Vertical Probe Development for Copper Bump Test Challenges

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Joint Development and Collaboration Effort Between K&S and Intel

Overview

- **Objective:** **Development of a vertical probing solution for Cu bump area arrays for next generation sort requirements**
- **Outline:**
  - **Sort requirements for copper probing and challenges**
    - Risk mitigation strategy - prioritizing critical requirements
  - **Addressing requirements by modeling and DOEs**
    - Pitch (area array)
    - Probe force variance
    - Contact resistance (probe tip geometry-DOE)
    - Current carrying capability
      - Thermal study

Critical Sort Requirements

- **Critical Requirements are prioritized through risk analysis**

Item	Requirement	Risk Prioritization
Probe Pitch	180 um	High Risk (Show Stopper) - If cannot meet, then will not be able to sort.
Probe Force	<16 g/probe @ Max OT	High Risk - Can cause damage to metal layer stack up.
Contact Resistance	< 0.5 Ω	Medium Risk - Will decrease sort yeild.
Probe Current Carrying Capability	> 400mA	Medium Risk - If do not meet, will increase cost of ownership.

Addressing Probe Pitch

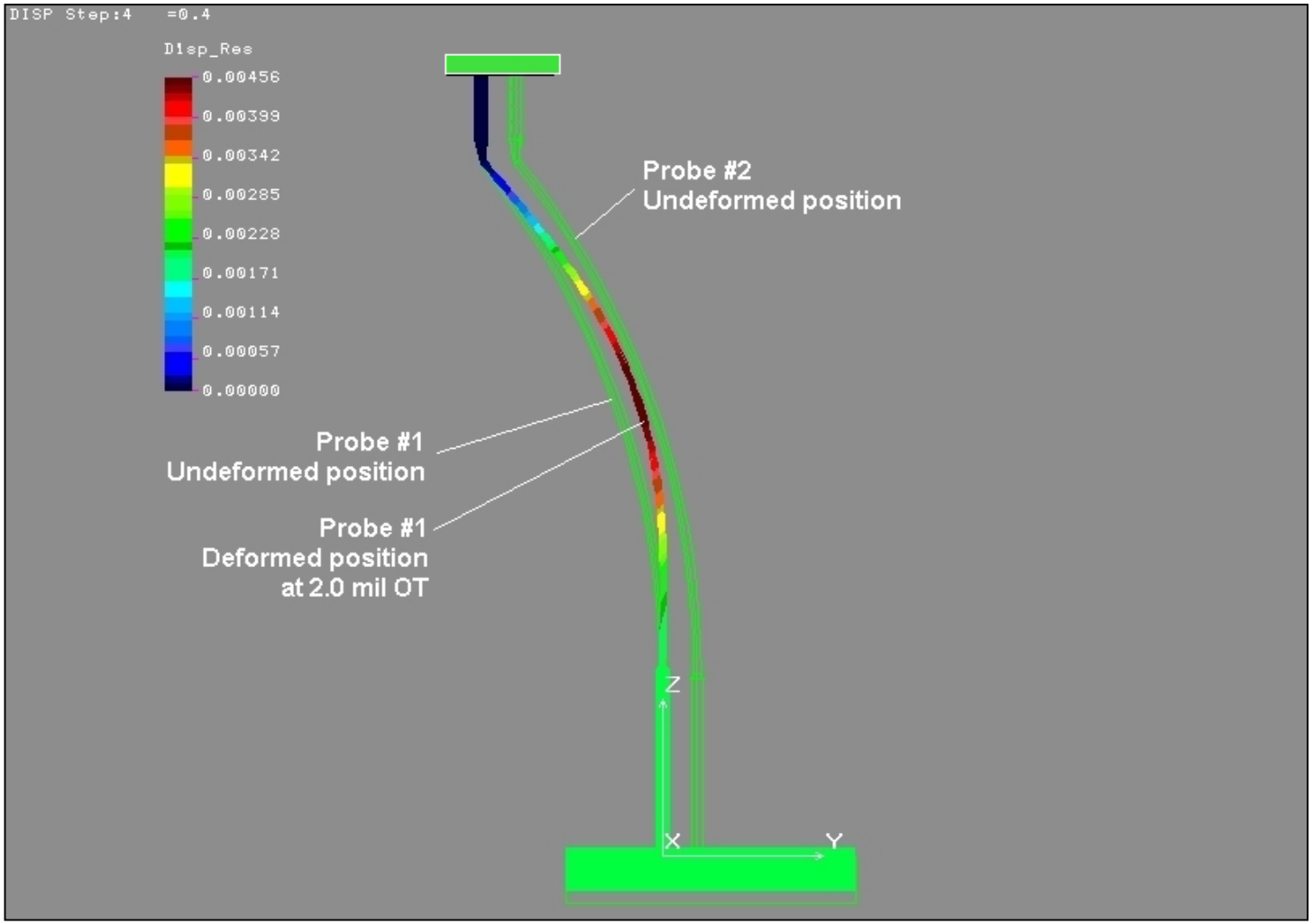
- **Concern**:
  - Probe to probe interference
    - **With multiple tolerances contributing to the different overtravels of adjacent probes, need to ensure probes will not interfere.**

Pitch from Probe Perspective

- **Model Conditions**:
  - Two probes in given configuration (see following model)
  - Probe pitch: 7 mil (180 um)
- Tops of both probes fixed at same Z – height.
- Probes deflected in 1 mil OT increments up to 5.0 mil overtravel
  - 1 probe deflecting up to 2 mils prior to the deflection of the adjacent probe.
- Success criteria:
  - Gap between the two probes > 0.5 mils at all overtravel conditions.

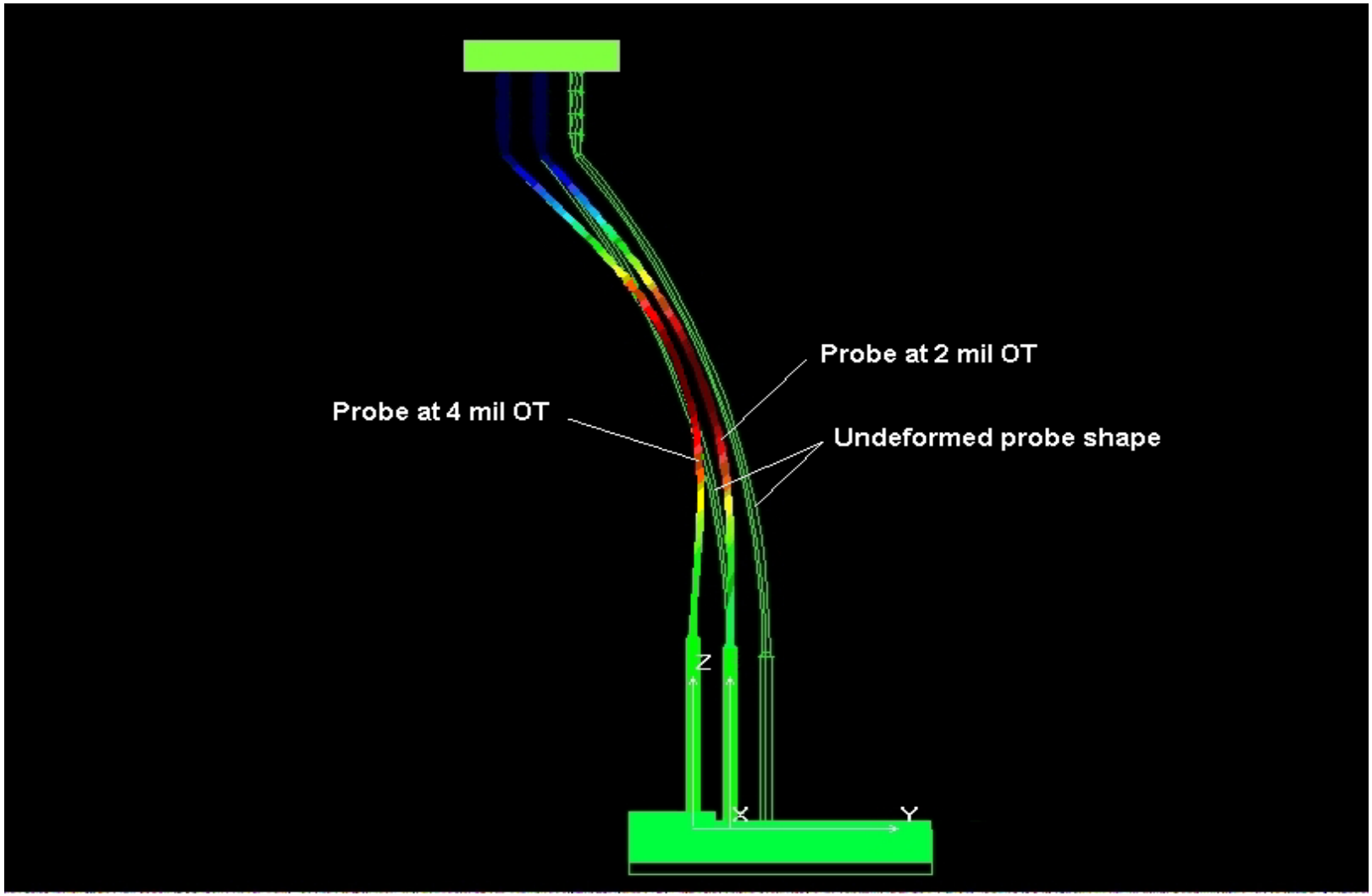
Pitch from Probe Perspective

- **Case #1: Probe deflection at 2.0 mil OT**



Pitch from Probe Perspective

- Case #2: Probe deflections at 2.0 and 4.0 mil OT



Pitch from Probe Perspective

Conclusion: ***Model gap analysis determined the probe geometry is a low risk of probe interference under overtravel conditions for the pitch considered.***

Addressing Probe Force

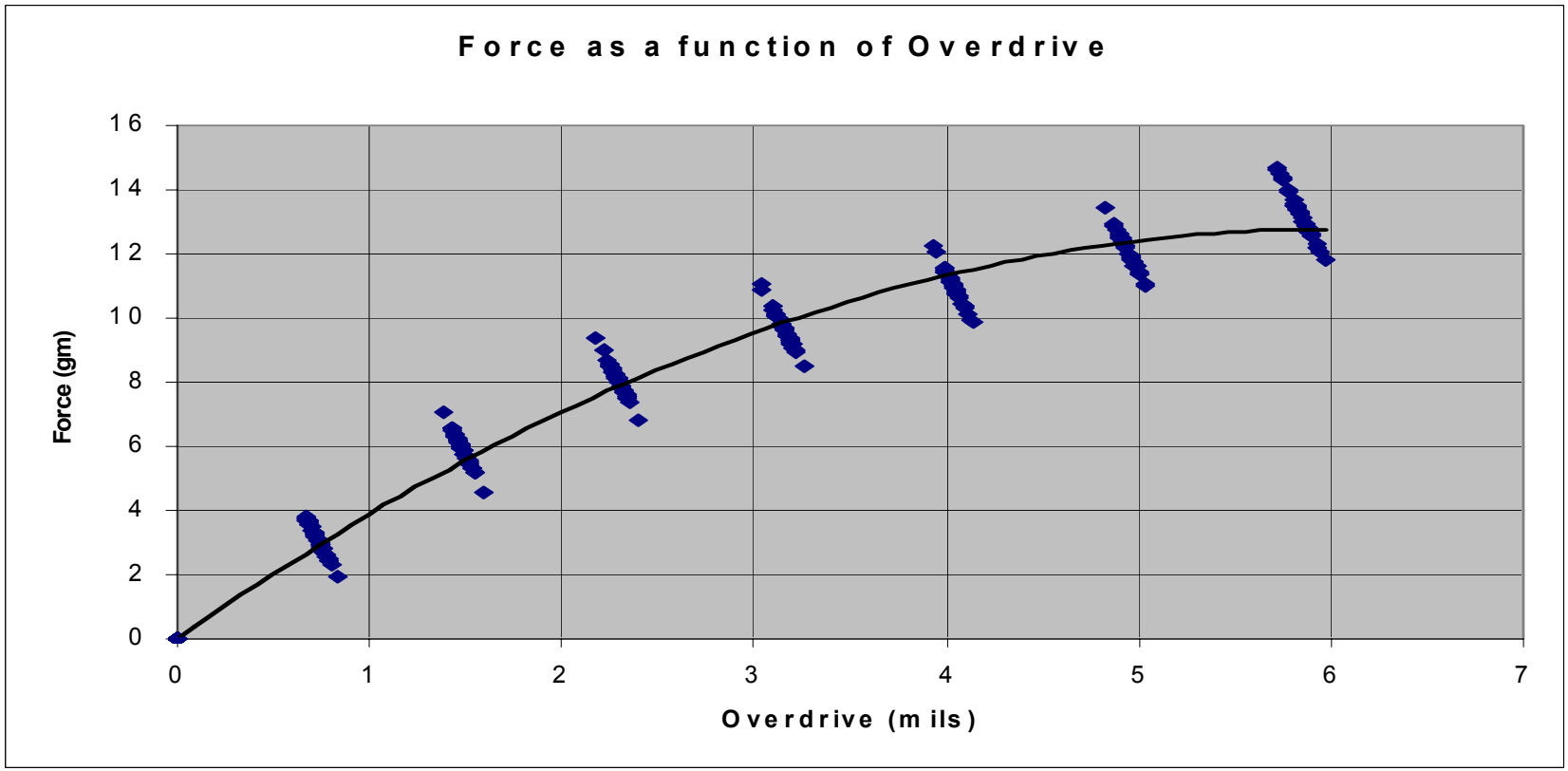
- **Two Concerns:**
  - **Probe to probe force variance**
    - Analysis of probe force variance across multiple overtravels
  - **Probe force variance across lifetime**
    - Analysis of probe force across the life of the probes.

Addressing Probe Force

- ***Probe force variance DoE setup***
  - ***Sample size - 40 probes***
  - ***Conditions:***
    - *Measured probe force in 1 mil overtravel increments up to 6 mils of overtravel.*
    - *Aged probes with 5 mils actual overtravel with probe cycling instrument.*
    - *Measured probe force in multiple increments across the probe lifetime up to 500K touchdowns.*
      - Initial, 100K, 250K, 500K

Probe Force Variance DoE

Data presents the probe force of the 40 probes across multiple overtravels and from initial to final cycling increments.



Conclusion: **Probe force meets force requirements and concluded that there is no statistically significant probe force variance across lifetime.**

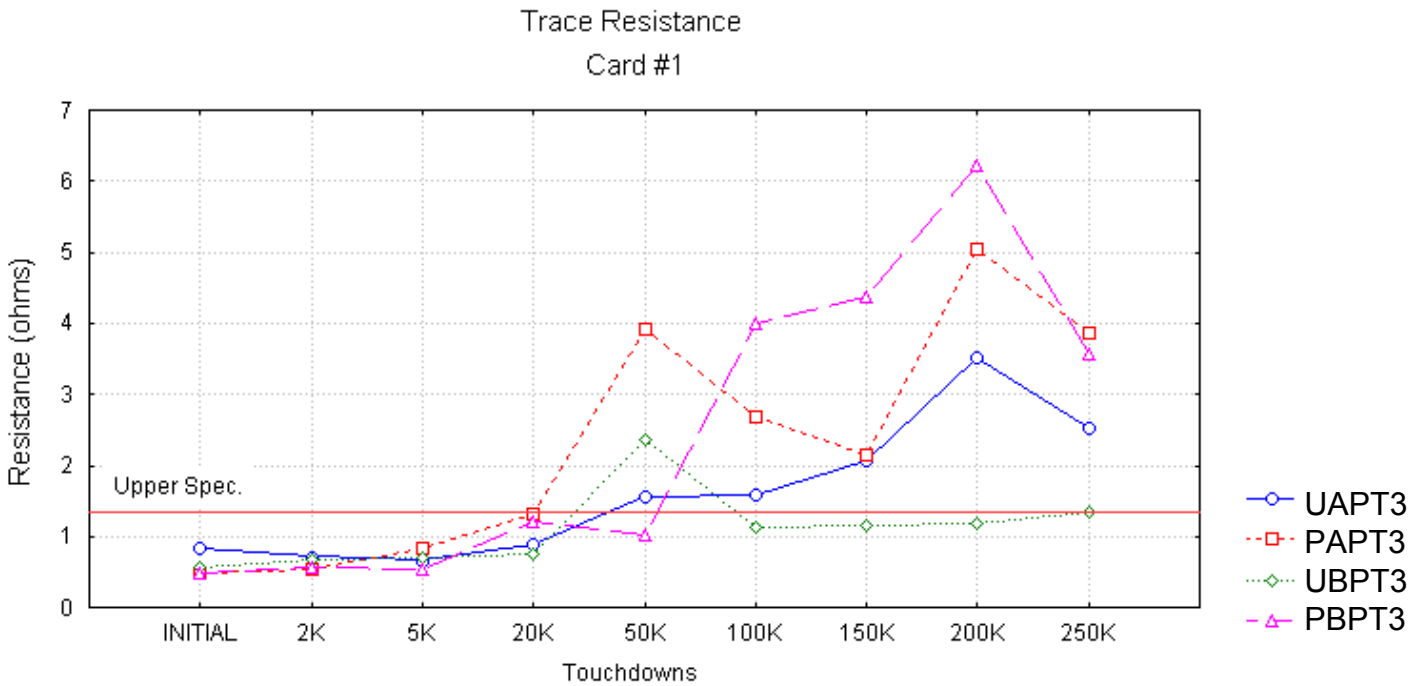
Addressing Contact Resistance

- **Purpose:**
  - To determine the best probe tip geometry and metallurgy for copper bump probing
- **Test Conditions:**
  - 4 cards/wired space transformers
  - Measure trace resistance
  - Measure at daisy chained bumps
  - Age probes and repeat measurements
    - Initial, 2K, 5K, 20K, 50K, 100K, 150K, 200K, 250K

Contact Resistance DOE

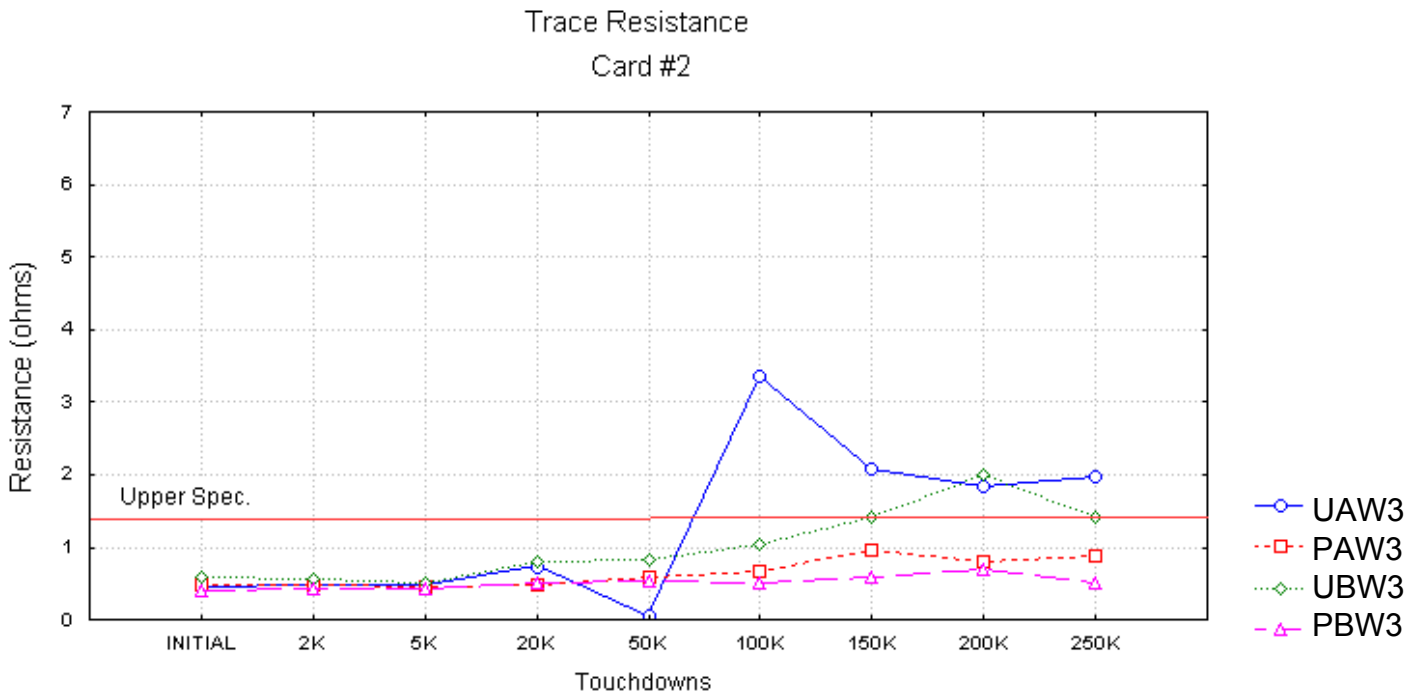
- Selected list of process variables
  - Probe Plating: Unplated, Plated
  - Tip Included Angle: A, B
  - Tip Shape: Pointed, Wedge
  - Probing OT: 3 and 5 mils
- Selected list of response variables
  - Contact Resistance on daisy chained Cu bumps
  - Probe wear – tip size
- Test conditions
  - Probe Diameter: 3 mil
  - Probe Metallurgy: BeCu alloy
  - Ambient temperature
  - Trace resistance spec limit: 1.4 ohms

Contact Resistance DOE



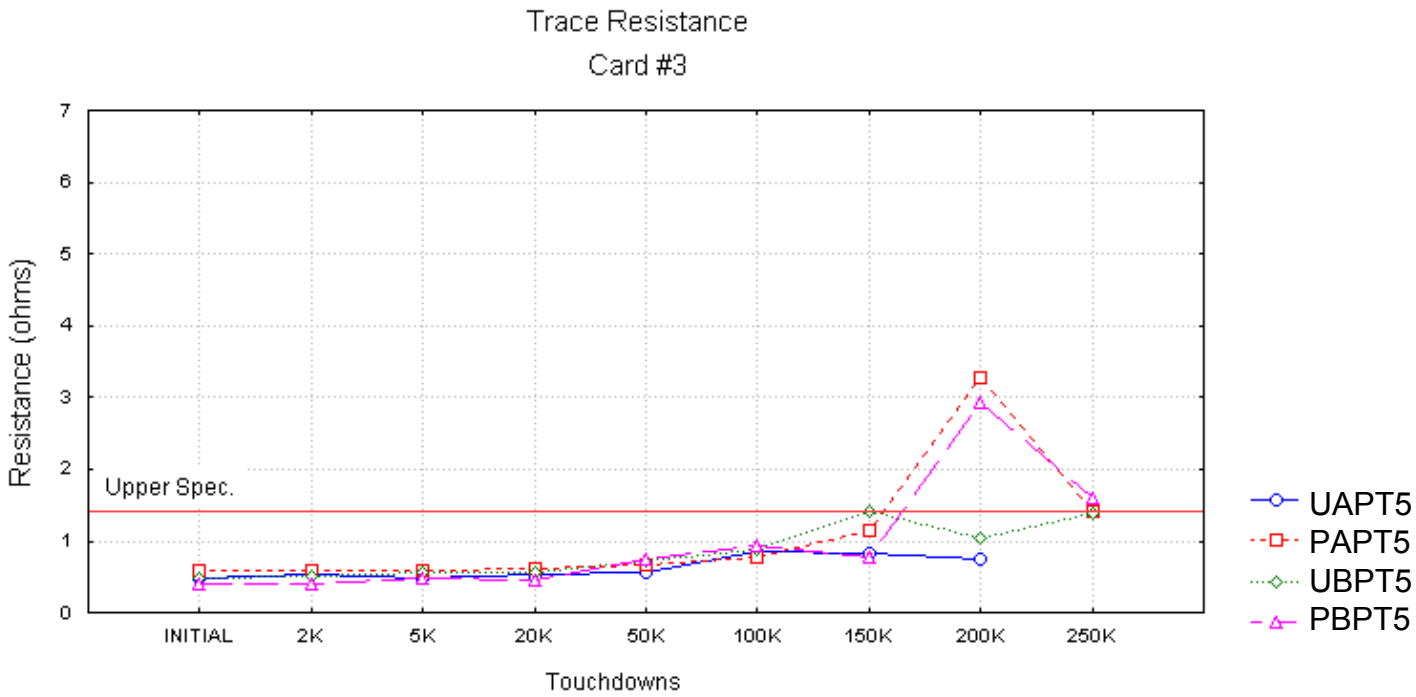
UAPT3: Unplated, A degrees, Pointed and 3 mil OD
PAPT3: Plated, A degrees, Pointed and 3 mil OD
UBPT3: Unplated, B degrees, Pointed and 3 mil OD
PBPT3: Plated, B degrees, Pointed and 3 mil OD

Contact Resistance DOE



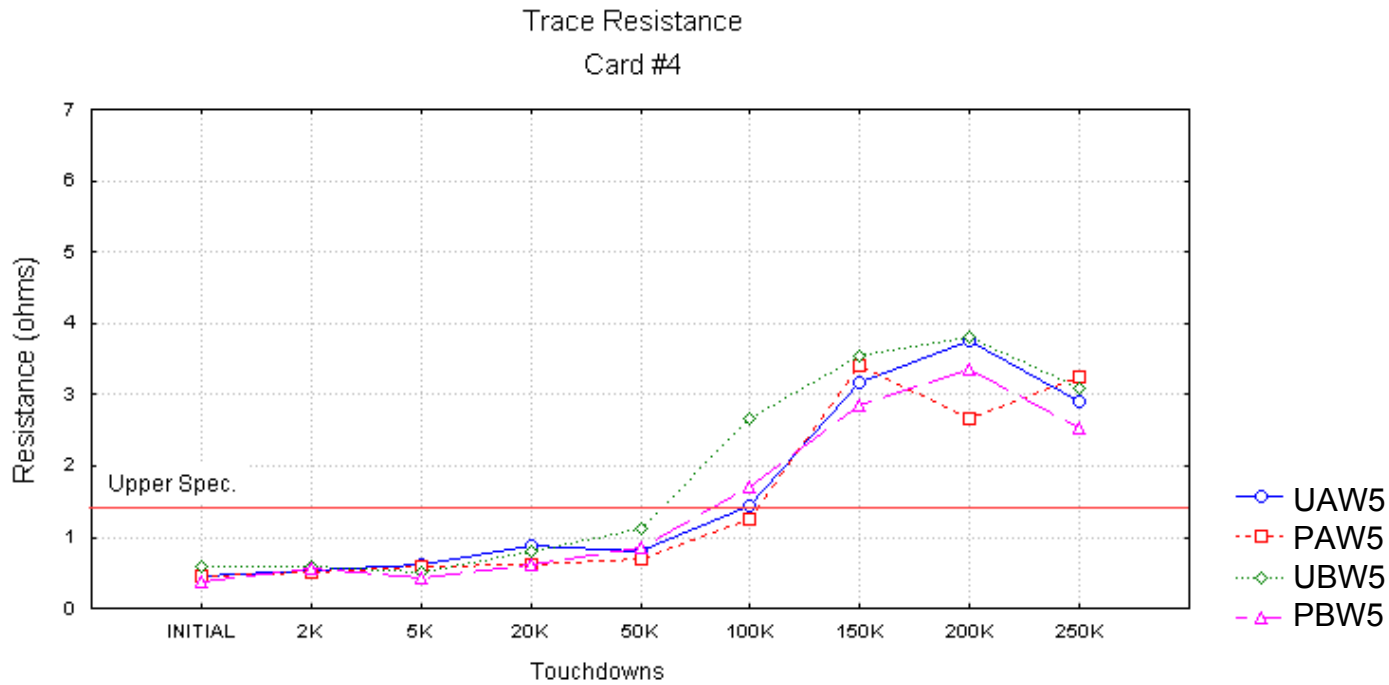
UAW3: Unplated, A degrees, Wedge and 3 mil OD

Contact Resistance DOE



UAPT5: Unplated, A degrees, Pointed and 5 mil OD

Contact Resistance DOE

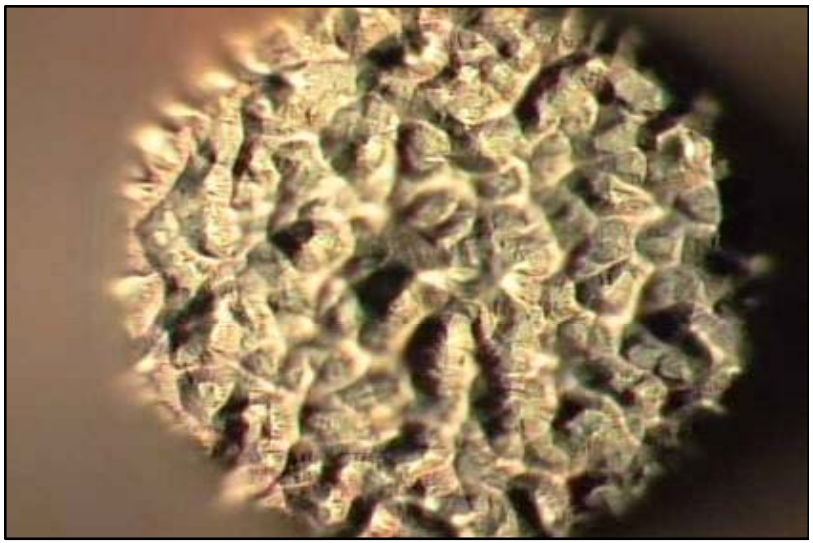


UAW5: Unplated, A degrees, Wedge and 5 mil OD

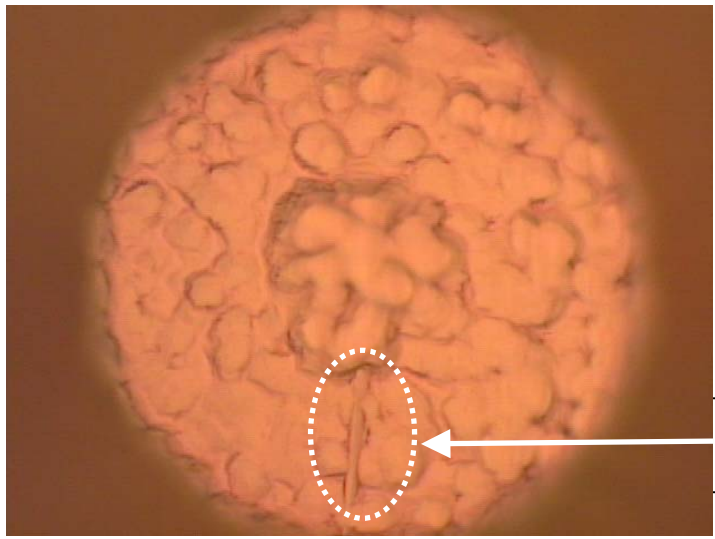
Contact Resistance DOE

Contact Resistance DOE Summary

- **Leading configuration- Angle B, plated wedge**



Clean Cu Bump

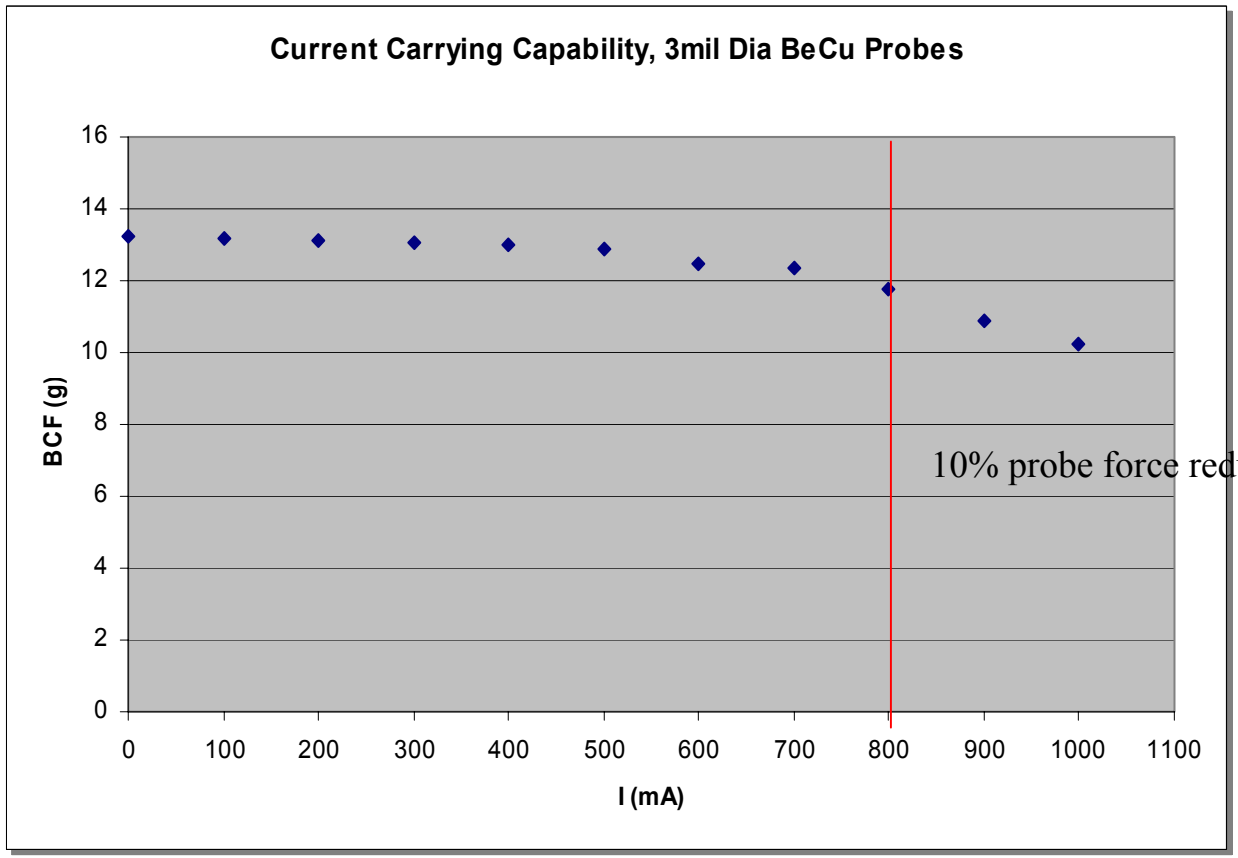


Probed Cu bump with Wedge probe

Current Carrying Capability DoE

- ***Purpose:***
  - ***To measure current carrying capacity of 3 mil-dia BeCu probes on a test head by using 10% probe force reduction criteria at 5mil OD***
- ***Criteria:***
  - **There is a critical dc current value above which the mechanical degradation of a probe is significant. There will be no damage to the elastic properties of the probe below a critical value. The criteria for the maximum current capability is the 10% drop in probe force.**
- ***Test Conditions:***
  - **Balance Contact Force station**
  - **Probe-head**
  - **5mil OD**
  - **1 min hold (current)**

Current Carrying Capability DoE



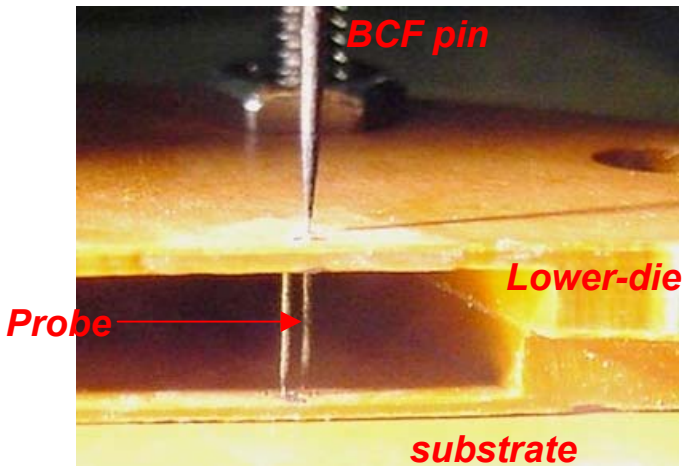
Current Capacity = 800 mA

Addressing Temperature vs Current

- **Purpose** is to characterize the probe temperature as a function of applied probe current.

- **Test Conditions:**
  - A cross-sectioned probe-head and a high-resolution IR thermal imager
  - 4 probes used for data collection of each current level
  - The temperature measurement accuracy due to reflectivity of BeCu surface is +-2 degrees

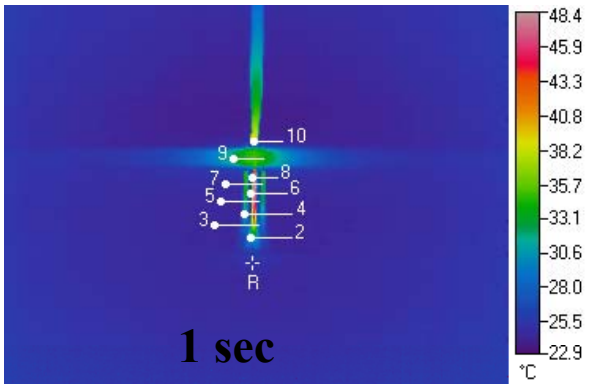
1. Upper die
2. Lower die
3. Measured probe
4. BCF pin
5. Gold plate

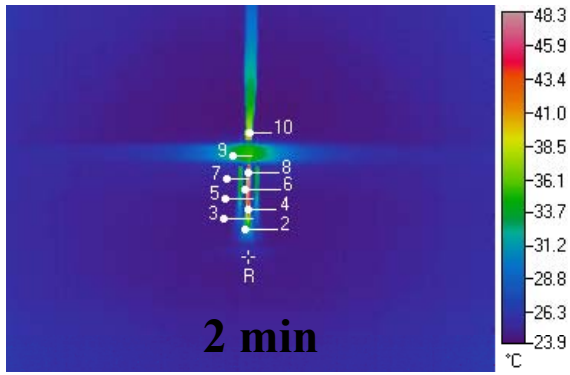


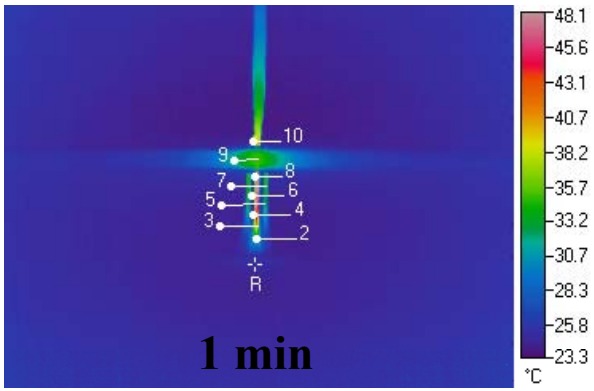
Probe head set up for IR measurement

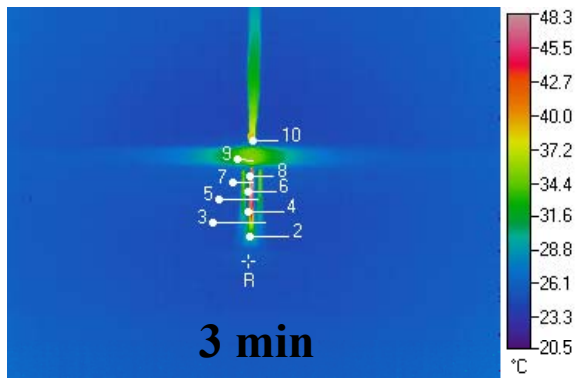
IR Probe Temperature Profiles

Thermal Images for 0.4 Amp Measurements





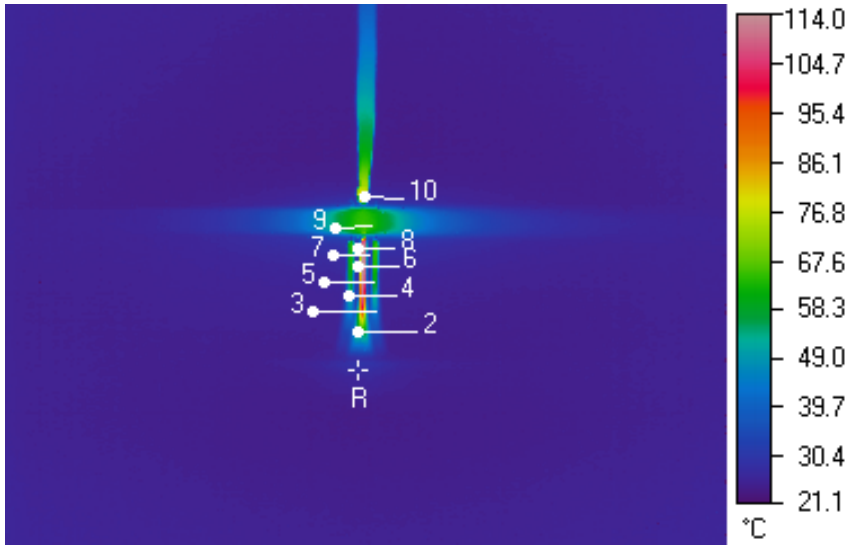




Temperature results for 4 probes at 0.4 Amp as a function of time
- Temperature is constant with hold time

IR Probe Temperature Profiles

Thermal Image of the probe-head for 0.8 Amp Measurement



Max probe temperature at max current carrying capacity (800 mA) determined to be 110°C.

Probe Temperature

Summary of Experimental Results

Current (Amp)	Max Temp,°C (BeCu Probe)
0.2	28.5
0.4	45.2
0.5	57.4
0.6	72.1
0.8	109.6
1.0	183.1
1.2	222.9
1.3	253.9

Conclusion: ***Probe current carrying capability is determined to be 800 mA and has a max temp. of 110°C at this current level. Temperature at the current requirement (400mA) determined to be 45°C.***

Summary

Item	Requirement	Risk Level
Probe Pitch	180 um	Low Risk - probe geometry capable of meeting 180 um pitch
Probe Force	<16 g/probe @ Max OT	Low Risk - Probe geometry produces < 16 g/probe @ max OT.
Contact Resistance	< 0.5 Ω	Low Risk - Probe configuration stable at < 0.5 Ω Cres out to 250 K TD.
Probe Current Carrying Capability	> 400mA	Low Risk - Current carrying capability determined to be 800mA with max probe temperature at 110°C. Temperature concluded to be 45°C at 400mA.

Risk level for each critical requirement reduced to low.

Acknowledgements

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