BiTS

Burn-in & Test Socket Workshop

March 2 - 5, 2003
Hilton Phoenix East / Mesa Hotel
Mesa, Arizona

IEEE COMPUTER SOCIETY

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Burn-in & Test Socket Workshop

Technical Program

Session 4
Tuesday 3/04/03 10:30AM

Modeling And Characterization

"A Standard Method To Measure Socket Current Carrying Capability"

Roger Weiss, Ph.D. - Paricon Technologies Corporation

"Compression Force Model For Sockets Using Response Surface Methodology"

Ila Pal - Ironwood Electronics, Inc.

"Effect Of Pin Tip Structure On Contact Resistance"

Jiachun (Frank) Zhou - Kulicke & Soffa Interconnect, Inc.

Jim Roundy - Kulicke & Soffa Interconnect Inc.

Alberto M. Campos - Kulicke & Soffa Interconnect, Inc.

Glenn A. Cunningham - Intel Corporation

PARICON®

Paricon Technologies Corporation

A Standard Method to Measure Socket Current Carrying Capability

or:

A Naive Attempt to Get Customers to Make Their Supplier’s Life Easier

Roger Weiss, PhD

Problem Definition

The Heat Generated by the Device and Interconnect is One of the most Critical Problems to Solve in the Development of Higher Performance Systems

Problem Definition

The Interconnect Structure is Becoming the Weak Link

- **Device Operating Temperature on Rise**
- **Higher Power per Device / Socket**
- **Contact Pitch Decreasing**
- **Current and Power Density demands on Contact and Socket are Rapidly Increasing**
- **Traditional Socket Provides Small Role in Removal of Heat**

Problem Definition

Generic High End Socket Specification

- **Device Operating at 80 °C (and higher)**
- **Up to 2 amps per Contact**
- **Contacts on 1 mm Pitch**
- **In Excess of 100 amps per socket**
- **Life to Exceed 500,000 Cycles**

Problem Definition

There Are No Industry Standards That Apply to Current and Power Characterization of Sockets*

- **EIA PN-3786 Does Not Apply**
  - **Passive Interconnect (Cable to Cable)**
  - **Ambient Thermal Environment**

*** That I have been able to find**

Problem Definition

Each Customer Defines and Qualifies Sockets to "In House Standards"

- **Thermal Cycling**
- **Power Cycling**
- **Current vs. Temperature**

The Differences Between Customers Requirements are not Insurmountable

Challenge

Develop Standard Characterization Process to Define Socket Capability That Works for Customer

Two Possible Directions:

- **Detailed Thermal Characterization**
- **Capability, Reliability and Failure Limits Using Standard Setup**

Standard Test Focus

Focus on Capability , Reliability and Failure Limits

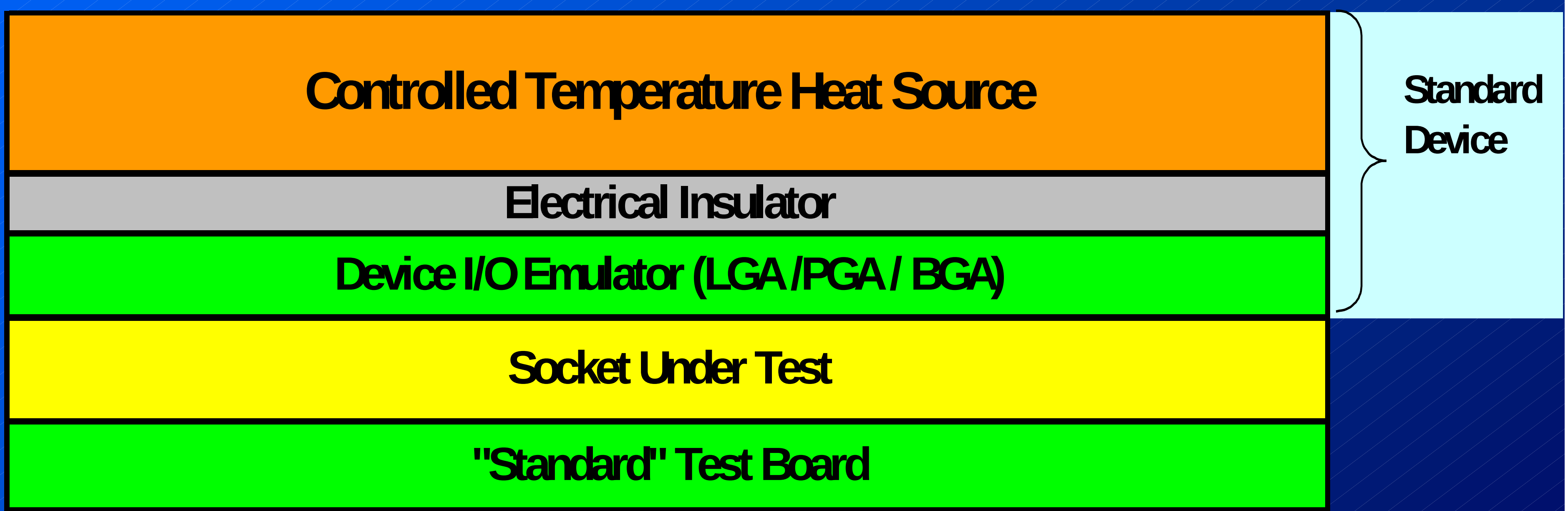
Standardized Test to Focus on:

- **Current Carrying Capability vs. Thermal Environment**
- **Power Cycling at Operating Current and Temperature**

Test Definition

- ***Universal Test Apparatus***
- ***Standard Measurement Process***
- ***Standard Test Procedure***

Universal Test Apparatus



Universal Test Apparatus

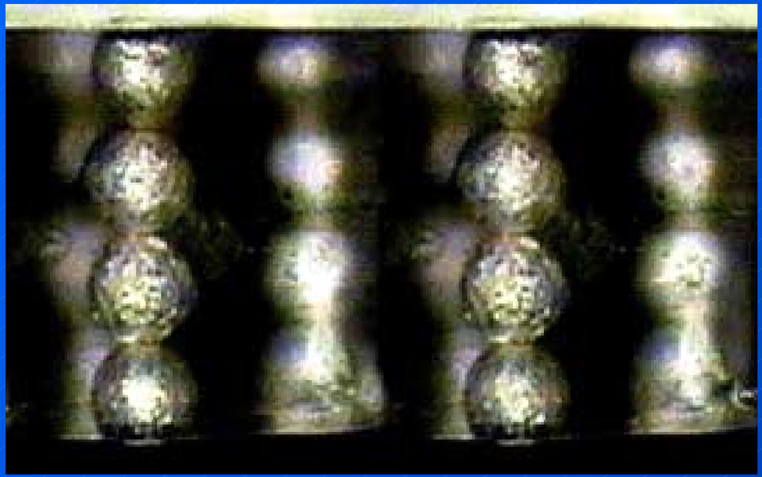
Standard Device Emulates Environment Created by Customer Device

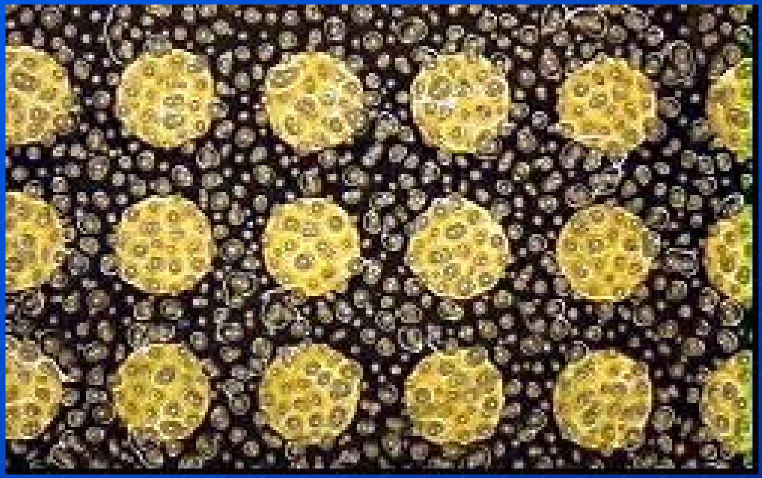
- **Heated to Device Temperature**
- **I/O Structure Matched to Device**
- **Same Contact Pitch as Device**
- **Current Through Contacts Matches Device**

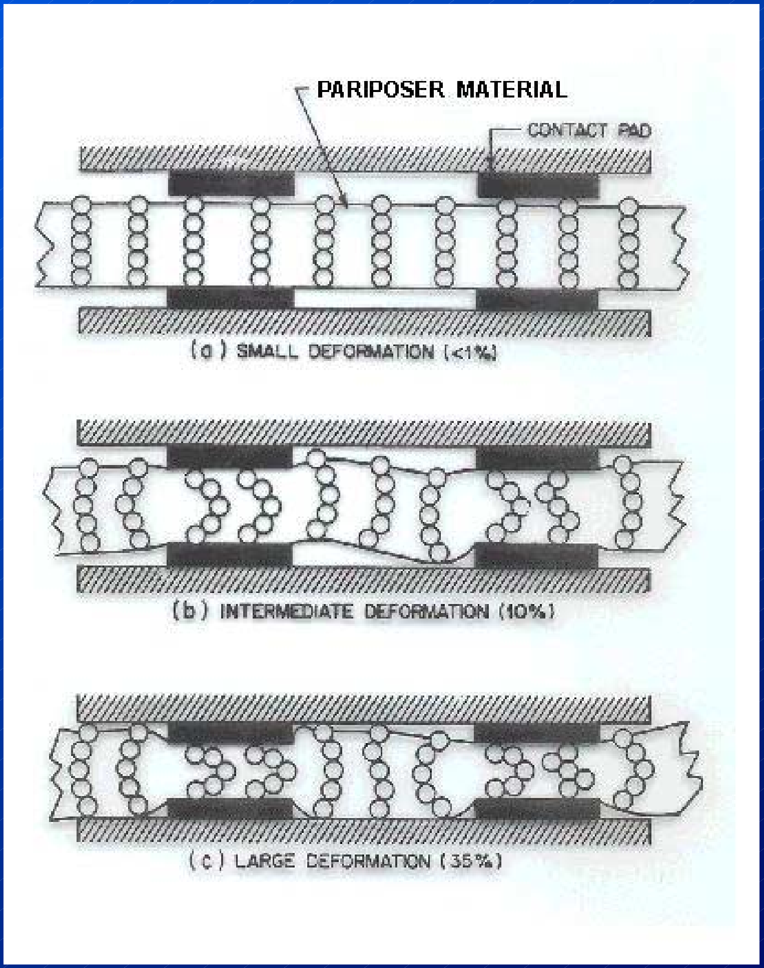
Example

Proposed Universal Test Applied to LGA Socket Using PariPoser® Connector System

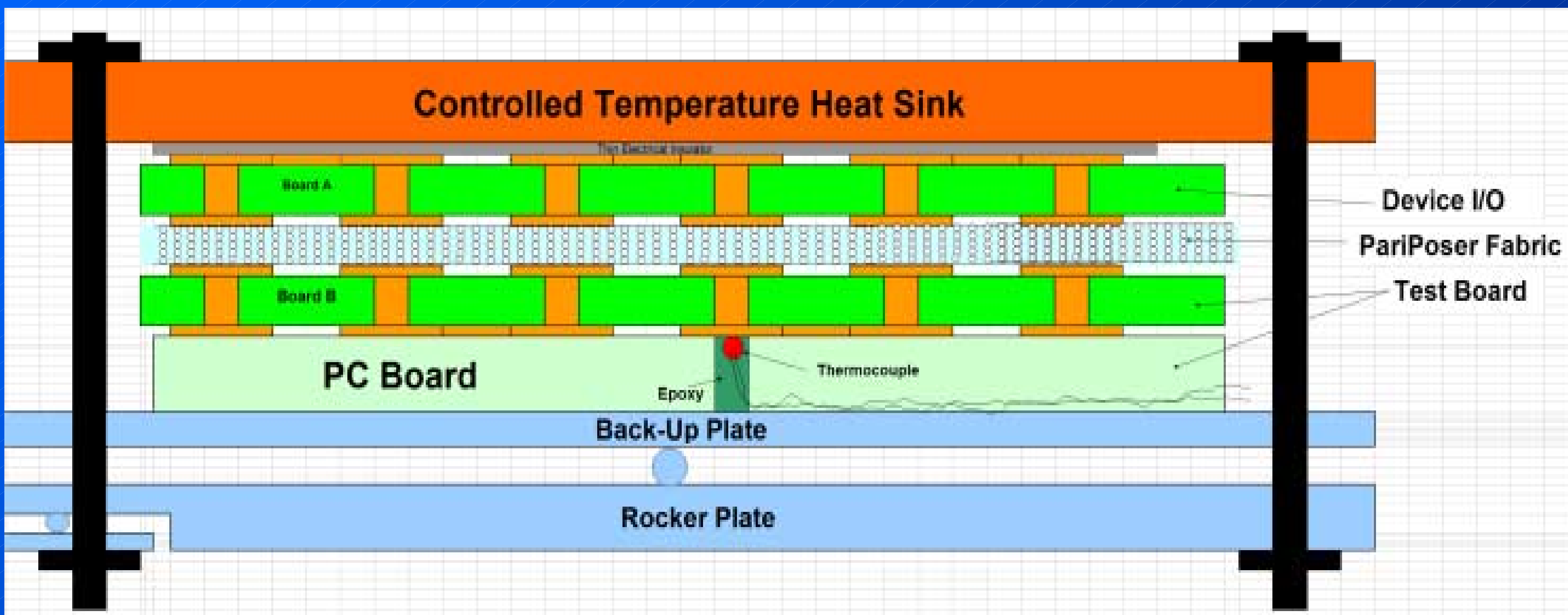
PariPoser® Interconnect



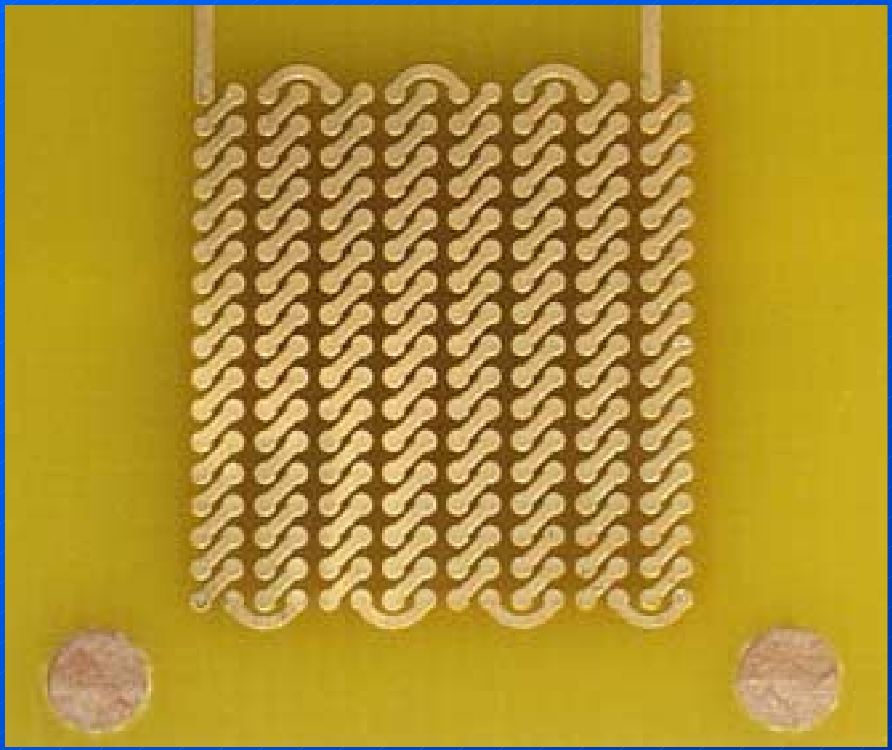




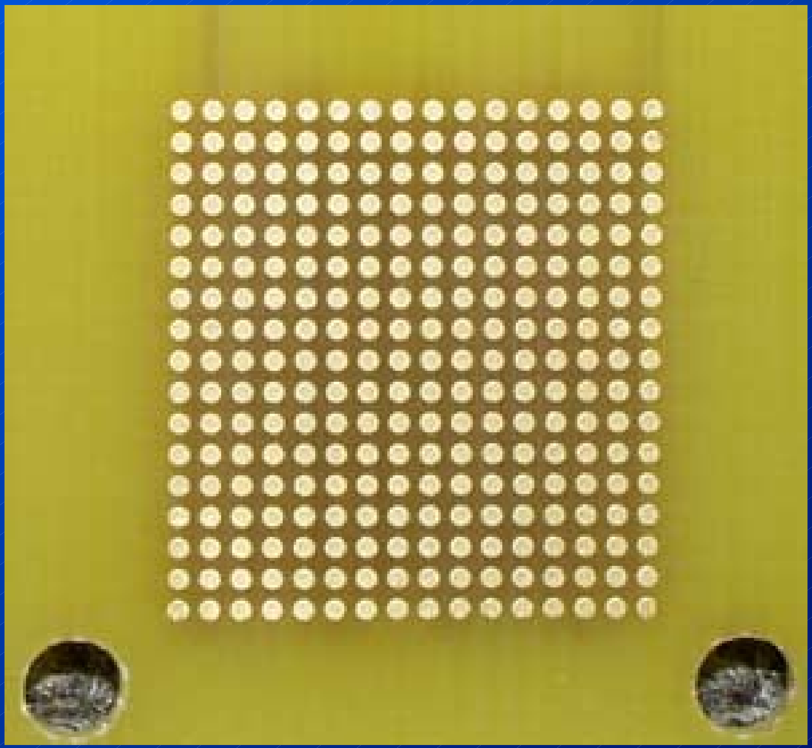
Apparatus


Controlled Temperature Heat Sink
Board A
Device I/O
PariPoser Fabric
Board B
Test Board
PC Board
Thermocouple
Epoxy
Back-Up Plate
Rocker Plate

Test Boards



Bus Side

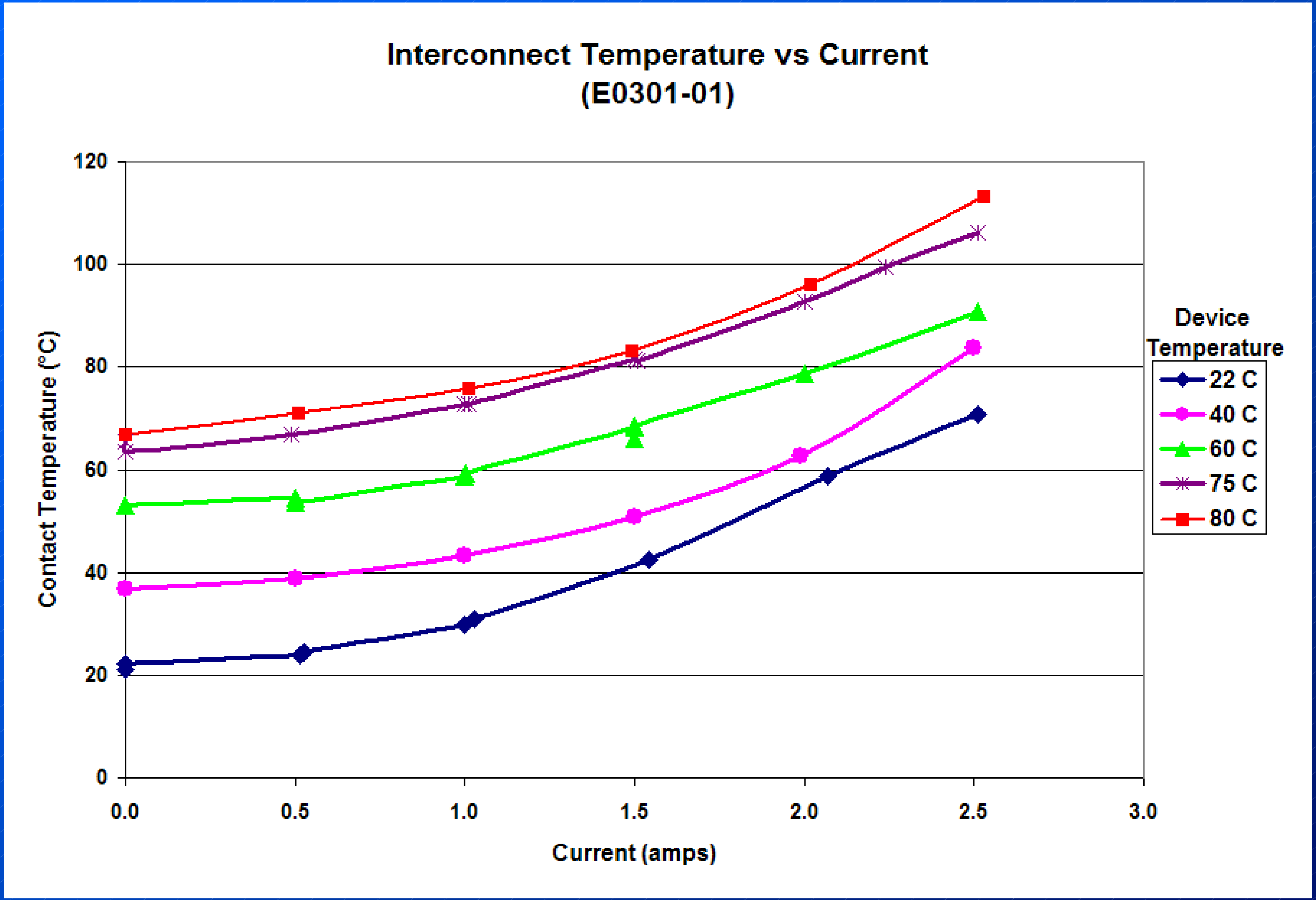


Contact Side

Setup

- 144 Daisy Chained Contacts (12 x 12)
  - (Current Carrying Study)
- 272 Daisy Chained Contacts (16 x 17)
  - (Power Cycling Study)
- 0.025” Pads on 1 mm Centers
- Thermocouples on Contact and “Device”

Current Carrying Capability

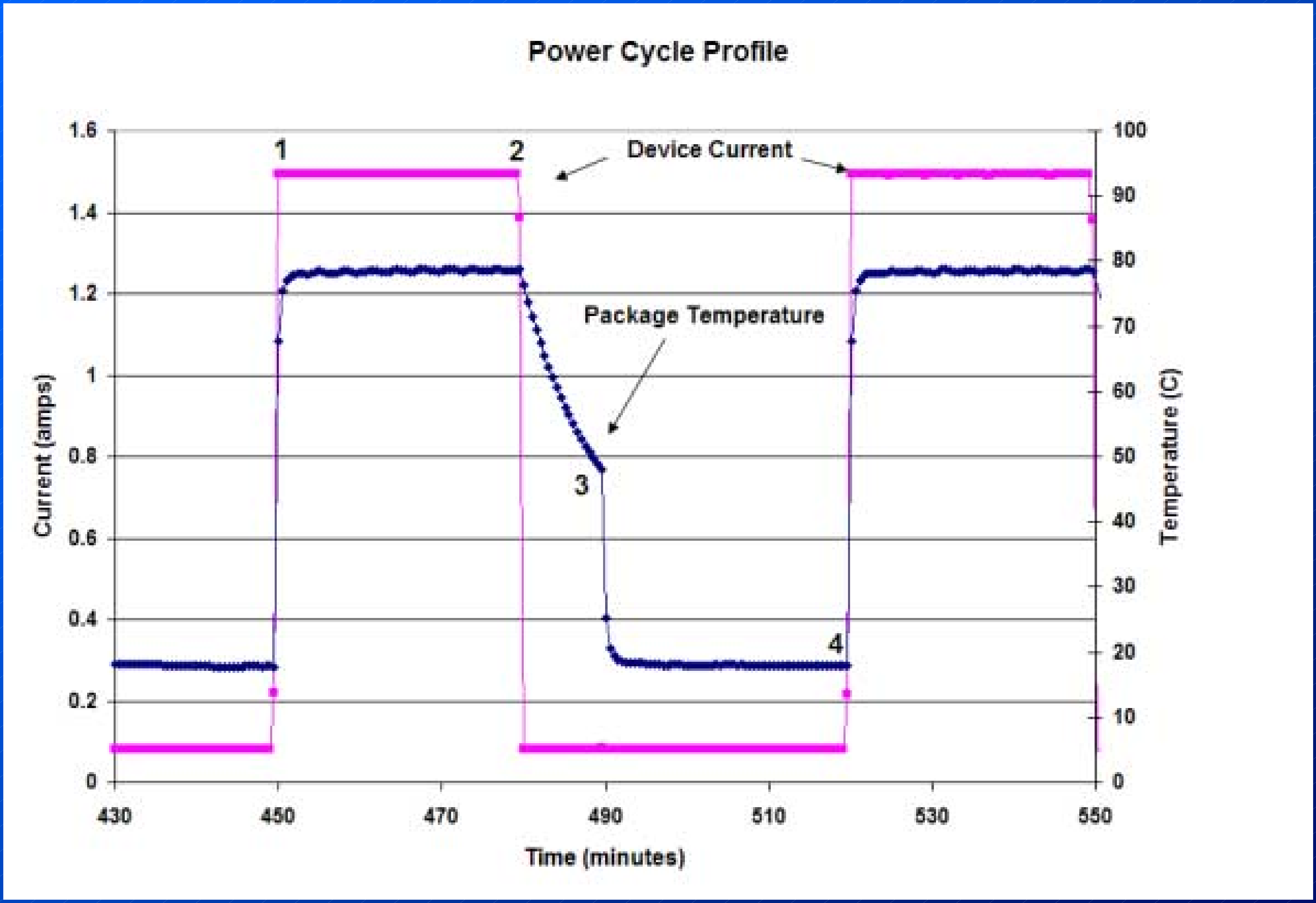


Power Cycling

Emulate Thermal Environment as Device is Turned on and off

- Device at Ambient for 30 Minutes
  - No Current Flow
  - Device Temperature Set at 20 °C
- Device in Operational Mode for 30 Minutes
  - Current set to 1.5 amps on 272 Contacts
  - Device Temperature Set at 80 °C

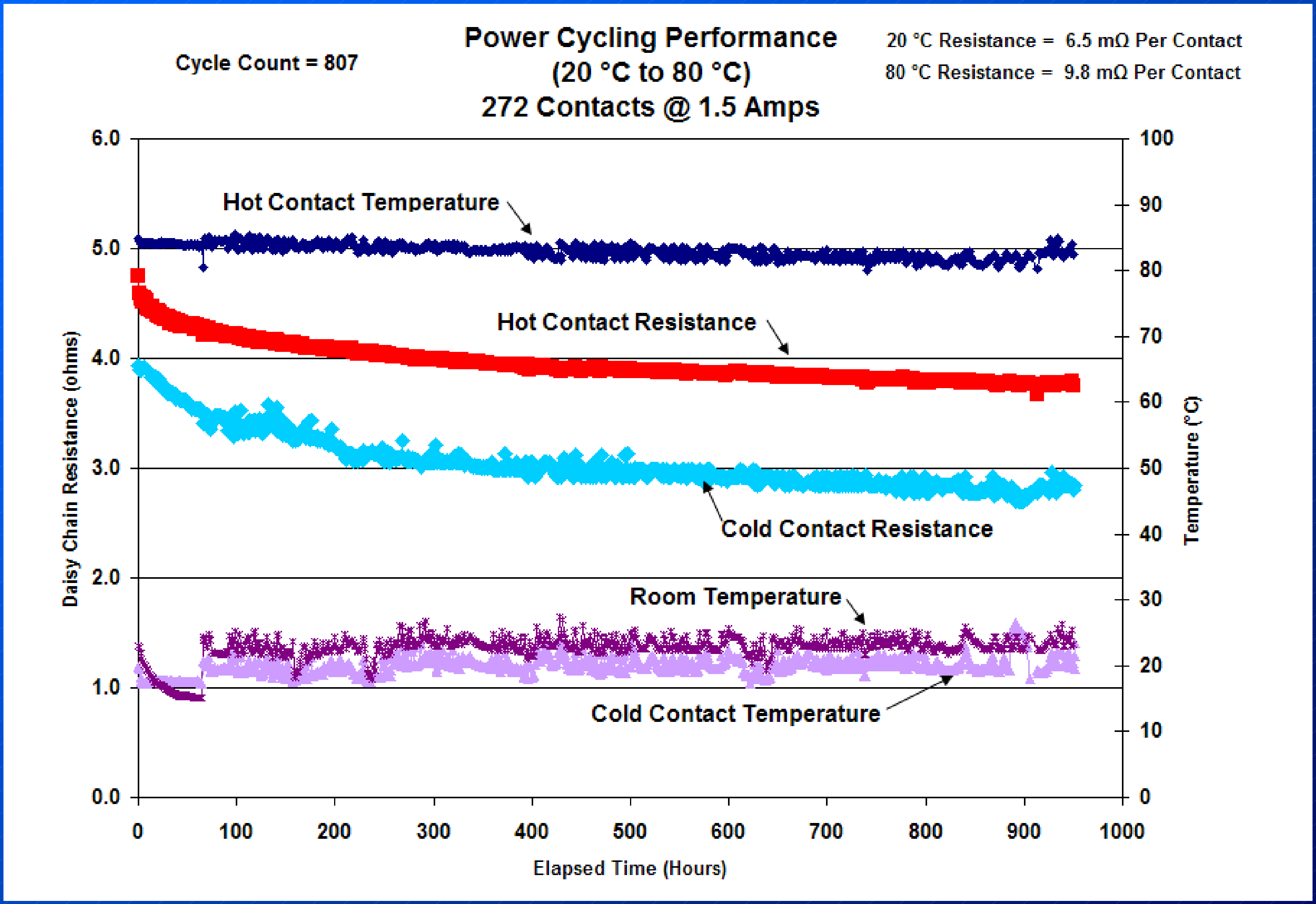
Power Cycle Profile



Power Cycling

Monitor Device Temperature, Contact Temperature, and Daisy Chain Resistance for 1000 Hours

Power Cycling



Conclusions 1

- ***Universal Test Process is Possible***
- ***Proposed System is Low Cost and Lends Itself to Broad Applicability***
- ***Without Customer Buy-In This Talk was a Waste of Time***

Conclusions 2

- ***PariPoser Contact can Carry More Than 2.5 amps on 1 mm Grid (0.025" Pad)***
  - ***1600 amps per square inch***
- ***No Degradation of PariPoser Contact with 1000 hours of Power Cycling***
  - ***1.5 amps on 1 mm Centers***
  - ***Device operating at 80 °C***

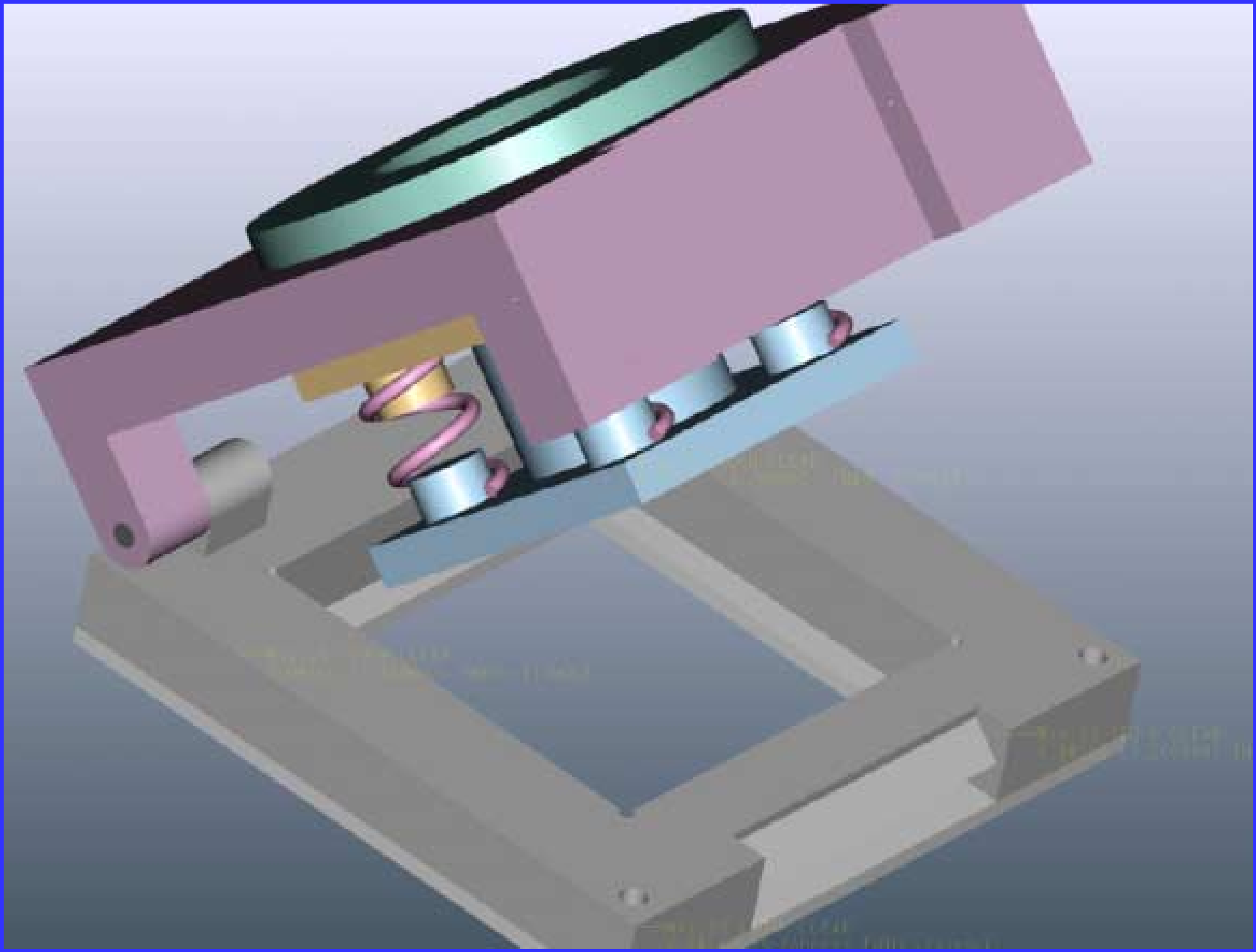
Compression Force Model for Sockets Using Response Surface Methodology

Ila Pal

Agenda

- Response surface methodology
- Compression force model
- Input/Output variables
- Design of experiments
- Estimation of parameters
- Analysis of results
- Conclusions

Clamshell Socket Lid Design



Postulation of a Mathematical Model

$$F = cN^{k}H^{l}D^{m}$$

F = Compression force (lbs)

N = Number of solder balls

H = Height of solder ball (mm)

D = Diameter of solder ball (mm)

c, k, l, m = Constants to be determined

$$\ln F = \ln c + k \ln N + l \ln H + m \ln D$$

Postulation of a Mathematical Model (continued)

$Y = b_o x_o + b_1 x_1 + b_2 x_2 + b_3 x_3 + €$

Y = Logarithmic value of the measured response (compression force)

$X_o = 1$

X_1 = Logarithmic value of number of solder balls

X_2 = Logarithmic value of height of solder ball

X_3 = Logarithmic value of diameter of solder ball

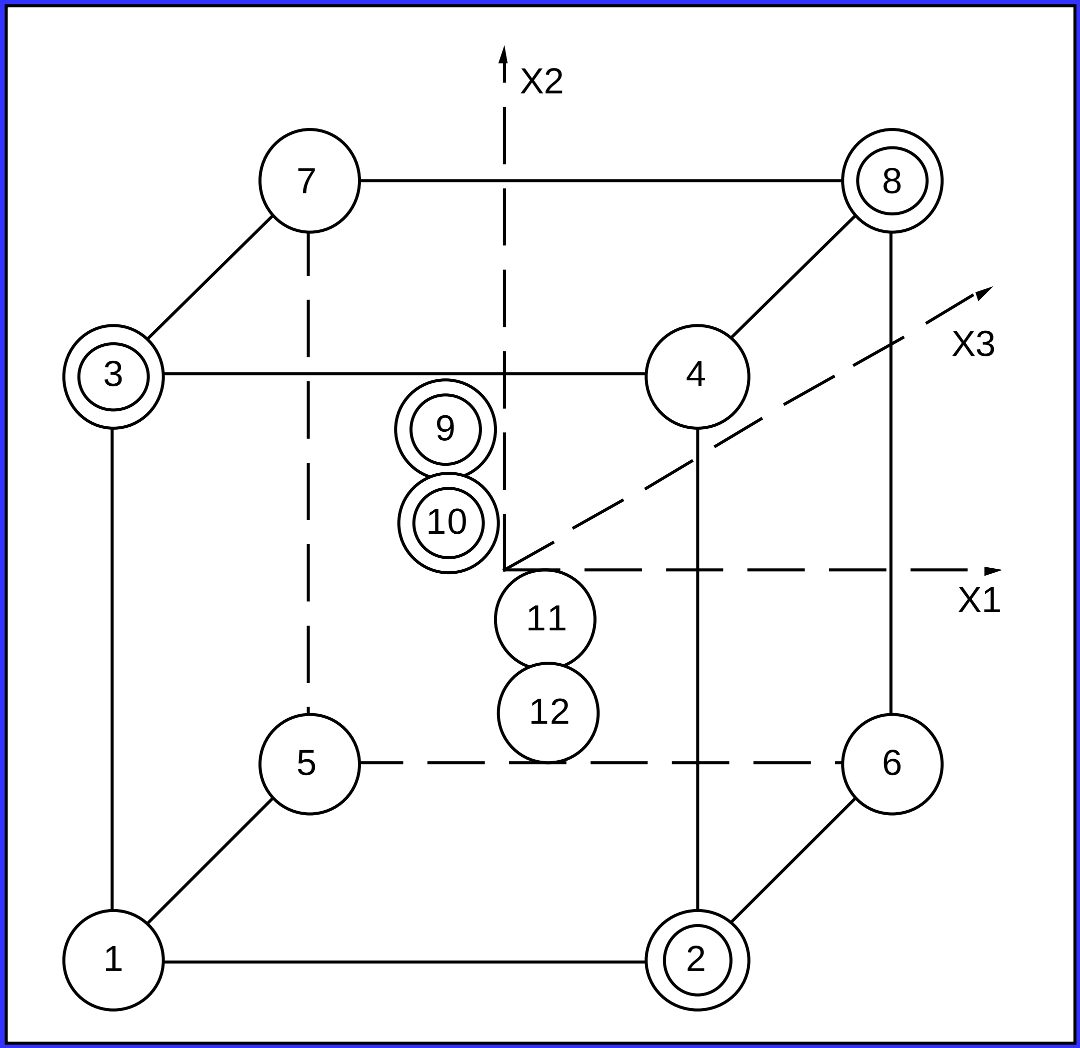
b_o , b_1 , b_2 , b_3 = Parameters to be estimated

€ = Experimental error

Experimental design and conditions

- Design of experiments
- 12 experiments
- 2^3 factorial design + 4 center points
- Two blocks of 6 tests each
- First-order model
- Can be extended to second-order model

Trial numbers of the composite design for the two blocks



Three levels of variables and coding identification

Level	Low	Center	High
Coding	-1	0	1
#of balls	200	400	800
height	0.5	0.6	0.7
diameter	0.6	0.75	0.9

Independent variables coding

$$X_1 = \frac{2(\text{Ln } N - \text{Ln } 800)}{(\text{Ln } 800 - \text{Ln } 200)} + 1$$

$$X_2 = \frac{2(\text{Ln } H - \text{Ln } 0.7)}{(\text{Ln } 0.7 - \text{Ln } 0.5)} + 1$$

$$X_3 = \frac{2(\text{Ln } D - \text{Ln } 0.9)}{(\text{Ln } 0.9 - \text{Ln } 0.6)} + 1$$

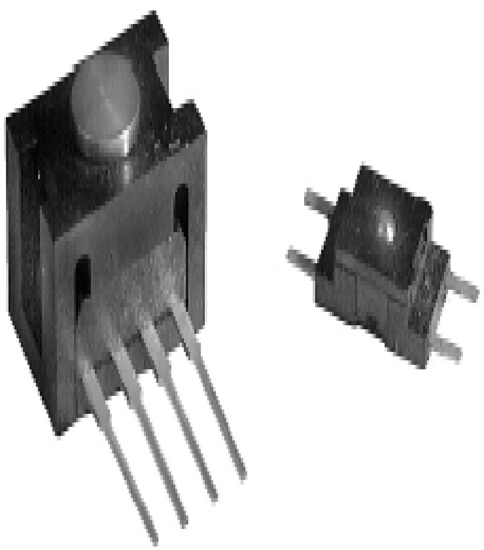
Experiment

Force Sensors

FS Series

FSG and FSL Series

NEW

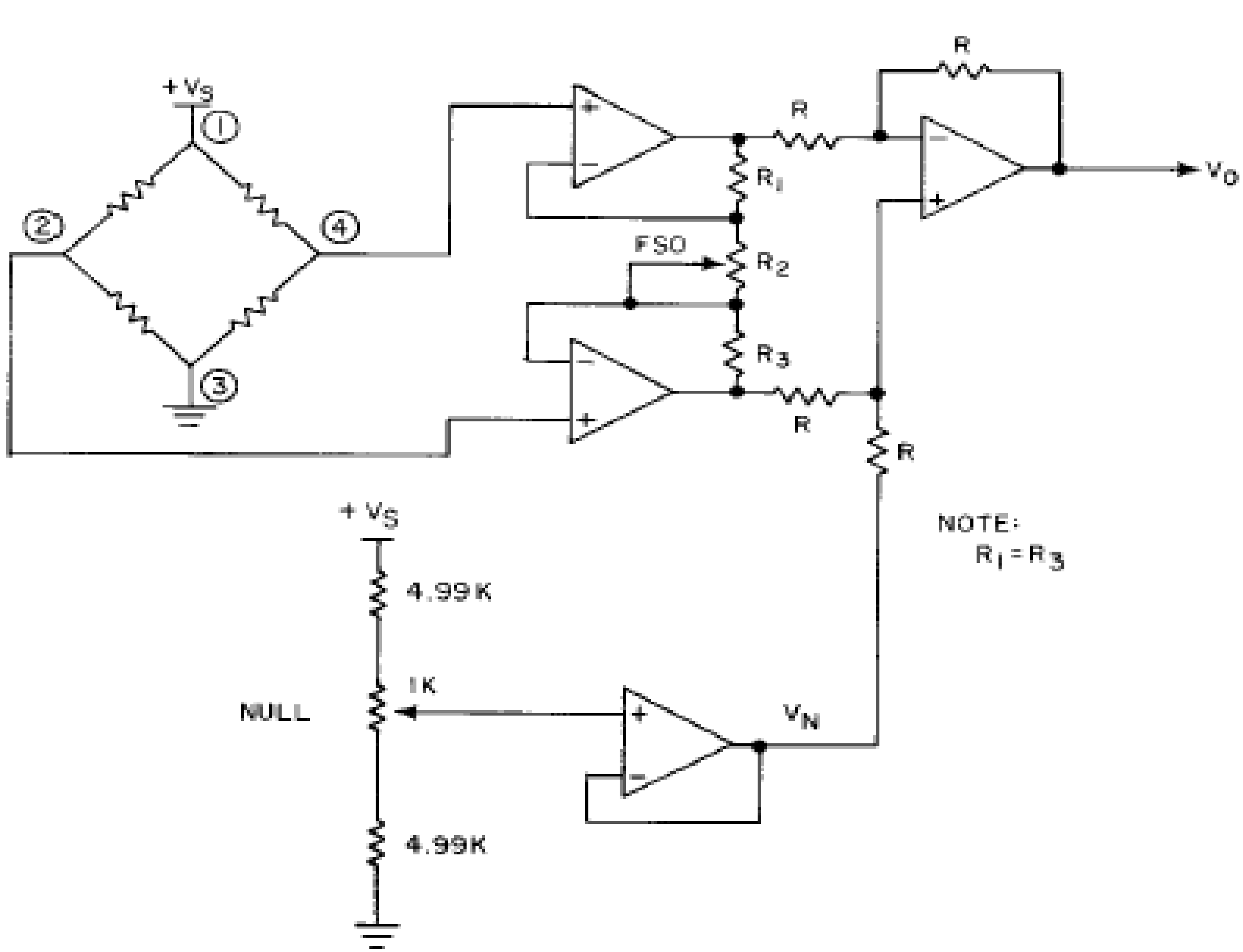


FEATURES

- Compact commercial grade package
- Robust performance characteristics
- Adaptable product design
- Precision force sensing
- Electrically ratiometric output
- Extremely low deflection (30 microns typ. @ Full Scale)
- High ESD resistance 10 KV
- Available signal conditioning
- Optional terminal configurations

Experiment (continued)

$V_o = (V_2 - V_4)(1 + 2R_1/R_2) + V_n$, Note: $R_1 = R_3$



Experiment (continued)

Experimental conditions, coding and results

Trial	Block	#of balls	height(mm)	diameter(mm)	x1	x2	x3	Force(lbs)	Ln F
1	2	200	0.5	0.6	-1	-1	-1	4.998	1.609038
2	1	800	0.5	0.6	1	-1	-1	19.99	2.995232
3	1	200	0.7	0.6	-1	1	-1	4.555	1.516226
4	2	800	0.7	0.6	1	1	-1	18.222	2.90263
5	1	200	0.5	0.9	-1	-1	1	7.869	2.062931
6	2	800	0.5	0.9	1	-1	1	31.476	3.449225
7	2	200	0.7	0.9	-1	1	1	7.157	1.968091
8	1	800	0.7	0.9	1	1	1	28.629	3.35442
9	1	400	0.6	0.75	0	0	0	12.282	2.508135
10	1	400	0.6	0.75	0	0	0	11.585	2.449711
11	2	400	0.6	0.75	0	0	0	12.217	2.502828
12	2	400	0.6	0.75	0	0	0	11.828	2.47047

Estimation of parameters

$Y = b_o x_o + b_1 x_1 + b_2 x_2 + b_3 x_3 + €$

Four coefficients in the model can be estimated by: $b = (X'X)^{-1} X'Y$

X =

X_0	X_1	X_2	X_3	Trial#
1	1	-1	-1	2
1	-1	1	-1	3
1	-1	-1	1	5
1	1	1	1	8
1	0	0	0	9
1	0	0	0	10

Estimation of parameters (continued)

$$(X'X) = \begin{bmatrix} 6 & 0 & 0 & 0 \\ 0 & 4 & 0 & 0 \\ 0 & 0 & 4 & 0 \\ 0 & 0 & 0 & 4 \end{bmatrix}$$

$$(X'X)^{-1} = \begin{bmatrix} 1/6 & 0 & 0 & 0 \\ 0 & 1/4 & 0 & 0 \\ 0 & 0 & 1/4 & 0 \\ 0 & 0 & 0 & 1/4 \end{bmatrix}$$

Estimation of parameters (continued)

$b_o = 1/6(y_2 + y_3 + y_5 + y_8 + y_9 + y_{10})$

$b_1 = 1/4(y_2 - y_3 - y_5 + y_8)$

$b_2 = 1/4(-y_2 + y_3 - y_5 + y_8)$

$b_3 = 1/4(-y_2 - y_3 + y_5 + y_8)$

Estimation of parameters (continued)

Block1: 6 tests

$Y = 2.481109 + 0.6926\ X_1 – 0.0469\ X_2 + 0.2265\ X_3$

Block2: 6 tests

$Y = 2.483714 + 0.6937\ X_1 – 0.0469\ X_2 + 0.2264\ X_3$

Analysis of Results

All: 12 tests

$Y = 2.482411 + 0.6932\ X_1 – 0.0469\ X_2 + 0.2264\ X_3$

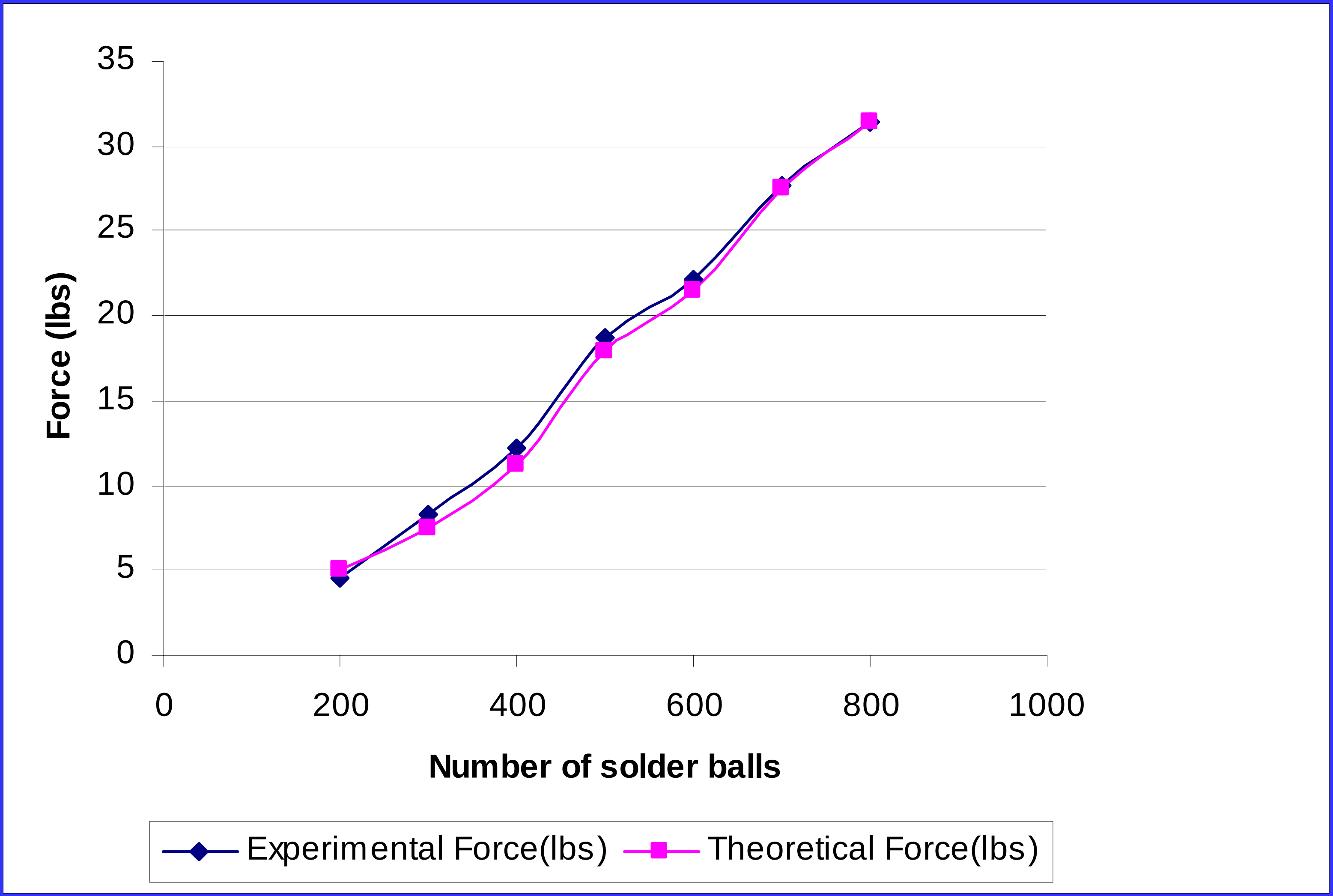
$F = 0.036518055\ N^{0.9995944}\ H^{-0.2791488}\ D^{1.1152464}$

200 = N = 800

0.5 = H = 0.7 mm

0.6 = D = 0.9 mm

Analysis of Results (continued)



Conclusions

- Force testing can be economically conducted by response surface methodology
- 12 tests are sufficient to develop predicting equation
- Second order model (24 tests) will make the predicting equation more precise.
- The reliability of predicting equation can be verified using ANOVA (Analysis of Variance).
- The response surface model makes it possible to visualize overall compression force and to study optimum selection.

Effect of Pin Tip Structure on Contact Resistance

Jiachun Zhou (Frank), Presenter
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Kulicke & Soffa Interconnect, Inc.

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BiTS 2003 Presentation

BURN-IN & TEST SOCKET WORKSHOP

Overview

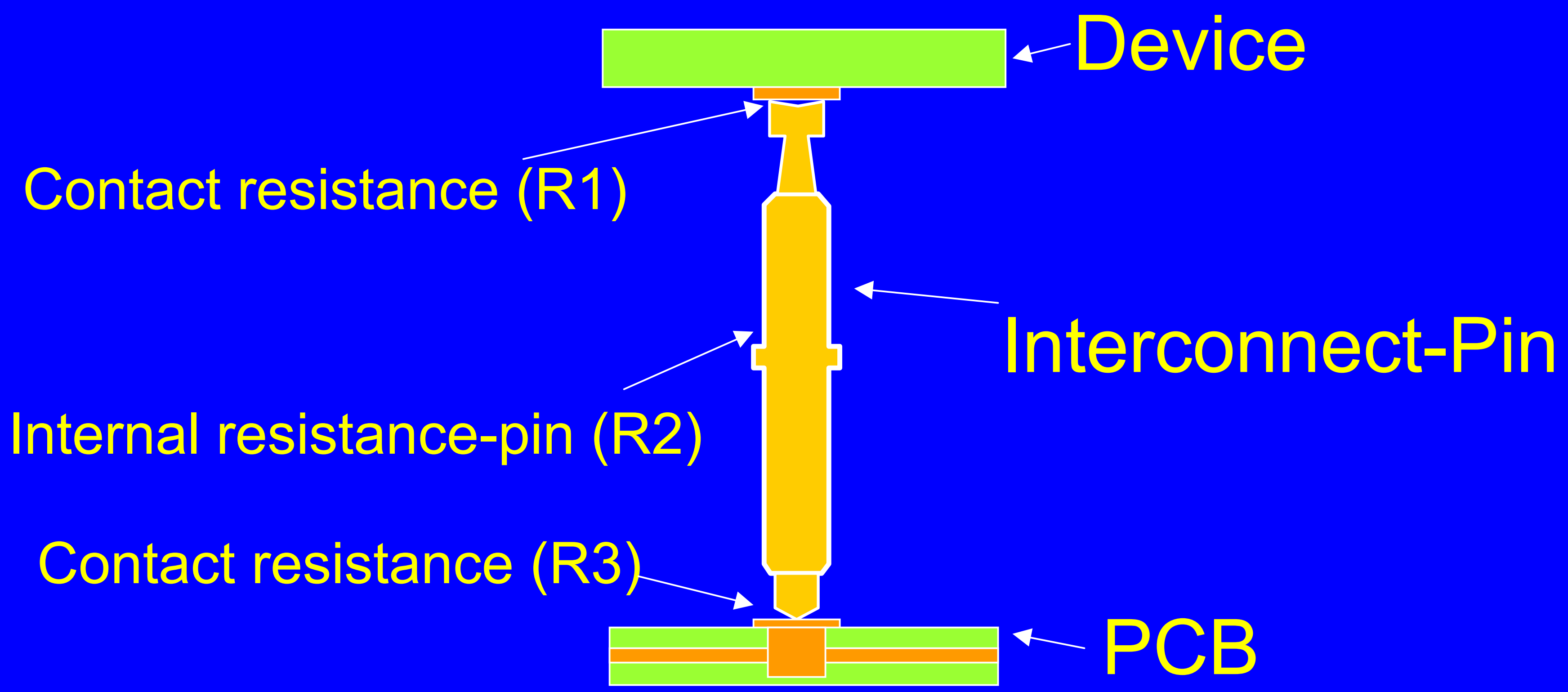
Introduction & Objective

Test Set Up

Test Results and Discussions

Summary

Introduction



Where does electrical resistance come from?
What features contribute most to high electrical resistance?
How does contact resistance affect total resistance?

Objectives

Measure the internal resistance of pins (R2).

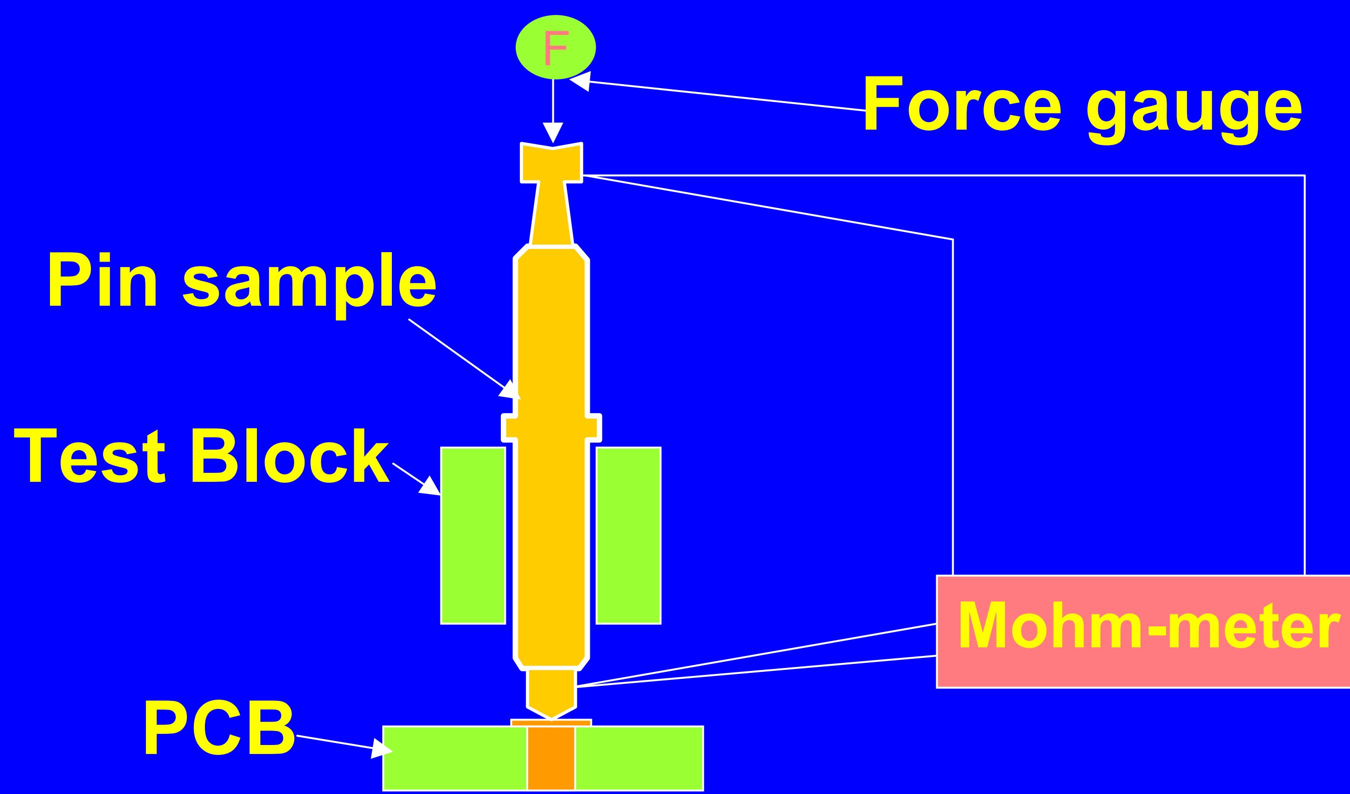
Measure the contact resistance (Cres) between pin tip and pad (R3).

Investigate the effects of pin tips on contact resistance.

Provide recommendations to pin designers about tip structure in order to minimize Cres.

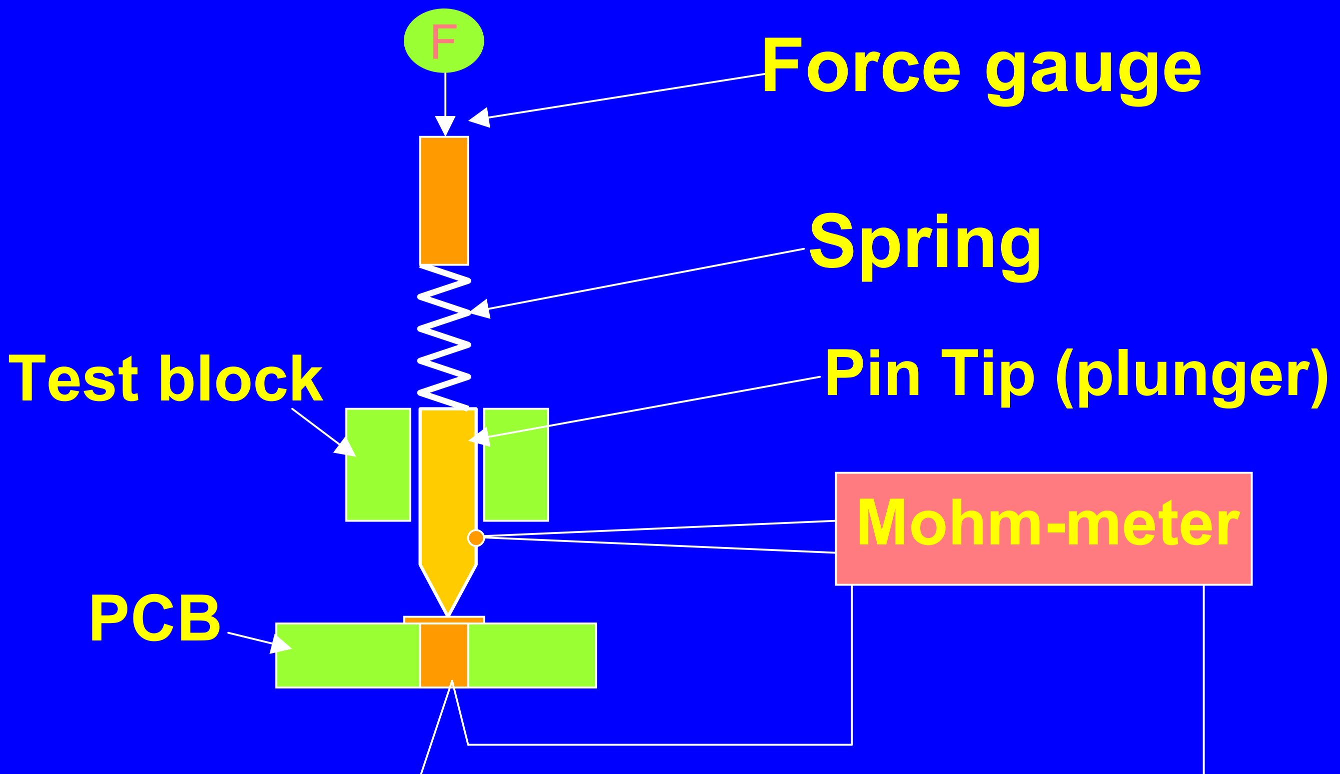
Test Setup – R2 measurement

Apply force (F) by gauge to control force and deflection;
Measure the internal electrical resistance, R2, of pin using 4-Wire Kelvin method.



Test Setup – R3 measurement

Apply force through force gauge and spring on the pin tip (plunger) contacted to pad;
Measure the Cres using 4-Wire Kelvin method (soldered wires on plunger and PCB via).

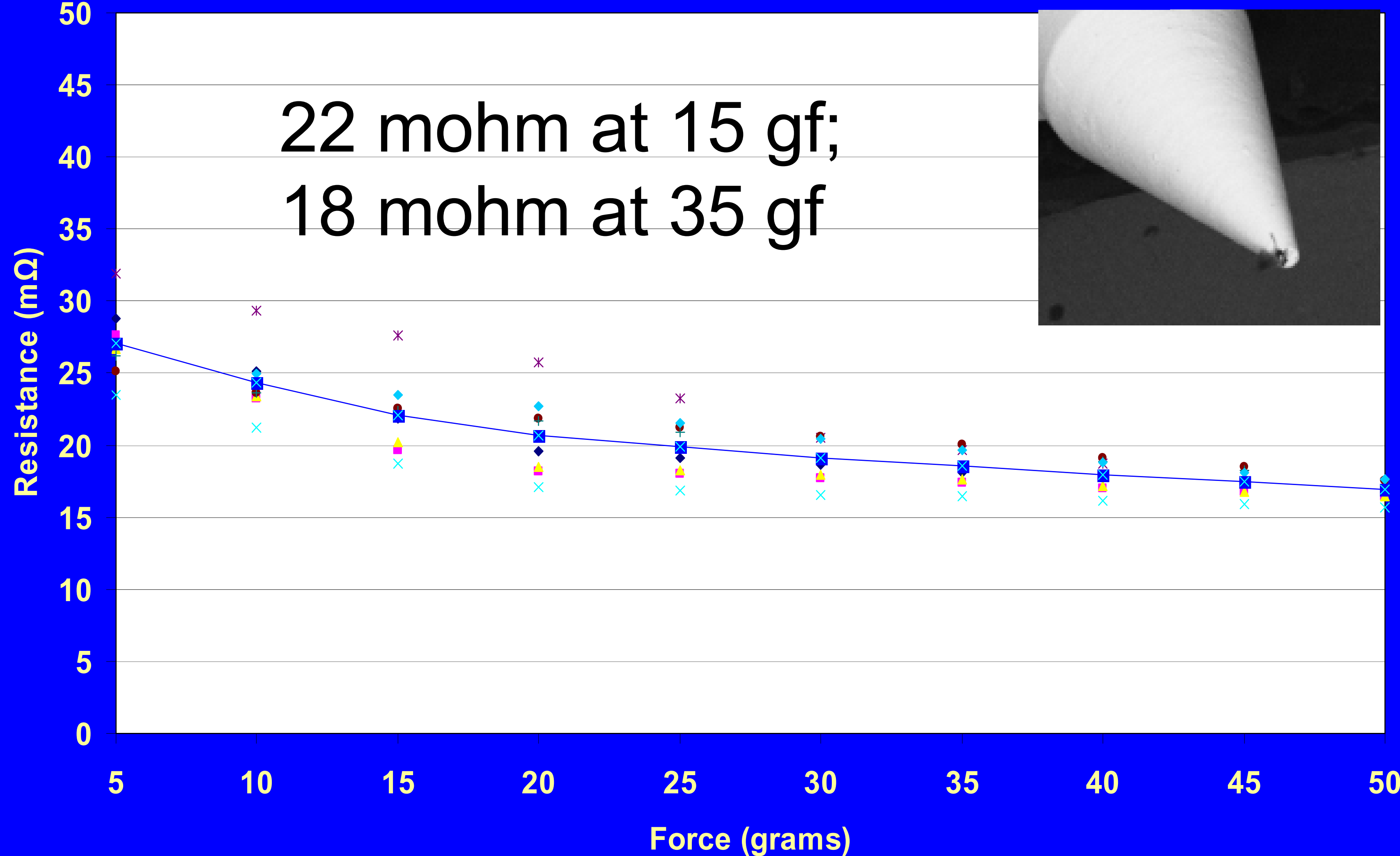


Examples of Pin Electrical Resistance
(R_2)

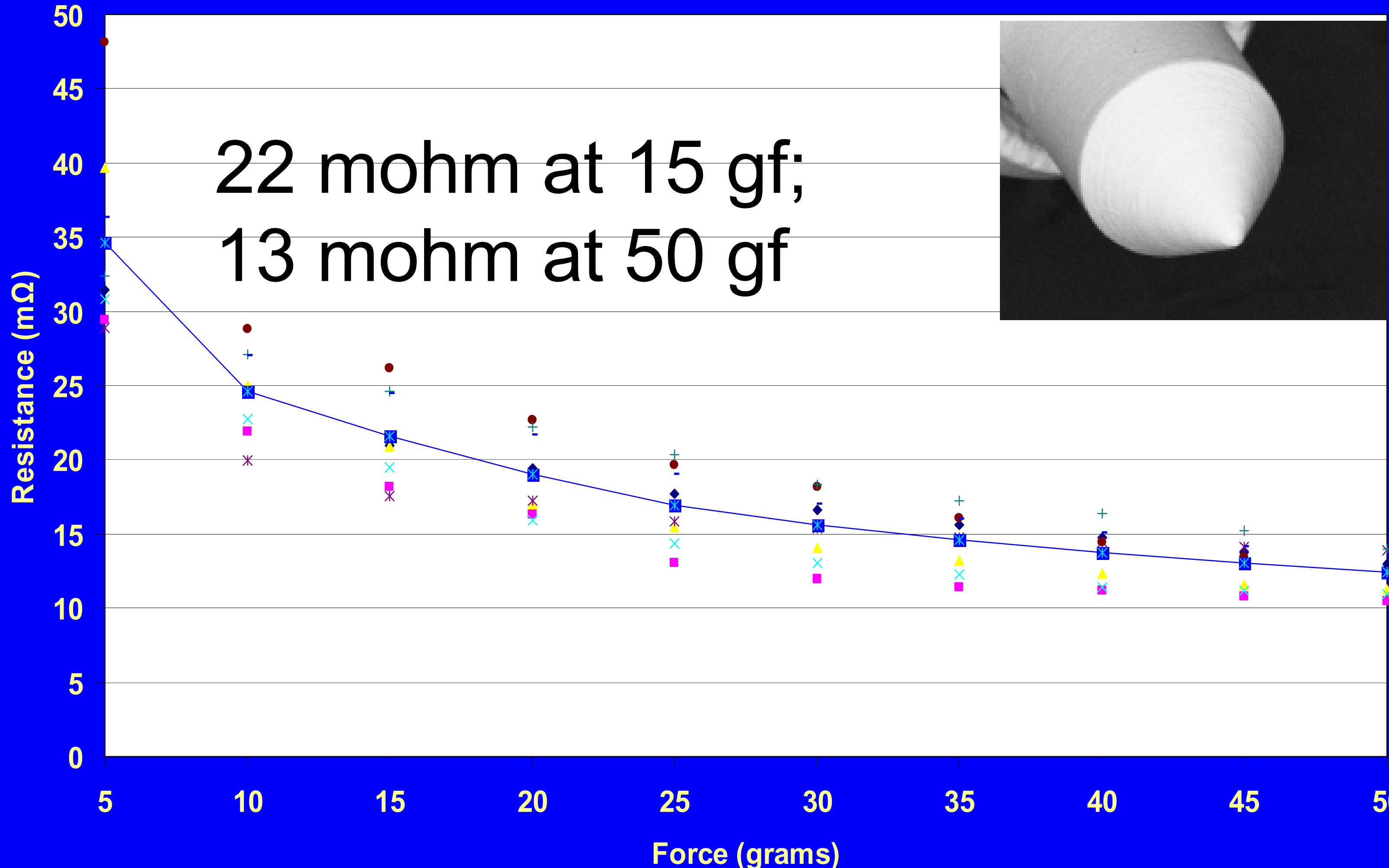
Pin# I				Pin # II			
Sample #	F(gms)	Def(mm)	R(mΩ)	Sample #	F(gms)	Def(mm)	R(mΩ)
1	28	1.20	9.9	1	38	0.55	3.2
2	29	1.20	10.2	2	38	0.56	2.9
3	26	1.08	11.4	3	36	0.50	3.8
Average			**10.5**				**3.3**

Lab test results;
Internal resistance, R2, of pin can be very small;
Pin development has reduced the internal resistance, R2, of pins significantly.

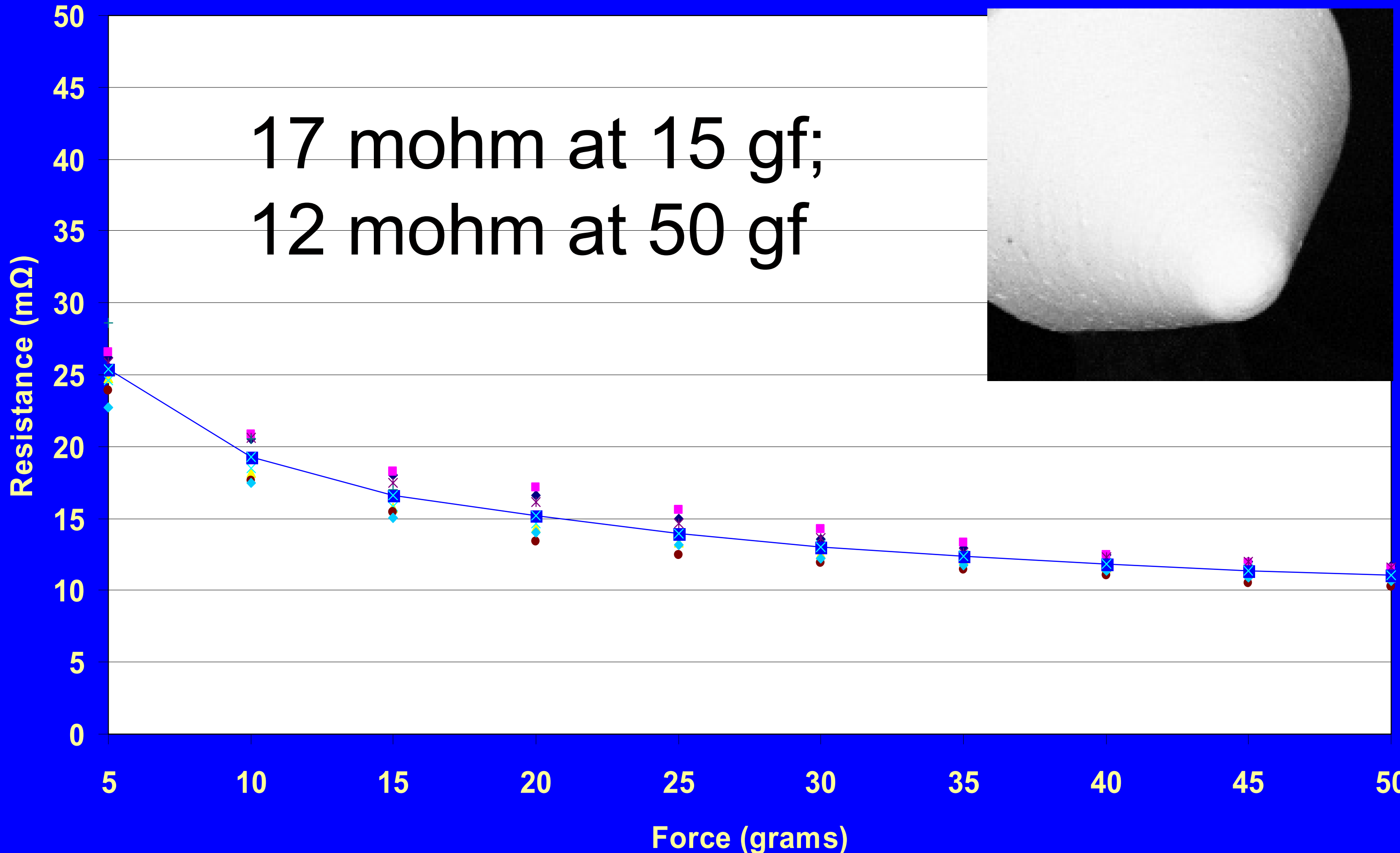
Cres vs. Force: Tip A



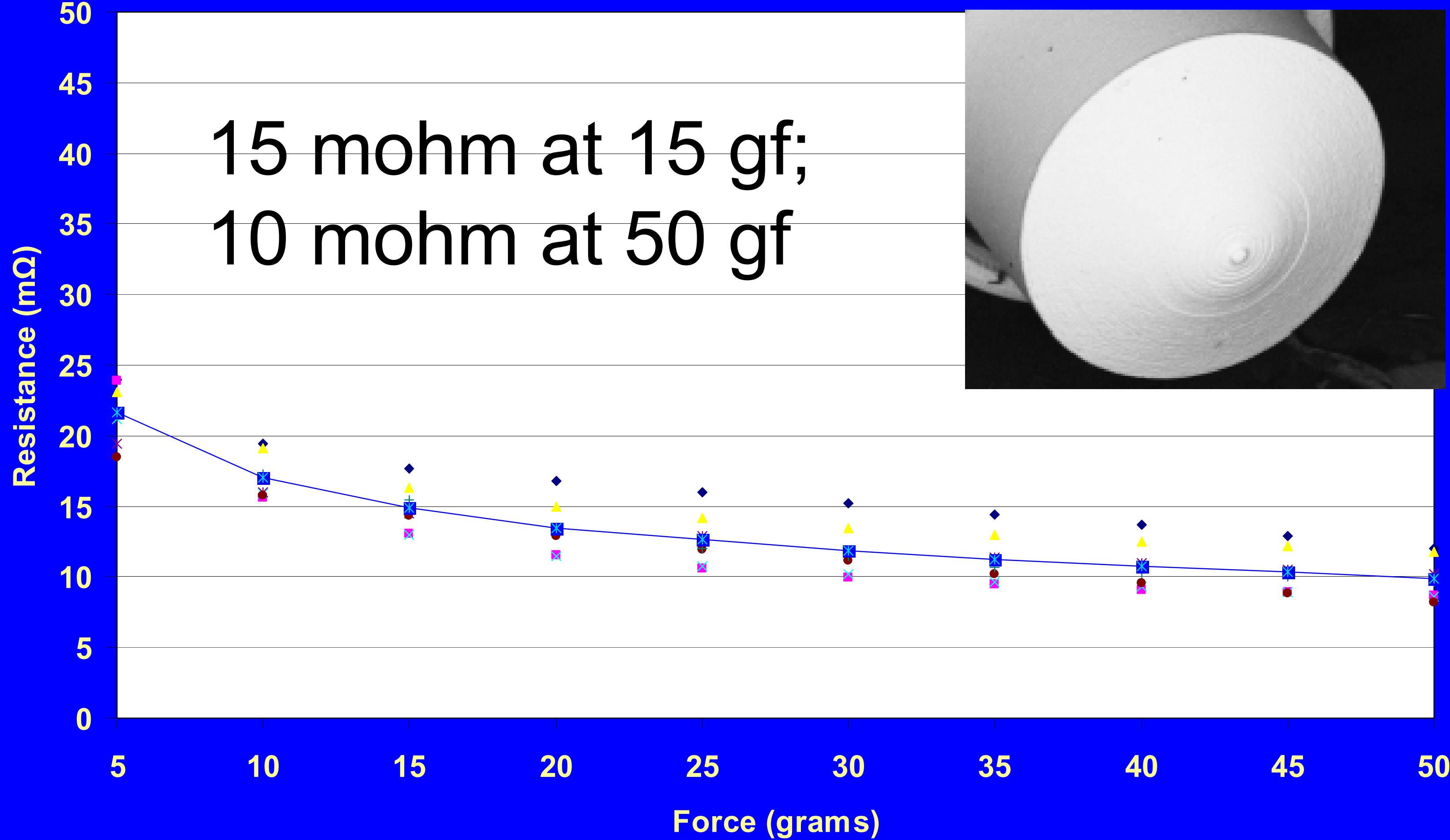
Cres vs. Force: Tip B



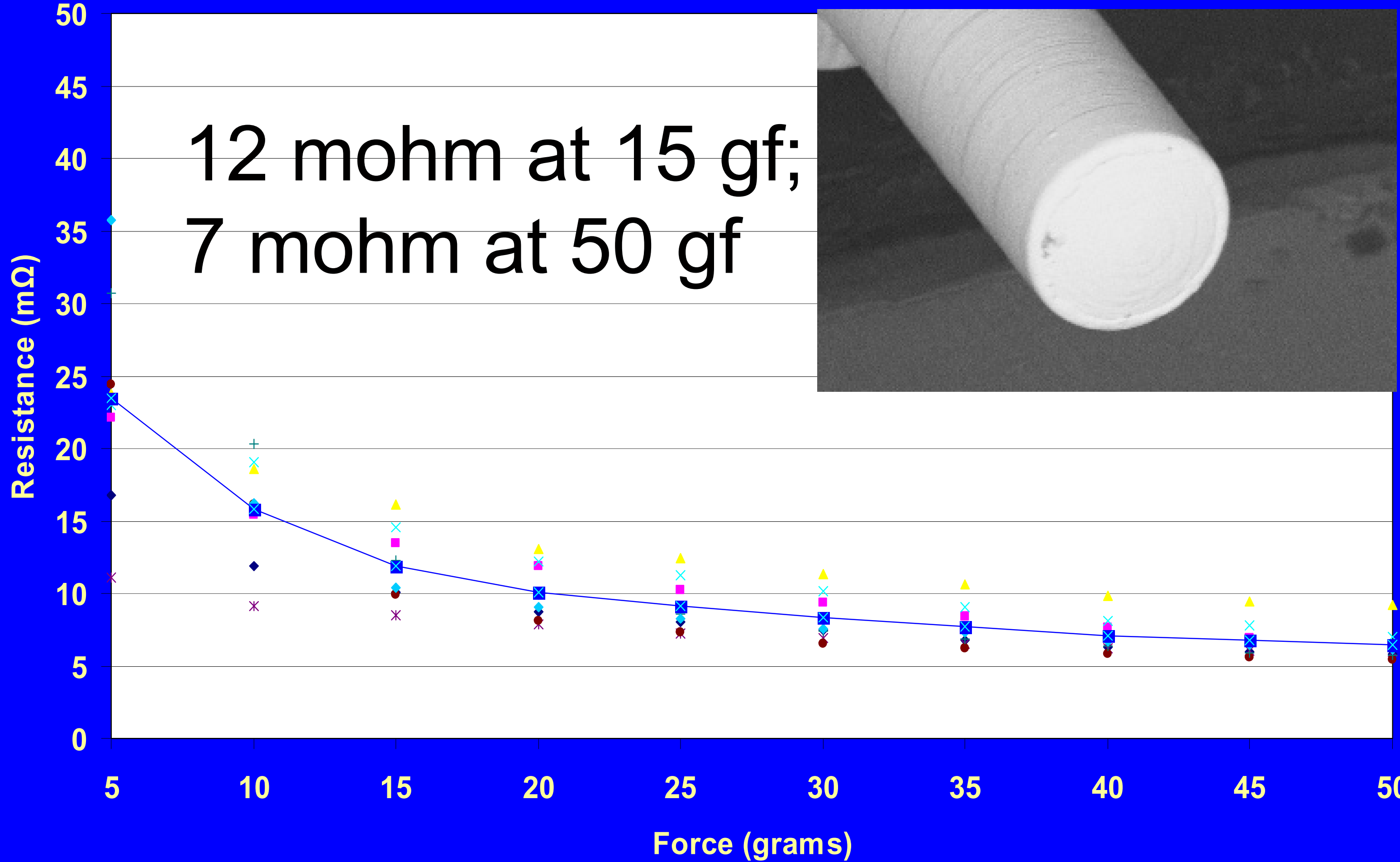
Cres vs. Force: Tip C



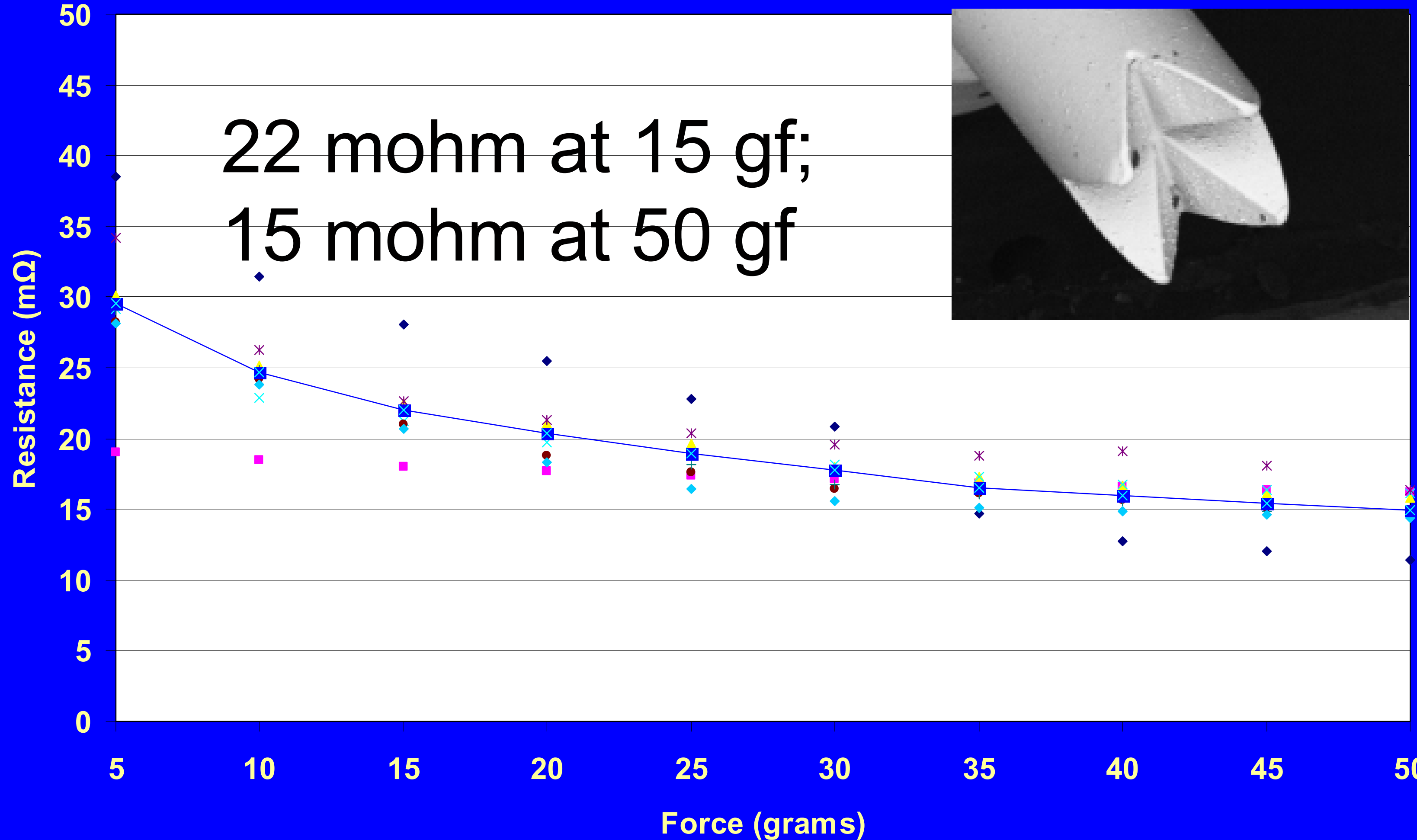
Cres vs. Force: Tip D



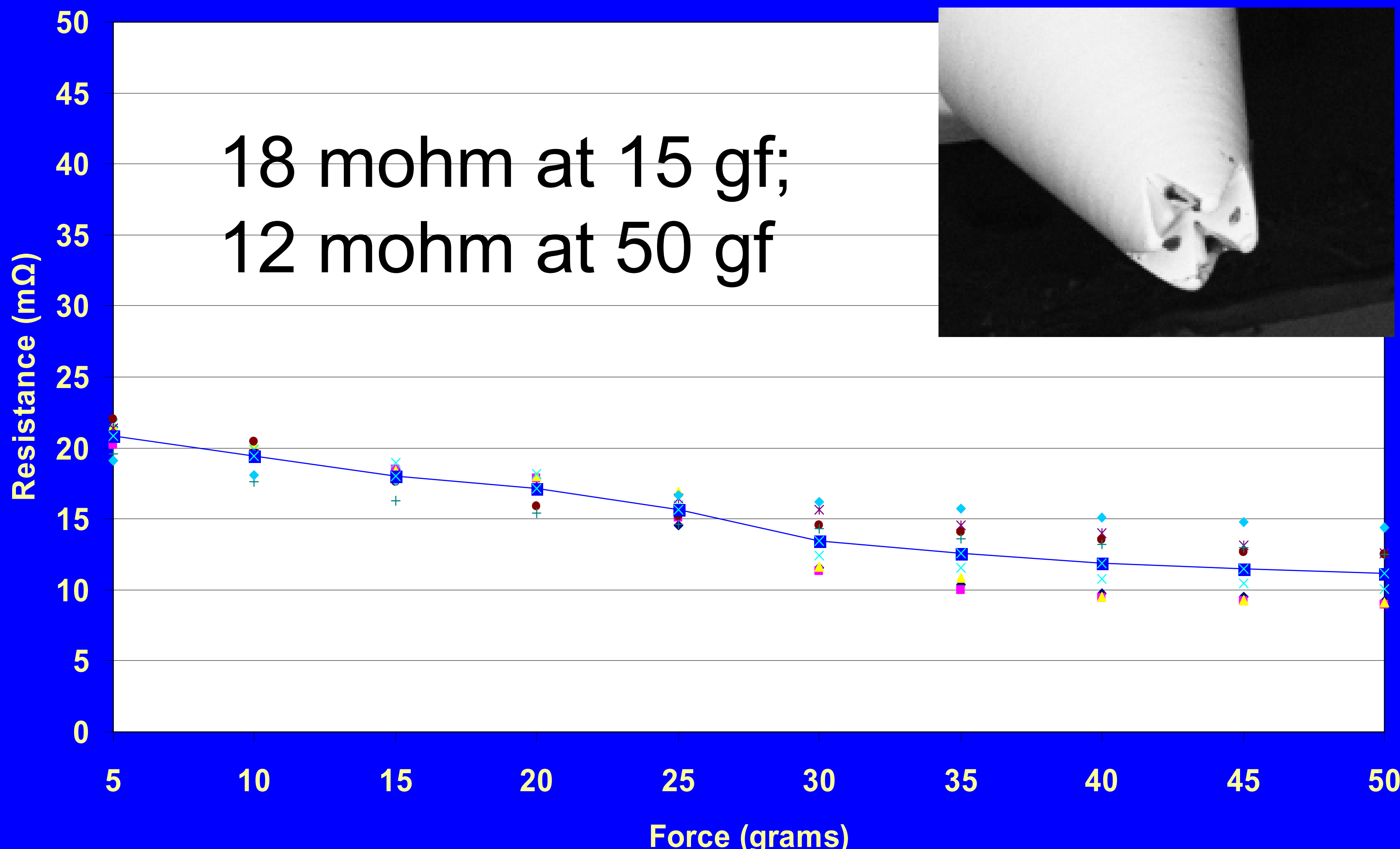
Cres vs. Force: Tip E



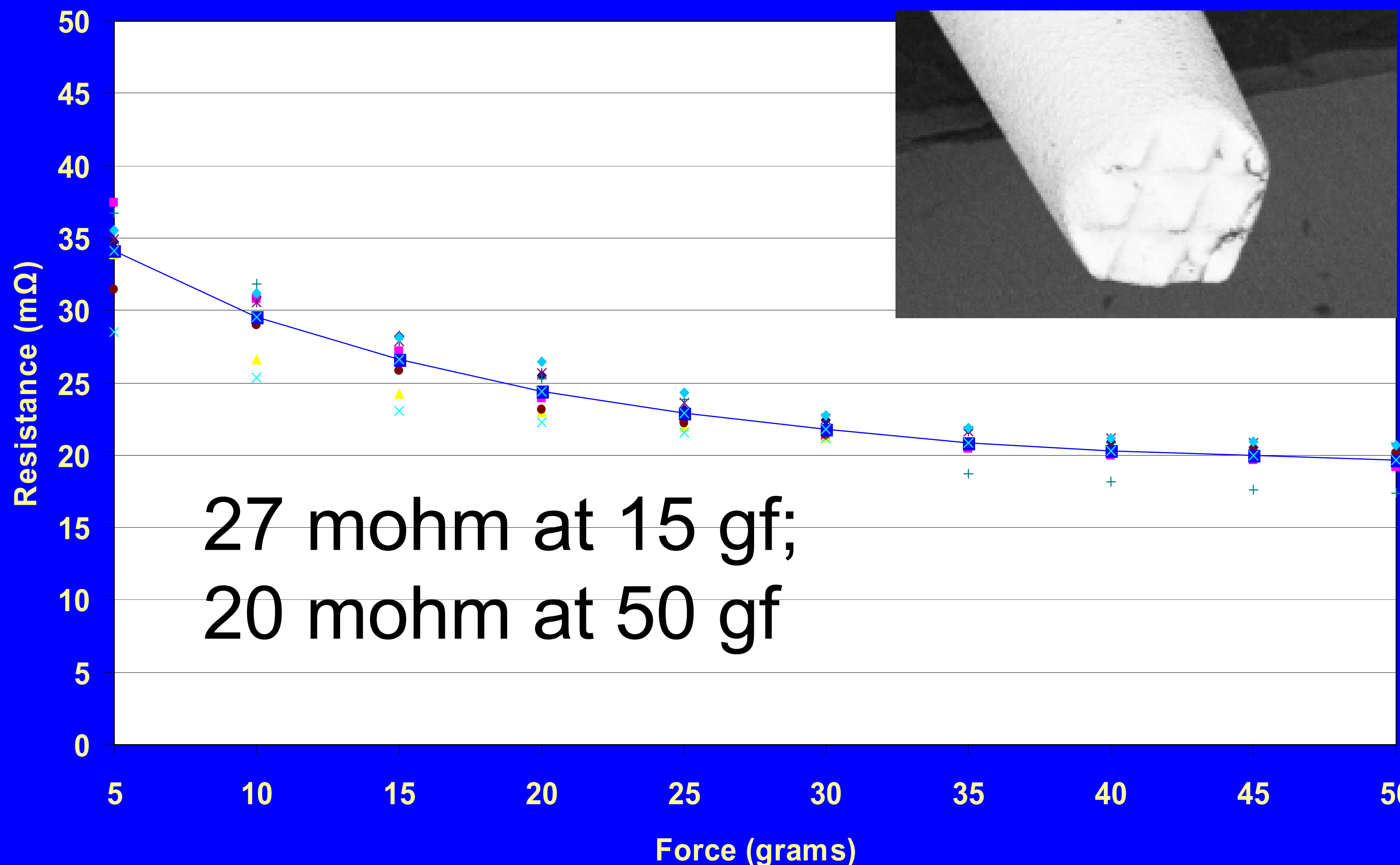
Cres vs. Force: Tip F



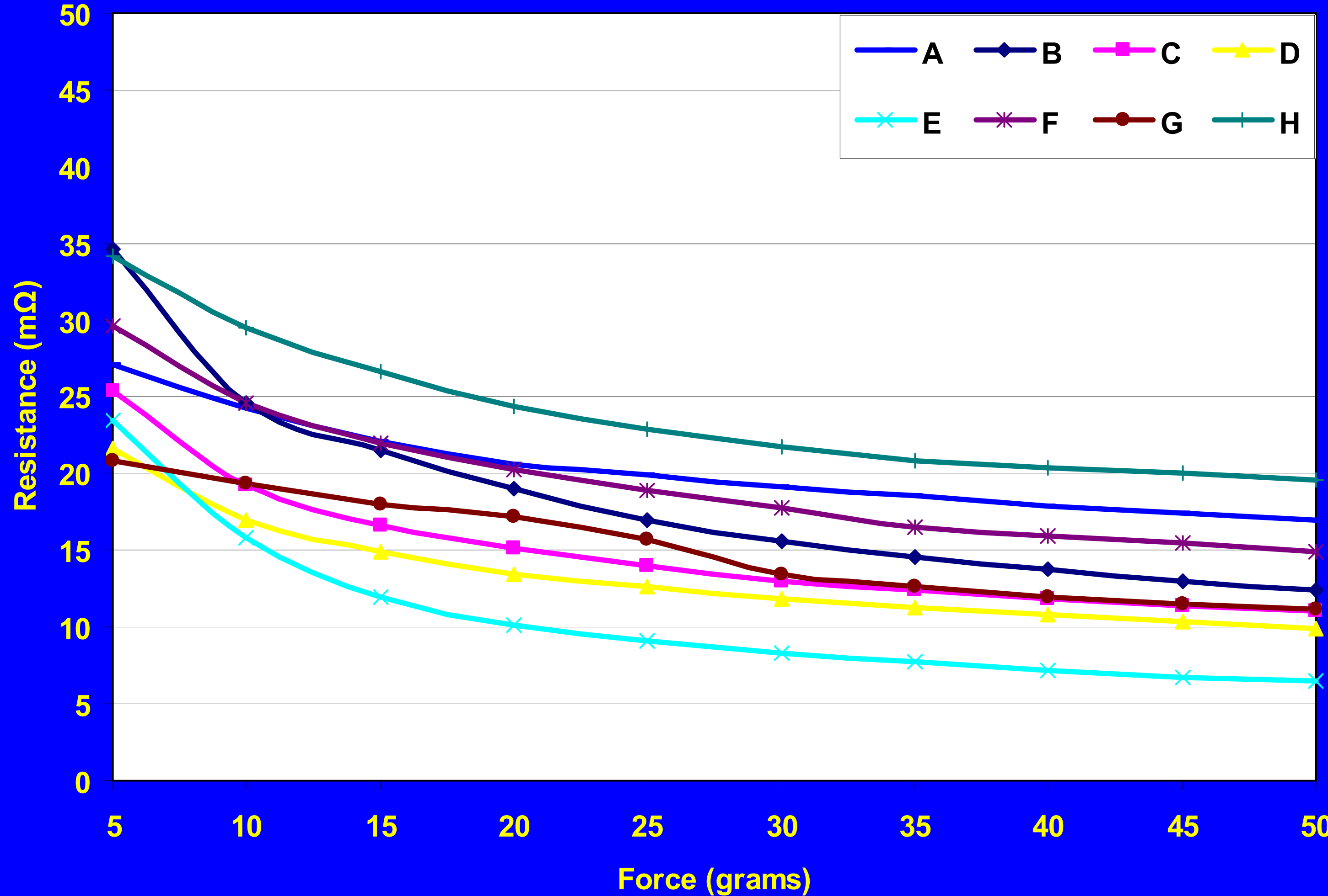
Cres vs. Force: Tip G



Cres vs. Force: Tip H



Cres vs. Force: Comparison



Summary

Smaller pin internal resistance (R2) achieved by improving pin design and manufacturing.

Contact Cres (R1&R3) becomes more significant as R2 reduces to very low level.

Cres can vary over 15 mohm due to different tip structure.

Cres of sharp tip is affected by radius and force. Generally, large radius or flat tip has low Cres, to ~7 mohm.

Four point tip has Cres range from 20 ~ 30 mohm. Higher Cres is mostly caused by tip defects (manufacturing difficulties)

About Authors

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