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Real Time Contact Resistance Measurement & Control

CYPRESS
PERFORM

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Agenda

- **Introduction**
  - Why is CRES control important?
- **Objectives of Real Time Method**
  - Offline Method Limitations & Goals of Real Time Method
- **Methods**
  - Implementation Requirements, Challenges, Techniques
- **Results**
  - Examples of Benefits of System
- **Summary**
  - What have we achieved?
- **Follow-On Work**

Why is CRES important in a manufacturing environment ?

- **Results of Poorly Controlled CRES at Test:**
  - Yield loss
    - Both obvious and hidden
  - Excessive overdrive (typical response to yield loss)
    - Probe Pad Damage
  - Unnecessary cleaning iterations
    - Premature Probe Card Wear-out
  - OEE loss (Overall Equipment Efficiency)
    - Rework, Downtime, Debug, etc.
  - Quality compromised
    - Device Parameters dependent upon low/consistent CRES improperly measured (e.g. band-gap trims)
- **What This Means:**
  - Loss of CRES control is expensive.

Offline Method: Limitations

- **Limitations With Offline CRES Measurement**
  - Without real-time CRES data, other metrics must be relied upon.
    - Overall Yield, hard-bin, & soft-bin monitors
    - Site Bin-Delta monitor
    - Consecutive Fail monitor

    These metrics are valuable, but are device specific. Lack of an easy standard to verify a quality setup result in slow response time, and may require engineering disposition.
  - Difficult to identify and investigate CRES driven test problems
    - CRES problems manifest at the second order (soft bins, distribution plots of subtle parameters, etc.)
  - CRES measurement is offline
    - Does not capture all sources of variation (probe temperature, pogo pins, system planarity)
    - Loss of information, and delayed/no reaction to problems.
- **What This Means**
  - Offline CRES monitoring has significant limitations

Real Time Method: Goals

- **Verify & Maintain a Known Good ATE Setup**
  - OEE and yield improvement
- **Real Time CRES Data**
  - Capture CRES data, every pin, every touchdown
- **Identify Yield Loss Causes (All Sources of Variation Captured)**
  - Hardware (pogo, needles, sites)
  - Probe process (cleaning, overdrive, soak-time)
  - Test program/device marginality (improper MGB)
- **Act Immediately**
  - Continue probing, clean, or alert operator
  - Empower operator, initiate electronic "OCAP" (Out of Control Action Plan) response tool
- **Minimal Test Time Impact**
- **Increase Probe Card Lifetime**
  - Intelligent cleaning frequency

Implementation Requirements

- **Measure & Control CRES While Probing**
  - Consistent & reproducible CRES results.
  - Measure CRES for all applicable pins
  - Measure CRES every touchdown
  - Measurement occurs within same “Z-UP” as product testing
  - All sources of variation captured
  - All CRES data saved in a file
  - Minimal impact to test time
  - Real time auto-chart creation to enable fast analysis
  - Develop automated process to respond to OOC CRES

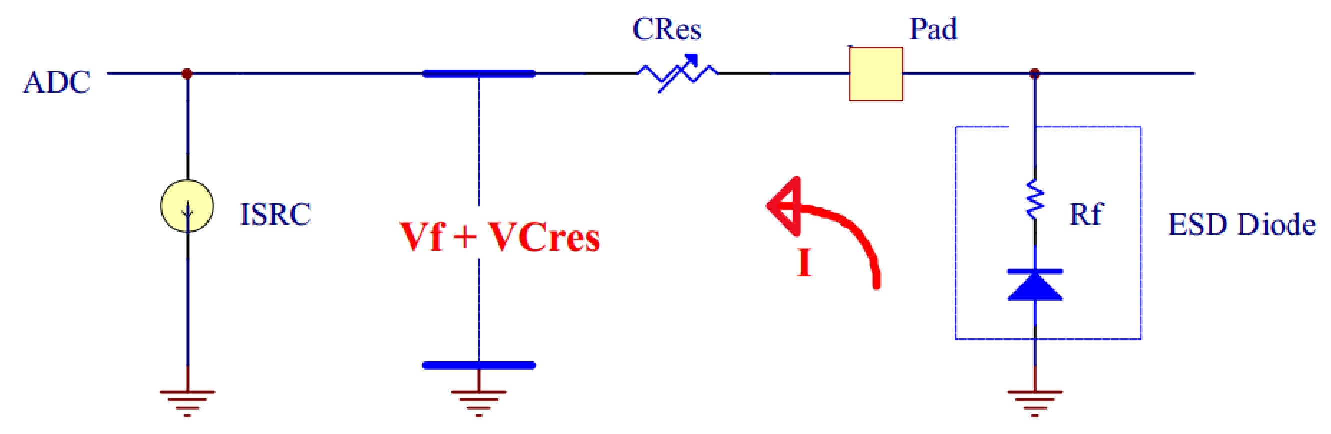
Real Time Method: Challenges

- **Accurate Measurement**
  - Measure while Z-up on device, during actual test.
    - Measuring during actual test eliminates false data
    - Measurement method includes ESD structure in series with contact resistance. This requires empirical data by device/pin for initial setup.
  - Predictable setup – Eliminate variability in setup
    - Create reliable Auto-Z software.
- **Test Time Overhead Minimized**
  - Measurement time.
    - Measuring while testing eliminates need to move off-wafer
    - Measurement time kept to ~ 50ms. (<< 1% overall test time/TD)
  - Write to file time. A lot of data (each pin, each touchdown).
    - Eliminate by using pipelining to store TD(n) data during TN(n+1).
- **Minimize Tool Stoppages**
  - Monitoring software triggers clean as first option.
  - Use both hard limits (empirical) and soft Limits (SPC) to control triggers
  - Operator owns OCAP trouble-shooting guide execution

Inline CRES Measurement: Method

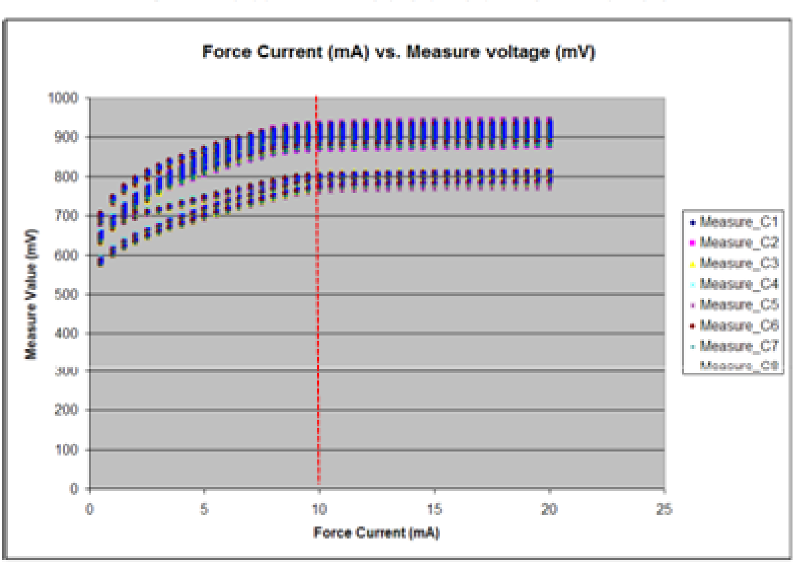
- **Measure the Total Path Resistance Using a Continuity Measurement Technique.**
  - FIMV (force negative current, measure voltage)
  - Measured value is summation of Voltage Drops:
  - Vmeas = Ohmic + Diode
    - Ohmic : V(CRES) = Hardware (pogos, PCB traces) + needle contact resistance
    - Diode : Vf = Forward biased ESD diode

Measurement Model



Inline CRES Measurement: Method

- **Inline measurement technique:**
  - Increase current to magnify ohmic CRES resistance
    - 10mA chosen as force current
    - PMU accuracy 10mV, then
    - CRES accuracy = 1 ohm
  - Vf (diode) is proportional to the natural log of the current
    - Vf = VT x ln (I/Is) [Shockley equation]
    - Diode voltage varies from ~ 400 mV to 800 mV, depending on pad type, and temperature
    - Vf is Comparable within each Touchdown
  - Technique works on both I/O and Power plane pins
    - Since Vf varies by pin-type, there must separate data by pin-groups.



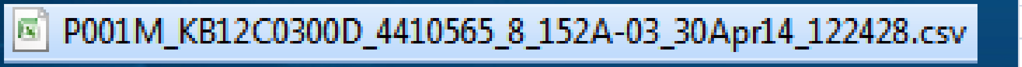
Vmeas [mV] vs. Iforce [mA]

Consistent CRES measurement: “Auto Z” Implementation

- **What is AutoZ?**
  - Automation that replaces manual Planarity Setup and Verify
- **What Does It Do?**
  - Guarantees equivalent setup at start of each wafer
  - Sets probing Z-height at electrical "First Contact“
  - Sets the probing overdrive (Setup Input Parameter)
  - Measures the probe card planarity (Setup Input Parameter)
  - Eliminates poor electrical contact related issues
  - Eliminates operator variability
- **Why Is It Critical for Real-Time CRES Control?**
  - Enables accurate and consistent measurements

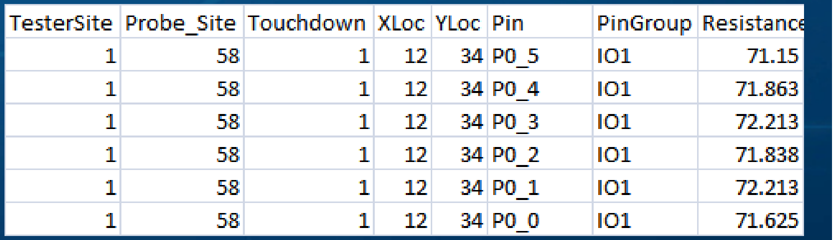
CRES Data Collection Method

- **Method of CRES Measurement and Data Storage**
  - Measure all pins used in testing (Except GND)
  - Measurement to be done after continuity test
    - To exclude bad die from data set
  - Group measurement by pin-group (VDDA, VDDB, IO1, IO2)
    - Grouping is based on pin type or measurement value
  - All data of every touchdown are saved in a .csv file



P001M_KB12C0300D_4410565_8_152A-03_30Apr14_122428.csv

.csv filename example

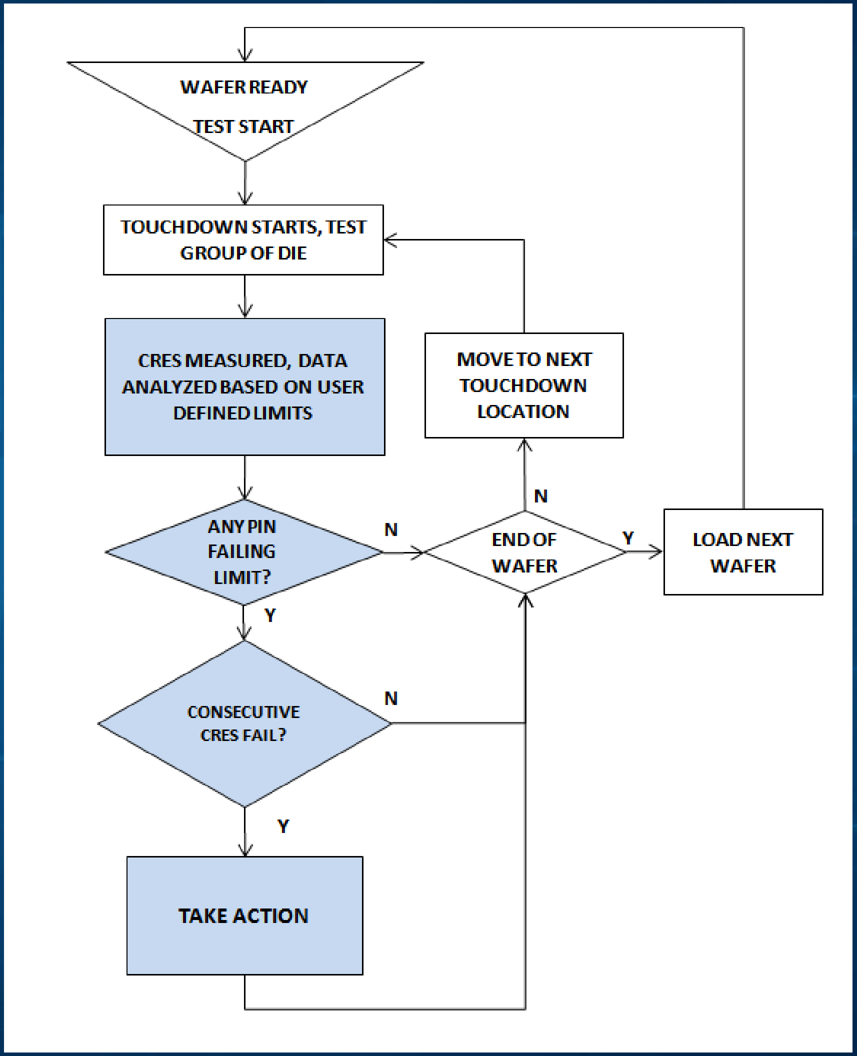


TesterSite	Probe_Site	Touchdown	XLoc	YLoc	Pin	PinGroup	Resistance
1	58	1	12	34	P0_5	IO1	71.15
1	58	1	12	34	P0_4	IO1	71.863
1	58	1	12	34	P0_3	IO1	72.213
1	58	1	12	34	P0_2	IO1	71.838
1	58	1	12	34	P0_1	IO1	72.213
1	58	1	12	34	P0_0	IO1	71.625

.csv file content example

CRES Real Time Control Method

- **Real Time CRES Control**
  - Control software integrated to probing/test software
  - Software reads CRES data and does statistical analysis per touchdown
  - Determines pass/fail result based on the limits
  - Take action upon fail:
    1) Continue probing
    2) Clean probe tips before continuing
    3) Stop probing & prober alarms



CRES Control Flow Chart

CRES Real Time Control: Limits

- **Setting Fail Limits**
  - Set using Fixed (empirical) and/or Standard Deviation (SPC based) limits
    - SPC based limits dynamically set per TD (identify outlier by pin)
  - Limits are set by pin group

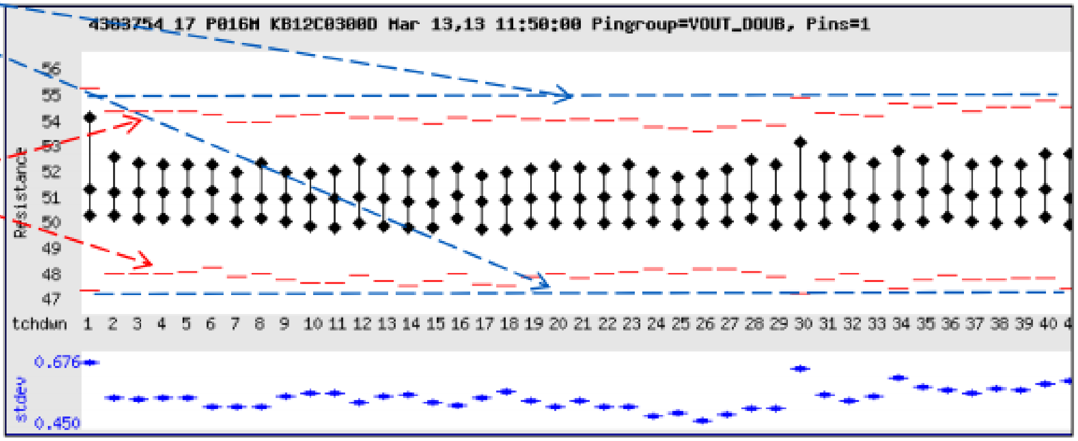
1) FIXED HIGH & LOW LIMIT

- Fails if Cres value is > high limit or < low limit

2) STANDARD DEVIATION LIMIT

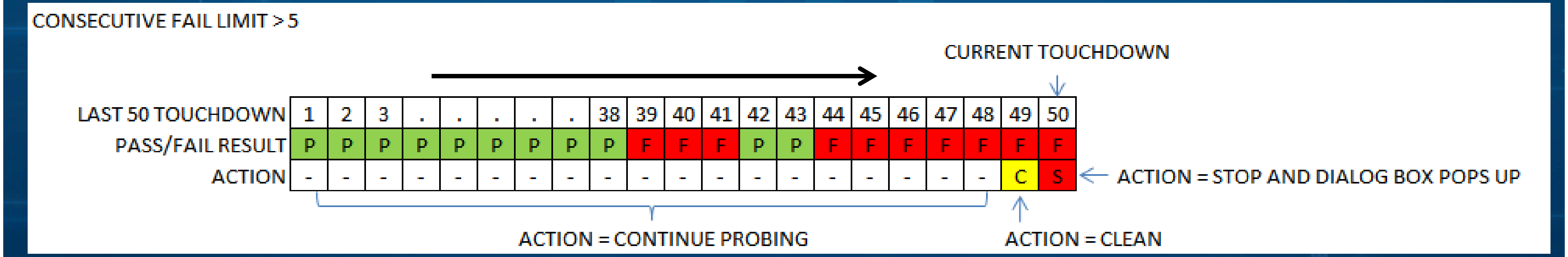
- Variable limit per touchdown (based on standard deviation).
- Limit will be:

Average +/- N * StdDev



CRES Real Time Control: Consecutive Fail

- **Consecutive Fail Monitor**
  - Software monitors consecutive failure status
  - Determines action based upon current and previous pass/fail results
  - Consecutive trip limit set to avoid false signals



CONSECUTIVE FAIL LIMIT > 5

CURRENT TOUCHDOWN

LAST 50 TOUCHDOWN	1	2	3	.	.	.	.	.	38	39	40	41	42	43	44	45	46	47	48	49	50
PASS/FAIL RESULT	P	P	P	P	P	P	P	P	P	F	F	F	P	P	F	F	F	F	F	F	F
ACTION	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	C	S

ACTION = STOP AND DIALOG BOX POPS UP

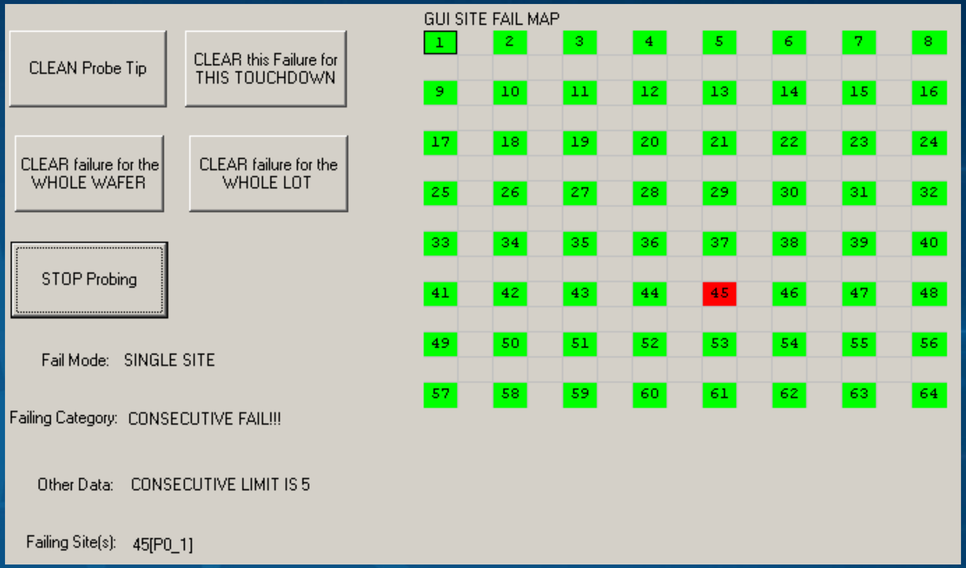
ACTION = CONTINUE PROBING

ACTION = CLEAN

Illustration Showing How Consecutive Fail Monitor Works

CRES Real Time Control: Dialogue Box

- **CRES Fail Dialogue Box**
  - Dialog box pop up
  - Probing pauses & alarms
  - Wait for operator
    - Stop probing , check setup
    - Clean probe tip
    - Clear failure



Fail Mode: SINGLE SITE

Failing Category: CONSECUTIVE FAIL!!!

Other Data: CONSECUTIVE LIMIT IS 5

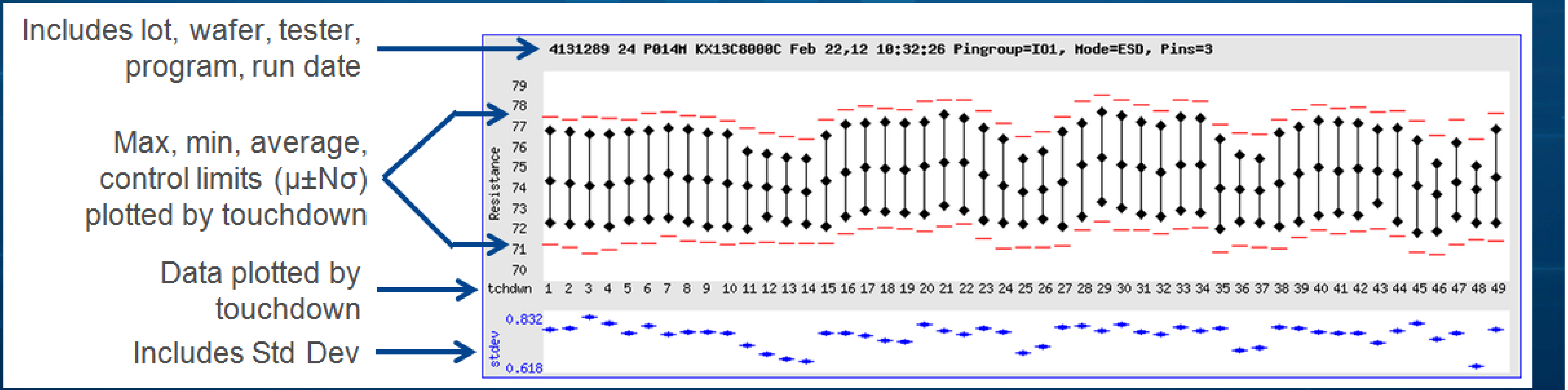
Failing Site(s): 45[P0_1]

Example Fail Dialog Box

- **CRES Out of Control Action Plan (OCAP)**
  - Step by step troubleshooting guide for manufacturing
  - Find and fix source of problem (Probe Card, Process or Pogo/Interface)

CRES Data Collection: Charts

- **CRES Chart**
  - One chart created for every we wafer test
  - Chart can be viewed using the web browser
  - CRES data can be viewed touchdown or by site
  - All data and charts are kept for one year



Includes lot, wafer, tester, program, run date

Max, min, average, control limits (μ±Nσ) plotted by touchdown

Data plotted by touchdown

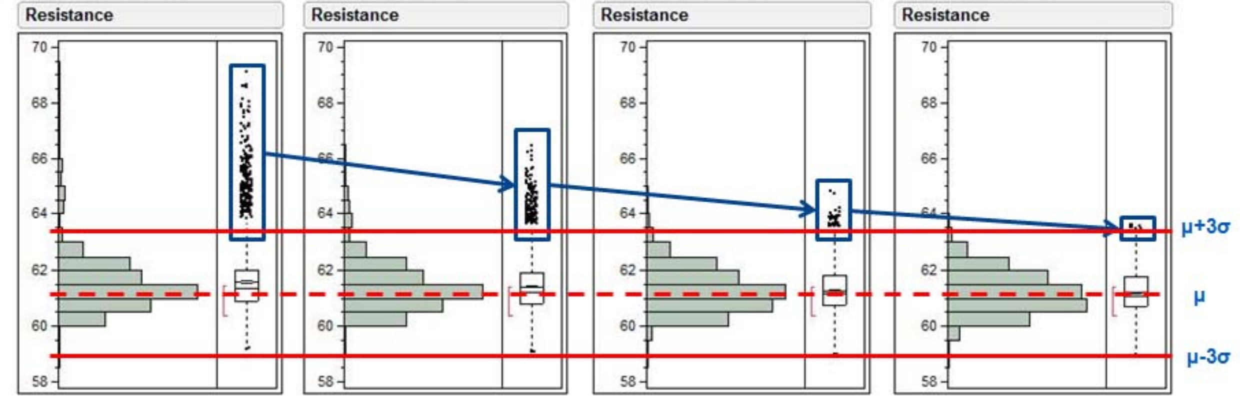
Includes Std Dev

4131289 24 P014M KX13C8000C Feb 22,12 10:32:26 Pingroup=I01, Mode=ESD, Pins=3

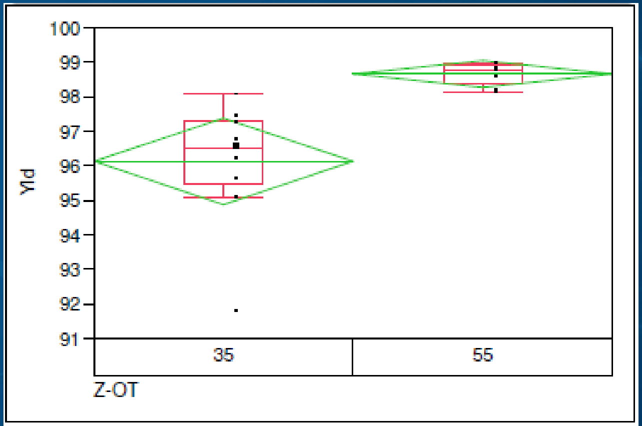
Example CRES Chart

Results: Test Process Improvement

- **What This Is**
  - CRES & wafer yield distribution by Z-overtravel value
  - Z-overtravel is set from 1st contact
  - Distribution plot =~75K data points



CRES Distribution by Overtravel Value

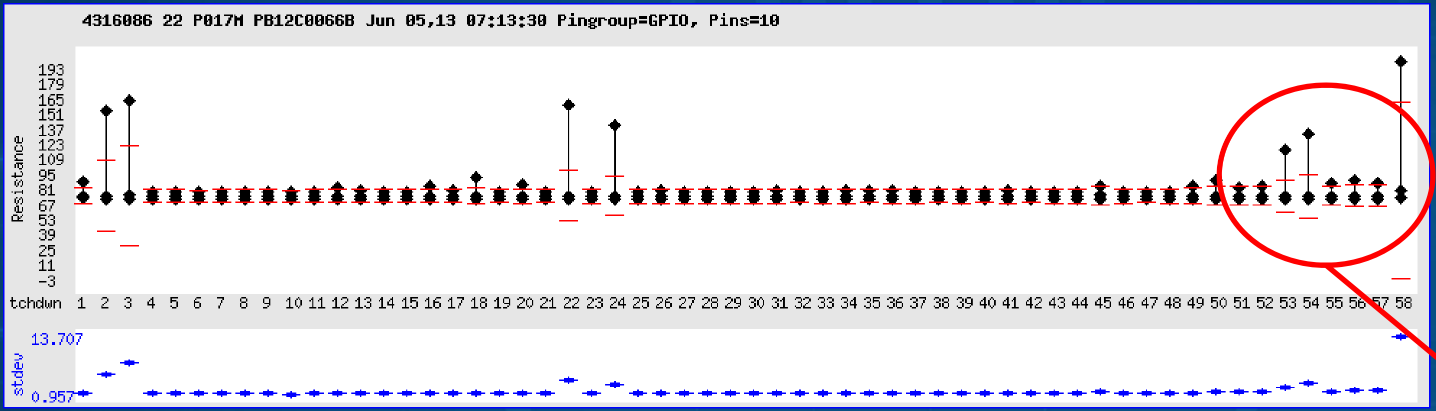


Yield [%] vs Overtravel [value]

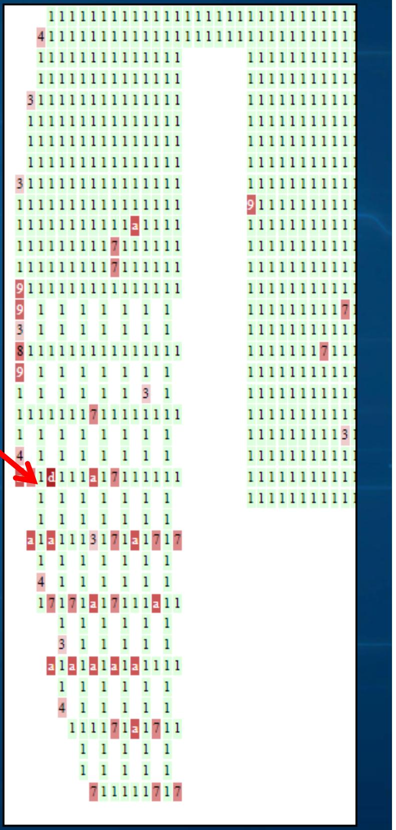
- **What This Means**
  - Overtravel parameter optimized using real time CRES data
  - Improvement in yield correlated to less CRES variation

Results: Test Process Improvement

- **What This Is**
  - Example Chart showing high CRES variation affecting DUT bin result
  - Each x-axis plot = 640 data points (64 sites x 10 pins)



CRES [ohms] vs Touchdown [count]

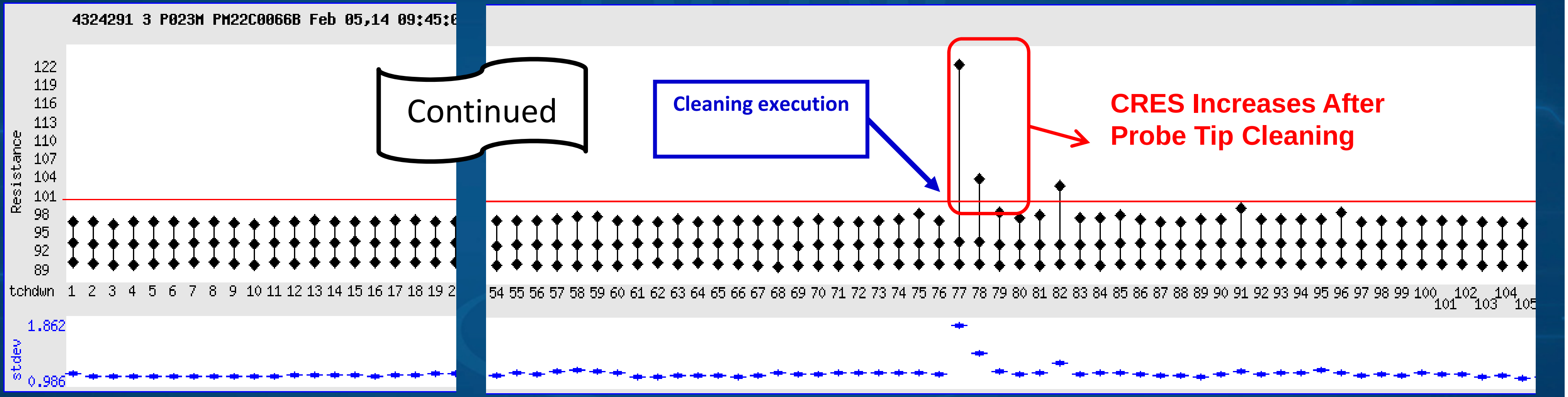


Wafer Map

- **What This Means**
  - Probing process is uncontrolled, tool stops frequently
  - High CRES correlated to high false test failures
- **What Have We Done**
  - Implemented Auto-Z to reduce CRES variation

Results: Test Process Improvement

- **What This Is**
  - A chart that shows CRES increases after probe tip cleaning
  - Each x-axis plot = 640 data points (64 sites x 10 pins)



Continued

Cleaning execution

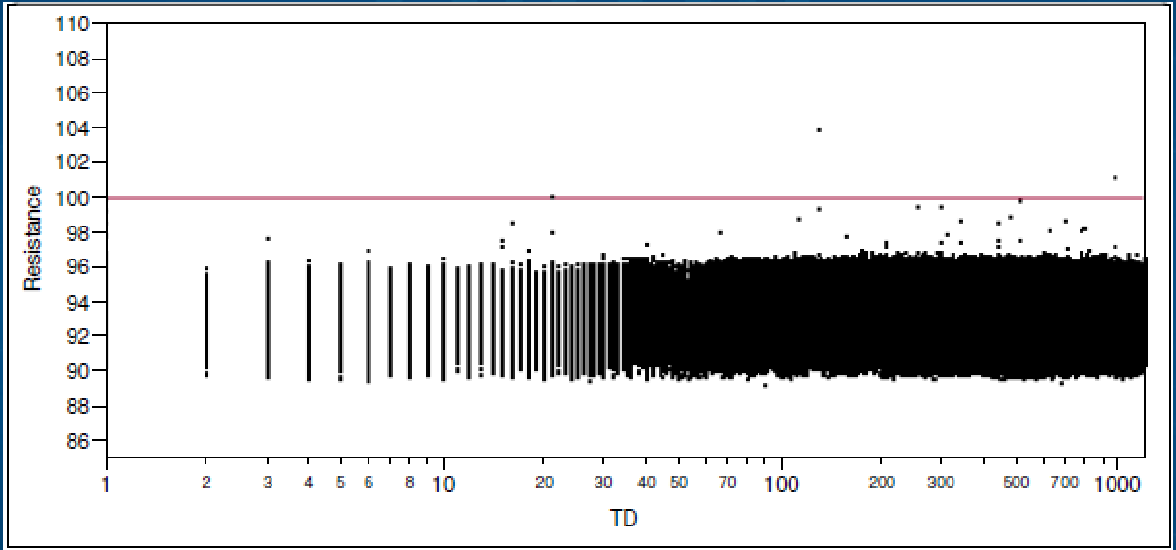
CRES Increases After Probe Tip Cleaning

CRES [ohms] vs Touchdown [count]

- **What This Means**
  - Cleaning can increase CRES if the settings are not optimized

Results: Test Cost Reduction

- **What This Is**
  - CRES data for 1000 touchdowns and no cleaning applied
  - Each x-axis plot = 640 data points (64 sites x 10 pins)



CRES [ohms] vs Touchdown [count]

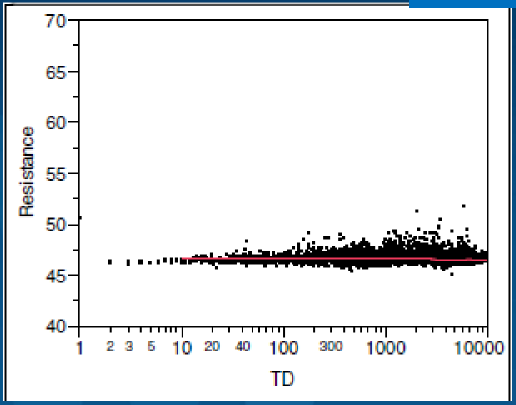
- **What This Means**
  - CRES did not significantly change when cleaning frequency was reduced
  - Frequency of probe tip cleaning can be reduced for certain device/probe card combinations

Results: Test Program Improvement

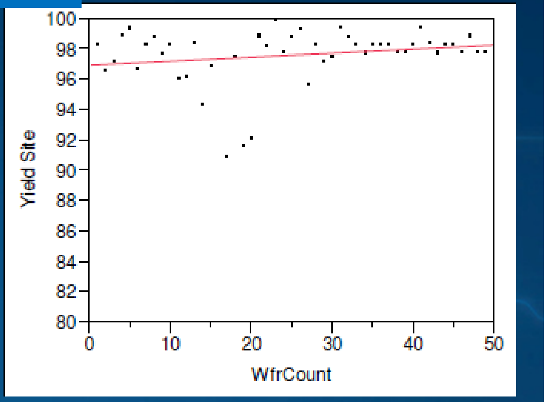
- **What This Is**
  - CRES and yield data that shows the effect of Cres to site yield.
  - A test program problem causes the CRES on VDD pin to significantly increase while probing

- **What This Means**
  - Test program problem was caught, analyzed and fixed quickly with the help of this system

Good Site

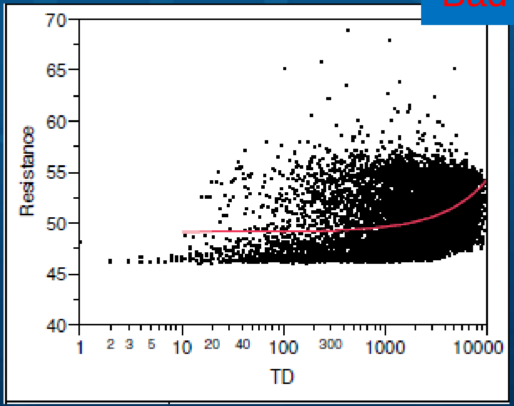


CRES [ohms] vs TD [count]

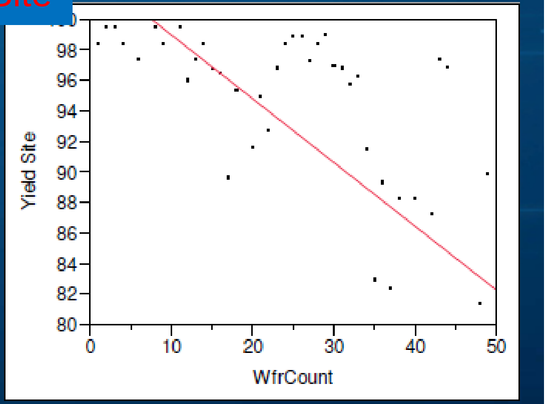


Yield [%] vs Wafer Count

Bad Site



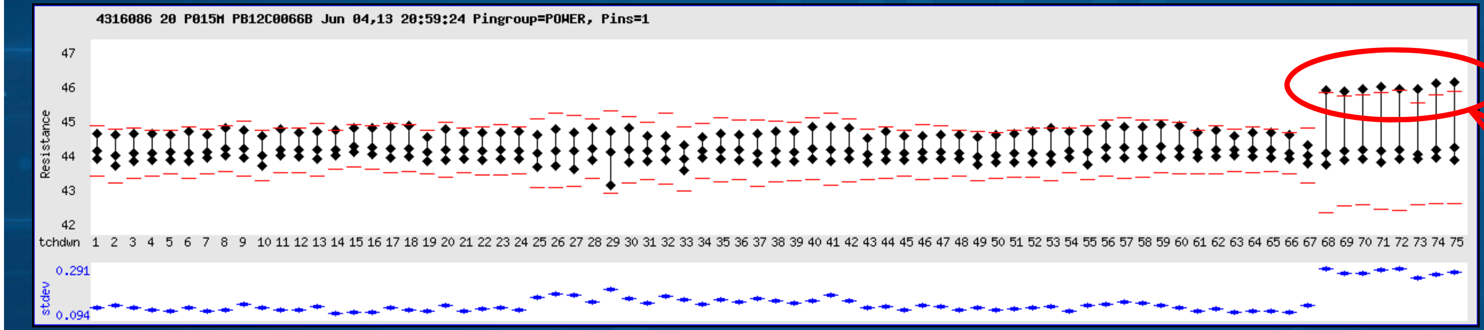
CRES [ohms] vs TD [count]



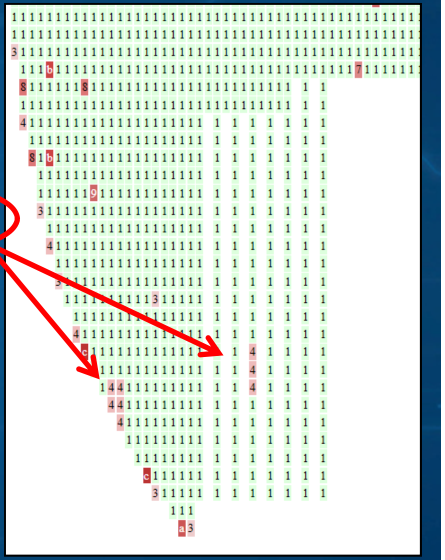
Yield [%] vs Wafer Count

Results: Test Program Improvement

- **What This Is**
  - Example data showing small CRES increase (~1.5 ohms) in a power supply pin resulted in specific test failure
  - Each x-axis plot = 64 data points (64 sites x 1 pin)



CRES [ohms] vs Touchdown [count]

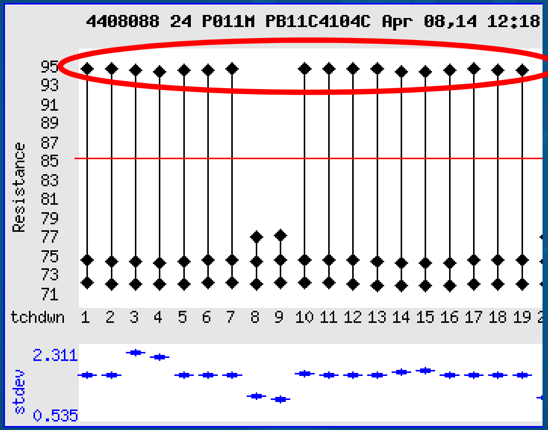


Wafer Map

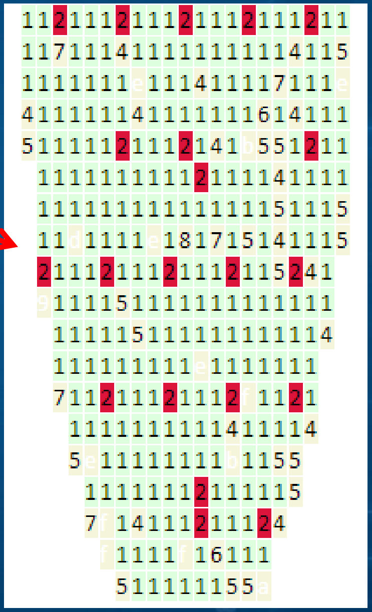
- **What This Means**
  - The real time CRES data collection and control enabled capability to get valuable data to analyze test program problem and implement fix

Results: Detects & Controls Other Source of CRES Problem

- **What This Is**
  - CRES data showing a pin that is 20 ohms higher than normal affected DUT bin result
  - Each x-axis plot = 480 data points (32 sites x 15 pins)



CRES [ohms] vs TD [count]



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112111211121112111211
117111411111111114115
1111111e111411117111e
411111141111111614111
51111121112141b551211
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 11111111111111151115
 11d1111e181715141115
 2111211121112115241
 9111151111111111111
  111115111111111114
  111111111e1111111
  711211121112f1121
   1111111111411114
   5e11111111b1155
    11111112111115
    7f1411121112 4
     f1111f16111
      511111155a
```

Wafer map

- **What This Means**
  - Detected & controlled high resistance problems of the full test setup (not just probe card)

Results: What We Achieved

- **Consistent, Reproducible CRES Data using Auto-Z**
- **Real Time Data, All Pins, Every Touchdown**
  - All sources of variation
- **Automated Process Control**
  - Immediate response, automated & manual
  - Verify & maintain a known good setup
- **Subtle Issues Identified Quickly**
  - Test program problems, device/fab sensitivities
- **Test Time Impact Minimal**
- **OEE & Yield Improvement -> $$**

Follow-On Work

What's Next:

- **Implement Cleaning on Demand**
  - Remove fixed cleaning intervals

Acknowledgments

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  - Jason Mooney
  - Anton Pratama
  - Paul Berndt
  - Dane Christian

Q & A