SW Test Workshop

Semiconductor Wafer Test Workshop

An Advanced Wafer Probing Characterization Tool for Low CRes at High Current

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Overview

- Motivation
- Understanding the Contact Resistance
- Existing CRes-Tool
- New CRes-Tool for High Current
- Preliminary Results
- Conclusion & Outlook

Test for Infineon's Product Range

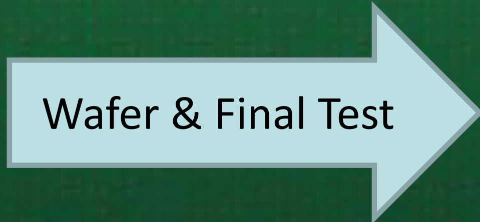
Automotive (ATV)

Industrial Power Control (IPC)

Power Management & Multimarket (PMM)

Chip Card & Security (CCS)

High Power Applications



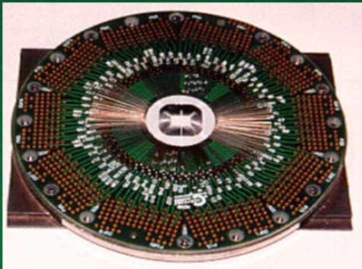
High Power Test Cell

Motivation

- **Requirement to assess current carrying capability (CCC) vs. CRes of various probe types (cantilever, vertical, MEMS, pogos, etc.) on different pad materials (Al, Cu, NiP, etc.)**
- **Demand from several meetings & discussions with business line's test engineers (need for verified test specifications)**
- **Test Technology department reacted to this demand with the development of a new instrument**
- **Prototype features are:**
  - Re-use of existing components (Prober, adapter)
  - Sourcing up to 10A impulse (peak)
  - Adjustable impulse length up to ~30ms
  - *NI-Labview* GUI
  - Multi-TD, cleaning process control

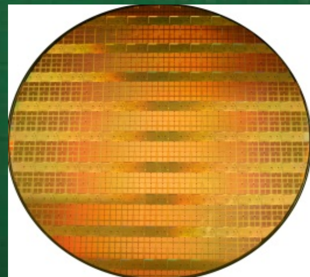
FE Test Cell Configuration

Tester-Wafer Interface
(electrical connection between wafer and tester)
Probe card with probes (needles)



Tester-Prober Docking
(mechanical adjustment and fixing)

Testhead



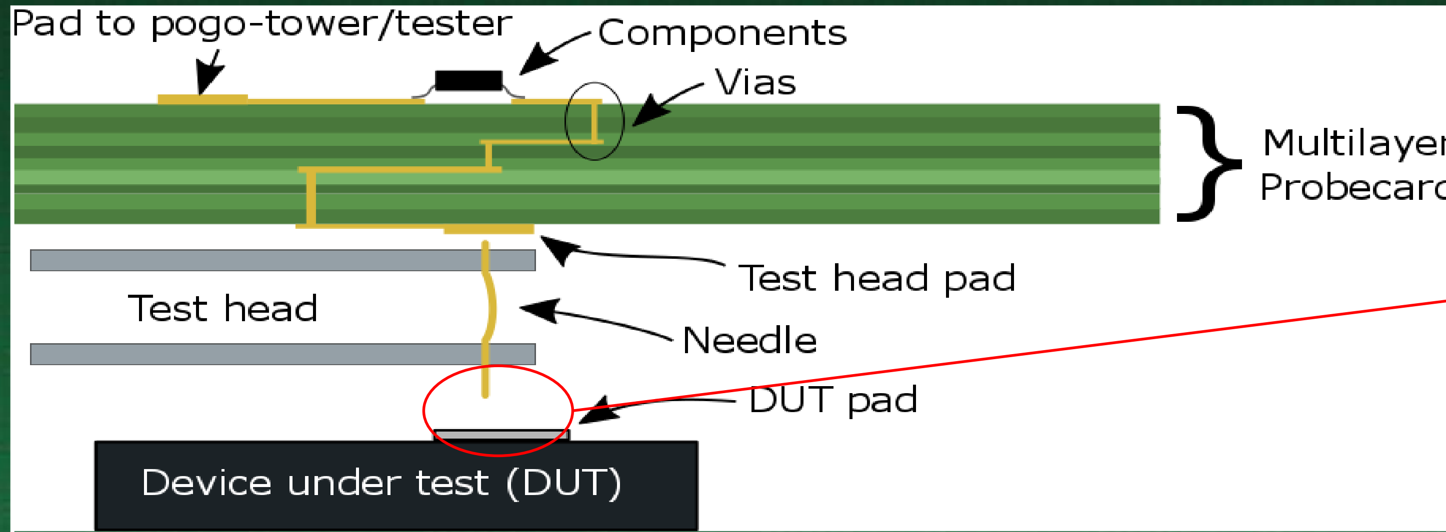
DUT

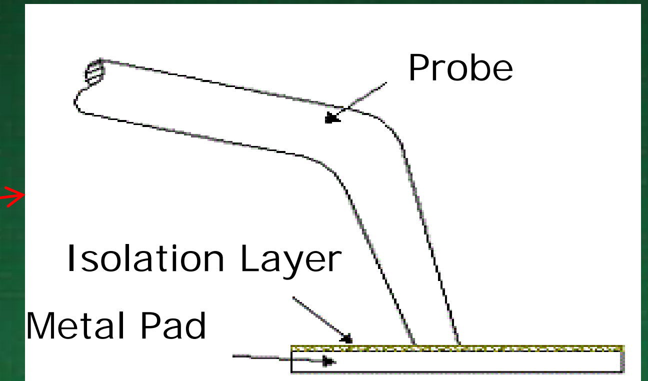
Prober
- handling
- temp. control
- placing

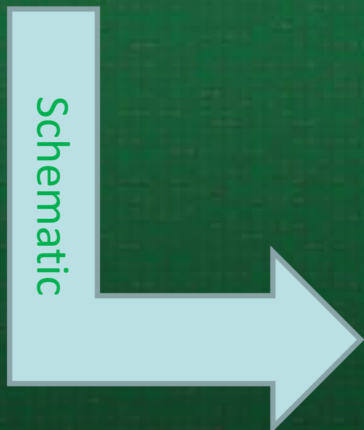
Tester
- Supply & measure …
  - current
  - voltage
  - frequency

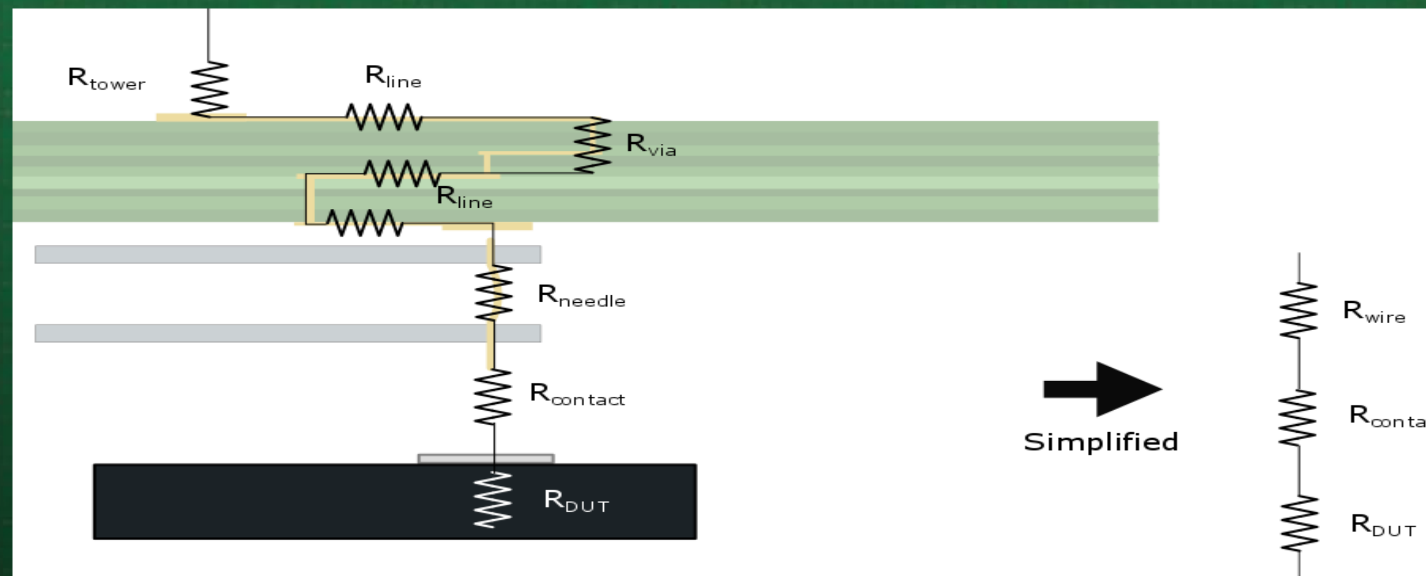
Wire connection

Simplified Resistance Path of a Probe Card

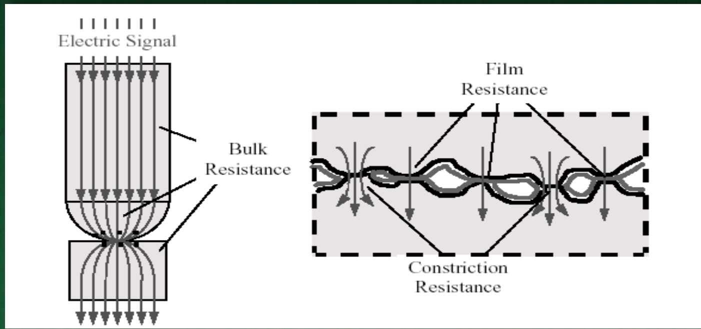








Influencing Factors of Contact Resistance



Contact Resistance

Constriction Resistance R_C

Film Resistance R_F

Specific Resistance ρ

Current Density
- Form
- Geometry

Contact Area
- Surface
- Elastic/plastic material behavior (hardness H)

Film layer
- Thickness
- Film creation process
- Chem. surface characteristics

Material Temperature

Atmosphere
- Humidity
- Pressure
- Temperature

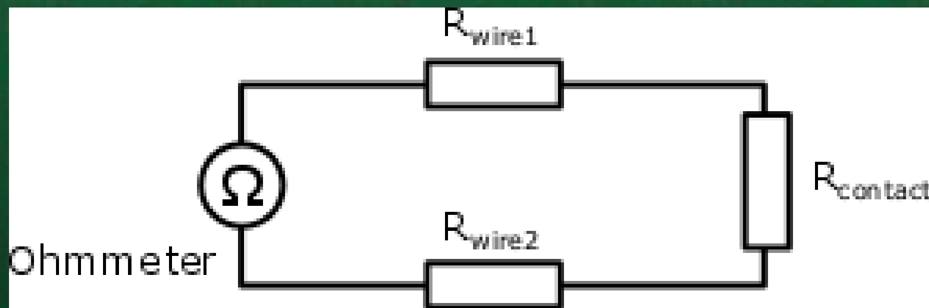
Electrical Load

Contact Force F

CRes Measurement

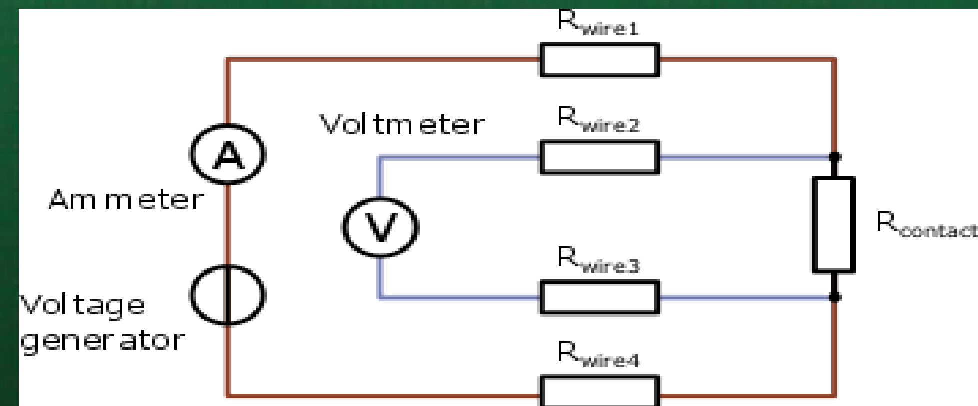
- Direct approach is with an Ohmmeter
- The wiring path inside the probecard is measured together with the cable and instruments necessary for the connections

$$R_{measured} = \mathbf{2} * R_{wire} + R_{contact} + R_{\mathbf{instrument}}$$



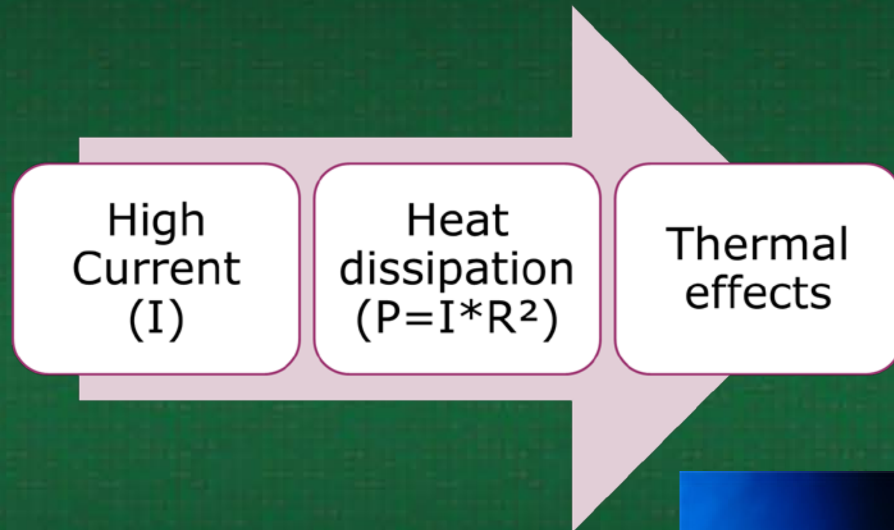
- Kelvin measurement is known as 4-wire measurement based on 4 wires: 2 forces, and 2 sense
- The force circuit (red) drives the current to flow through $R_{contact}$ (DUT)
- The sense circuit (blue) reads out the voltage at $R_{contact}$
- Most accurate measurement for the contact resistance (eliminating path resistance)

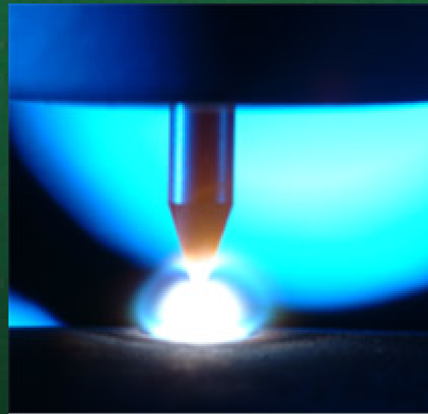
$$R_{contact} = \frac{U\ (Voltage)}{I\ (Current)}$$



CRes @ High Current

- **Cause-effect diagram**

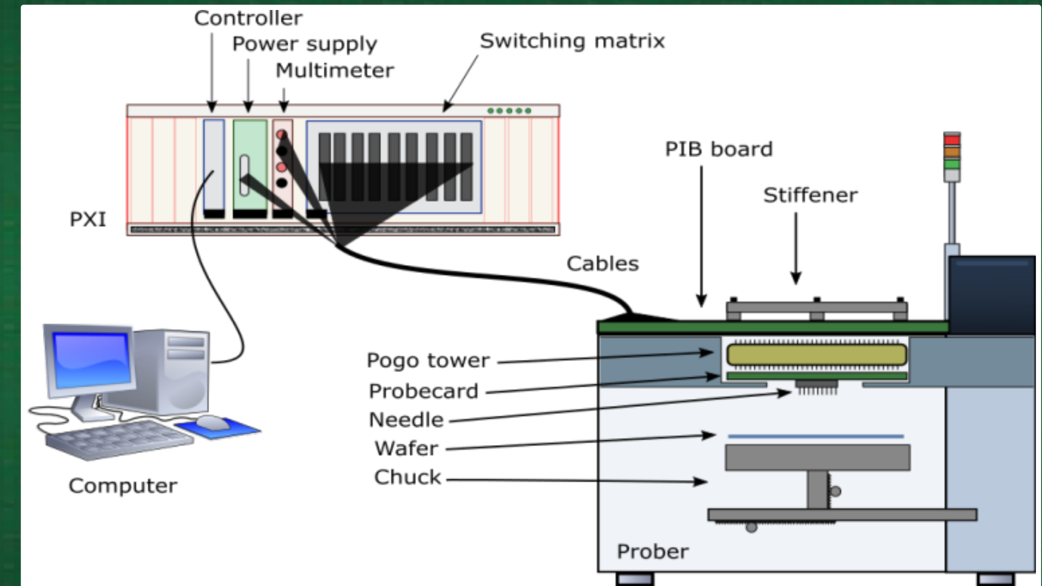


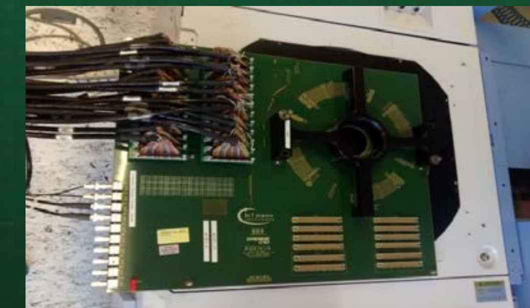


- **Possible failure modes caused by material heating:**
  - Contact force reduction due to material property behavior
  - Probe or pad softening/melting
- **Other failure modes:**
  - Electromigration (current driven material (ion) transport)
  - Arcing

Realized Tool: CRes 2.0

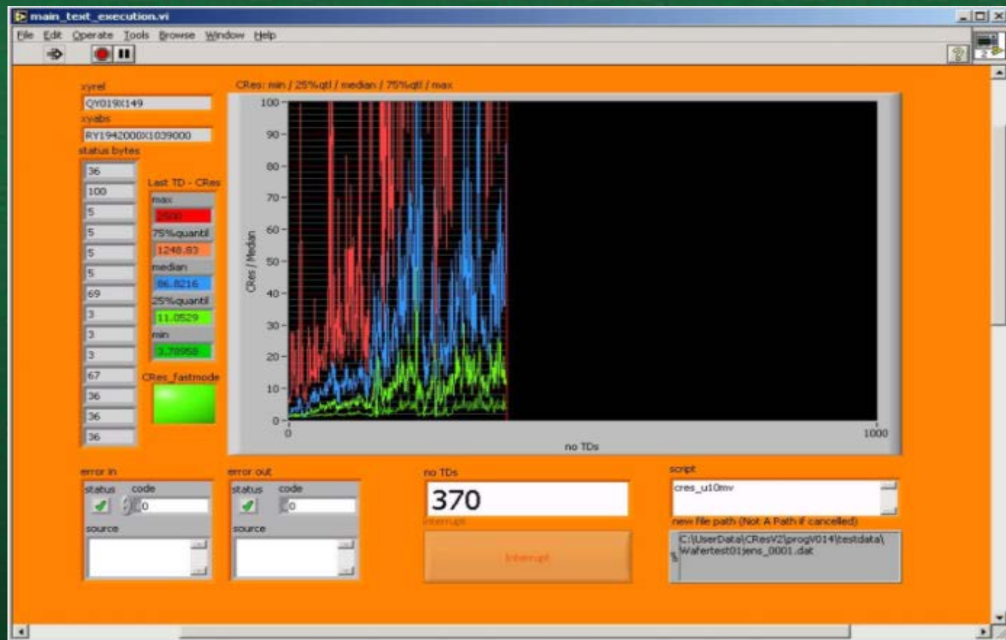
- **CRes 2.0 is a laboratory tool used to characterize and qualify contact resistance, probing process, and lifetime of probe cards (new & existing)**
- **Based on a Kelvin resistance measurement concept**
- **Consists out of several instruments inside a PXI case:**
  - Power Supply Unit (*VXI*)
  - DMM (*National Instruments*)
  - Switching matrix (*Pickering*)
  - external probecard interface board (*IFX*)
  - Automatic 200mm Prober (*Accretech*)
  - Computer & *NI-LabView*

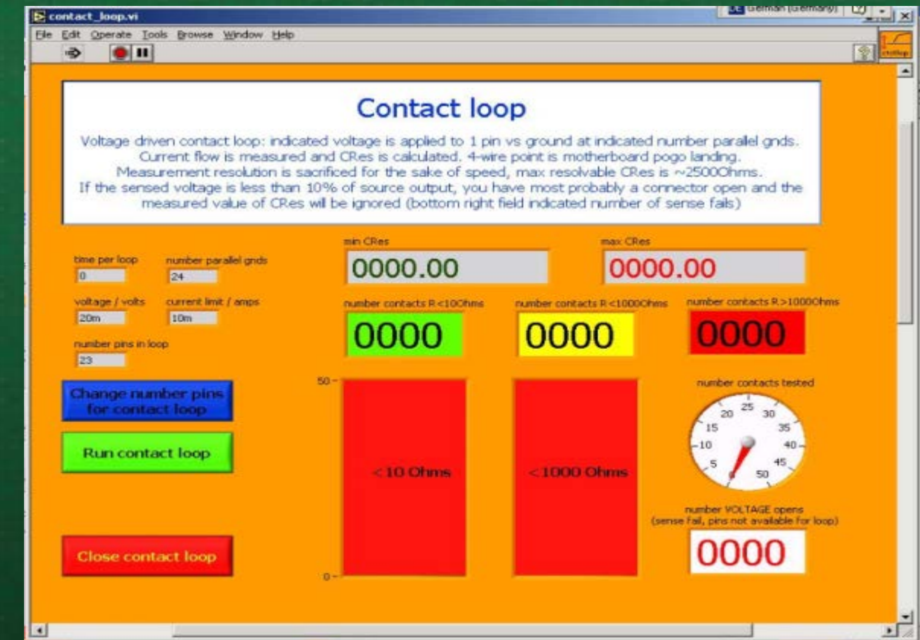




CRes 2.0 Control SW & GUI

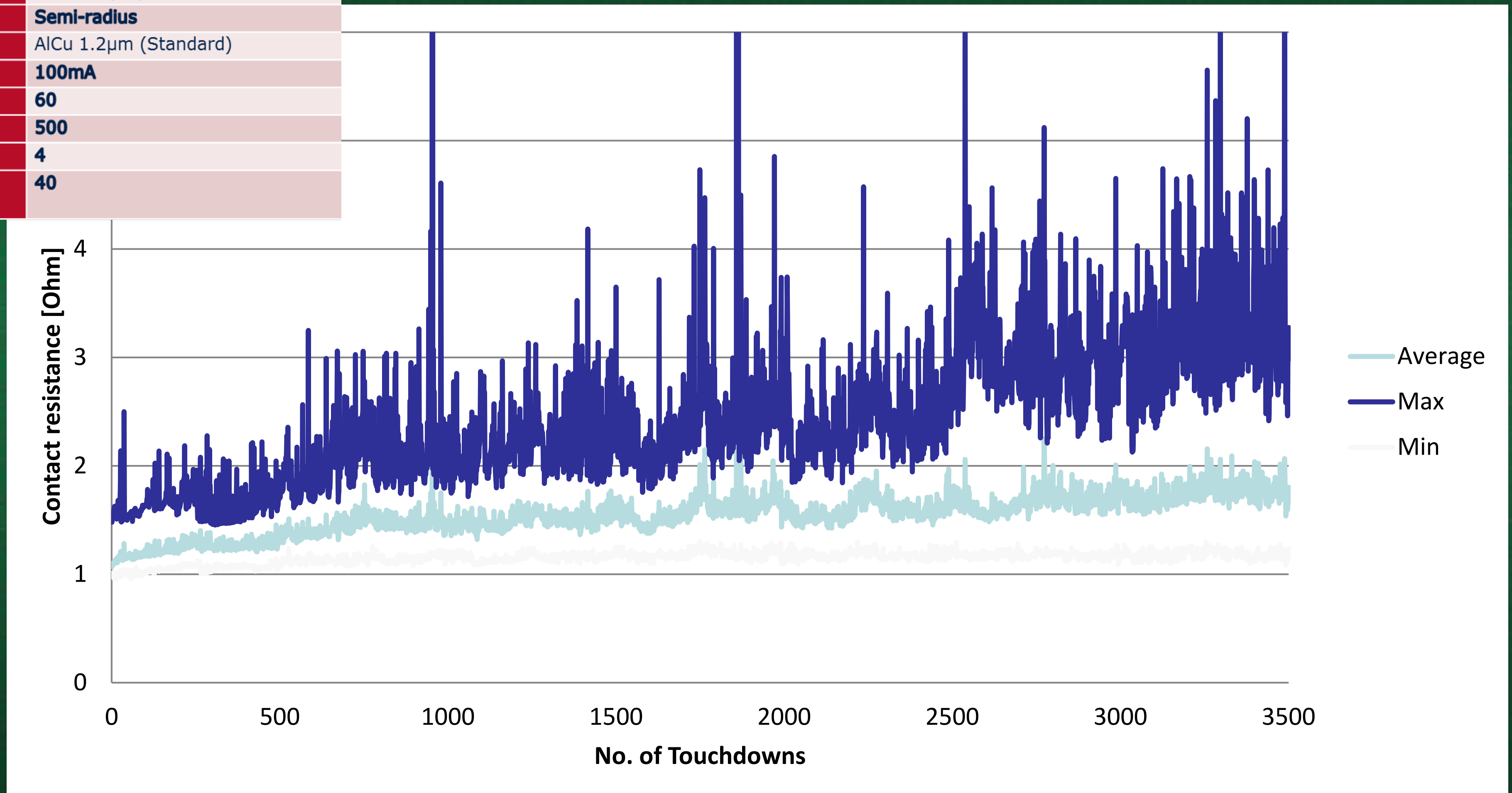
- **Instruments and prober are configured and synchronized through a computer running a NI-*Labview* software**
- **It allows to perform a contact loop and subsequently a contact resistance "marathon" test**





CRes 2.0 Application Example

Chuck Temperature	120°C
Probing Overdrive	100
Probe Card Type	Cantilever (M3054)
Cleaning Material	Probe-Lap 3µm
Initial Tip Shape	Semi-radius
Wafer	AlCu 1.2µm (Standard)
Forcing Current	100mA
Cleaning Overdrive	60
Cleaning Intervall	500
Cleaning Touchdowns	4
Total Number of Cleaning Touchdowns	40



Limitations of CRes 2.0

- *Hybrid* Kelvin measurement performed at PIB level includes the pogo-tower, traces, and probe resistance inside the probecard
- Maximum allowed current is 500mA, due to the switching matrix (reed relays)
- Software is not optimized for fast measurements, special ground configuration, or for special current profiles

New Solution: CRes 2.5

- **Concurrent operation with existing CRes version 2.0**
- **Evaluation of contact resistance with currents up to 10A**
- **Pulsed measurement with up to 8 high-current channels**
- **Measurement as close as possible to contact (dedicated path)**
- **Modular concept**
- **Based on several instruments inside a PXI case:**
  - PSU: TOE 8800 → 16V, up to 10A
  - Pickering Card → 8-Channel Power Multiplexer, 16A
  - *Arduino* Control Board
  - Automatic 200mm Prober
  - Computer & NI LabView

CRes 2.5 Tool Configuration

Power supply

1234 1234

Toeller

GPIB

PC

USB

Cable

PXI case

Arduino inside

Extra-PCB

Production of the output voltage, buffered with high power OP-AMP
DAC: TI DAC8830, 16bit, 1µs, 5V
OP-AMP: TI OPA549, 8A (10A peak)

Note: 10A peak means delivers 10V on 1Ohm load

Active cooling necessary

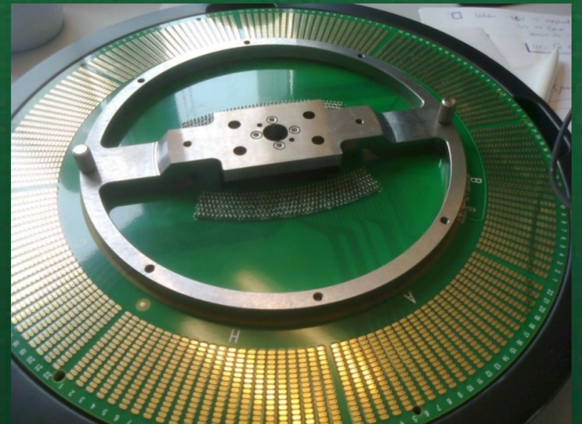
Pickering High Current Switching

To Probecard

A

CRes 2.5 PCB

Measurement of the current through analogue sensor
C-Sensor: Allegro ACS712, ±20A

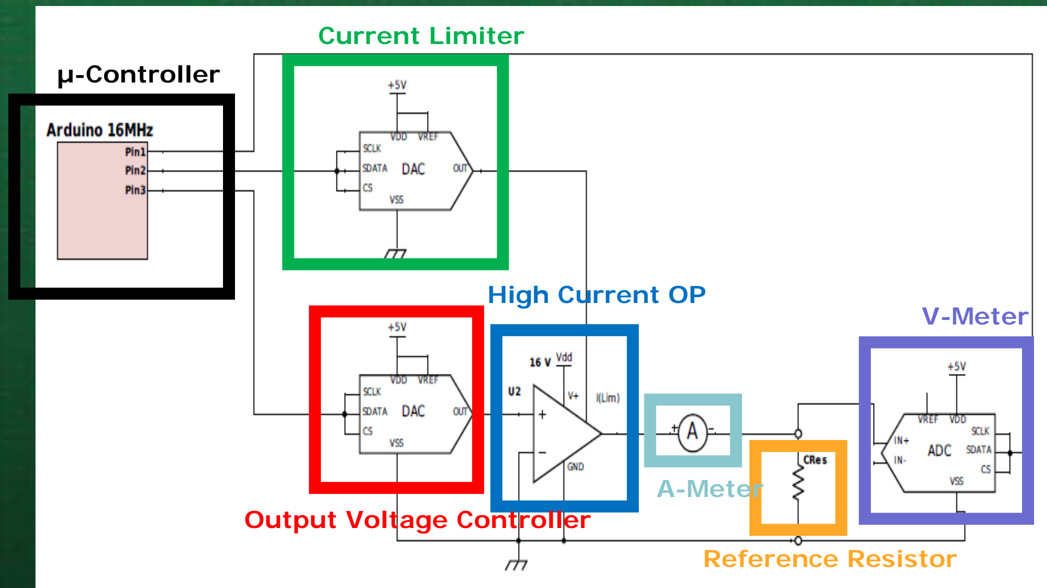


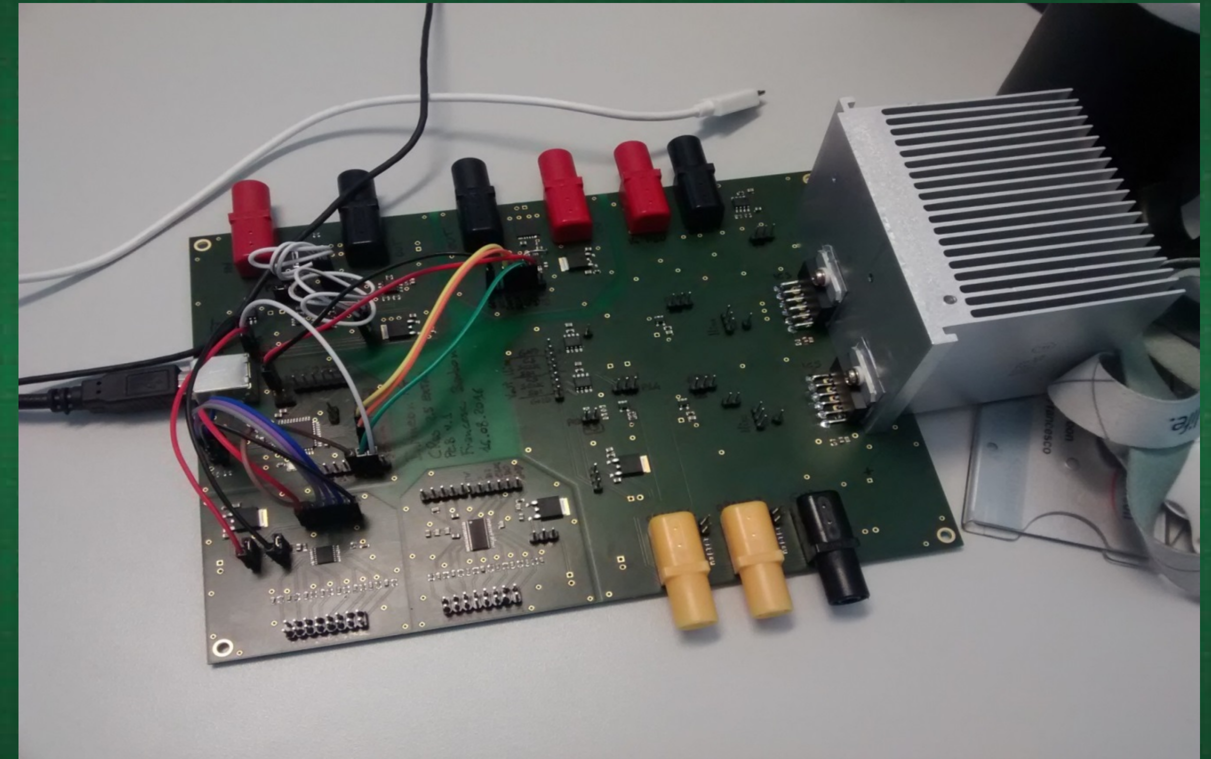
CRES 2.5 Control Board („Extra PCB“)

***Arduino* triggers …**

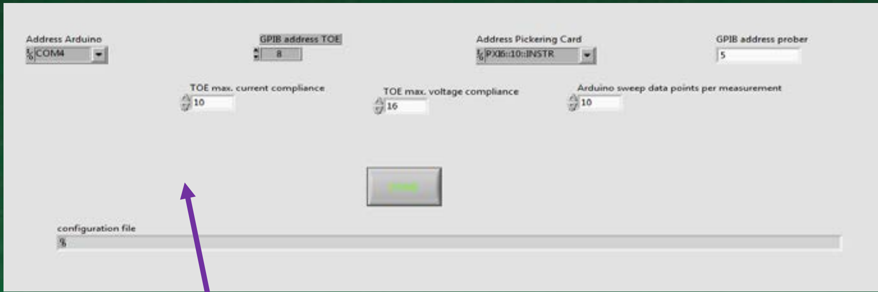
- output voltage of OPV
- start of current measurement
- start of voltage measurement

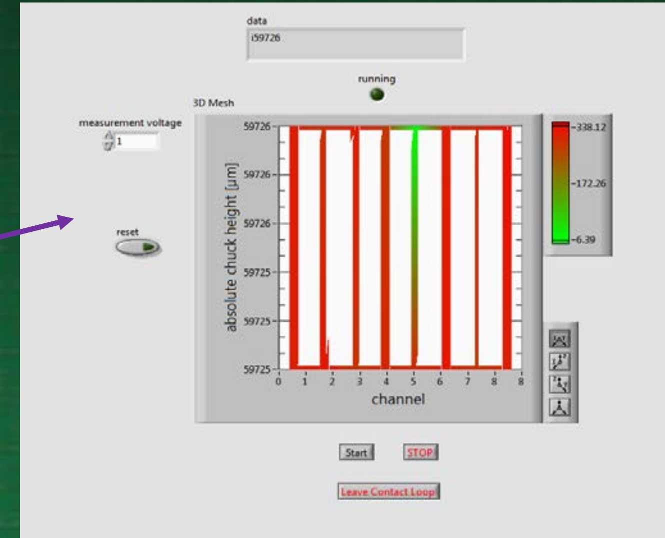
***Arduino* receives and stores (in RAM) up to 200 data points, and transports data via USB-port to LabView program**

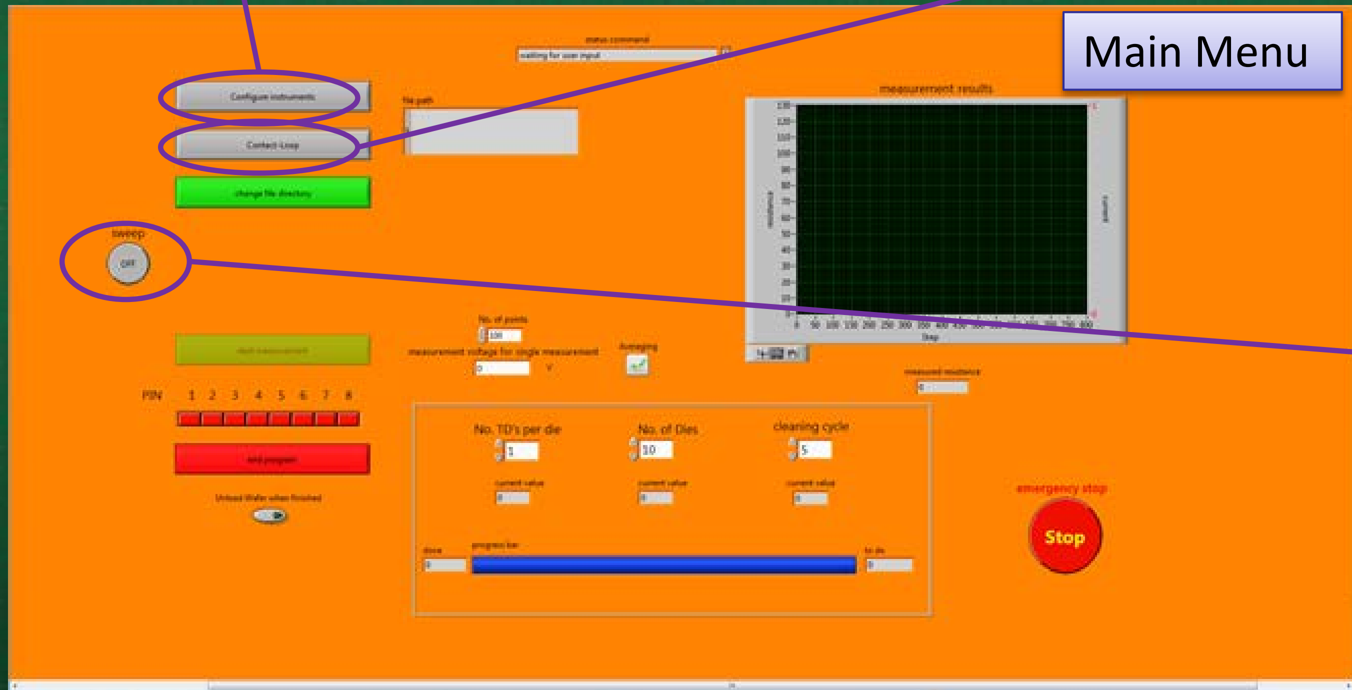


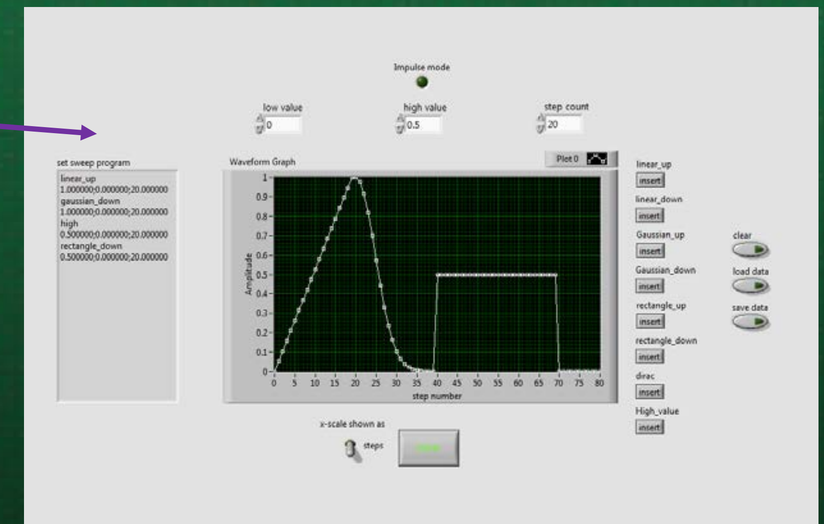


CRes 2.5 Software Features









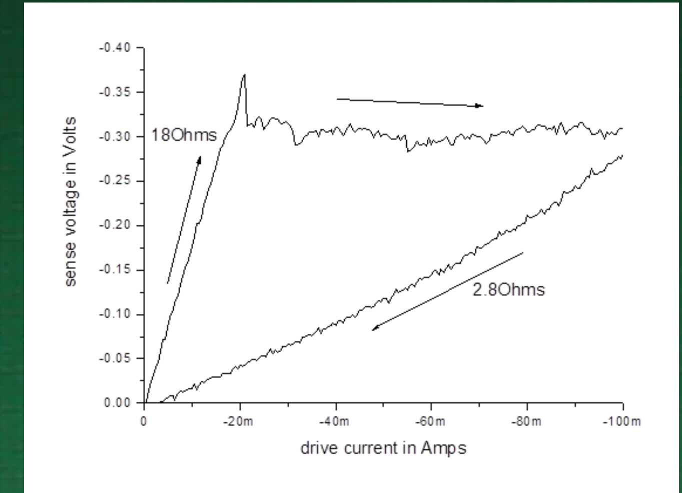
CRes 2.5: Example #1

Question:

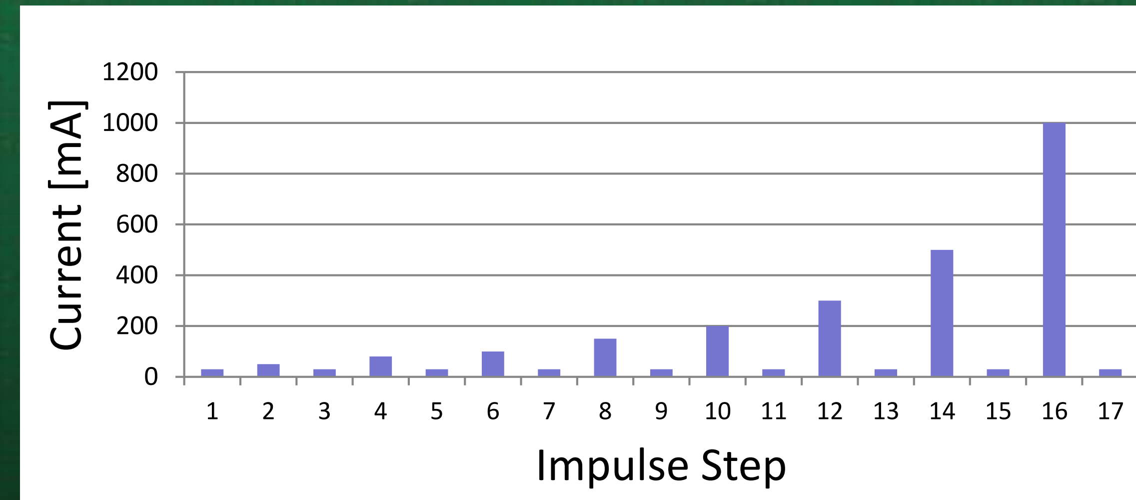
Is contact fritting on Cu-pads possible and does it affect the contact behavior?

Process sequence:

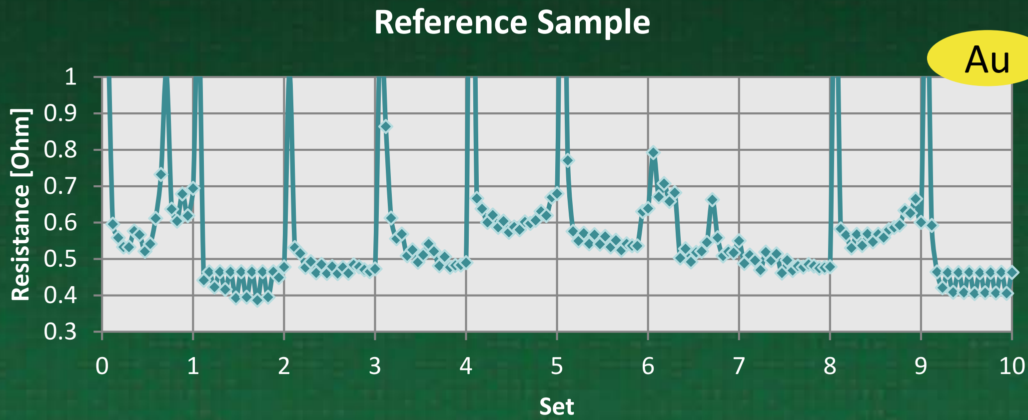
- Generation of different Cu-oxidation film (RT, 1h@100°C and 300°C)
- Measurement at small current (30mA)
- Fritting at higher current (50mA, 100mA, 150mA, 300mA, 500mA, 1A)
- New insertion for each set with totally 17 current impulses

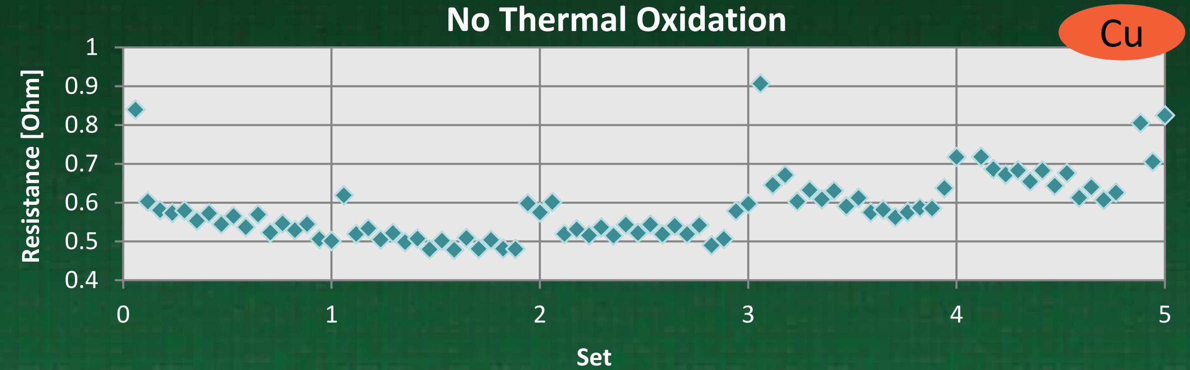


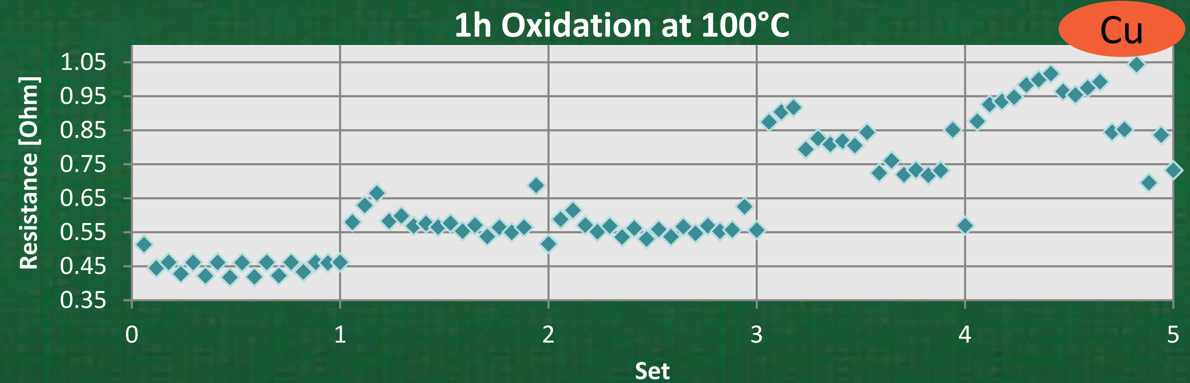
Source. C. Degen, SWTW 2006

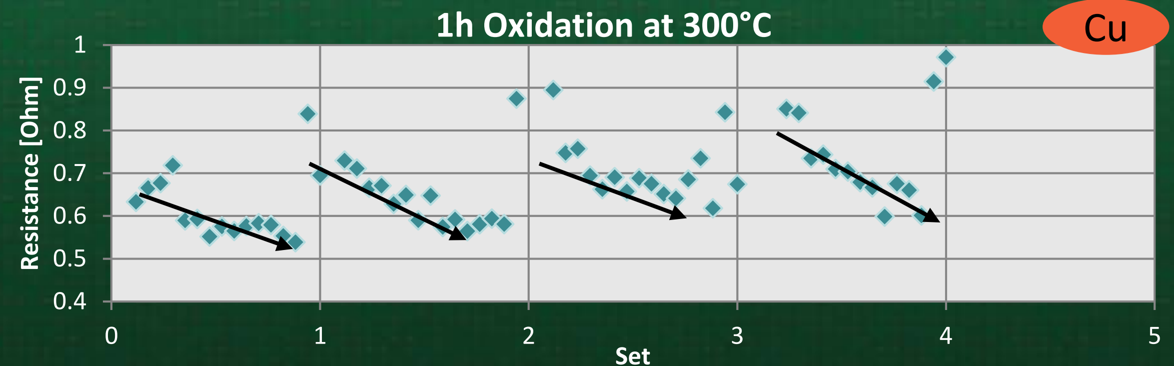


Example #1: Results









- Reference on gold → no fritting effect visible → no oxid layer
- CRes gets lower with increasing current → B-fritting
- With increasing oxide layer thickness, fritting effect is more frequent and uniformly visible

→ Fritting effect demonstrated

Summary

- It is mandatory to understand and predict the influence of the contact resistance during wafer test to avoid performance and quality issues
- A new contact resistance instrument (CRes 2.5) operating at Infineon has been presented
- CRes 2.5 tool is used to evaluate electrical contacts (probes) for probing-pad technology qualifications under production conditions
- CRes 2.5 tool can operate up to 10A on 8 channels including a current/voltage function generator
- First measurements have shown current-related effects (fritting and CCC evaluation)
- Debugging and tool upgrades are ongoing
- Further results will be presented within 2017 (@Semicon Europe)

Contributors

- Francesco Barbon
- Christian Schwarz
- Michael Horn
- Martin Wagenpfeil
- Christian Degen

Thank You!