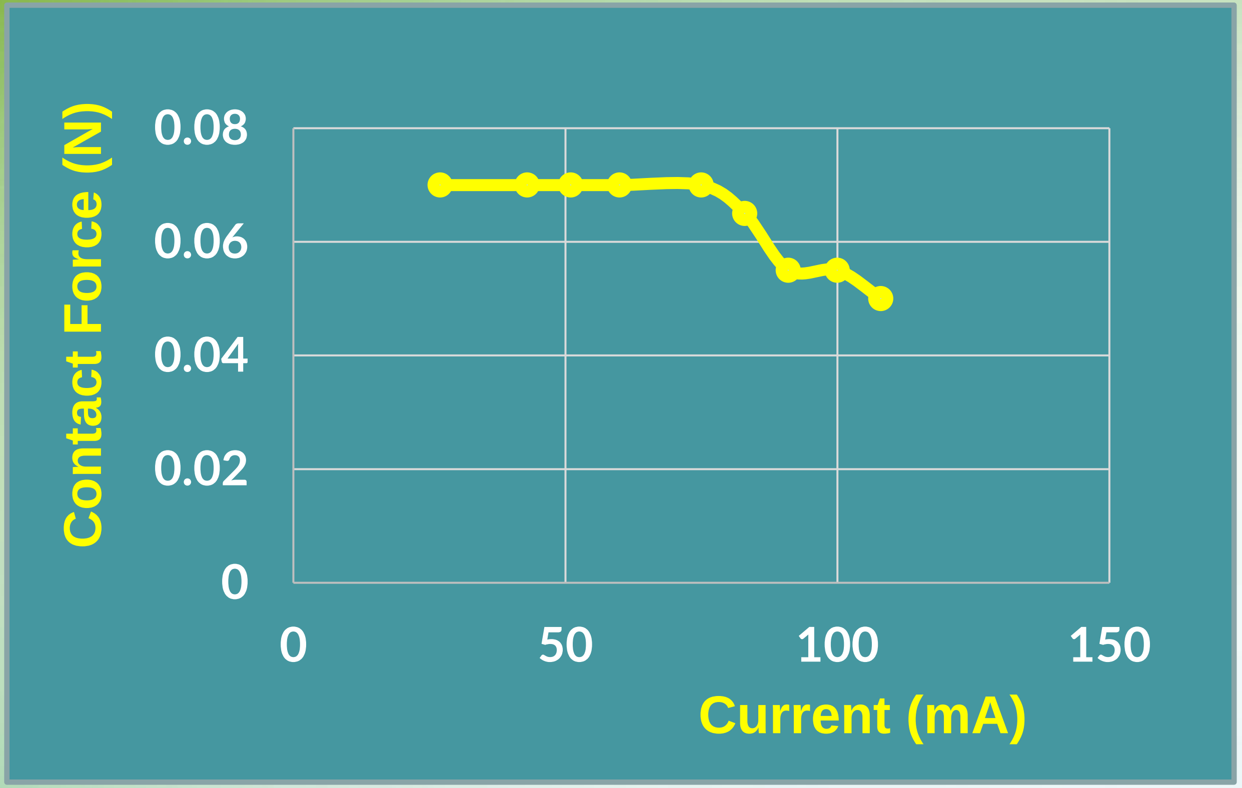
Figure 4-8 Data of CCC
: Φ30μ, Iridium

Followed strict ISMI Procedure

Current Input two minutes → Current Input two minutes → Current Input two minutes →

Current Cut for **10 seconds** and Check Contact Force

Current Cut for **10 seconds** and Check Contact Force



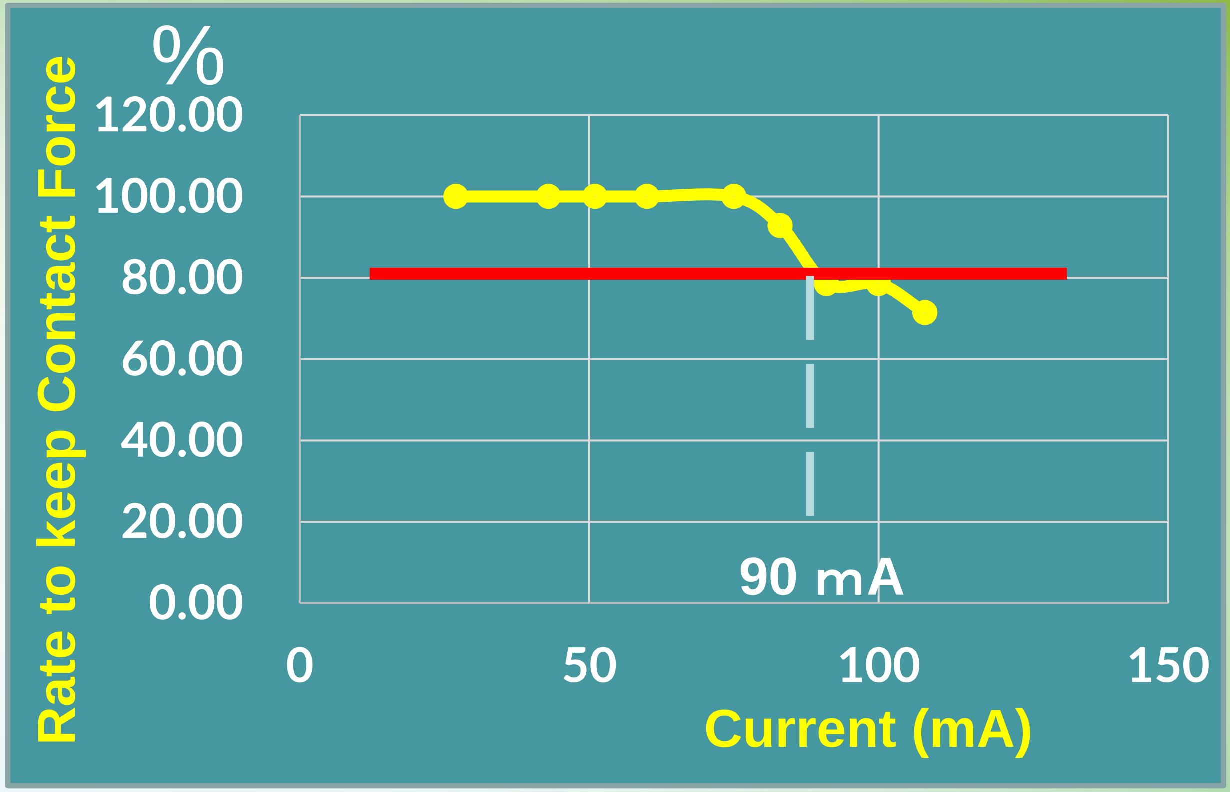


Figure 4-9 Data of CCC
: Φ30μ, Rhenium Tungsten

Followed strict ISMI Procedure

Current Input two minutes → **Current Input two minutes** → **Current Input two minutes** →

Current Cut for 10 seconds and Check Contact Force

Current Cut for 10 seconds and Check Contact Force

4.2. Automated Pins Inserting Test, data and prospect

The test of Automated Pins Inserting was done with the help of IDEX CO., LTD in Japan.
Table 4-1 shows the test conditions and results. (When you ask IDEX, ask by email not by phone.)

From these test results, analysis and prospect to successful pins inserting have been brought in next page.

Table 4-1 Test conditions and results of Automated Pins Inserting

Photo NO.	Test conditions	Test Results
Photo 4-2	Apertures to be inserted: Pitch 0.050mm x 256 apertures (16x16) of diameter Φ0.035 mm	
Photo 4-3	Pins Inserting for Φ30 μ x 256 pins	Pins of 100% pierced upper apertures, but pins of 31% did not pierce lower apertures.

Apertures to be inserted: Pitch 0.050mm x 256 apertures (16x16) of diameter Φ0.035 mm

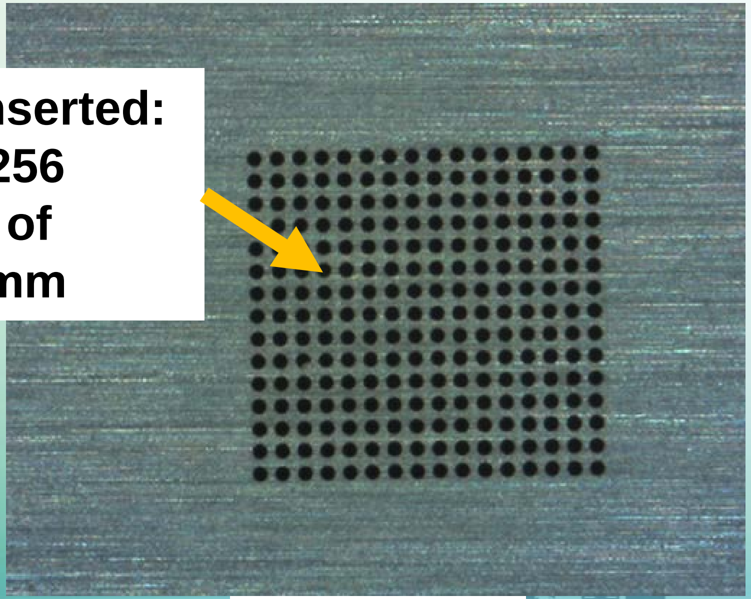
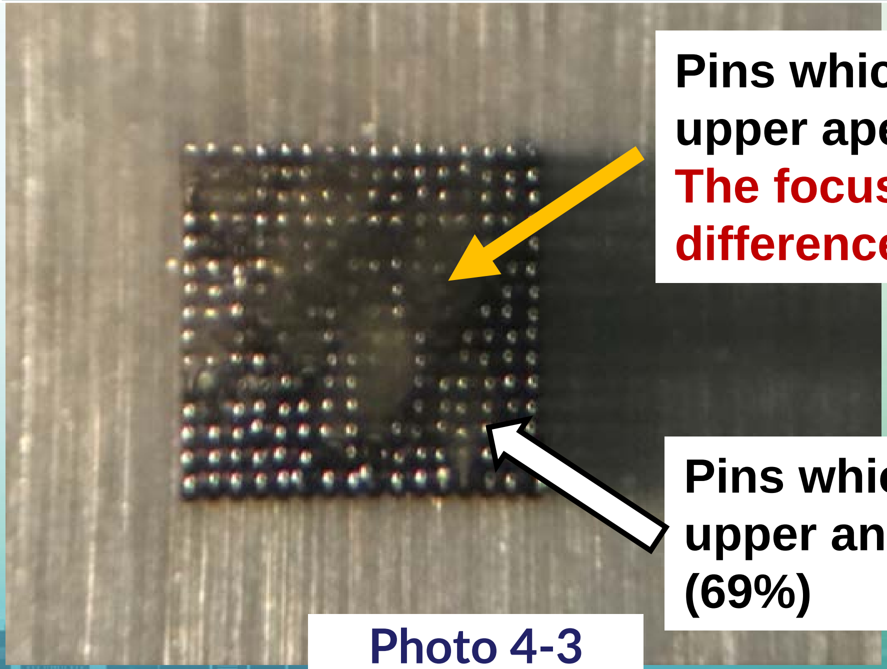


Photo 4-2



Pins which pierced only upper apertures. (31%) The focus faded by the difference in the height.

Pins which pierced both upper and lower apertures. (69%)

Photo 4-3

You can see the reasons of miss inserting from figures below.

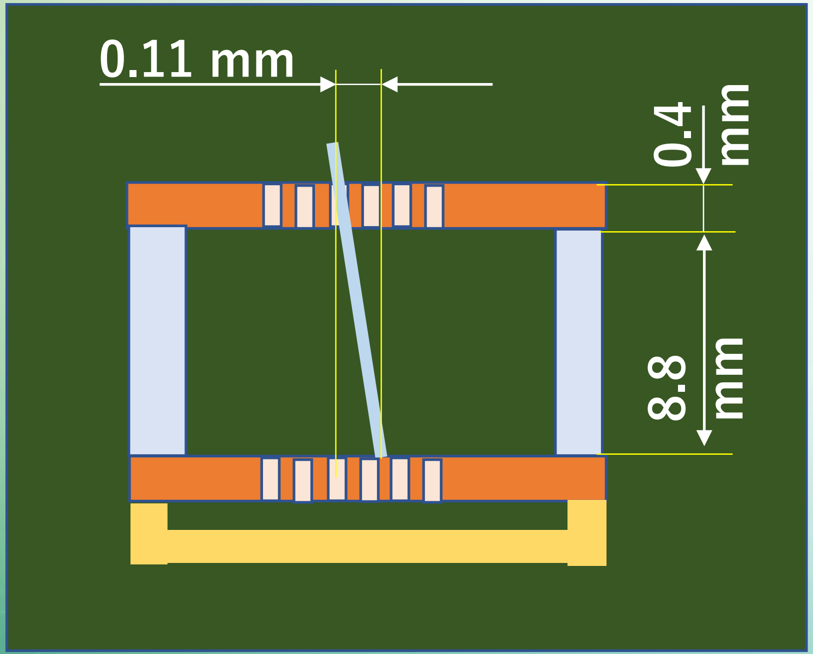
[Cause of miss inserting]: At the lower aperture plate, some pins entered adjacent apertures by swing around the upper side.

Judging from the test results and analysis, the solution to successful inserting is as follows:

[Solution to successful inserting]:

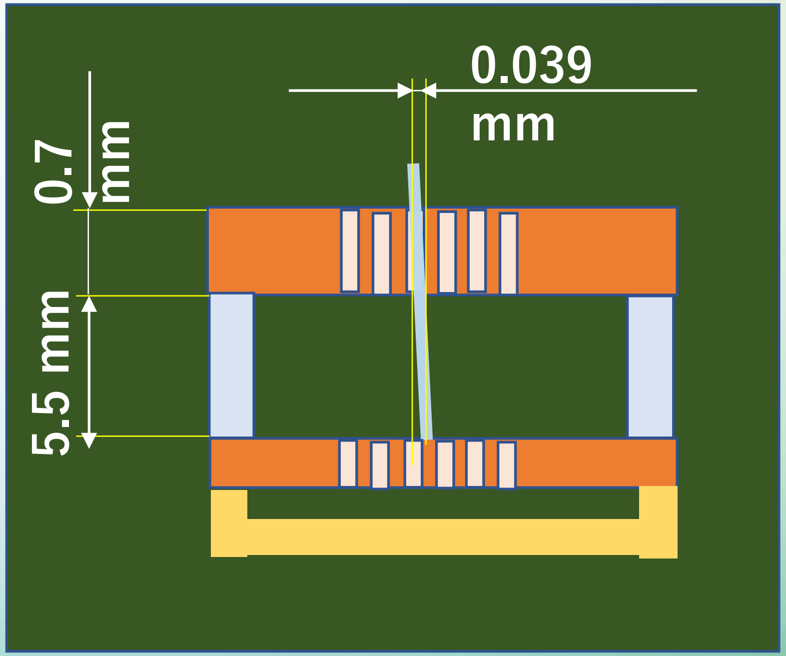
(1) Make the length of upper aperture longer to make the pin guide longer.

(2) Shorten the distance between upper and lower aperture plates.



0.005/0.4x8.8
=0.11 mm
＞Pitch 0.05
NG
0.05mm
=Clearance in hole with pin

Figure 4-10 Test Result Analysis



0.005/0.7x5.5
=0.039 mm
＜ Pitch 0.050
OK

Figure 4-11 Improvement in Pins Inserting

5. Development subjects left to be solved in a few years:

(1) Insulating Coating, Parylene Coating, to thin straight pins.

Test of thin (1～2μ) insulating coating is under way.

Performance	Key Technology
High Productivity	• In application of automated pin inserting to coating apertures, how to prevent coating material from invading the hole gap.
Quality Assurance	• How to check coating thickness in process, shipping and acceptance inspection by common tool with consistency.

(2) Durability Test in case of 500,000 ～1,000,000 T/D

Performance to be confirmed	Necessary Reason
Repeatability of BCF	▪ In repair, uniformity of BCF after many T/D is required.
Durability of tip of probe	▪ Degree of tip wear or deformation and pile of debris must be checked.

(3) Confirmation of Repair Method

We already have a plan to realize on site repair pin by pin.

In 4th Step (2023/9～2025/9), following developments are planned on condition of using Japanese government subsidy system

(1) To achieve performance equality in many probes, we must develop non-linear simulation tool.

(2) To stabilize VPT Process, we must stabilize the start point of plastic deformation, in other words, we must check material quality of Iridium and manage it.

(3) In evaluation of probe life, objective viewpoint and systematic test is required.
⇒ We will proceed as joint research with public institute.

6. Discussion

(1) Difference between Simulation and BCF data

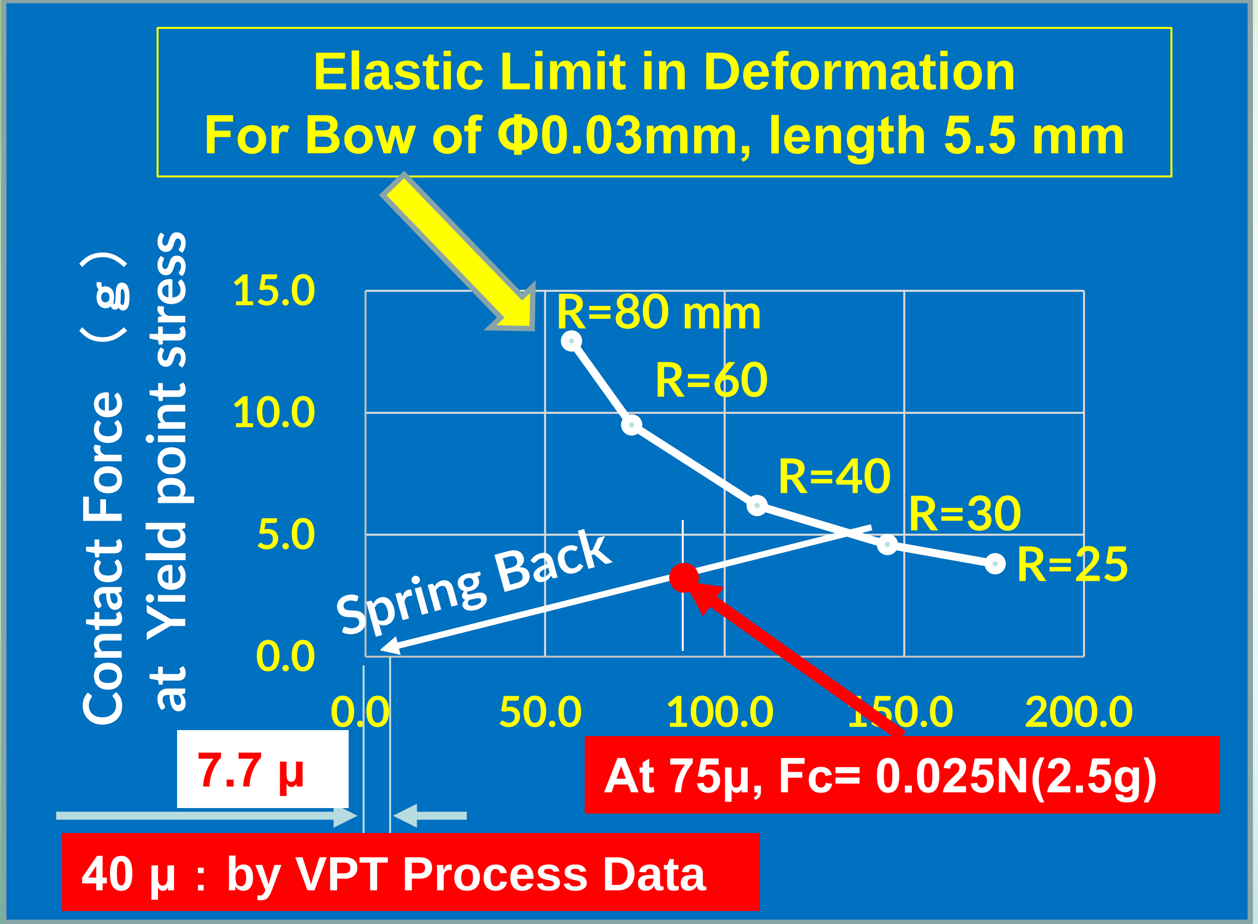


Figure 4-2 Simulation Result in Linear Model

Due to resolution limit in load cell output, there are fluctuations in data within 0.01 N. Data are shown as average in fluctuation.

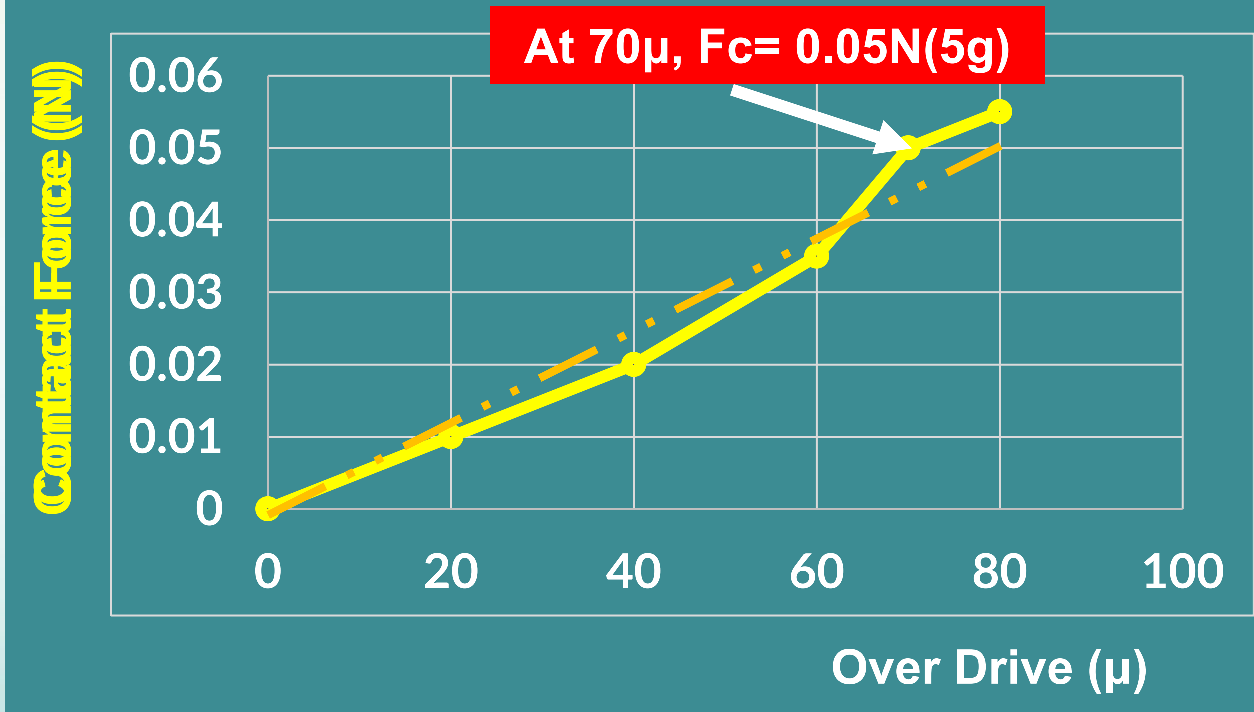


Figure 4-6 Typical BCF (Contact Force/Over Drive)

Difference in spring rate and residual deformation may be explained by the difference of Liner Model and Non-Linear Model.

In Linear Model, deformation energy given by Contact Force and Over Drive is not consumed by plastic deformation at both ends of Bow. So, all energy is supposed to be spent only to reduce radius of Bow, resulting in lower spring rate.

In Non-Linear Model, deformation energy is consumed not only in plastic deformation of Bow, but also in plastic deformation at both ends of Bow, resulting in larger radius of Bow and larger spring rate and larger residual deformation.

For more detail, we need simulation by Non-Linear Model.

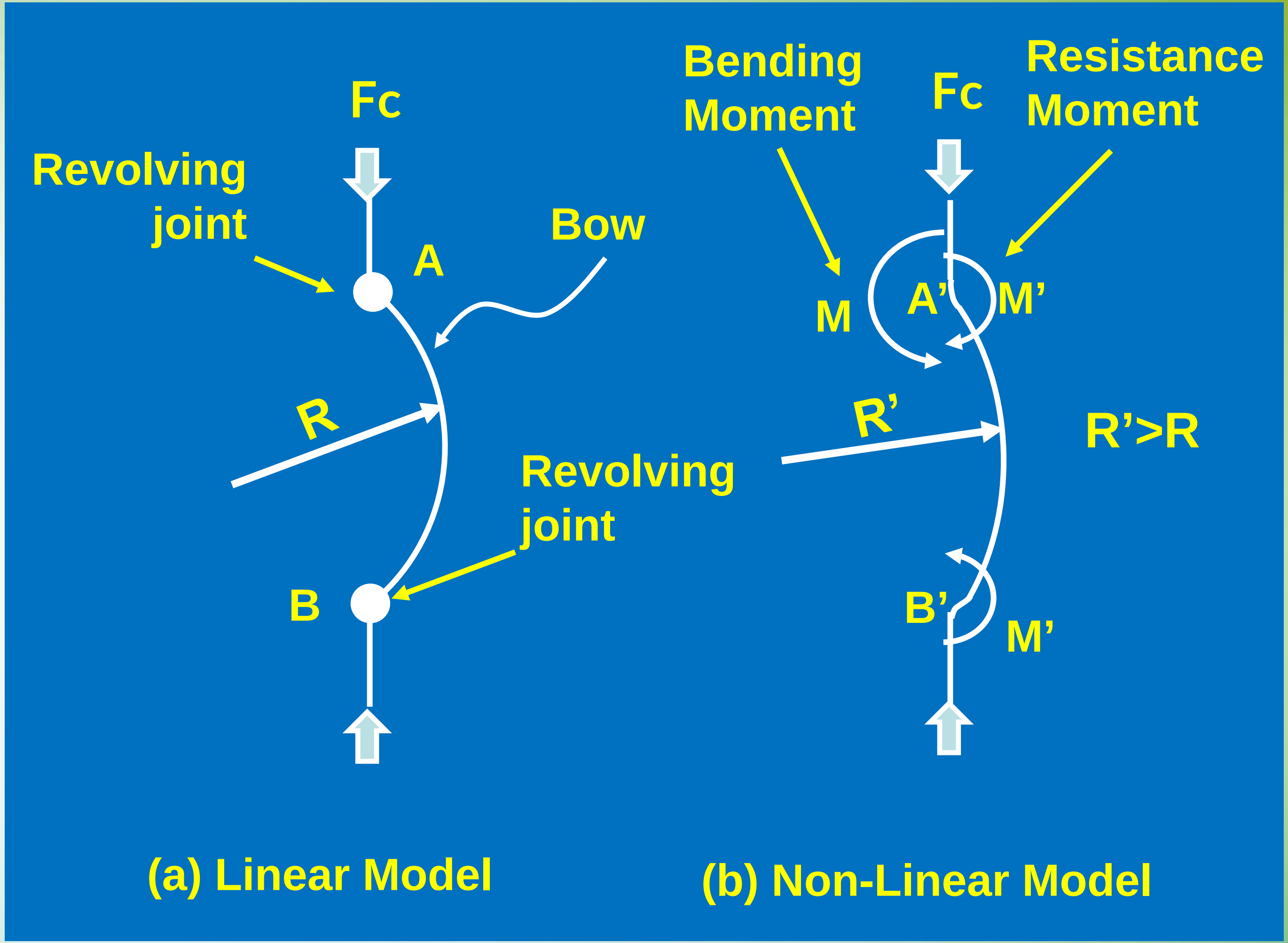


Figure 6-2 Linear and Non-Linear Model of VPT Process Simulation

(2) CCC Data:

Looking at the CCC data of iridium probe, CCC may seem smaller than expected.

* One reason may be that test method followed strict ISMI Procedure.
* But looking at the data compared with CCC of Rhenium Tungsten, **there is no doubt about the advantage of Iridium.**

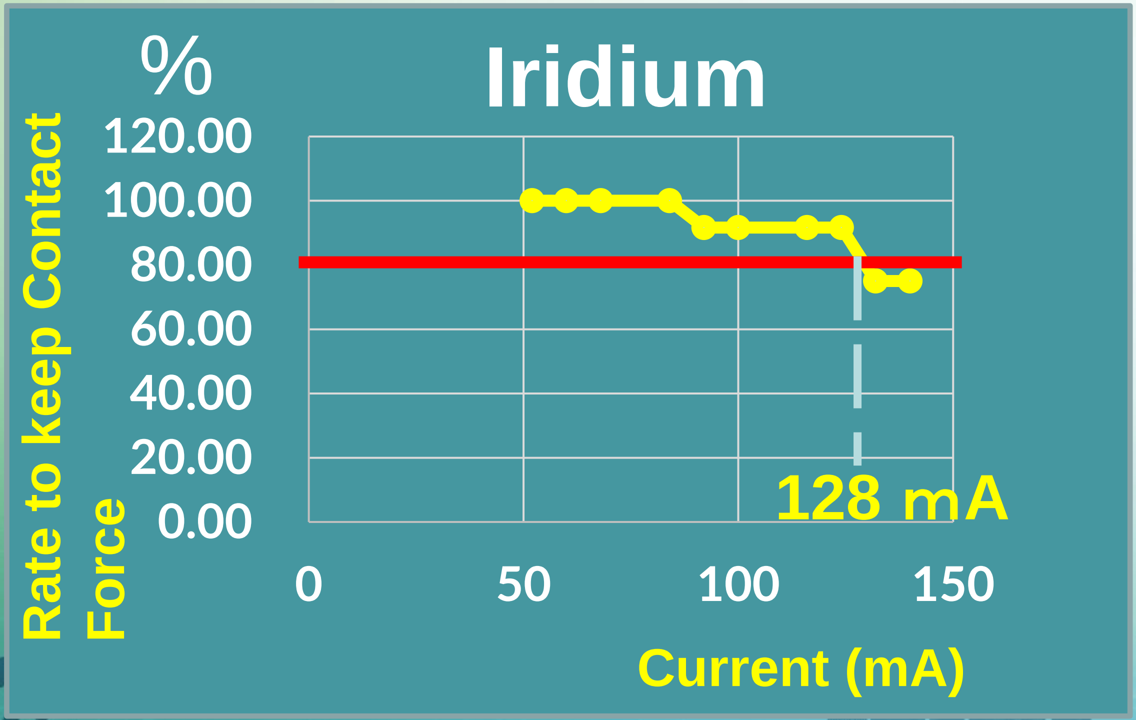
Followed strict ISMI Procedure

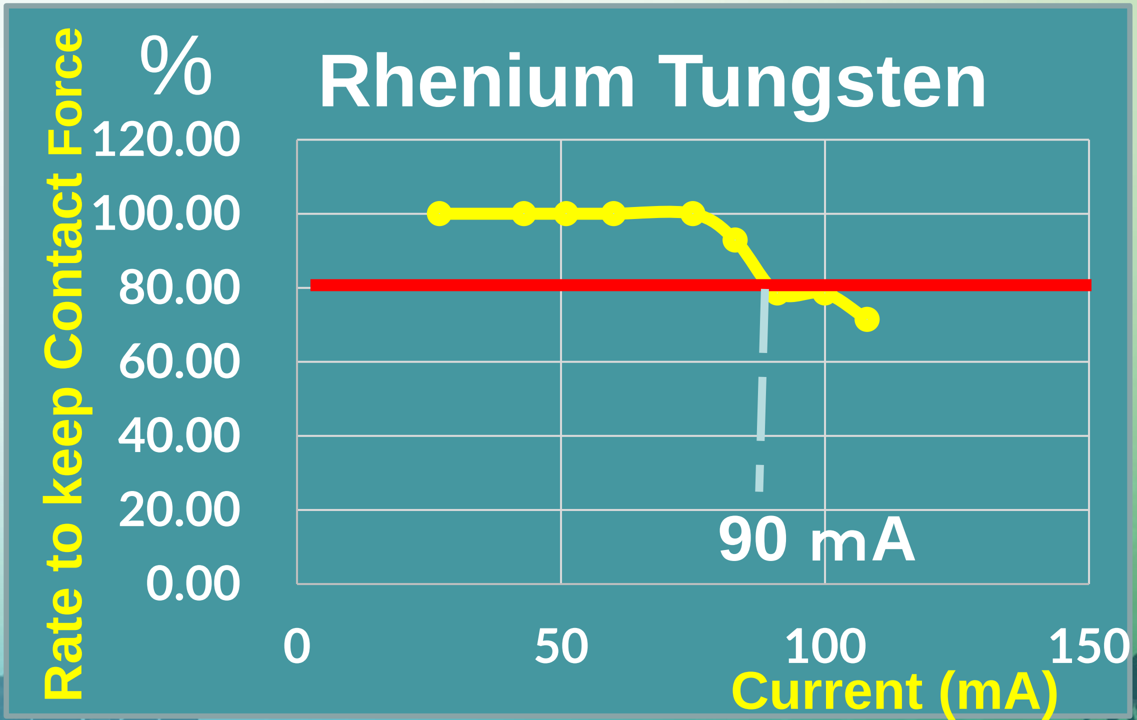
Current Input two minutes → **Current Input two minutes** → **Current Input two minutes**

Current Cut for **10 seconds** and Check Contact Force

Current Cut for **10 seconds** and Check Contact Force

%





7. Summary:

We wish we could say "We will fix development subjects in a few years". But we would like to say, "We hope we can fix development subjects soon". Then, *VPT may emerge* as *Ultimate Solution to Vertical Probe*. VPT may deserve it, as it will realize following merits:

Merits	Basis: By what?
Advantageous in Full Array Fine Pitch	VPT Process and Iridium
High Productivity	Automated Pins Inserting and Smart Jig
High Performance of Probe	VPT Process and Iridium
Long Probe Life	▪ Non-Affinity of Iridium to pad material ▪ Non-Abrasive Cleaning Gel