SW Test Workshop
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Production Parametric Test -

Challenges and Surprising Outcomes Running in a High Volume Manufacturing Environment

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Overview

- Introduction
- Background
- Expected Outcome and Goals
- Actual Data
- Unexpected Results
- Side Benefits
- Conclusions
- Follow-on work

Introduction

What was the original motivation to consider other probe card suppliers?

Expanding test capabilities to support 90nm technology, requirements included:

- Smaller pad sizes
- Improved data resolution at parametric test
- Longer probe card life

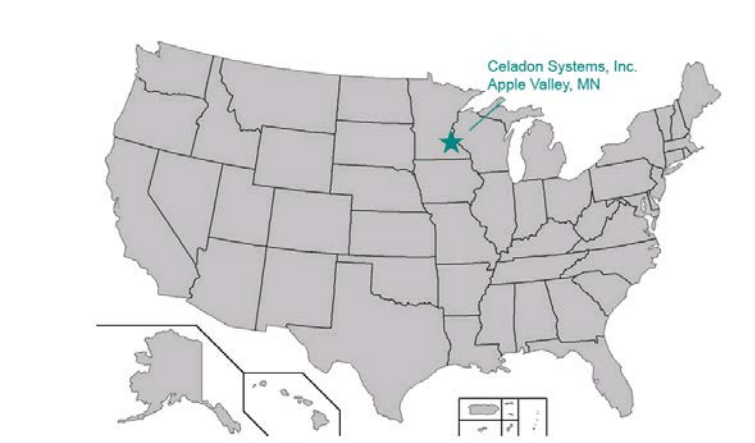
Introduction

- **Why are we here?**
  - Unexpected benefits:
    - Exceptionally long lifetime performance
    - Low cost of ownership

Background

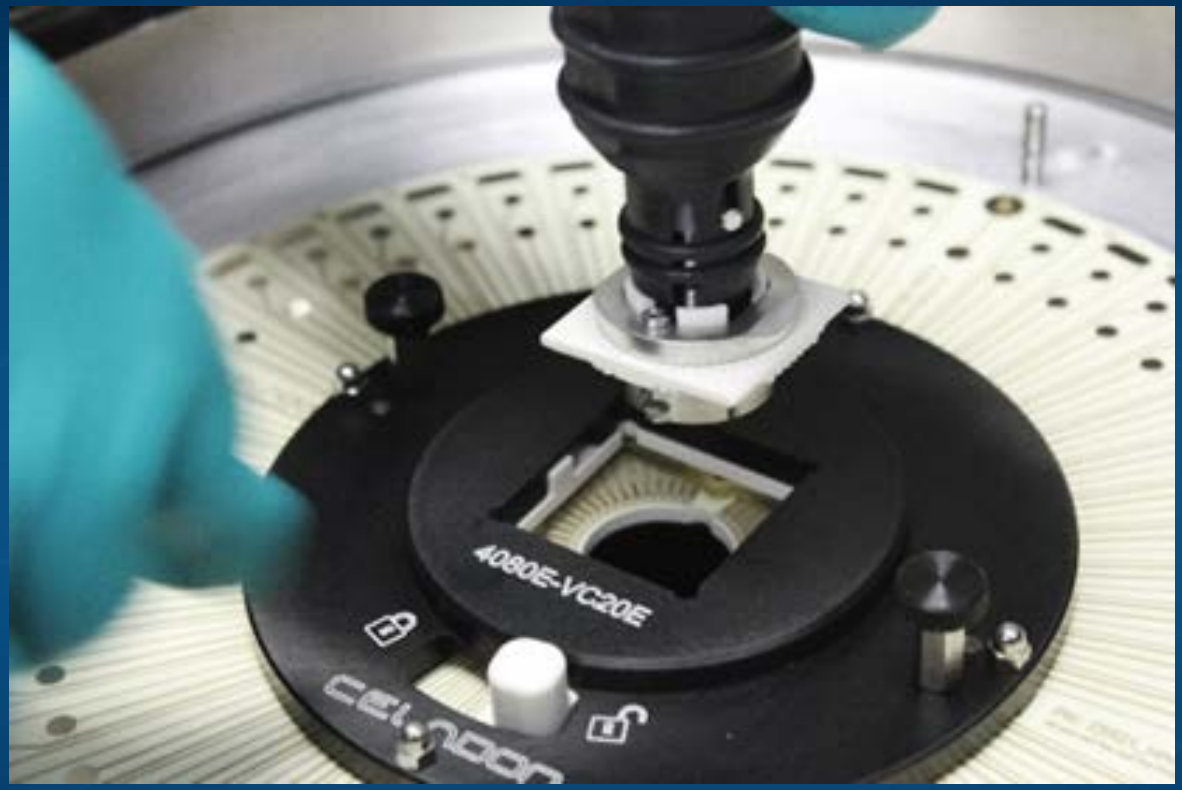
- Freescale and Celadon began working together over 10 years ago in the device lab. The lab used Celadon's VersaTile™ probe cards.
- The VersaTile™ probe cards performed well in the device lab. Freescale test engineers decided to evaluate the VersaCore™ probe card for production parametric probe, with Celadon participating in the qualification process.

Background – Who is Celadon Systems?



- Celadon is a well established 18 year old privately held company with Headquarters in Apple Valley, Minnesota.
- All engineering, manufacturing and most repair is done in Minnesota. Celadon has a support center in Taiwan to support customers in Asia.
- 200+ global customers
- Core competencies: high performance probe cards, low leakage cables and interfaces

Background – VersaCore™ VC20E



Modular design – changeable core

Rated for -65C to 200C

Ultra low leakage, less than 5 femto amps/volt - room temp to 75C

Up to 48 channels

Expected Results - Goals

- **Electrical Performance Goals:**
  - Contact resistance: less than 2 ohms
  - Leakage: less than 5 pico amps
- **Mechanical Performance Goals:**
  - Scrub marks less than 50% of pad
  - Exceed 1.5 million touch downs

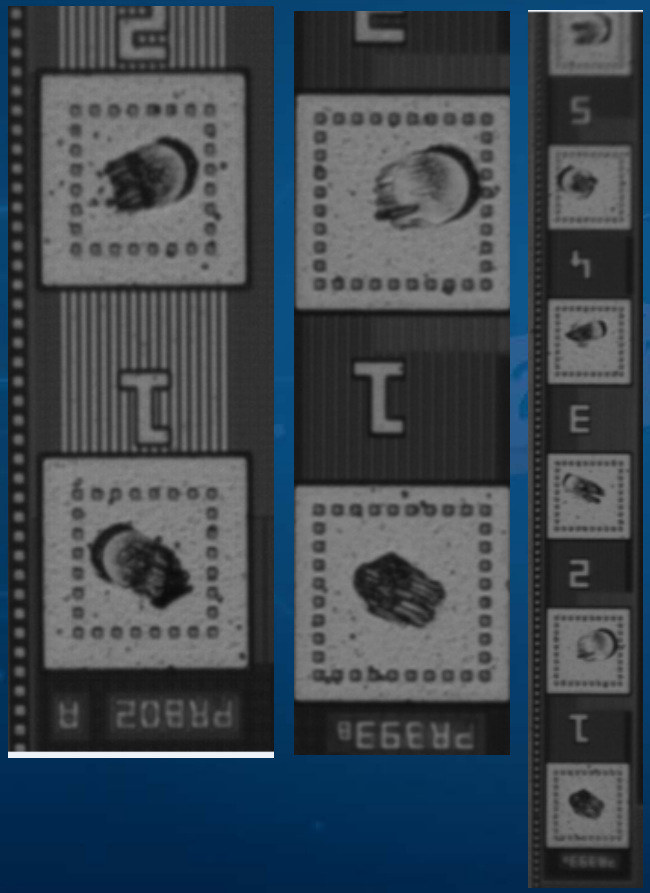
Qualification, Test Environment

Technology node: 90nm

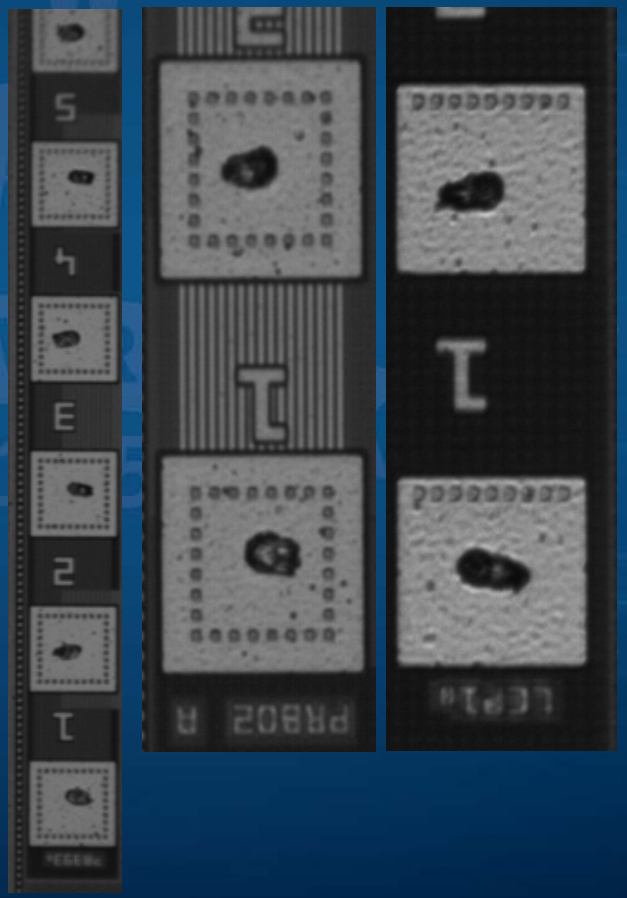
- Pad Size: 70 microns => 50 microns
- Minimum Pitch: 100 microns
- Probe Material: Tungsten with 3% Rhenium
- Pad Material: AL, CU
- Probe angle: 9 degrees from Vertical
- Probe tip size:
  - 5-7 microns at start, later conditioned to 8-9 microns to support prober camera threshold
- Tester: Agilent 4070 series
- Probers: Tokyo Electron Limited (TEL) P8 series
- Test Temperature: 25C

Actual Results – Probe Marks

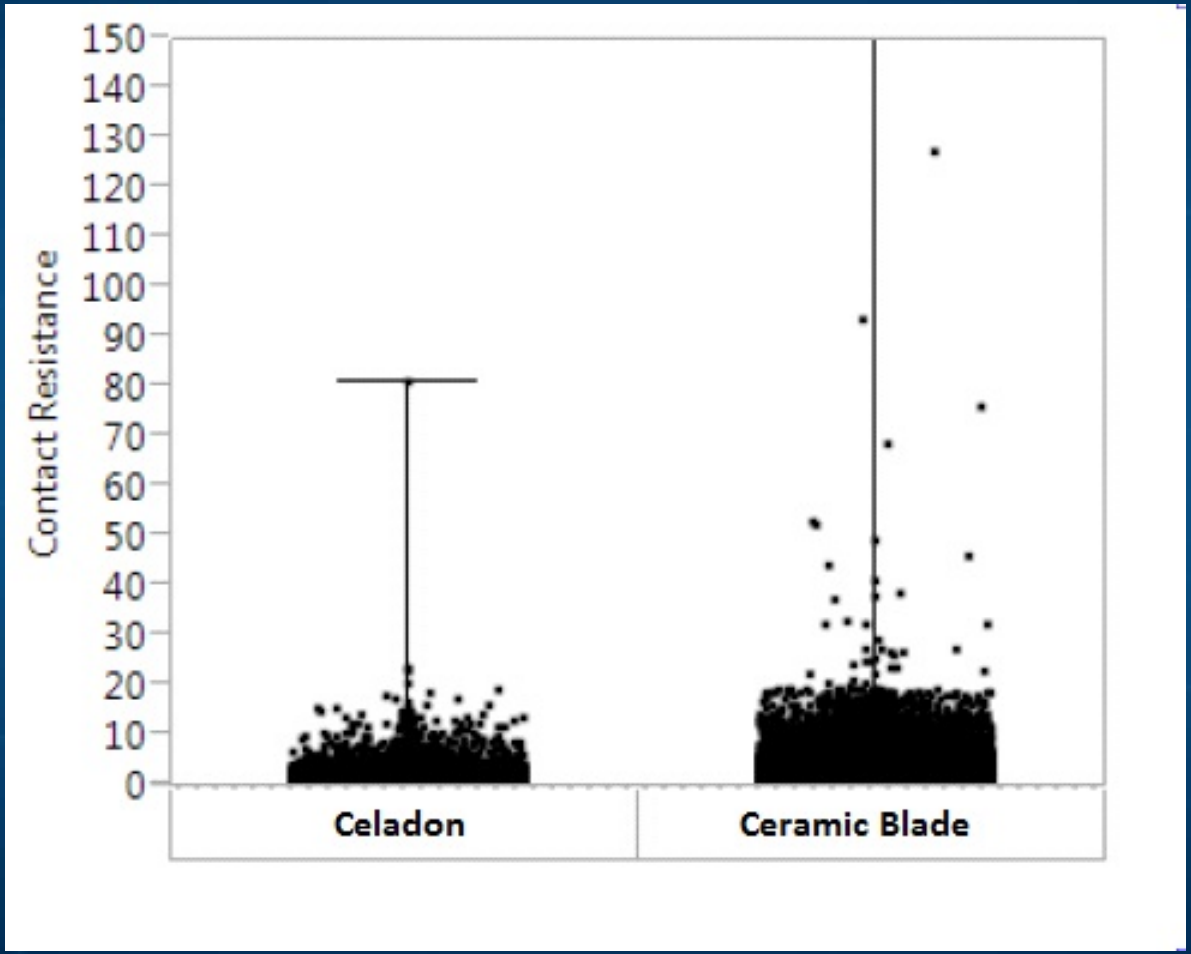
Blade Probe Marks



Celadon VC20E™ Probe Marks

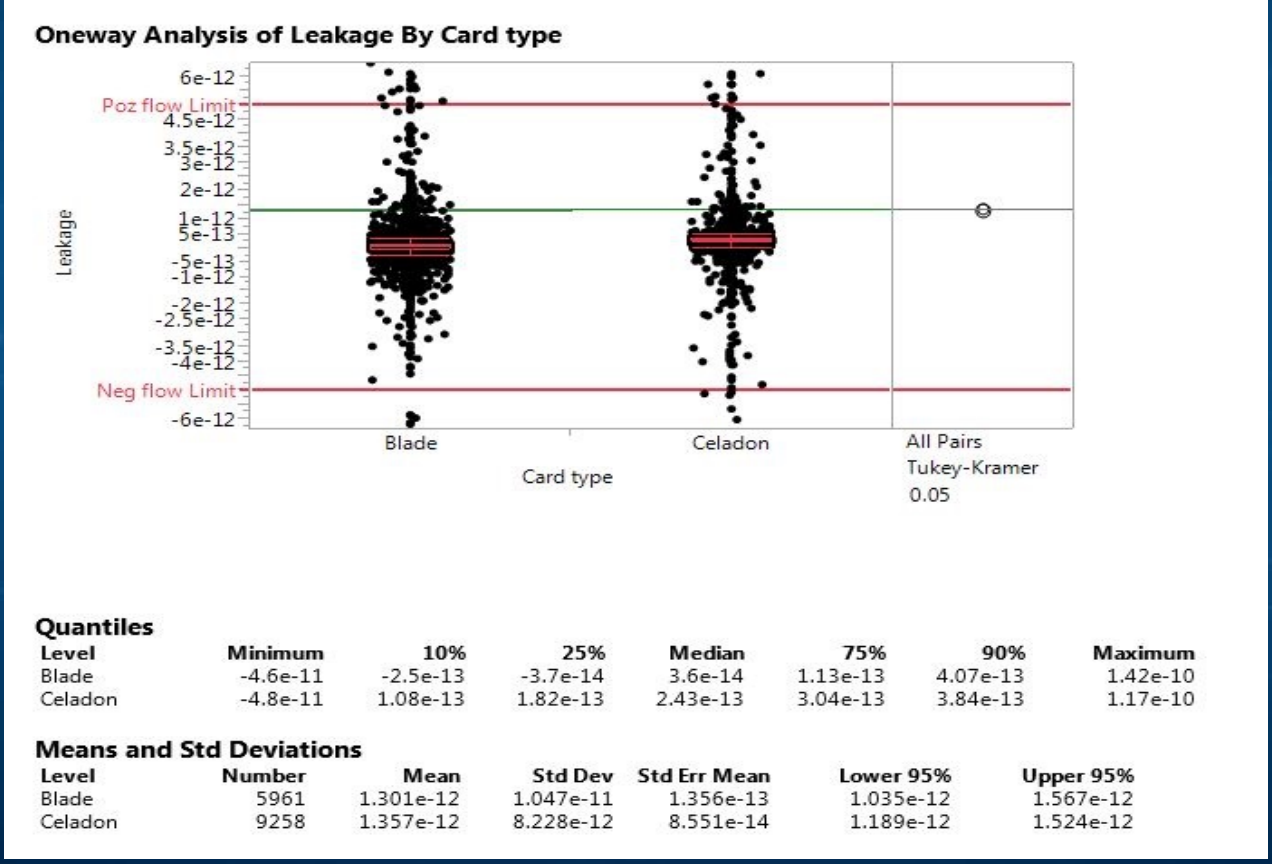


Actual Results – CRES in ohms



Actual Results - Leakage

Leakage signature had to match that of a ceramic blade card
Limit = 5e-12 femtoamps



Quantiles

Level	Minimum	10%	25%	Median	75%	90%	Maximum
Blade	-4.6e-11	-2.5e-13	-3.7e-14	3.6e-14	1.13e-13	4.07e-13	1.42e-10
Celadon	-4.8e-11	1.08e-13	1.82e-13	2.43e-13	3.04e-13	3.84e-13	1.17e-10

Means and Std Deviations

Level	Number	Mean	Std Dev	Std Err Mean	Lower 95%	Upper 95%
Blade	5961	1.301e-12	1.047e-11	1.356e-13	1.035e-12	1.567e-12
Celadon	9258	1.357e-12	8.228e-12	8.551e-14	1.189e-12	1.524e-12

Actual Qualification Summary

- Celadon's electrical performance and ability to probe small pad geometries met specifications
- Freescale chose Celadon to be the vendor of choice for specific technology nodes and is currently running high volume manufacturing using Celadon's VC20E Versacore™

Unexpected Results

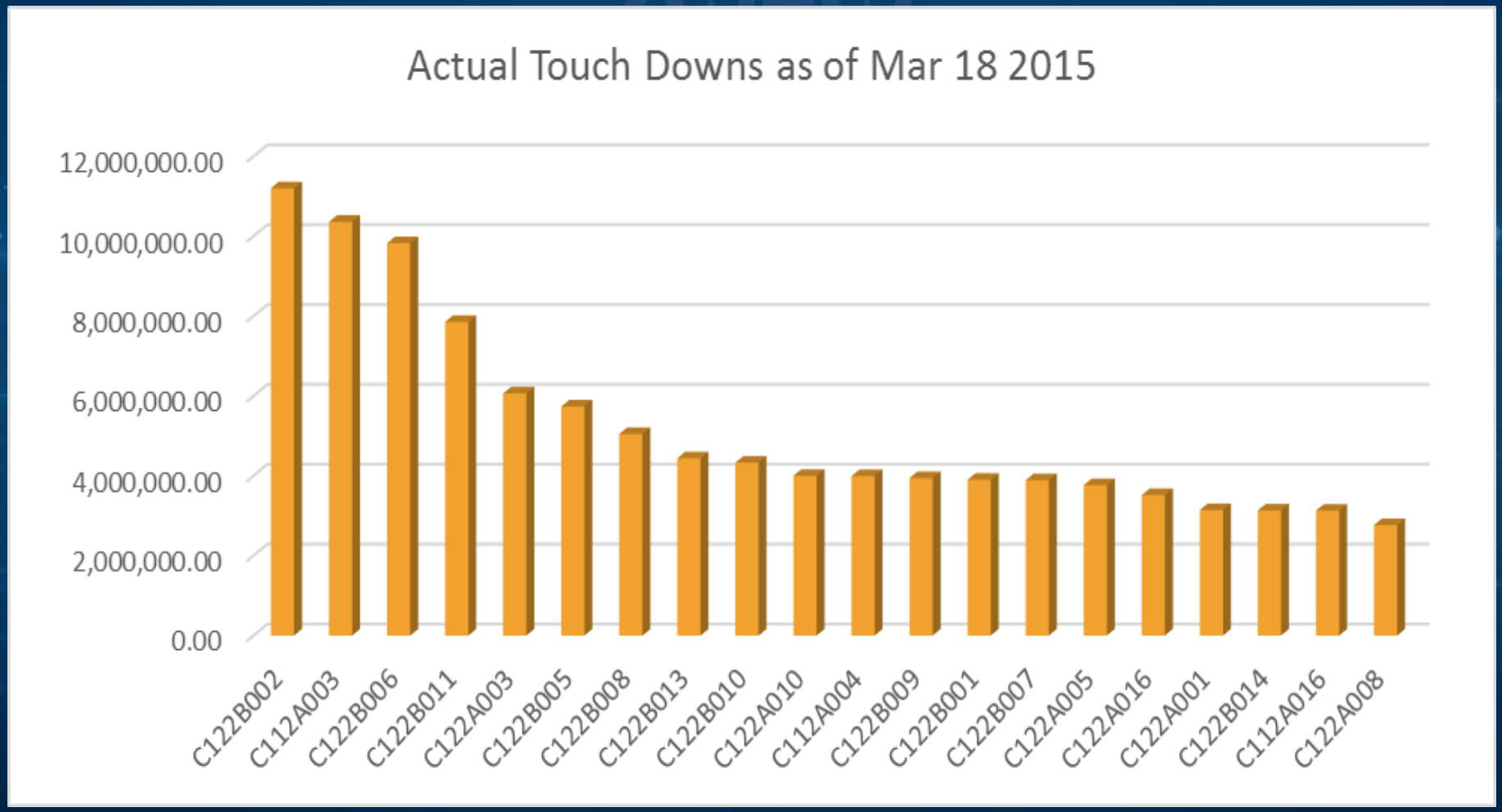
- Unusually low mechanical wear. Touch down data took time to collect and has been monitored quarterly.
  => initial goal was to exceed 1.5 million touch downs until rebuild.
- Freescale probe floor began migration in Q2-2013
- In Q2-2014, Celadon VC20E VersaCore™ probe cores in use exceeded touch down goal
- Celadon has shipped 65 cores to date to Freescale

Unexpected Results

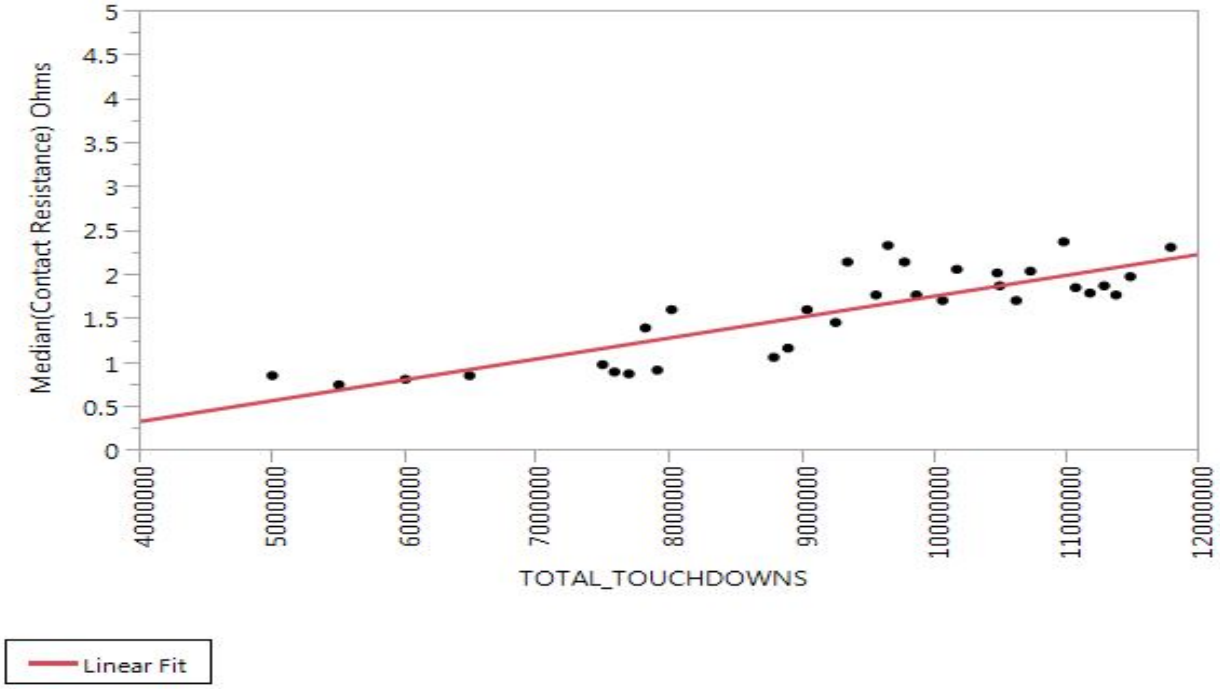
- To date, zero VersaCores™ have been returned for wear
- Touch down data presented in next slide is a snapshot of data taken March 2015

PLEASE NOTE: *100% of production probe cards are still in use at Freescale and none have been rebuilt due to probe wear*

Actual Touch Down Data March 2015



Oldest VersaCore™, actual touch down data vs. CRES, 4/30/2015



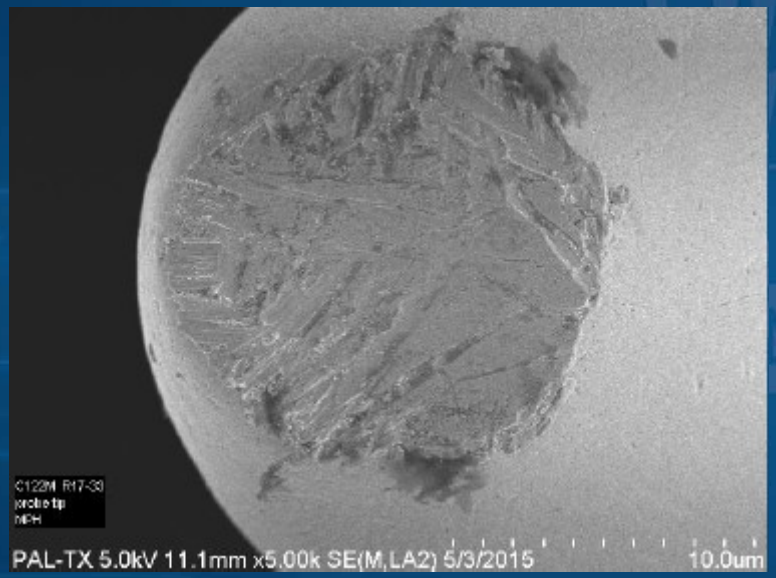
Linear Fit

Median(Contact Resistance) = -0.608053 + 2.3775e-7*TOTAL_TOUCHDOWNS

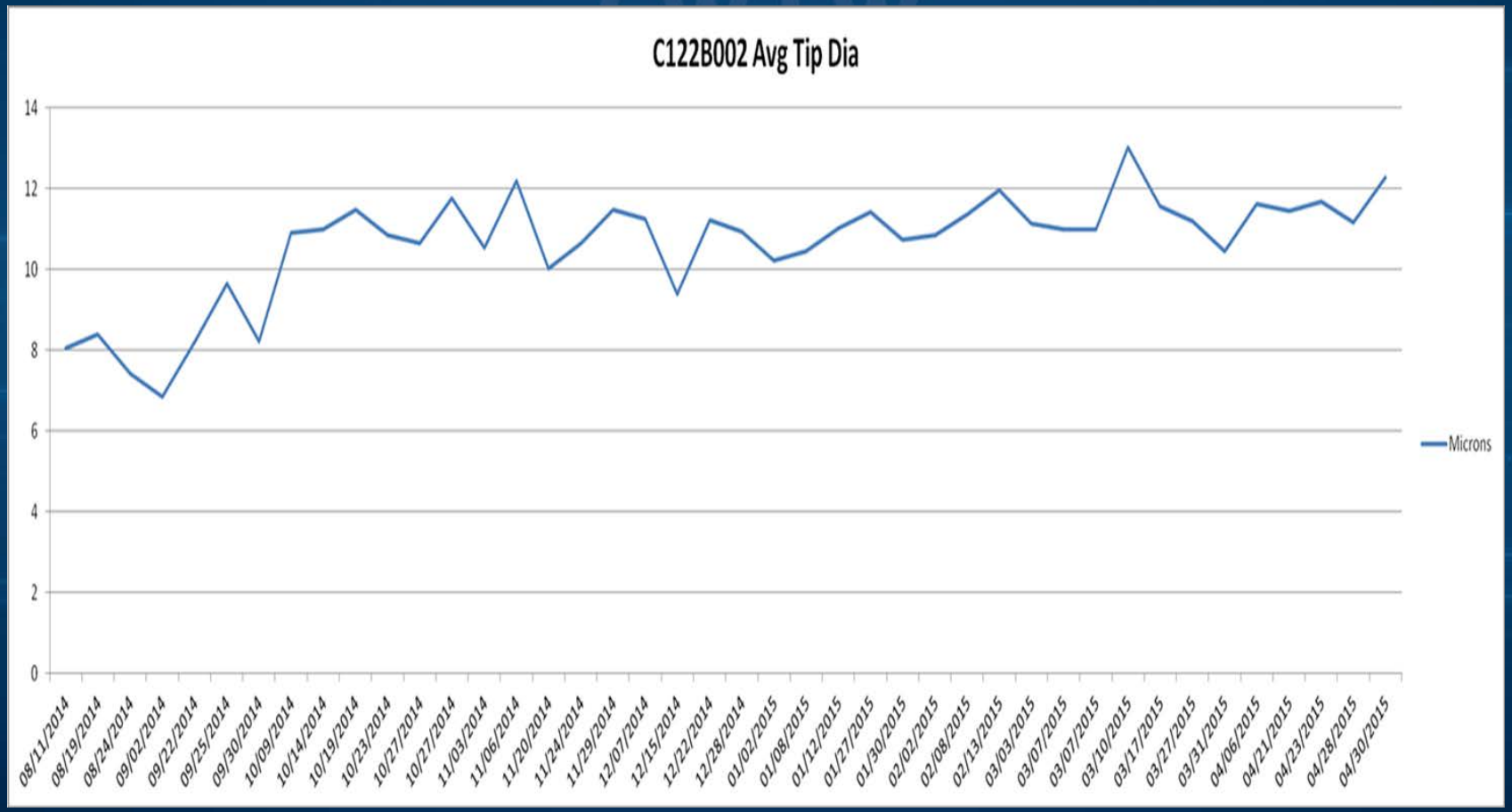
Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	5.8675410	5.86754	74.7396
Error	30	2.3551933	0.07851	Prob > F
C. Total	31	8.2227343		<.0001*

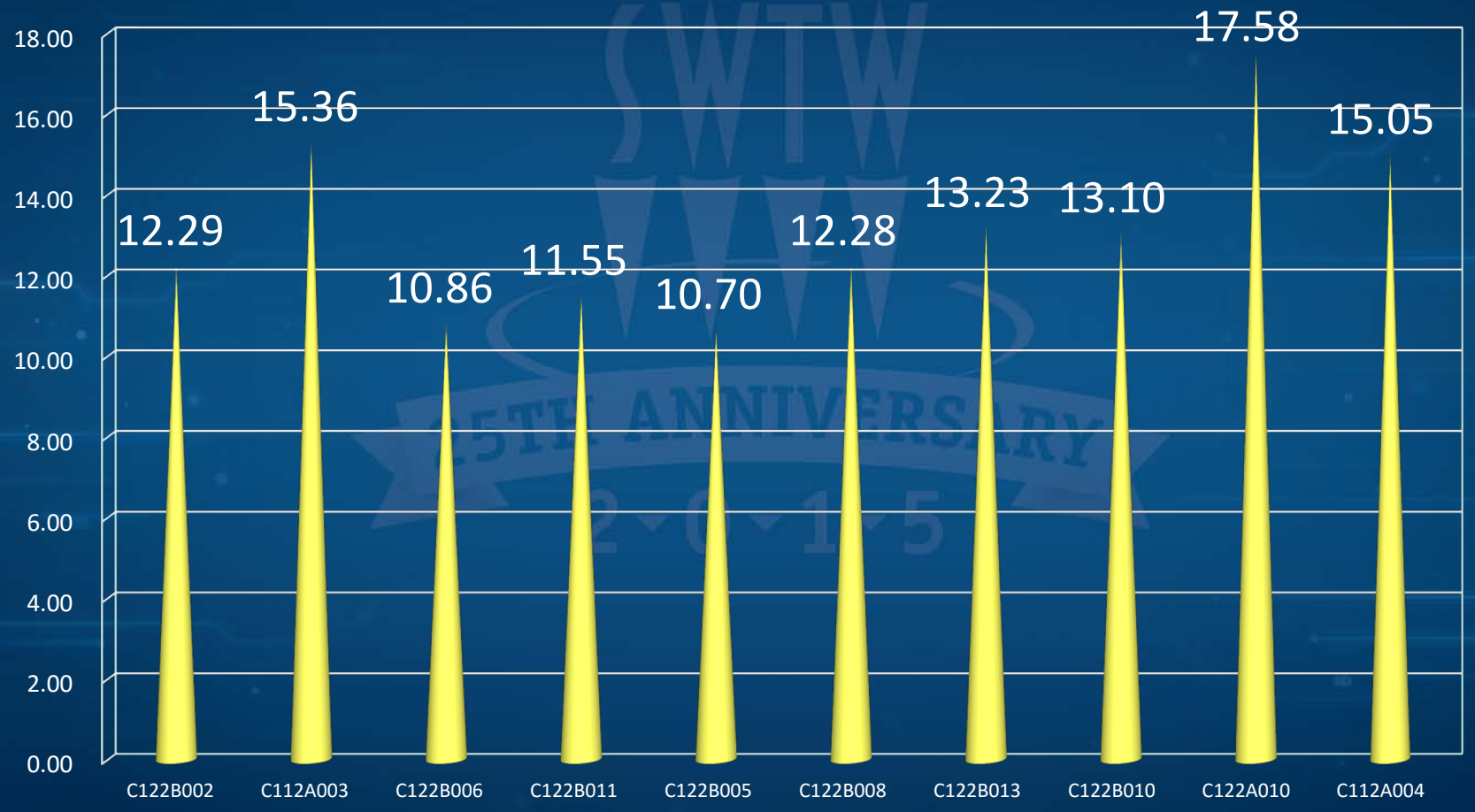
Actual Probes on VersaCore™ C122B002 after 12 Million Touchdowns



Actual Probe Tip Diameter for VersaCore™ with 12M TDs



Longest Running VersaCores™
Actual Current Tip Diameters in microns



Estimated Tip diameter Wear Rate for 10 Longest Running VersaCores™

- Celadon conditioned tips to ~8 microns at outgoing
- Average current tip diameter is ~13.2 microns
- Average TDs ~5.7 million
- *Average wear rate for longest running ten cores: ~1,000,000 TDs/micron of tip wear*

Why are probes lasting so long?

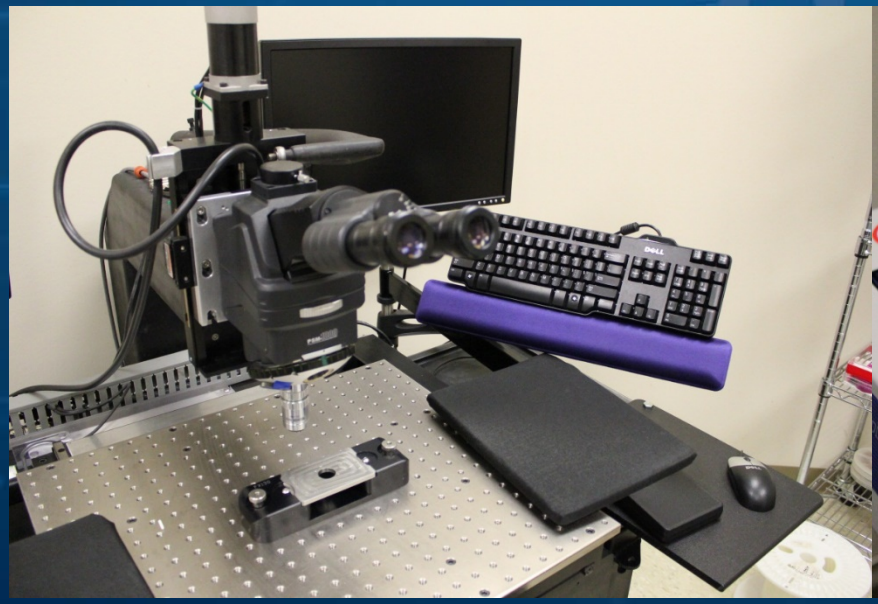
Two key factors:

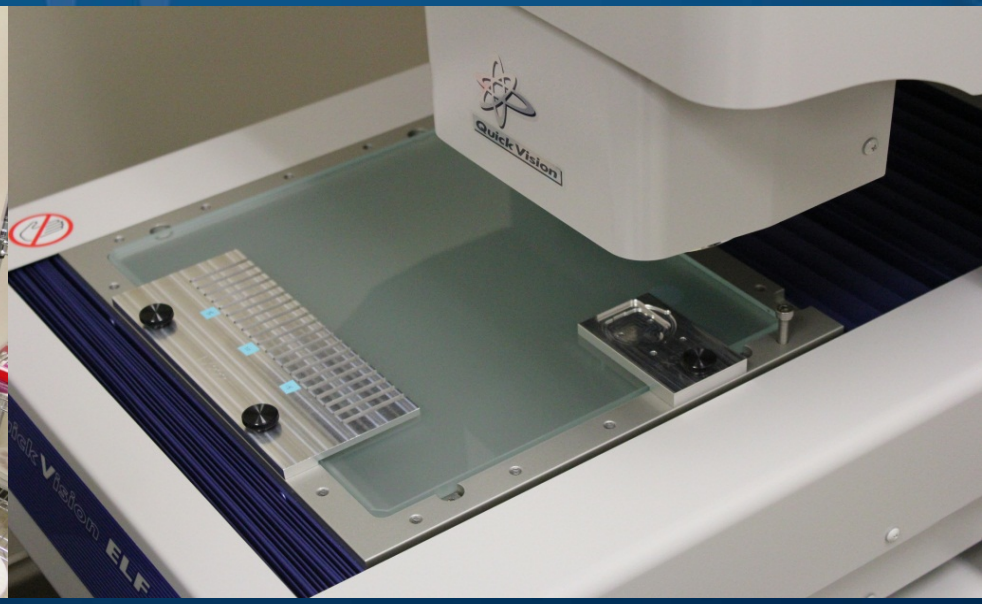
1 - *Probe profiling*: Celadon's ability to "tune" the scrub and force on the pad to optimize probe-pad interaction

2 – *Optimized probe cleaning*: in-situ and off-line

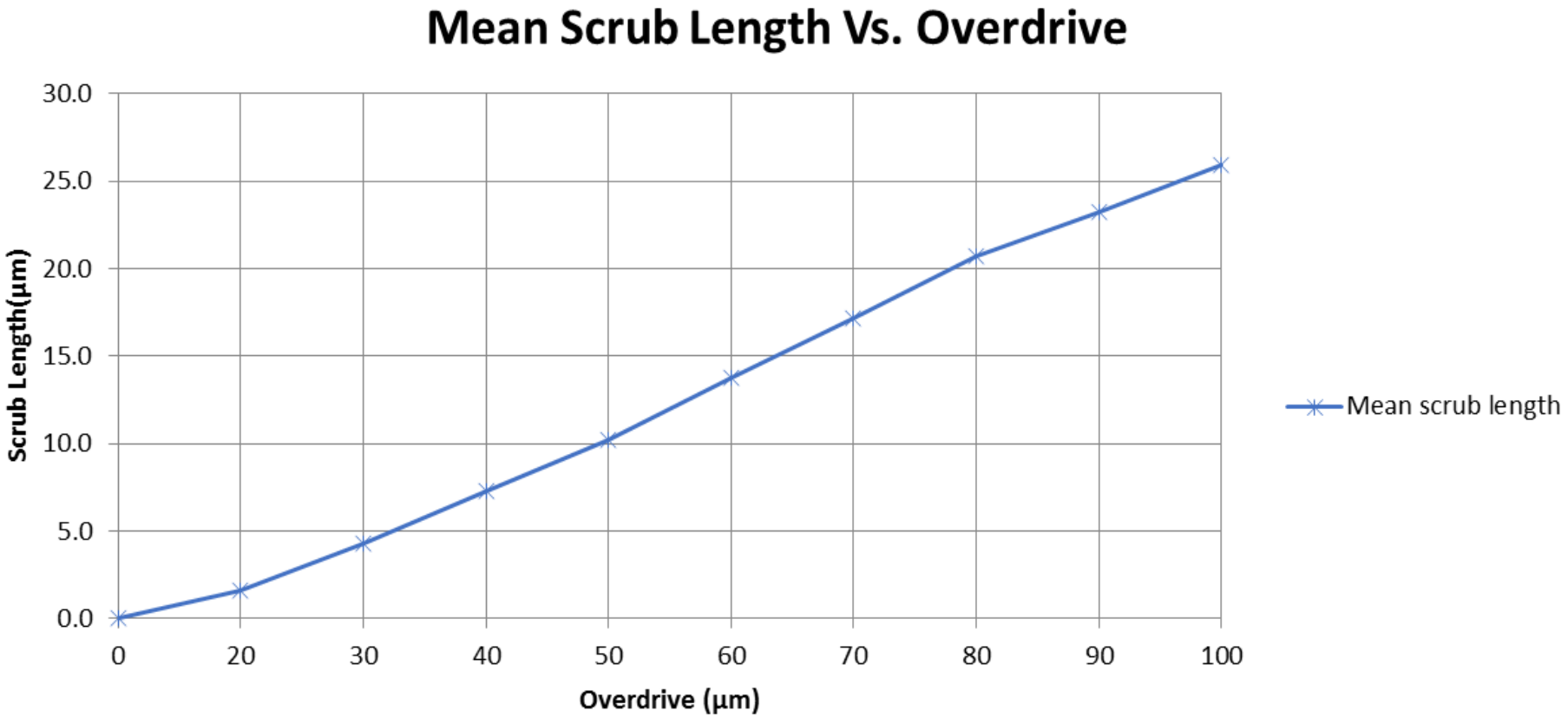
VersaCore™ Probe “Tuning”

Celadon utilizes proprietary processes to allow for precision probe profiling during development and then automation in the manufacturing process

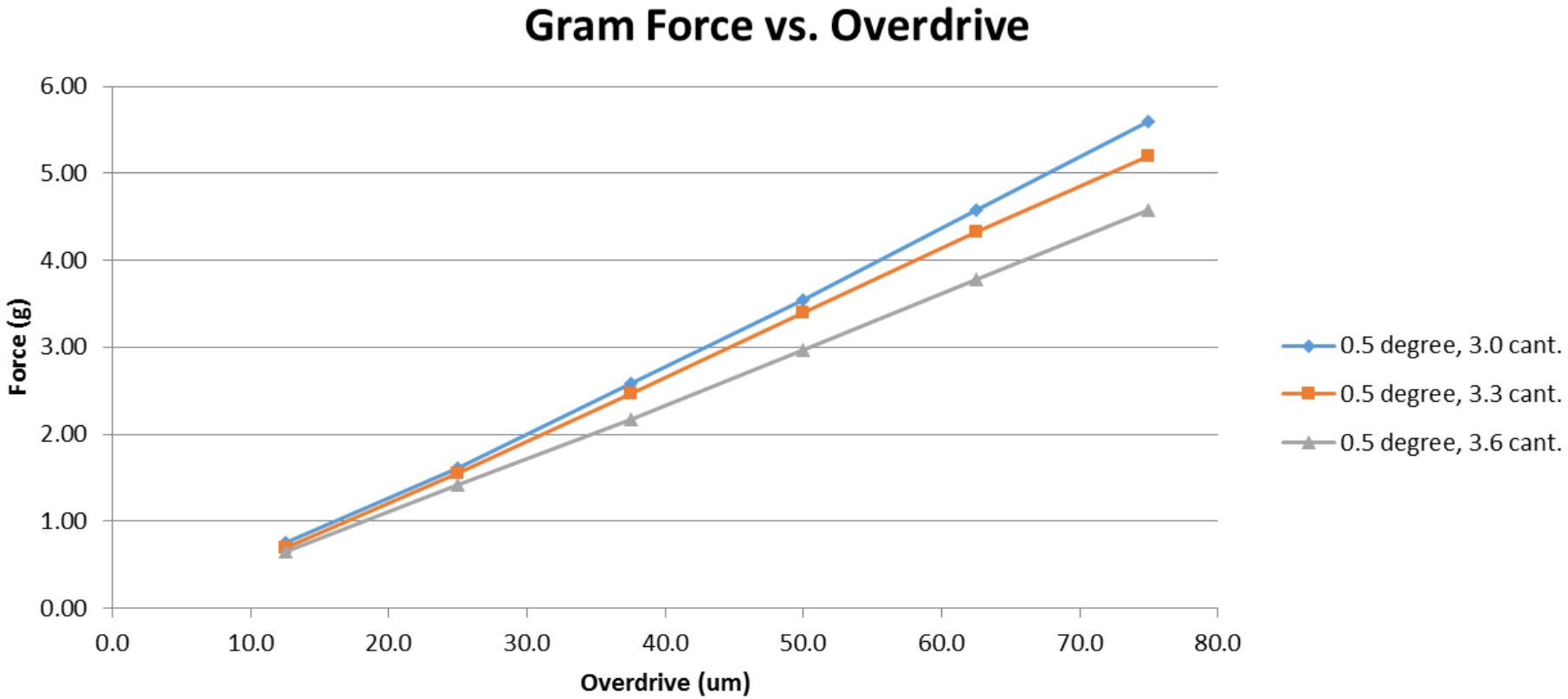




VersaCore™ Probe "Tuning" – Scrub Length vs. Overdrive



VersaCore™ Probe "Tuning" – Gram Force vs. Overdrive

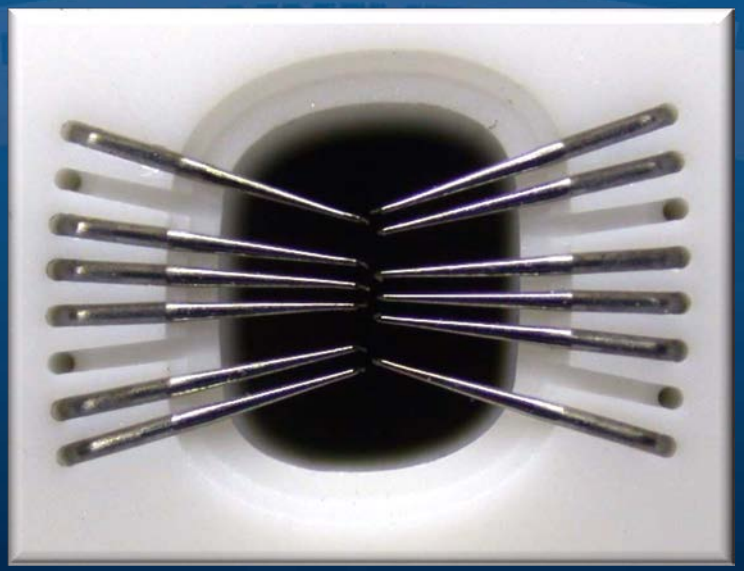


Non-aggressive Cleaning Regime

- **Celadon recommends a soft toothbrush along with ethyl alcohol in the device and modeling labs.**
  - The toothbrush method was not practical in production.
- **Freescale developed an in-situ and regular off-line cleaning process utilizing ITS Probe Polish (PP-2001-9903SCM) 99% grit media, coupled with the more aggressive ITS Probe Form media on occasion.**
  - These methods have resulted in minor wear to the probe while maintaining acceptable CRES.

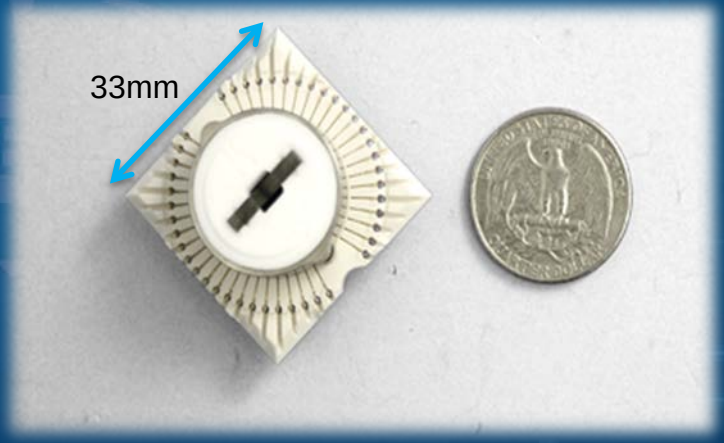
Side Benefit – Superior Tip Placement Control

- Celadon's patented Crash Resistant Technology™ provides additional tip placement control over the blade style card, with smaller probe tip diameters on reduced pads sizes.
- Additionally, there have been no significant issues with probe tip placement or probing off pad using the Celadon cards on several thousand wafers of C86 run so far.



Side Benefit – Reduced Storage Space

- **33mm VersaCore™ storage requirements have significantly reduced storage space requirements on the test floor.**
- **System is comprised of two standard 19” rack enclosures.**
- **Storage drawer [19” x 3.5”]**
  - VC20E™ Motherboard – 2 EA
  - VC20E™ Core – 20 EA
  - Probe card Maintenance Fixture
- **Storage drawer [19” x 7”]**
  - Probe Card Transfer Storage



- **Dell Computer Workstation – for electronic tracking of assets.**

Side Benefit – Reduced Storage Space

Conclusions

- **Precise probe profiling during the development phase, coupled with patented tip placement control, enables controlled force and scrub on the pad resulting in reduced wear.**
- **Dialing in a non-aggressive in-situ + periodic off line cleaning regime maintains the CRES while reducing wear.**
- **The final conclusion is that the VersaCore™ offers the best of both worlds:**
  - very low leakage probe card with the ability to probe smaller pads
  - exceptionally long probe card life resulting in a *lower cost of ownership*

Follow-on work

- Freescale and Celadon will continue to monitor VersaCore™ probe card touch downs and wear.
- Adjustments will be made as needed to cleaning and maintenance programs to create a predicable rebuild model over time.
- Celadon plans to run DOE's to further understand probe wear vs. probe bends.

Acknowledgment

A huge thank you to the following people for supporting the engineering development effort through out the VersaCore™ implementation process.

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