An Analysis of Contact Resistance between Probe Tip and Gold Pad

Chang-Hoon. Hyun
Samsung Semiconductor Institute of Technology

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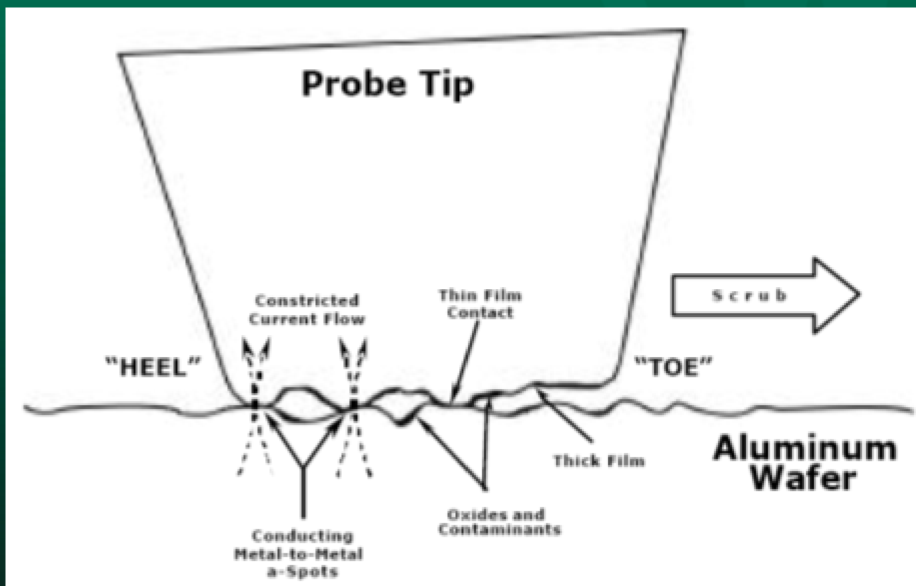
- Summary

Key Points

- Modeling of Ti Oxide Creation
- Probing Result of Fine Pitch Bump
- The Surface Analysis of Gold Pad
- Ohmic Heating by Work Function Difference
- Contact Resistance Measurement by ATE

Model of Probe Tip Contamination by Al Oxide

Source : Jerry J. Broz, "Probe Contact Resistance Variations during Elevated Temperature Wafer Test" Test Conference,1999



$$T_{a-Spot} = T_{Bulk} + \sqrt{\frac{U^2}{4\alpha\rho\lambda} + \frac{1}{\alpha}} - \frac{1}{\alpha}$$

U : Voltage drop(U = Forcing Current × Cres)

T_{bulk} : Ambient Temperature

α : Temperature Coefficient of Resistivity

ρ : Resistivity at the Bulk Temperature

λ : Thermal Conductivity

※ a-Spot : Real Inter-Metallic Contact Area

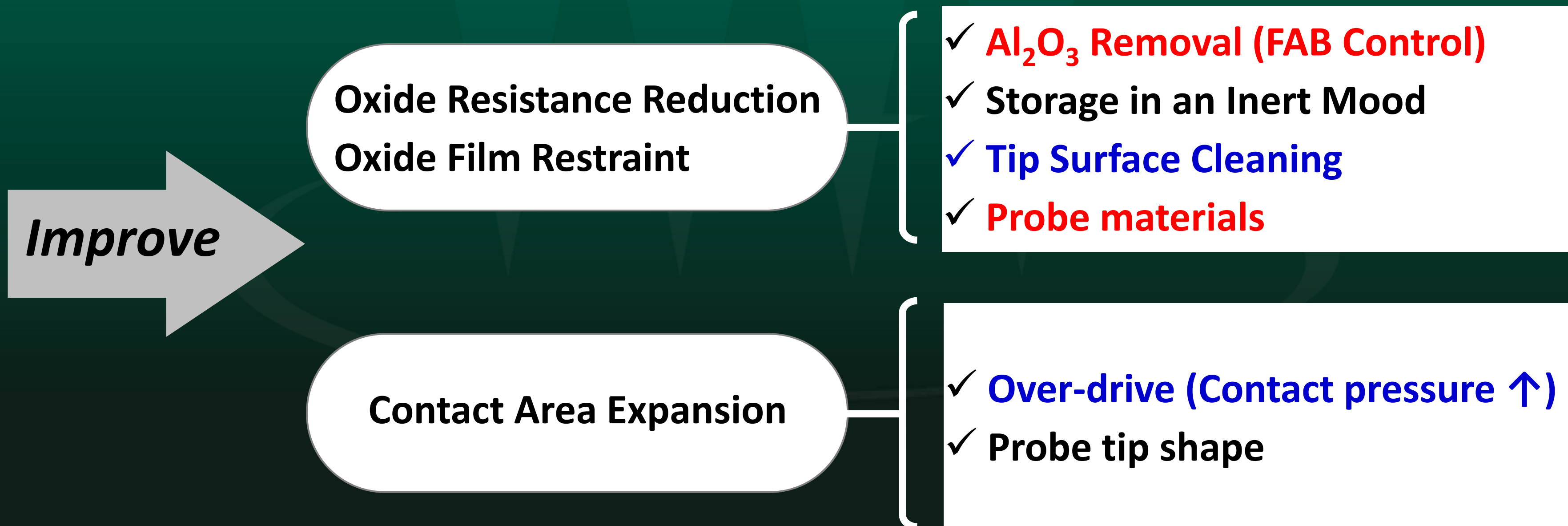
Conducting Metal to Metal a-Spots → Localized Joule Heating in a-Spot Area during Test → Al Oxide Film growth on Pad. → Probe Tip Contamination

Model of Probe Tip Contamination by Al Oxide

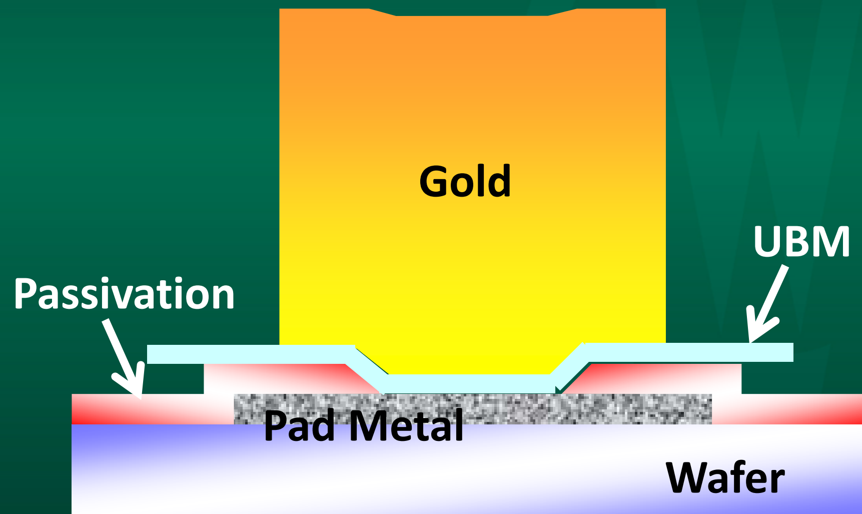
$$C_{RES} = \overbrace{\frac{(\rho_{probe} + \rho_{substrate})}{4na}}^{CONSTRICTION-RESISTANCE} + \underbrace{\frac{\sigma_{oxide-film}}{A_{contact}}}_{FILM-RESISTANCE}$$

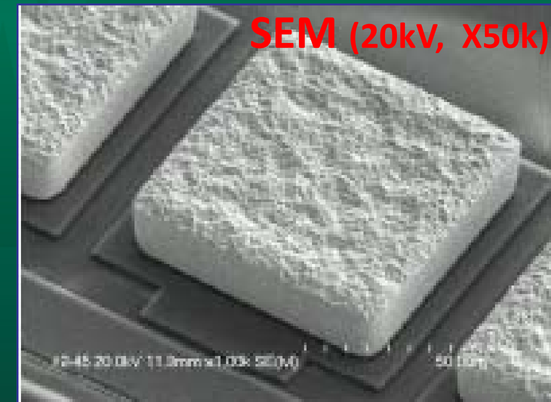
Resistance of Contact Area

$\sigma_{oxide-films}$: Oxide film resistance
$A_{contact}$: Contact area

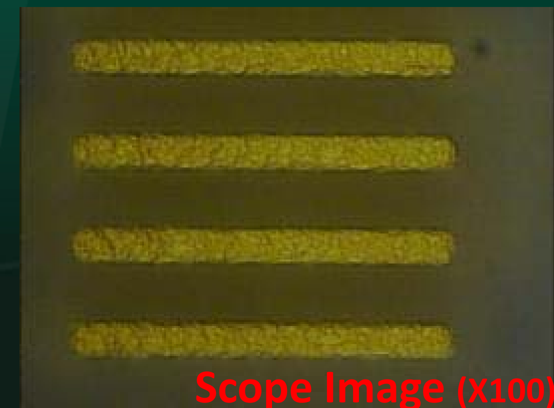


Introduction to Gold Pad Structure





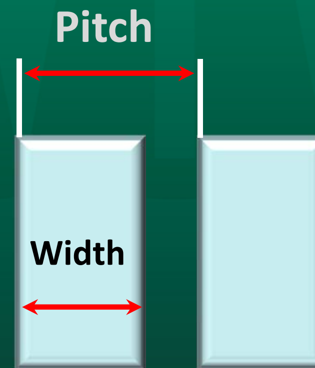
- Pad Material
  - ✓ Aluminum
- UBM (Under Barrier Metal)
  - ✓ For Adhesion (Between Pad Metal and Gold)
  - ✓ Materials are Ti and W
- Gold Material
  - ✓ Purity : 99.9%



Relationship of Fine Pitch and Resistance

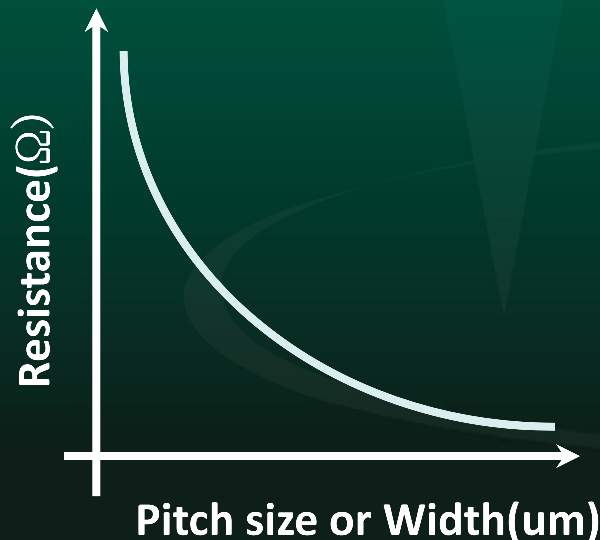
A. Relationship of a-Spot Reduction and *Cres*

- What is Fine Pitch Gold Bump Pad?
  - ✓ Pad Pitch : Under 30um
  - ✓ Pad Width : Under 20um



[um]

Width	Tip Diameter
30	12~10
25	9~10
20	7~8
15	5~6



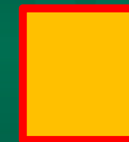
$$C_{RES} = \frac{\overbrace{(\rho_{probe} + \rho_{substrate})}^{CONSTRICTION-RESISTANCE}}{4na}$$

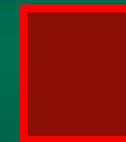
α : Diameter of contact spot
n : Number of contact spot

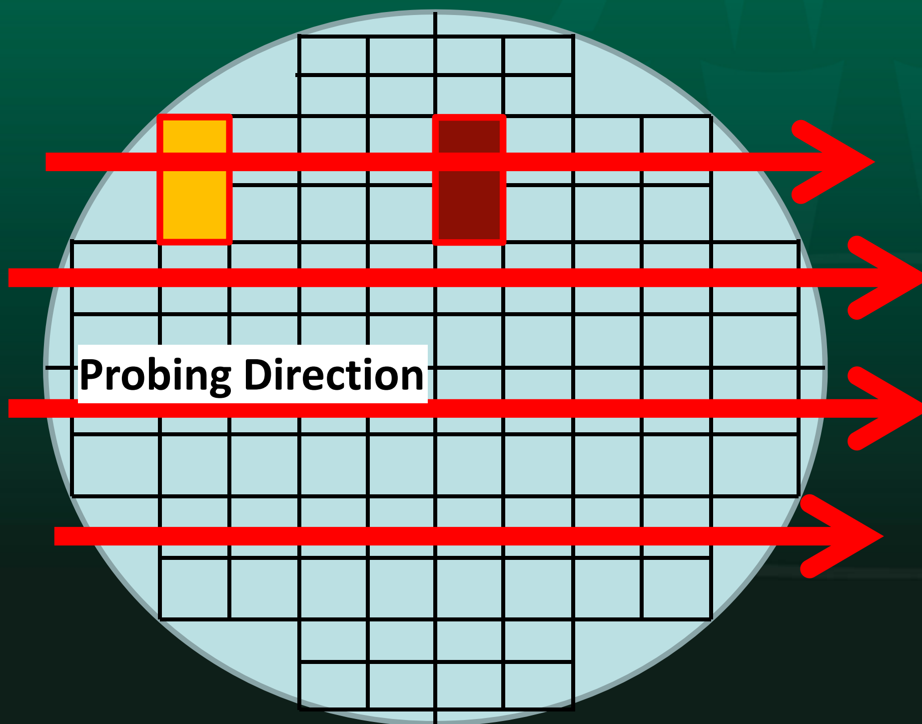
Relationship of Fine Pitch and Resistance

B. Experiment of Fine Pitch Probing

- We made another Bump Width on Wafer
  - ✓ Tip Diameter : 6um
  - ✓ Yield Monitoring by using ATE

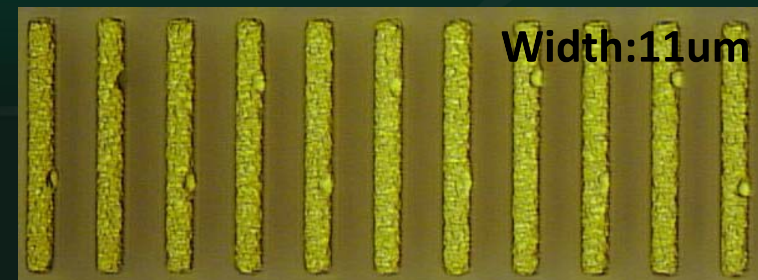

15um


11um



25um

10um(Pad to Pad)



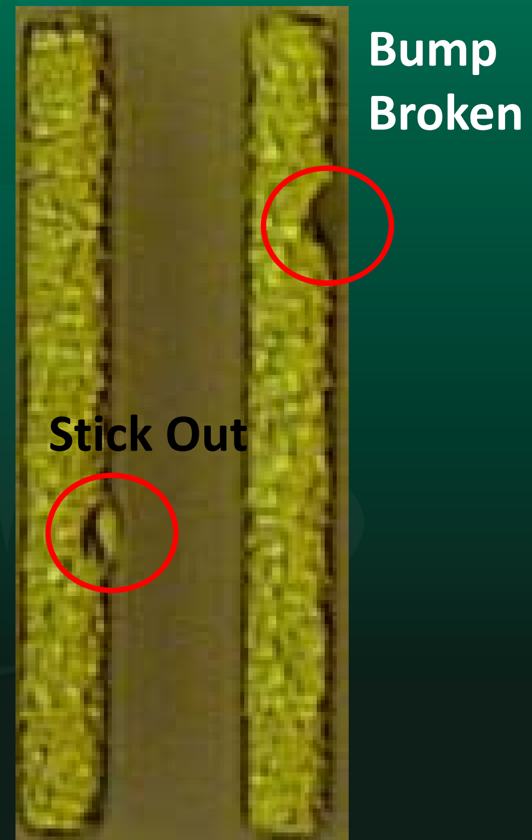
Relationship of Fine Pitch and Resistance

C. Experiment Result

Measure	Pad Width	
	11um	15um
Open Fail Ratio (Non Cleaning)	93%	87%
Open Fail Ratio (Interval 50Chip)	10.4%	1.5%
Bump Damage	50.7%	3.2%

- Number of Total Chips : Etch 1000 die
  - ✓ Z-Height : Electrical First Pass + 10um
  - ✓ Needle Polish Paper : 3M AlO_3 Lapping Film
  - ✓ Cleaning T/D : 20 up-down

Visual Fail (SEC Standard)



Contact Resistance of Gold Pad

A. Model of Probe Tip Contamination by Ti Oxide

Step 1 : Reaction of between Ti and H_2O_2

Step 2 : Reabsorption of TiO_2 on Bump Surface

Classification	Ti	TiO_2
Resistivity (μΩ·cm)	43.1	10^{18}
Dielectric Constant	-	110.00

TiO_2 (↓)

Ti+

WO_5^{2-}(aq)

Anneal

Tip

Probe Tip

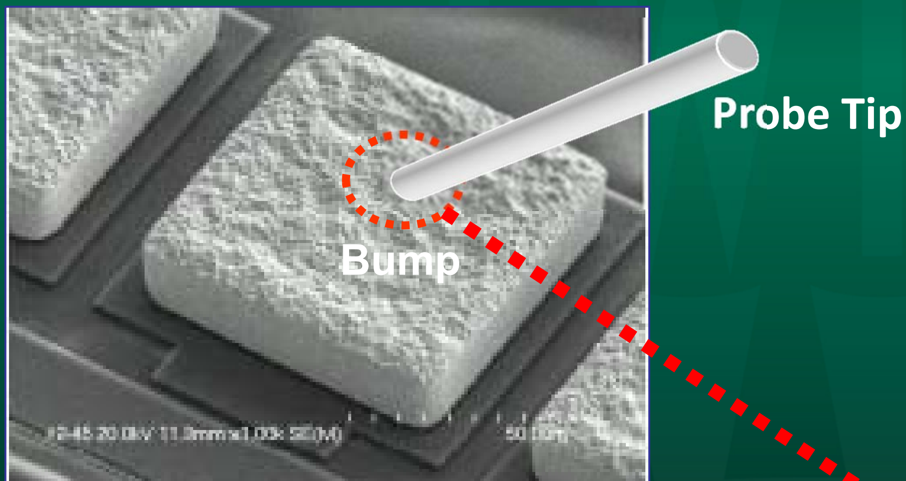
Au Bump

TiW Etching (by H_2O_2)

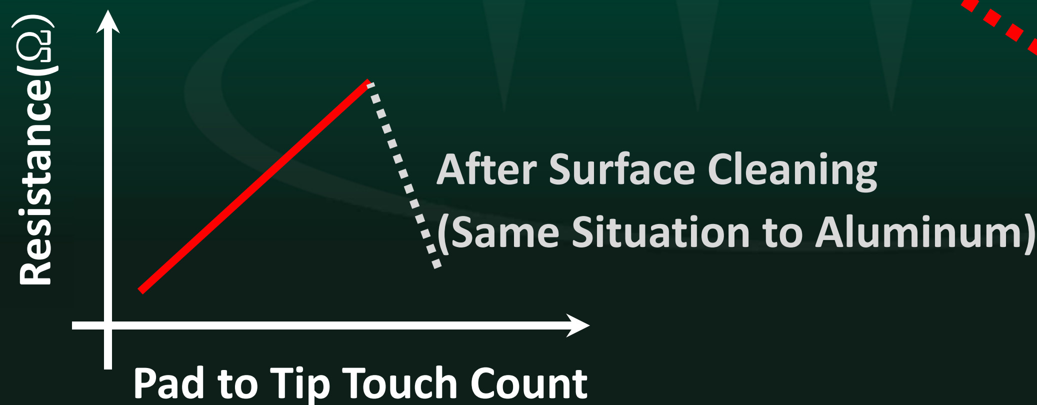
Wafer Electrical Test

Contact Resistance of Gold Pad

B. Resistance vs. Contact Count

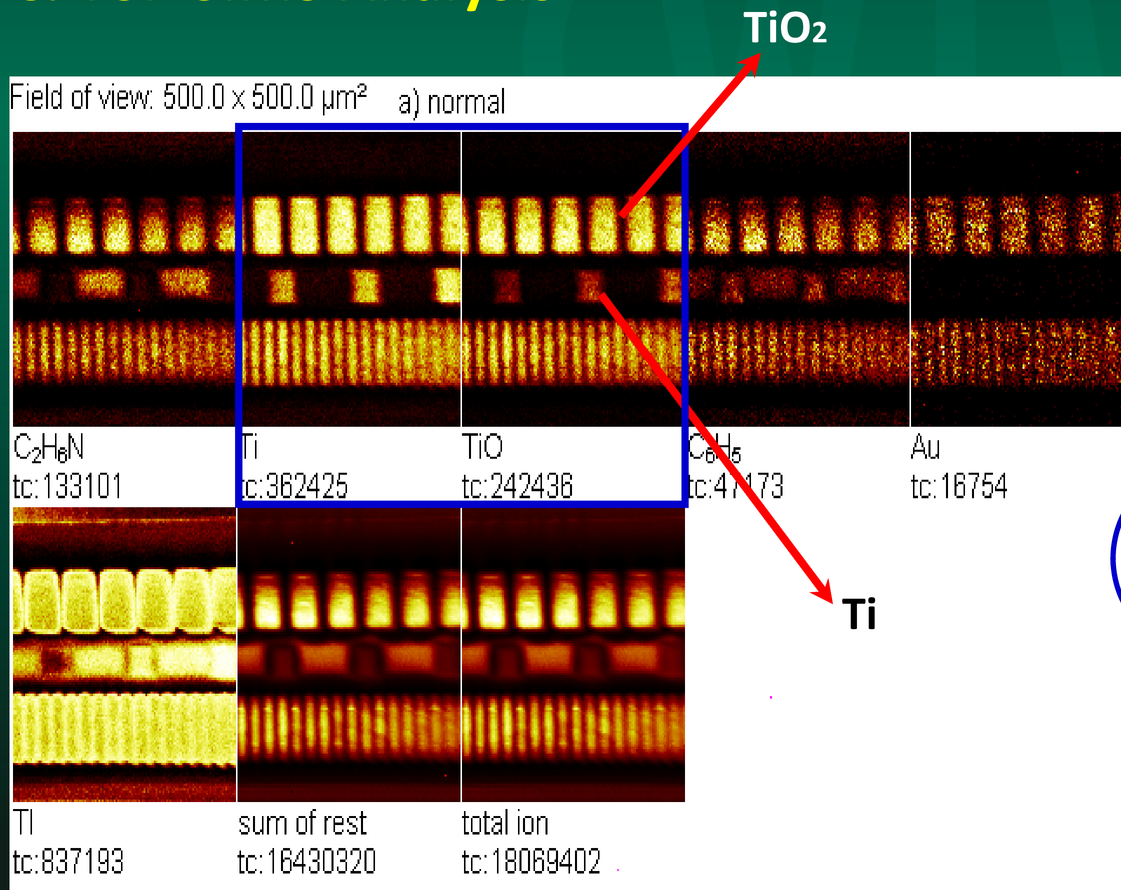


Oxide Film Absorption

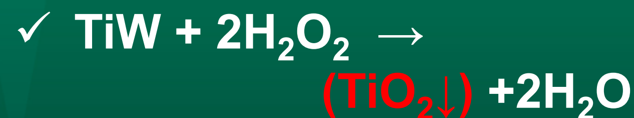


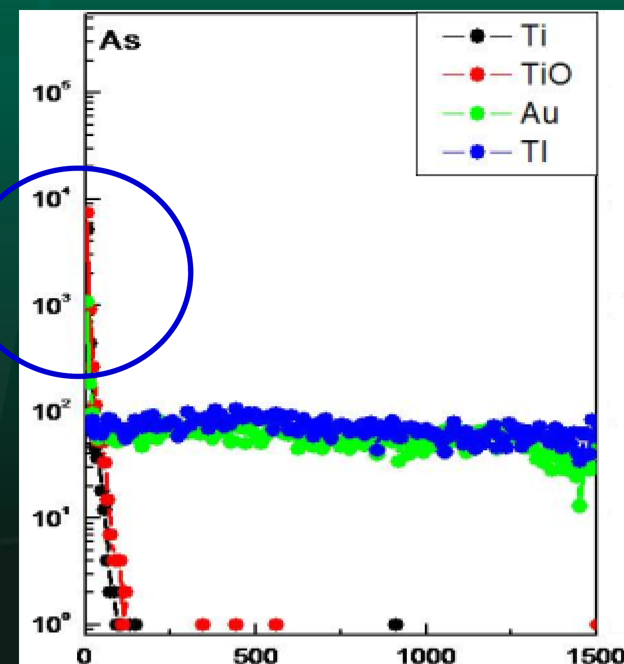
Contact Resistance of Gold Pad

C. ToF-SIMS Analysis



- **Finding of Insulation Ingredient**
  - ✓ **TiO**
  - ✓ **$TiW + 2H_2O_2 \rightarrow (TiO_2\downarrow) + 2H_2O$**





Sputter Time (sec)

Work Function of Tip & Pad Materials

A. Relationship of Material's Work Function

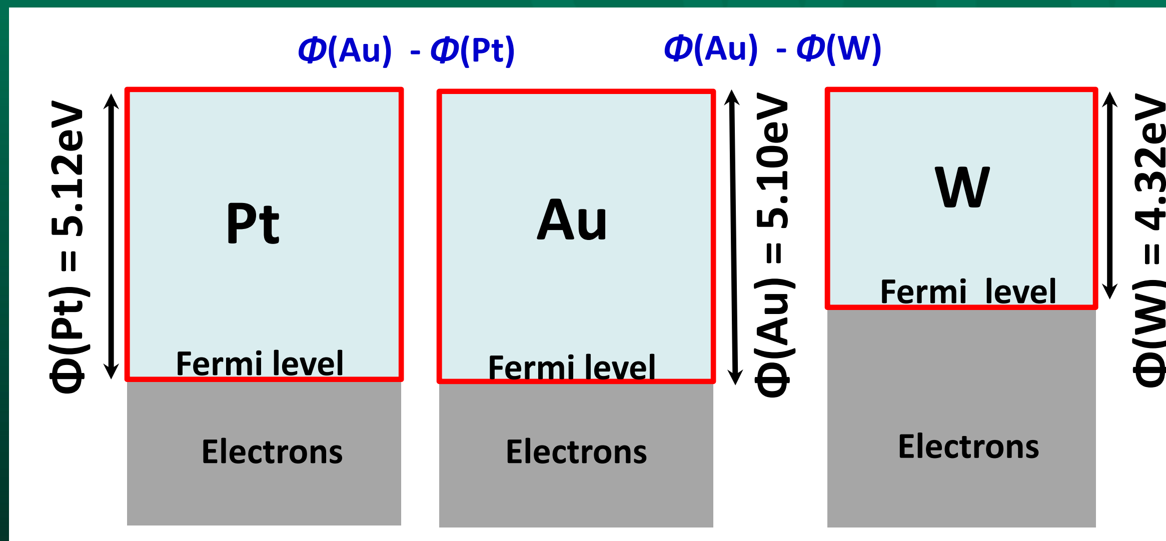
Classification		Work Function (φ) [eV]
PAD	Aluminum	4.06 ~ 4.26
	Gold	5.10 ~ 5.47
TIP	Tungsten (ReW)	4.32 ~ 5.22
	Platinum	5.12 ~ 5.93

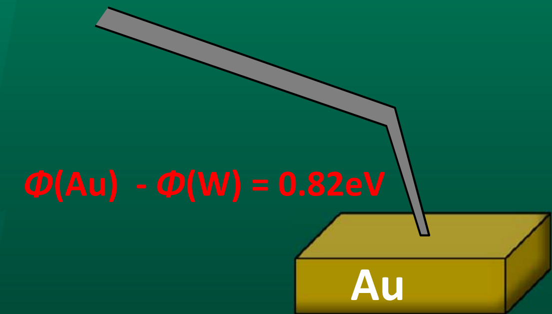
- We had to needle cleaning on Gold bump pad when used ReW Tip
  - ✓ Cleaning Interval : Average 35 Chip → Card Life Time Reduction
  - ✓ Wafer Moving Time Increase : 30~40 min/Wafer → Production Loss

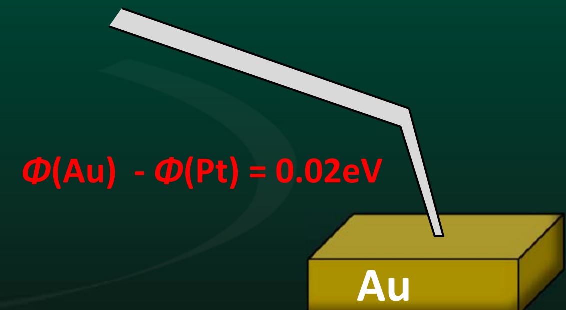
- **Tip Material Change → Cleaning Interval : 1 Time a Wafer**
- **Assumption : If Same Work Function of Material…**

Work Function of Tip & Pad Materials

B. ReW or Pt Tip to Gold Pad Contact



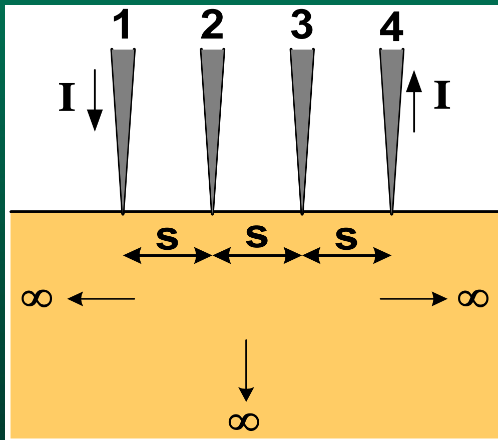




- An Ohmic contact is a junction between a metal and a smaller work function metal
- Joule heating, also known as ohmic heating and resistive heating
- If *ΔeV* increase, Ohmic heating will increase

Contact Resistance Measurement of Gold Pad(ReW vs. Pt Tip)

A. Tip Material Resistivity Measurement



$$\rho = 2\pi s \frac{V}{I} \quad \Omega - cm$$

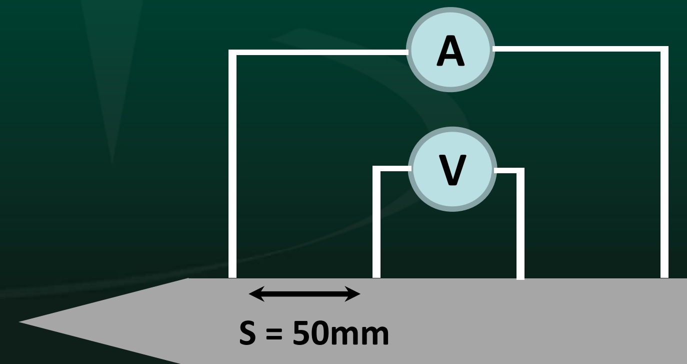
$$V_2 = \frac{I\rho}{2\pi}\left(\frac{1}{s} - \frac{1}{2s}\right); \quad V_3 = \frac{I\rho}{2\pi}\left(\frac{1}{2s} - \frac{1}{s}\right)$$

$$V = V_{23} = V_2 - V_3 = \frac{I\rho}{2\pi}\left(\frac{1}{2s} - \frac{1}{s} - \frac{1}{2s} + \frac{1}{s}\right) = \frac{I\rho}{2\pi s}$$

Source : D. K. Schroder, "Semiconductor Material and Device Characterization", 3rd edition, 2006

KEITHLEY 2750 / Cmpl V : 2.1 / I = 100mA

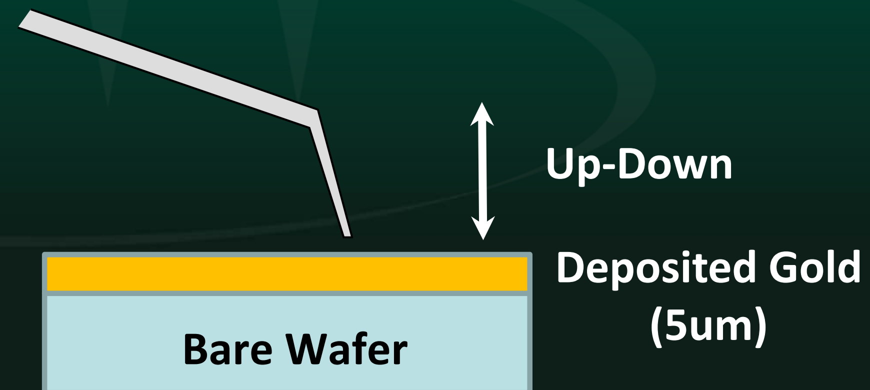
Tip Material	Resistance (Ω)	Resistivity (uΩ· cm)
Rhenium-Tungsten	0.93	9.35
Platinum	3.48	35.01



Contact Resistance Measurement of Gold Pad(ReW vs Pt Tip)

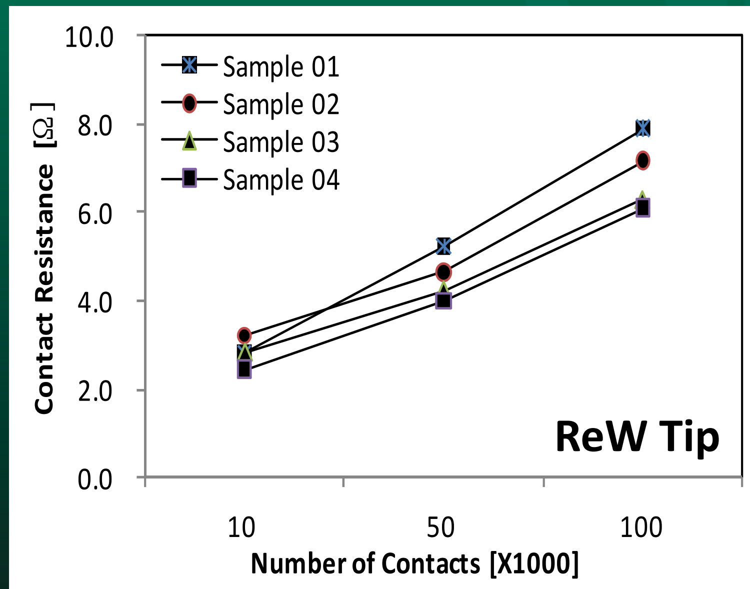
B. General Method Using DMM

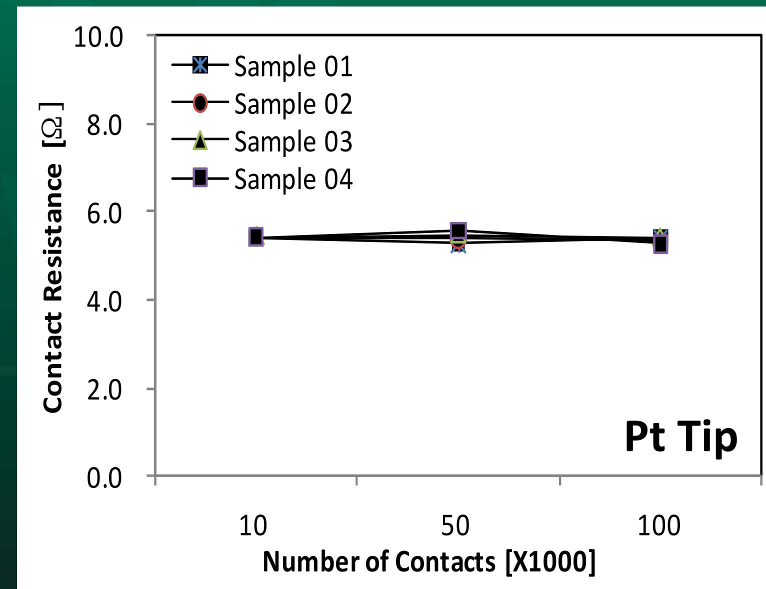
- Source : Keithley 2750
  - ✓ Multimeter/Switch/Data Acquisition system
- Prober
  - ✓ Wafer Handler
  - ✓ Pad to Tip Automatic Contact & Probing
  - ✓ P-8 (TOKYO Electronics Ltd.)



Contact Resistance Measurement of Gold Pad(ReW vs Pt Tip)

C. Measurement Result (DMM)





- Measurement Condition
  - ✓ Sample : 5um Gold Deposition on 8" Bare Wafer
  - ✓ Touch down : 100,000
  - ✓ Cmpl = 1V, I = 10mA, Over Drive = 30um

Contact Resistance Measurement of Gold Pad(ReW vs Pt Tip)

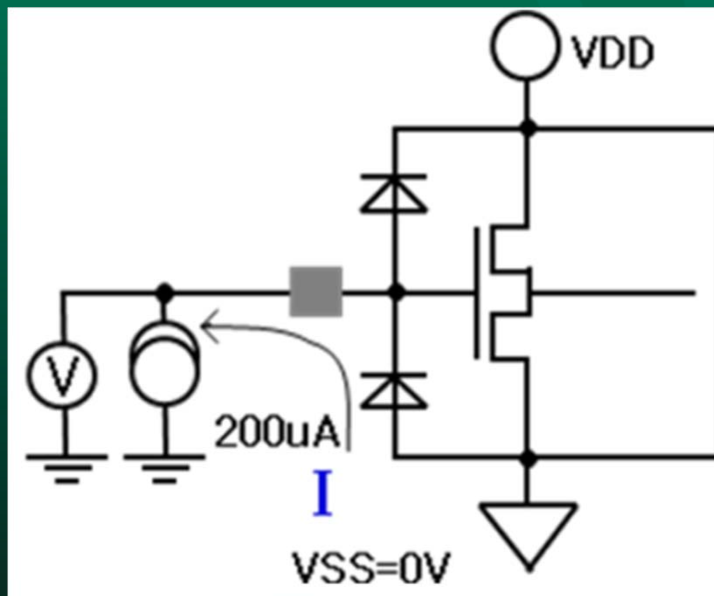
D. Automatic Tester Equipment (ATE) used for the Fist Time.

- ATE (Electrical Tester)
  - ✓ For Testing DC & Function Source
  - ✓ Chip GO-NOGO Judge(Good or Fail)
  - ✓ TS6700 (YOGOGAWA Co.)
  - ✓ The General Tester For Testing of Display Drive IC(DDI)

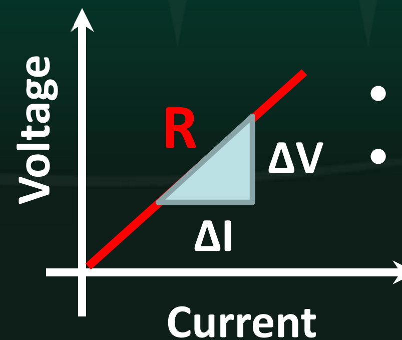
- Wafer Prober
  - ✓ Wafer Handler
  - ✓ Pad to Tip Automatic Contact & Probing
  - ✓ UF200 (TOKYO SEIMITSU Co.)

Contact Resistance Measurement of Gold Pad(ReW vs Pt Tip)

E. Measurement Using ATE



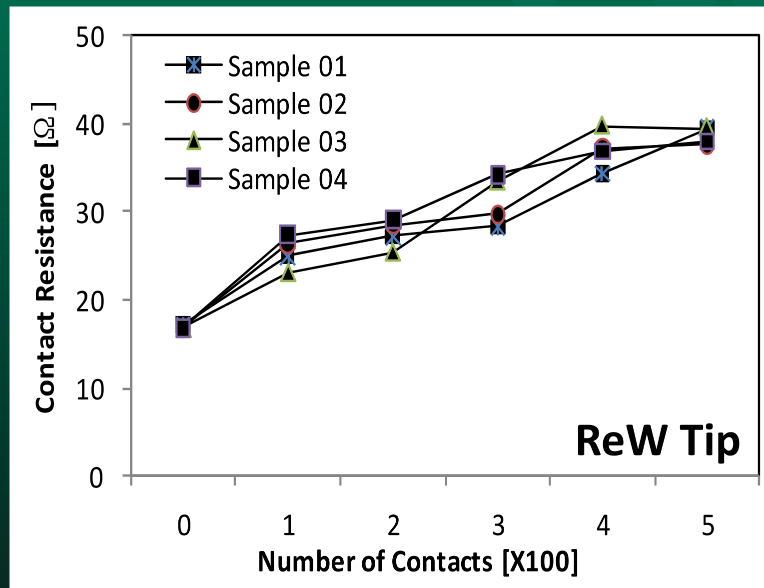
- Contact Test
  - ✓ This Item is more important than others
  - ✓ Good Contact → Good Signal Conduction
- Using Protection Diode
  - ✓ This test method is so general
  - ✓ When using the under diode, negative current was pulled from tester DC source
  - ✓ It is principle of ISVM (Current Source Voltage Measure)



- Ohm's Law
- $\Delta I = 2mA$ ($I_1 = 3mA$, $I_2 = 5mA$)

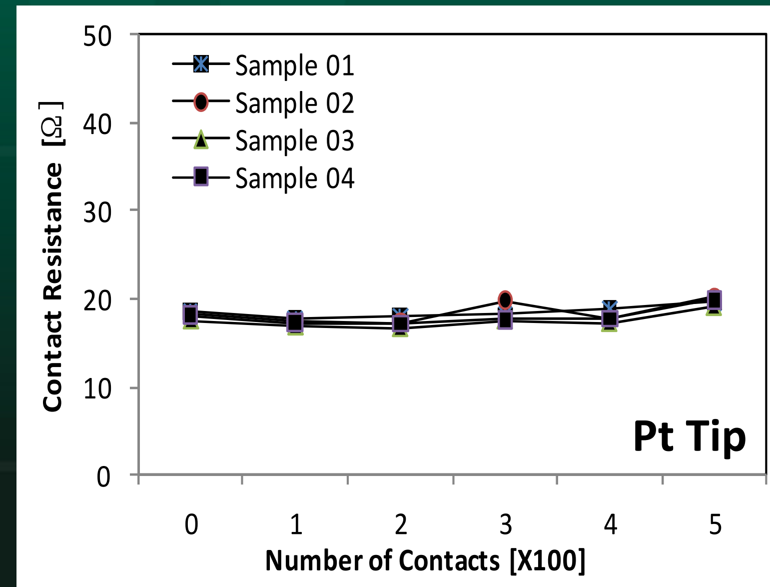
Contact Resistance Measurement of Gold Pad(ReW vs Pt Tip)

F. Measurement Result (ATE)



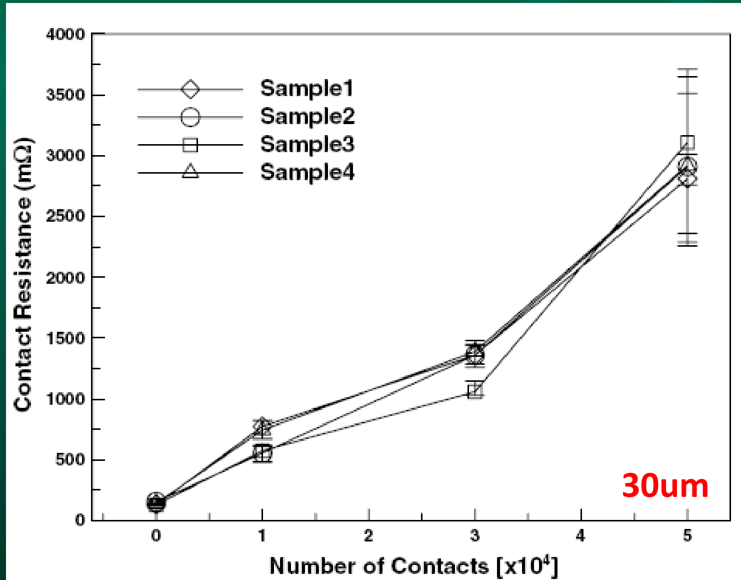
- *Cres* increases linearly
- This Situation is same as Al pad
- The cause is Ti oxide

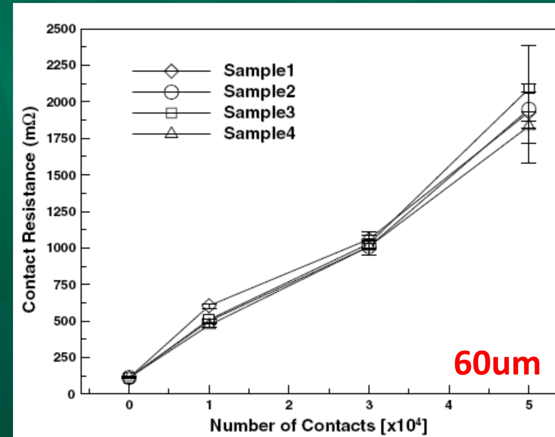
- *Cres* is Stable
- Platinum and Gold are similar characteristics
- Why is Ti Oxide not affected ?



Comparing of Other Results

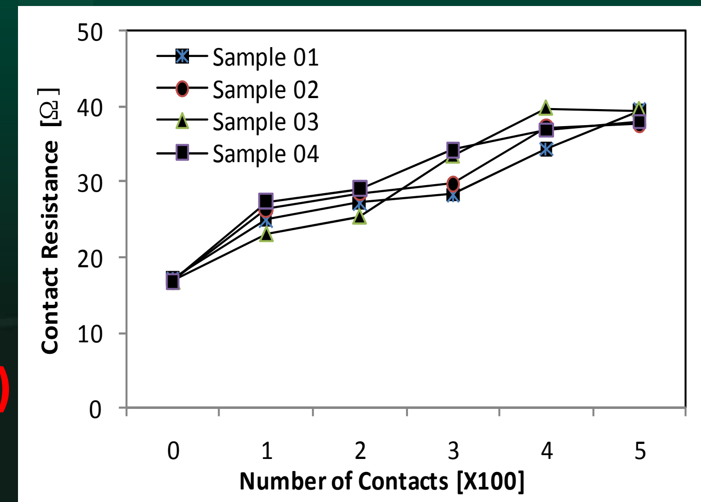
Source : D. S. Liu, "Measurement and analysis of contact resistance in wafer probe testing", 3rd edition, Microelectronics Reliability 2006



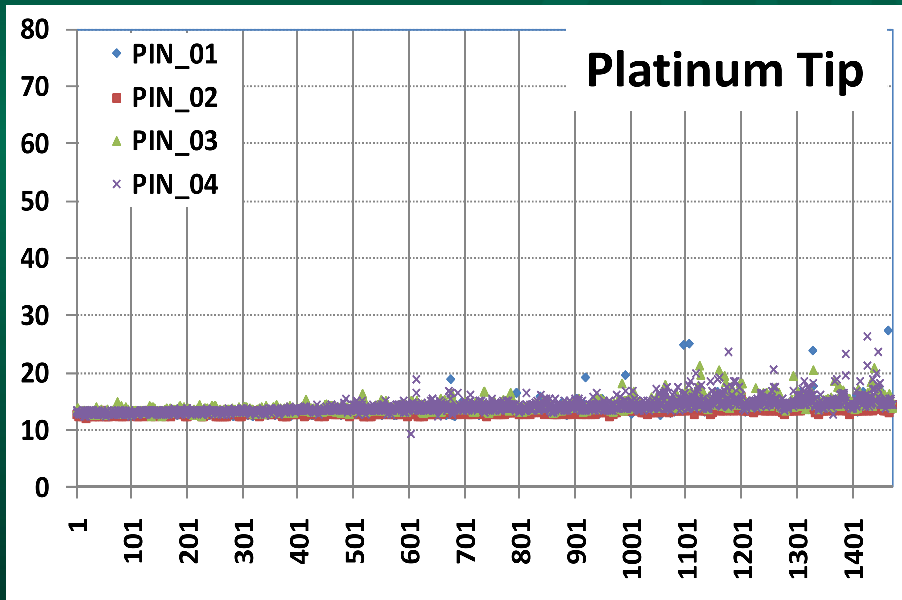


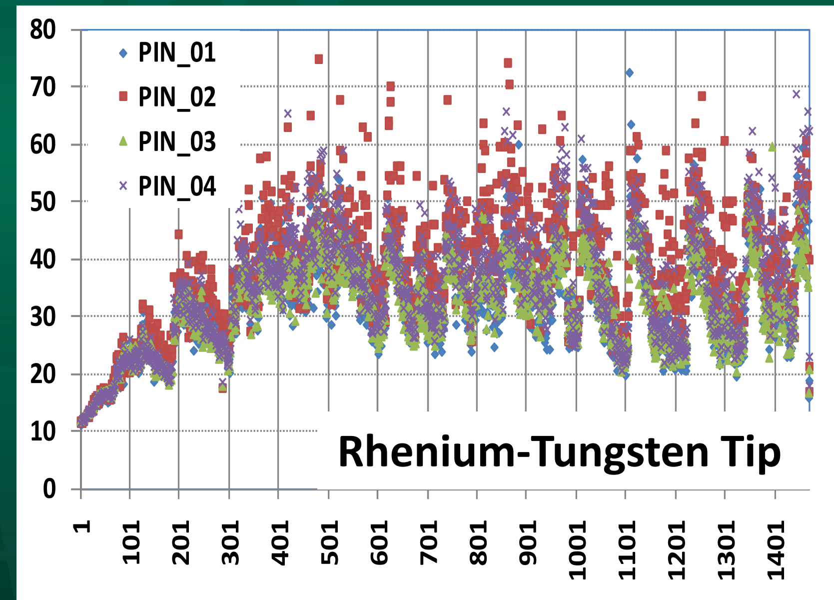
Variation of contact resistance with number of prior contacts for constant of 30um and copper specimen

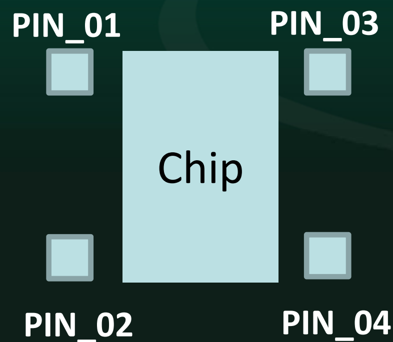
- Using ATE (Circuit Resistance include)
- The result is resemblance



Continuous Probing Result (ReW vs Pt)







The Method of Reduced C_{res}

- ✓ **TiO_2 Removal (FAB Control)**
- ✓ Storage in an Inert mood
- ✓ Tip Surface Cleaning (→Card Loss)
- ✓ **Need with the same φ a Probe tip material**

Summary

- We discovered a Ti oxide film as studied in Al oxide has similar characteristics by ToF-SIMS analysis
- The contact resistance tendency of Gold pad resembles Al pad
- There is advantage that the measurement using ATE get function & resistance data together
- Platinum probe card showed a good result in Gold pad
- When probe card material is chosen, The work function must be carefully investigated

Next Steps

- Need to a method to remove the Ti oxide film
- As a solder bump business increases, we will study solder bump pad deeply

Acknowledgements

- **Samsung Bump Process Engineering Team**
  - > Yong-Ho. Kim (Senior engineer)
- **Teaching Professor in SSIT**
  - > Jeong-Taek. Kong (General Director)
  - > Hyun-Ho. Park Ph. D.
- **Will Technology Engineering Team**

Thank You.