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Electrical Contact Resistance - The Key Parameter in Probe Card Performance

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Overview

- Test cell & Contact Resistance measurement system
- Contact Resistance processes applied to probe cards
- Probe parameters related to Contact Resistance
- Contact Resistance stability
- Characteristic performance of selected probe designs on AL & Cu surfaces
- Summary
- Acknowledgements
Test Cell & Contact Resistance Measurement System

- TEL P12 & EG 2080 prober interfaced to Measurement system in Clean Room environment

- Keithley 2750 Multimeter/Switch/Data Acquisition System

- Agilent E3640A Programmable DC Power Supply

- Custom LabVIEW program for system control/data capture
  - GPIB Interface
Contact Resistance Processes Applied to Probe Cards

- Contact Resistance, Force/Deflection Relationship
  - Determine preliminary deflection to meet Cres objective
  - Add safety factor to compensate for process variation
  - Maximum allowable Mechanical stresses determine maximum deflection
- Contact Resistance, Repeatability
  - Multiple cycles with no cleaning
  - Observe cycle number at which cres exceeds specification
- Cleaning Method Effectiveness
  - Cleaning media
  - Cleaning frequency

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Contact Resistance Process Capability

• Statistics in determining Cres capability
  – Performance Parameters:
    • Max allowable cres as upper specification limit (e.g. 0.5 Ohm)
    • Mean Cres specification
    • Std Dev Cres specification
    • % quantile Cres specification
  – Cpk Value determines process control capability (Cpk>1.3 desired)
• Statistics used in determining cleaning capability
  – Compare Cres Statistics Before-After Cleaning

Before Cleaning

Cpk (USL = 0.5 Ohm) : 0.212

After Cleaning

Cpk (USL = 0.5 Ohm) : 4.752
Cleaning Method Effectiveness

Before Cleaning

The 99.5 quantile: 1.6023, Cpk (USL = 0.5 Ohm) : 0.212
Mean (Normalized_Cres): 0.3371
Std Dev (Normalized_Cres): 0.2563

After Cleaning

The 99.5 quantile: 0.275, Cpk (USL = 0.5 Ohm) : 4.752
Mean (Normalized_Cres): 0.0533
Std Dev (Normalized_Cres): 0.0313
Probe Parameters Related to Contact Resistance/Cleaning

- Tip diameter/size change as fn of cleaning cycles
  - Affects alignment to pad
  - Ultimately detrimental to Cres
- Tip length change as fn of cleaning cycles
  - Minimum clearance between wafer and lowest probe card component
- Tip’s plating wear

MEMS-Vertex™ Probe Tips

Fine Pitch Vertical Probe Tips

Tip Length can be consumed during cleaning
Contact Resistance Stability
- Key Components

• Contact metallurgy
  – Formation of non-conductive films on probe’s contact surface
  – Probe-Pad (bump) metallurgical interaction. Adhesion of pad & tip materials
  – Formation of polymers on surfaces under friction

• Contact micromechanics
  – Penetration of non-conductive films in the Z-down cycle
    • Aggressive penetration not allowed when probing ACUP, Low_K pads
  – Probe self-cleaning in the Z-up cycle
    • Probe’s designed motion wipes off the tip’s critical contact section in the Z-up cycle
    • Removal of adhered, adsorbed particulates

• External cleaning
  – Compensates imperfections in the listed above

Contact Resistance Stability
- Probe Contact Micromechanics

- Penetration of non-conductive films in the Z-down cycle
- Aggressive penetration not allowed when ACUP, Low_K pads

• Probe Self-cleaning in the Z-up cycle
Three technologies with different modes of contacting wafer resulting in different scrub motions
Probe Micromechanics – Location of Contact Stresses

Deflection
Contact Resistance Stability
– A Case of “good” Contact Metallurgy

- Near ideal probe-pad contact behavior
  - Platinum probe tip/Rhodium Pad data shown
  - Cres approaches steady state within short OT
  - Long, Flat working range of Cres
  - Cres loop “reversible”

Cpk = 5.9
Contact Resistance Stability Study
- Pt, Vertical P7, WRe Cantilever & MEMS-Vertex™ on Rhodium Wafer

- Characteristic cres loops per probe type on Rh Wafer
- “Reversible” cres loop for ideal metallurgy vs. real probe metallurgy/micromechanics
- Applied as a method for quick evaluation of probe design performance
Contact Resistance Stability – Current Effects, WRe on AL

- Stability of Cres improves at low range of deflection at 320 mA
Contact Resistance Stability – Current Effects, WRe on Cu

- No improvement in stability of Cres due to current

![Graphs showing contact resistance stability](image)
Contact Resistance Stability
– Current Effects, MEMS-Vertex™ on AL

- No major improvement in stability of Cres at 320 mA

- 0.5 mil OT, 1 mA
- 3.0 mil OT, 1 mA
- 0.5 mil OT, 320 mA
- 3.0 mil OT, 320 mA
Contact Resistance Stability – Current Effects, MEMS-Vertex™ on Cu

- Current improves stability of Cres at low deflection

0.5 mil OT, 1 mA

0.5 mil OT, 320 mA

3.0 mil OT, 1 mA

3.0 mil OT, 320 mA
Contact Resistance Stability – Current Effects, Vertical P7 on AL

- No major Improvement of Cres stability at 320 mA
Contact Resistance Stability – Current Effects, Vertical P7 on Cu

- No improvement in stability of Cres at 320 mA, marginal OT setting
Summary/Next Steps

- The presented three probe technologies: Cantilever, Vertical and Mems-Vertex interact with wafer surface in different mechanical mode producing different Cres levels.
- At marginal deflection levels on Al, cantilever WRe probe shows cres stabilization with higher current levels. Probe Cres at adequate overdrive levels is not affected by 320 mA current level (within 500 touch downs range).
- Mems technology allows for use of specific metallurgy for the probe body (perfect spring) and a different metallurgy for the tip (perfect contactor) providing best cres performance on Al and Cu.
- Presented Cres results are representative of specific wafer/probe tip metallurgies used in this study. Wafers were provided by MicroProbe's customers.
- Next Step: additional tests with wider range of current levels/deflections.
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