CELADON™
A Wholly Owned Subsidiary of MPI CORPORATION

Community of On-Wafer Test & Reliability Experts

Fully Automated High Temperature WLR Test Solutions with an Integrated Probe Card Changer

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March 21, 2025

Content

1. Advanced Semiconductor Test: Short Introduction
2. Wafer Prober Automation: Product Overview
3. Wafer Prober Integration of automated probe card exchanger: Indexer™ from Celadon Systems
4. Indexer™ ….from Dalton

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MPI's Advanced Semiconductor Test Division

At the glance:

- Started in 2013…from "zero" and developed:
  - >40x different types of base probe stations
  - >50x patents and patent pending's (incl. on manual stations)
  - >150x different RF probes (up to 220 GHz) & >20x cal. substrates
  - 2x SENTIO® & QAlibria® software solutions
- Addressing various engineering and niche production (PIC, RF, HP) markets
- Market leader in certain regions (EMEA, China) and market segments (e.g. RF & mmW, Load pull, 1/f…)

MPI AST Main Markets and Applications

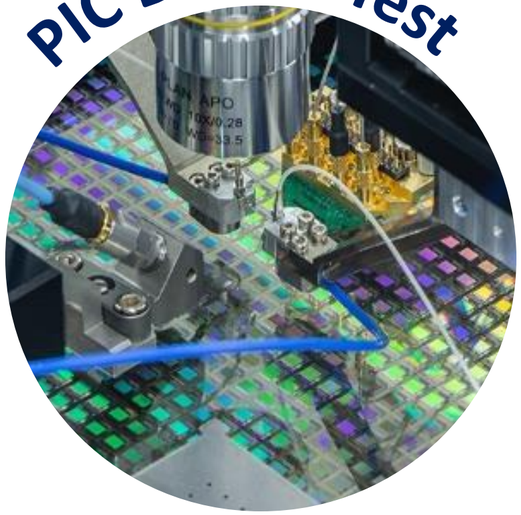
APPLICATION

RF and mmW

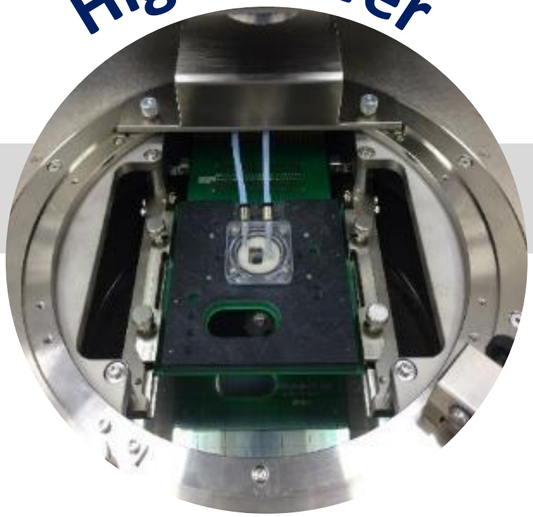
Device Modeling & WLR

EXPERTISE

PIC Device Test



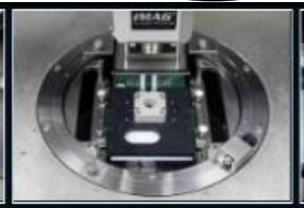
High Power



CORE COMPETENCE

→


Device Characterization



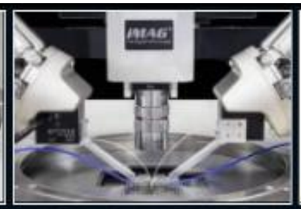
High Power

RF-mmW

Design Validation

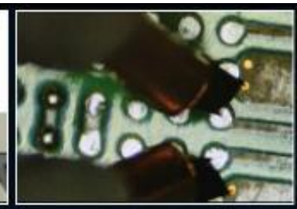

Failure Analysis


Wafer Level Reliability



Silicon Photonics

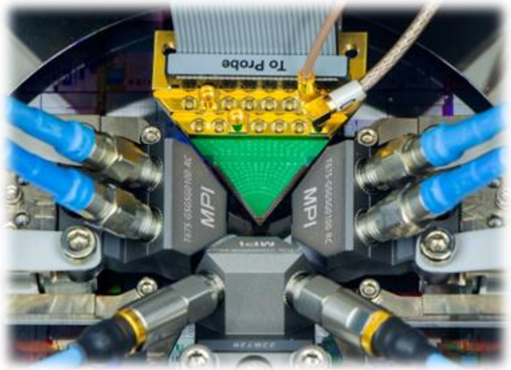

MEMS Test


Signal Integrity

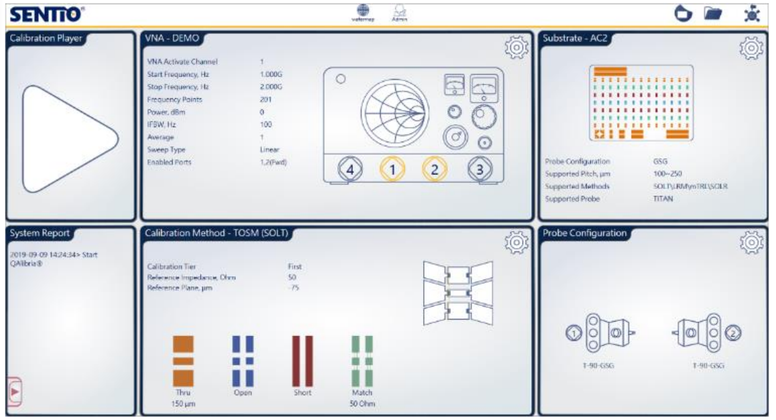
AST Product Overview

1. Advanced Wafer Probe System

2. RF Probes & Accessories



3. Prober & Calibration Software



KEYSIGHT TECHNOLOGIES
Solutions Partner

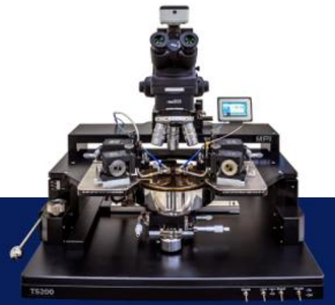
MPI Engineering Probe Systems

Offers 20 Different Manual Probe Stations

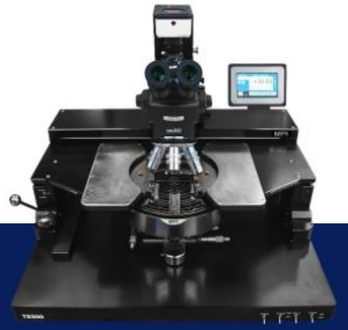

TS50

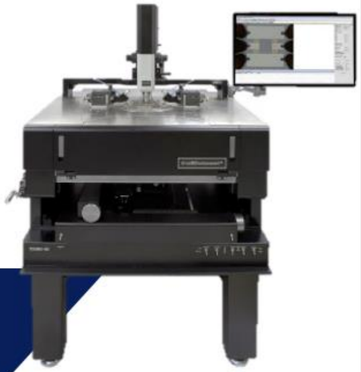

TS150


TS150-THZ


TS200


TS200-SE/-IFE /-THZ


TS300


TS300-SE/-HP

20 (50 mm … 300 mm)

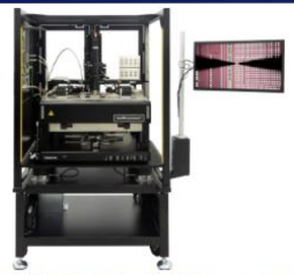

QAlibria®

SENTIO®M


T150-AIT/TS200-THZ


TS150-DP


TS200-DP


TS200-HP


TS300-IFE/-THZ


TS300-PCB/MS


TS600-PCB

MPI Engineering Probe Systems (cont.)

Offers 21 Different Automated Probe Stations

8x Models in 24/7 Production


TS2500-SE


TS2500-DP

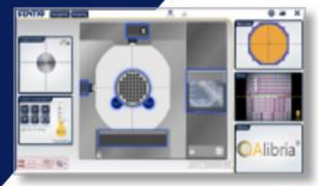
TS2000-IFE/SE/HP

TS3500

TS3000-HP

TS3500-HP

21 (200 mm … 300 mm)



SENTIO®
QAlibria®


TS2500-RF

TS2000

TS2000-D/-DP

TS2000-SE

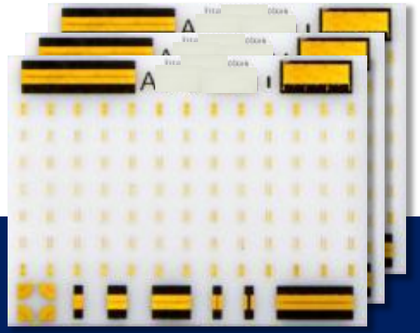
TS2000-HP

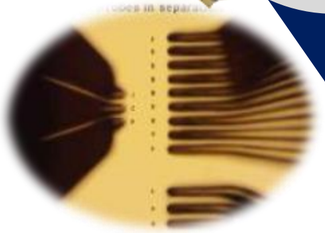
TS3000

TS3000-SE

TS3500/-SE

TITAN™ RF Probes Technology Overview





Wide Range
of RF Probes

26-220 GHz

QAlibria®

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MPI TS3XXX Series: The Most Versatile Portfolio

Base Systems Main Features	TS3000	TS3000-IFE	TS3000-SE / TS3000-HP	TS3500	TS3500-IFE	TS3500-SE* / TS3500-HP
XY-Stage (HR-Option*)	310 x 320 mm			305 x 520 mm		
Thermal Range	20…300°C	-60…300°C		20…300°C	-60…300°C	
Chamber	No	IceFreeEnvironment™	ShielDEnvironment™	No	IceFreeEnvironment™	ShielDEnvironment™
PTPA	No			Option		
WaferWallet® Family	No			Option		

12 Different
9 with MHU

- **Unsurpassed upgrade path in the field**
- **Various configurations for various budgets and various applications**

WaferWallet® Family

WaferWallet® **or** **WaferWallet®MAX**

150mm

and/or

200mm

and/or

300mm

5 **wafers** **25**

or

150mm

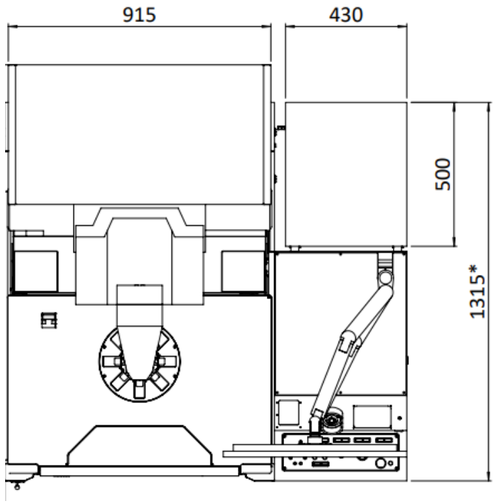
200mm

WaferWallet® - The Ultimate Automation for the Lab

- **For Device Modeling & WLR Labs**
- Designed with five individual trays for manual, ergonomic loading of **150, 200, or 300 mm** “modeling” wafers
- No cassette handling, flexible set-ups, cost-effective automation

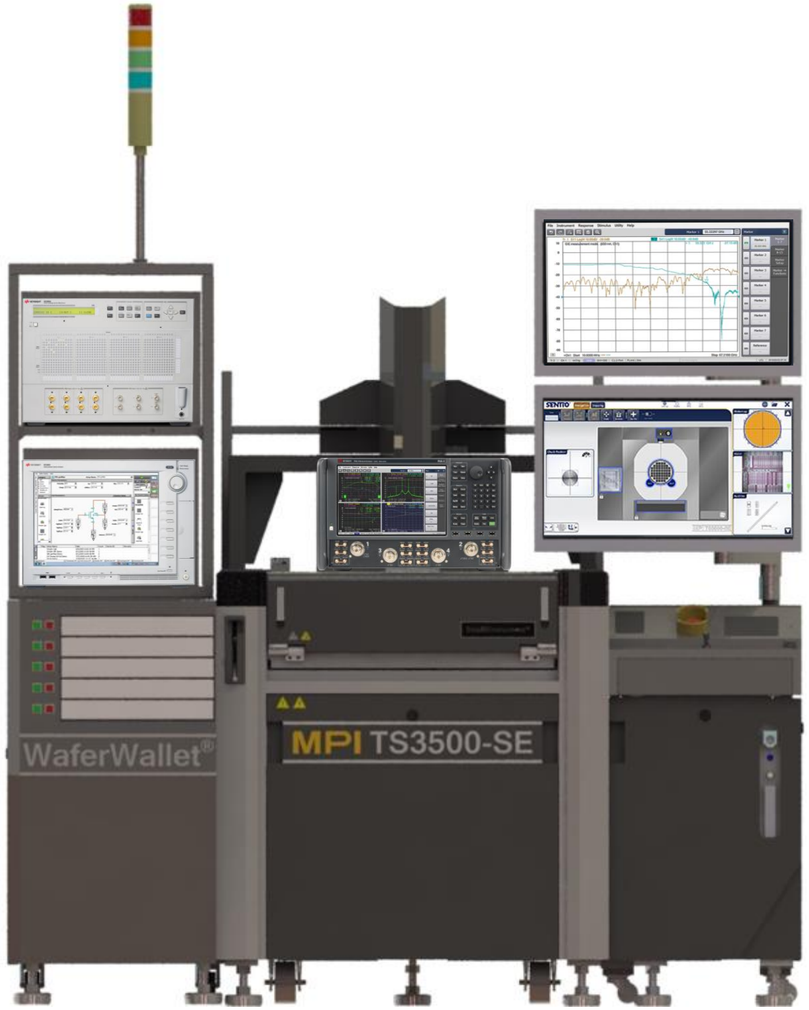
- Automated tests at multiple temperatures (RF, Celadon)
- Hot- or cold wafer swapping (soaking time)
- Pre-aligner, Wafer-ID reader optional

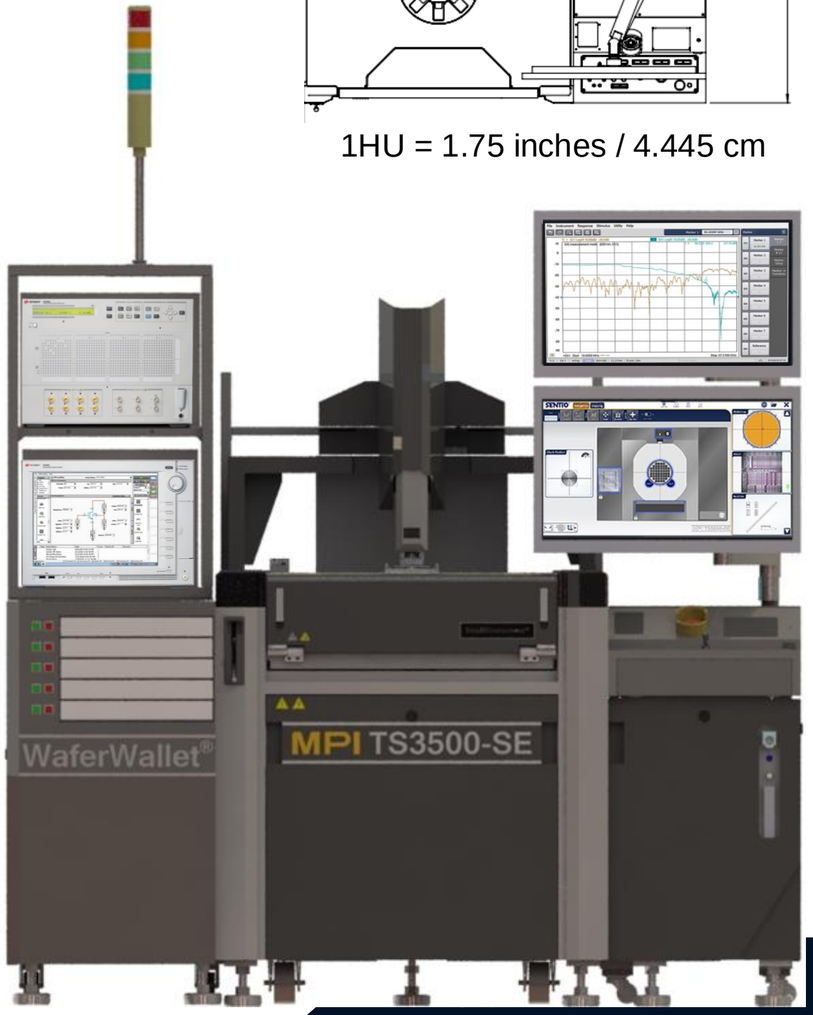
WaferWallet® Saving Footprint



1HU = 1.75 inches / 4.445 cm

- Each with 2x 27” monitors, 4x 7HU* instrument shelfs





WaferWallet®ULTRA – The latest family member

- Designed for direct test head docking → targeting 25um pitch probing
- OHT option

* Overhead Hoist Transfer ready

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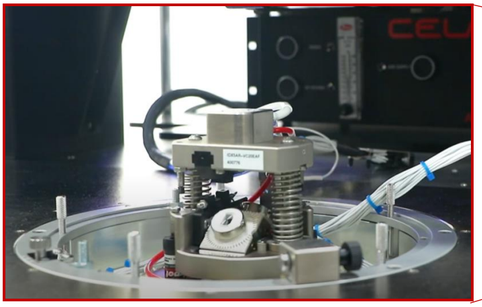
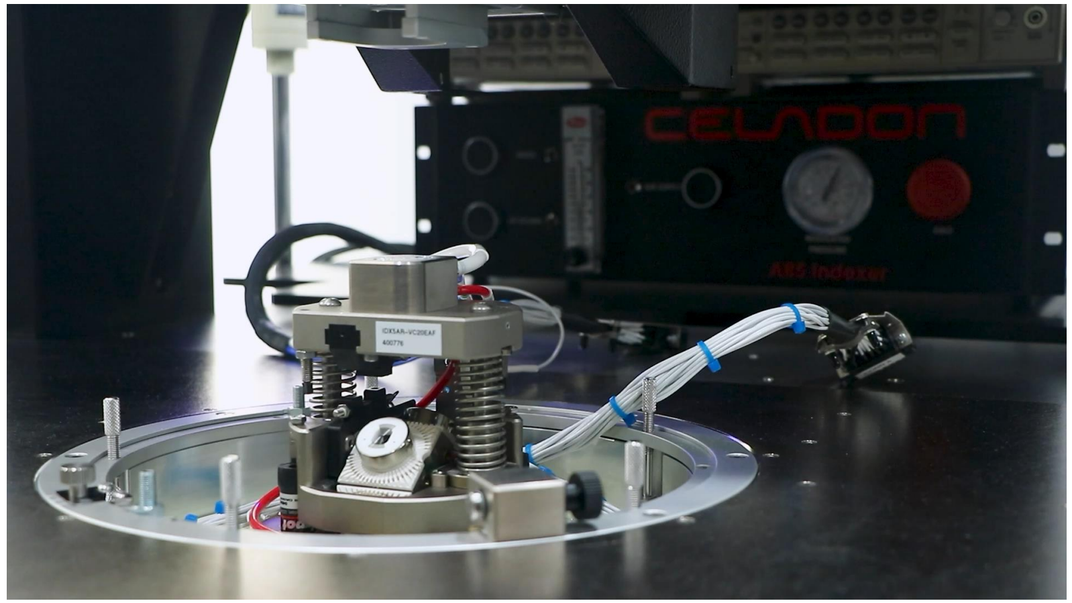
MPI WaferWallet® Family with Celadon‘s Indexer™

- Celadon Indexer™ → **Automated Probe Card Changer**
- Combining **Multiple Wafers** with **Multiple Probe Cards** (VC20s)
- **Fully Automatically** (remotely accessible over SENTIO®) ☑

→ **Unsurpassed Automation and Flexibility**

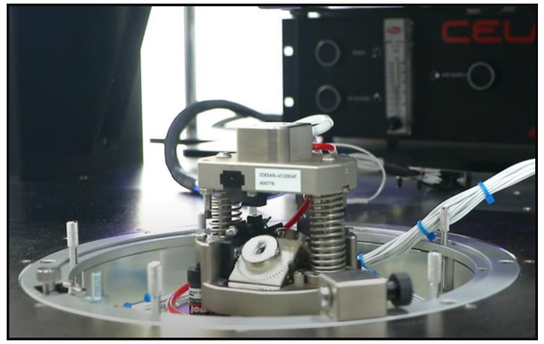


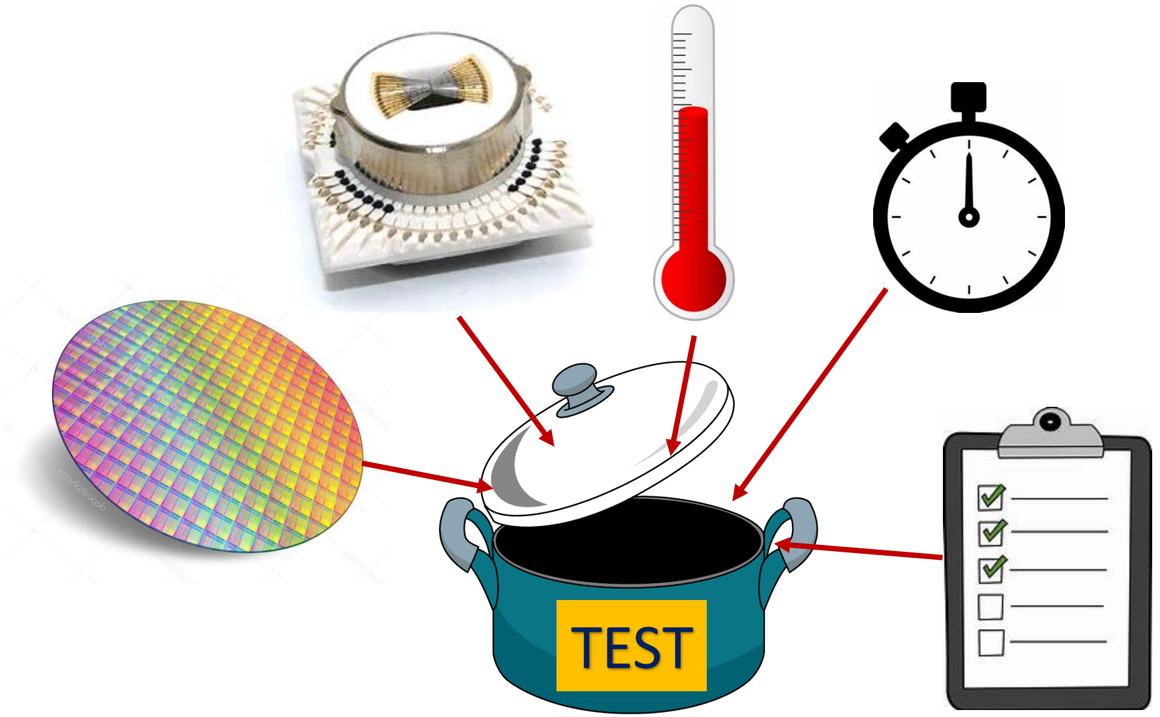


SENTIO® Test Executive Assist Manager

- GUI and remote interface to configure test automation including:
  - Wafers (systems with loader)
  - Alignment options (PTPA)
  - Temperatures
  - Soak times

  …
  - VC20 Probe cards (Indexer™)





Use Case of Test Executive Assist Manager

- For systems with MHUs: WaferWallet® Family
- Simplify test executive development
  - Fewer remote commands required
  - Implement automation procedures to SENTIO®
- Simplify management of complex test setups
  - Define wafer selection
  - Define probe cards for different wafers/”off-line” measurements
  - Define test setups
  - Memorize wafer selection & test setup on the prober
  - Managing the soak time at different test temperatures

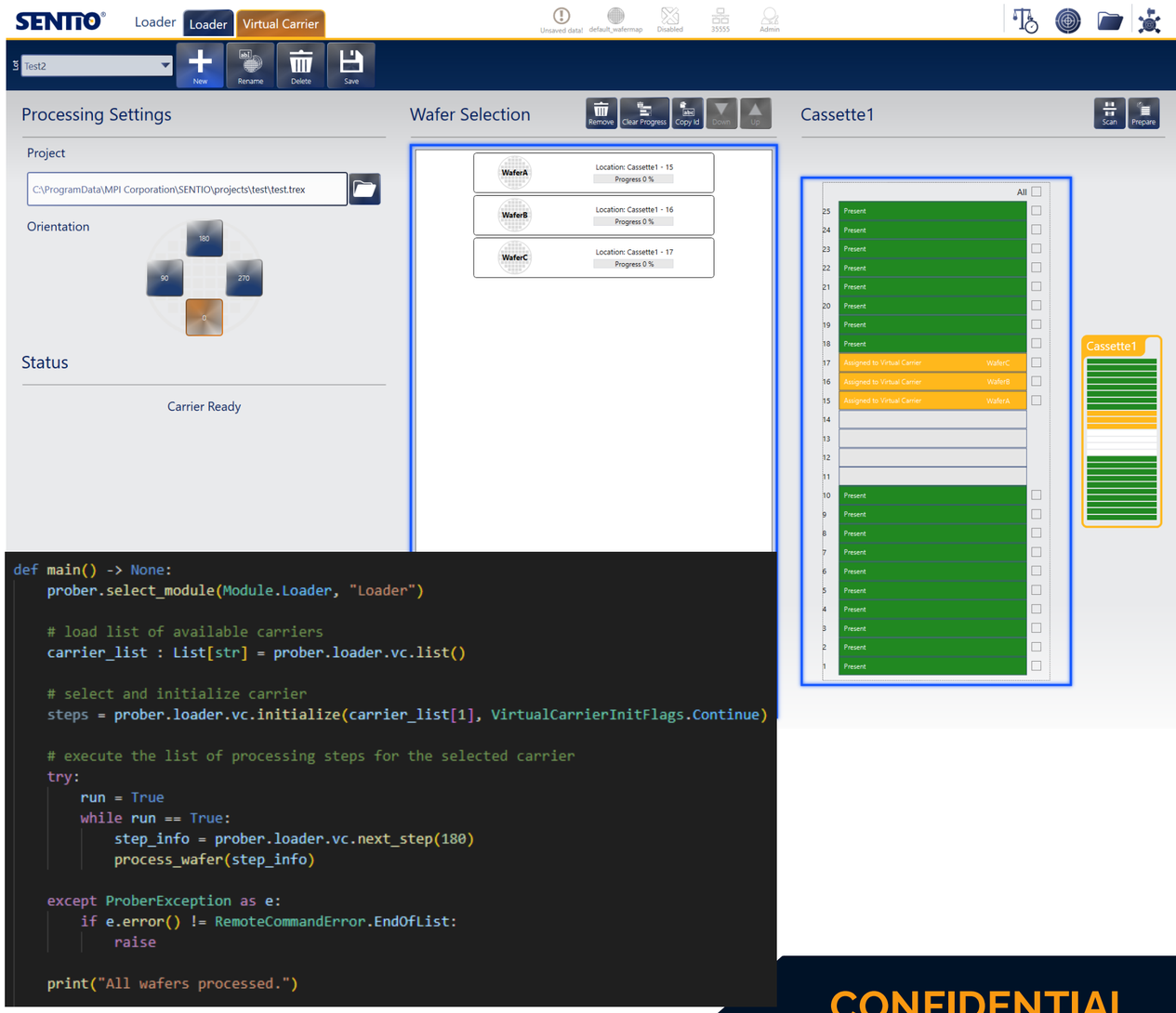
Phase I - Virtual Wafer Carriers

- Virtual carrier is like lot in production environments
- Physical location of wafers becomes flexible
- Each virtual wafer carrier has the potential to contain: One to 5 or to 25 wafers
- Enables convenient integration into test executive software for production environments

SENTIO® Test Executive Assist Manager Roadmap

- ☑ Support multi-wafer processing
- GUI implementation
- Remote interface
- Github available for free

- Phase II:
  - Automated alignments
  - Probe cards automation (Indexer™)
  - Temperature automation

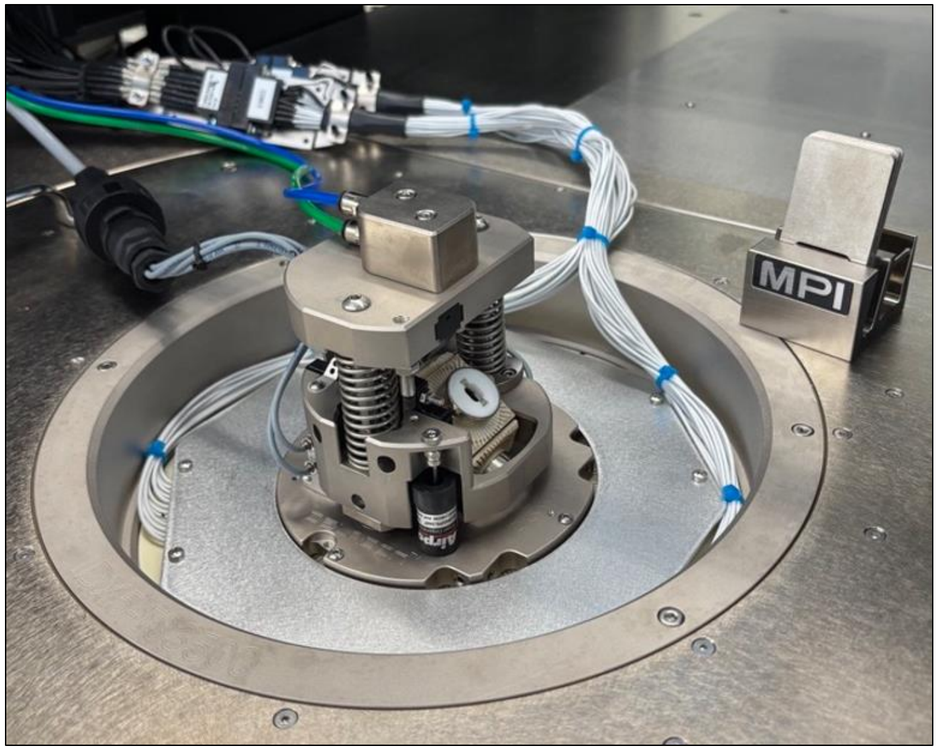



```python
def main() -> None:
    prober.select_module(Module.Loader, "Loader")

    # load list of available carriers
    carrier_list : List[str] = prober.loader.vc.list()

    # select and initialize carrier
    steps = prober.loader.vc.initialize(carrier_list[1], VirtualCarrierInitFlags.Continue)

    # execute the list of processing steps for the selected carrier
    try:
        run = True
        while run == True:
            step_info = prober.loader.vc.next_step(180)
            process_wafer(step_info)

    except ProberException as e:
        if e.error() != RemoteCommandError.EndOfList:
            raise

    print("All wafers processed.")
```

Celadon Indexer Purpose and Valuation

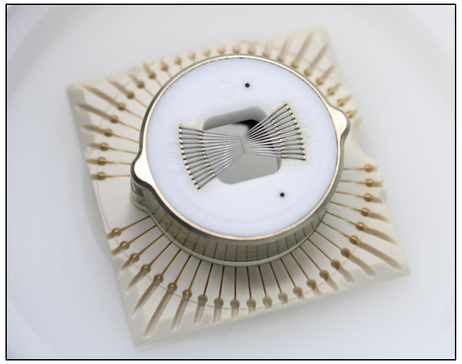
Dalton Roehl

The Celadon Indexer



The Indexer is an Automatic Probe Card Changer that increases throughput of Devices by lowering operator interaction time.

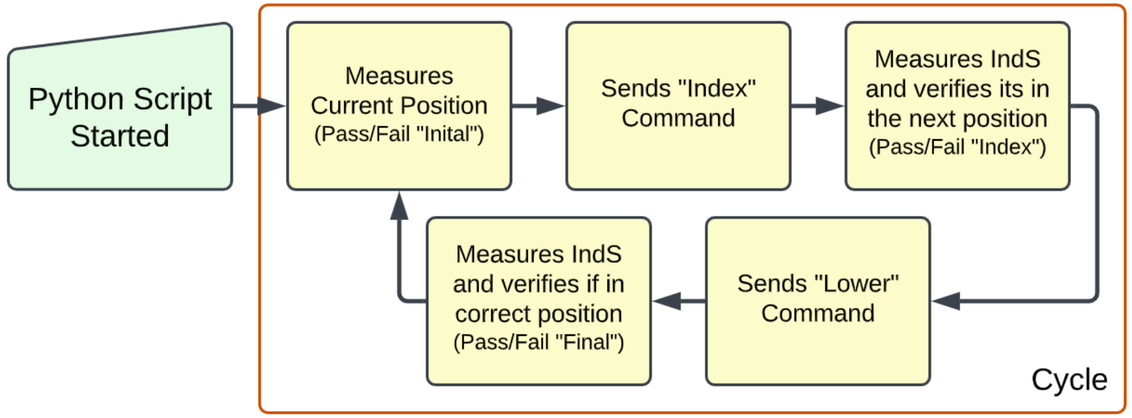
- Holds up to 5x Celadon VC20E Probe Cores
- -65 to 200C Operational Temperature
- Easily Replaceable and Swappable VC20E Probe Cores
- Touchless Inductance Sensors for measuring active position
- Highly customizable for specific test equipment and requirements
- Remote control through TCP-IP commands
- Interlock for Safe Testing



Indexer – Lifetime Validation

The Celadon Indexer was validated for lifetime cycle count on an MPI TS3500 at Room Temperature and 200C.

- At Room Temperature, the system achieved 100,000 cycles over constant use for 22 days with 0 failures detected.
- At 200C, the system achieved 40,000 cycles over constant use for 5 days with 0 failures detected.

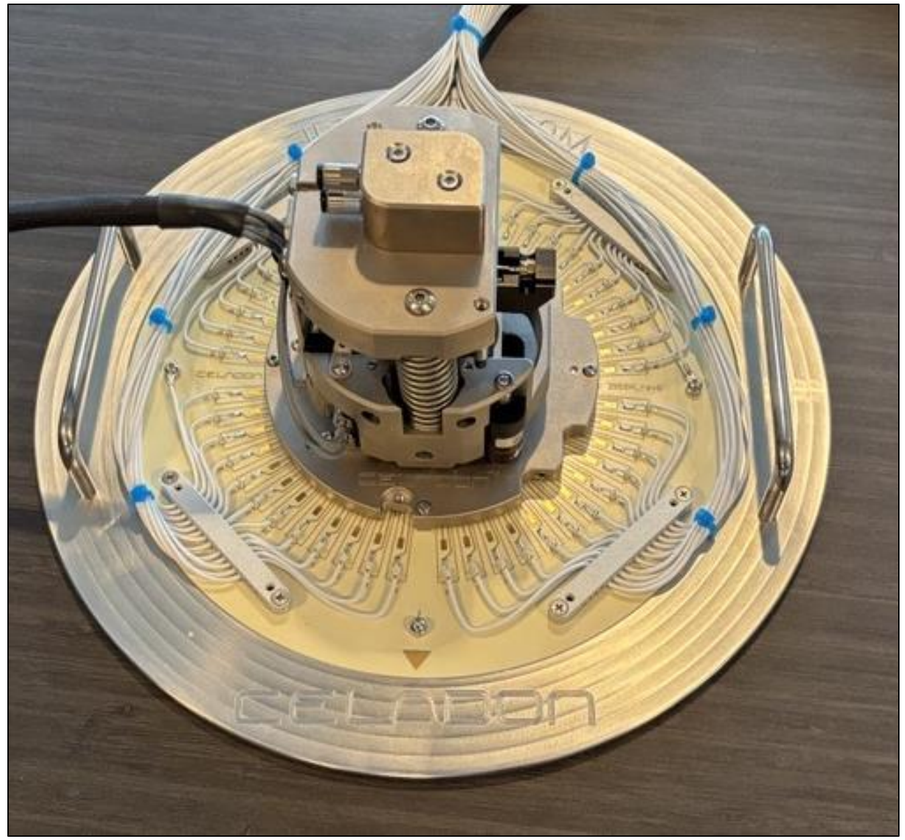


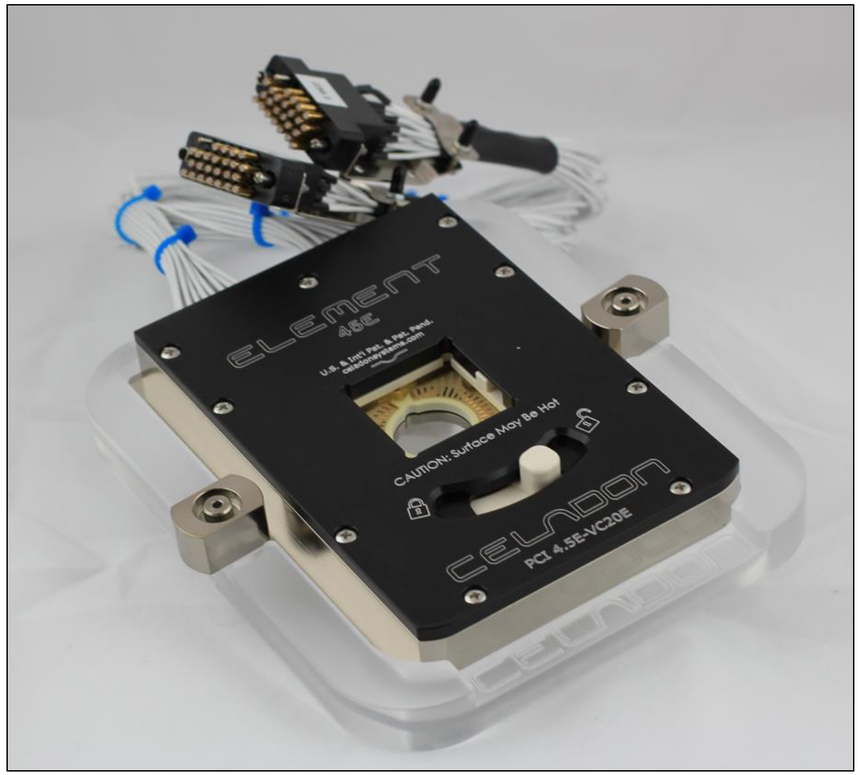
Current Cycle count Results on the Lifetime Test						
	Pass "Initial"	Fail "Initial"	Pass "Index"	Fail "Index"	Pass "Final"	Fail "Final"
Room Temp	106,400	0	106,400	0	106,400	0
200C	41,700	0	41,700	0	41,700	0

Indexer – Electrical Validation

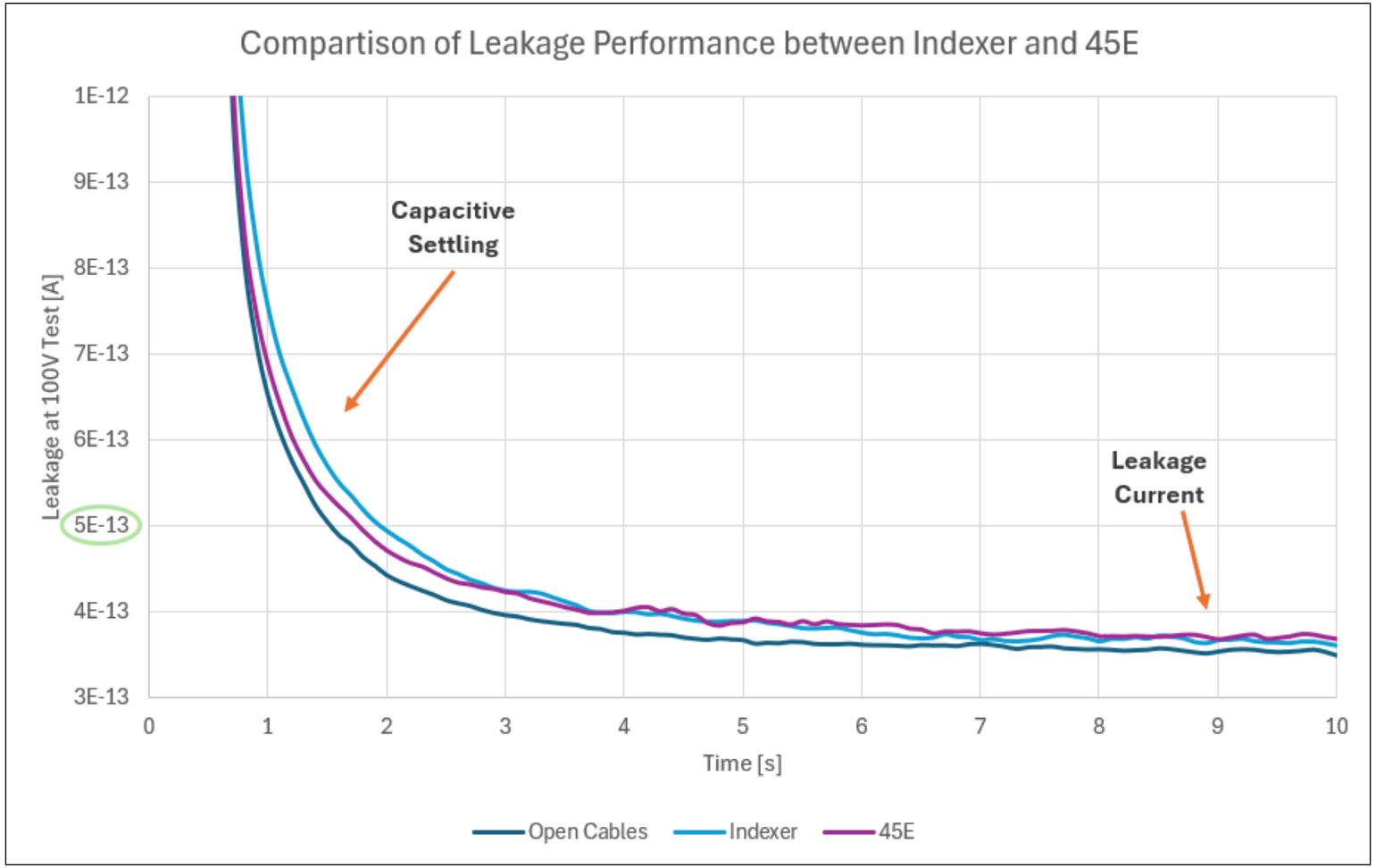
The electrical performance of the Celadon Indexer was compared to the standard Celadon 45E.

- Signal to Signal Leakage of <**5fA/V** at 10s and 25C
- Signal to Guard Isolation of >**1TΩ** at 5s, 100V and 25C





Indexer – Electrical Validation



Electrical Performance		
Time [s]	Leakage [fA/V]	Isolation [TΩ]
Indexer IDX5I		
1	7.63	3.22
3	4.25	5.95
5	3.89	8.20
7	3.69	
10	3.62	
45E PCI		
1	6.93	3.79
3	4.23	6.16
5	3.88	10.03
7	3.74	
10	3.67	

Indexer – Thermal Drift Validation

The Celadon Indexer Thermal Drift Performance

- System heated to 200C until stable
- Chuck moved to off-axis camera (North) for 2min cooling effect
- Move chuck back and measure X/Y/Z shift due to shrink

Based on the position of the wafer, the maximum Z shrink was about 61um with an unmeasurable X/Y shift.

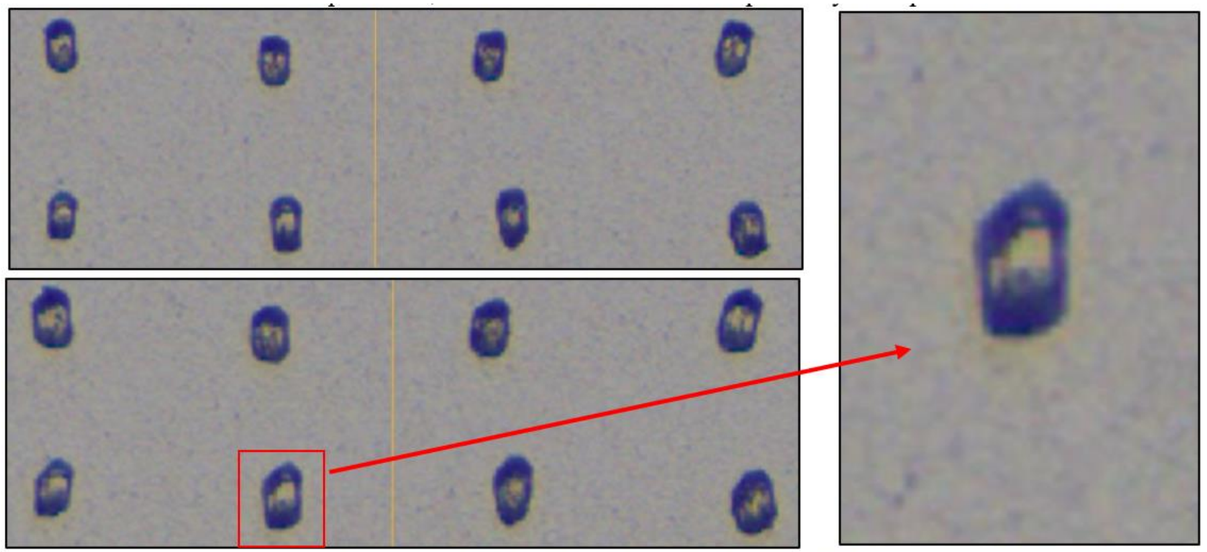


Figure: X/Y shift of scrubs after the cooling 2min period

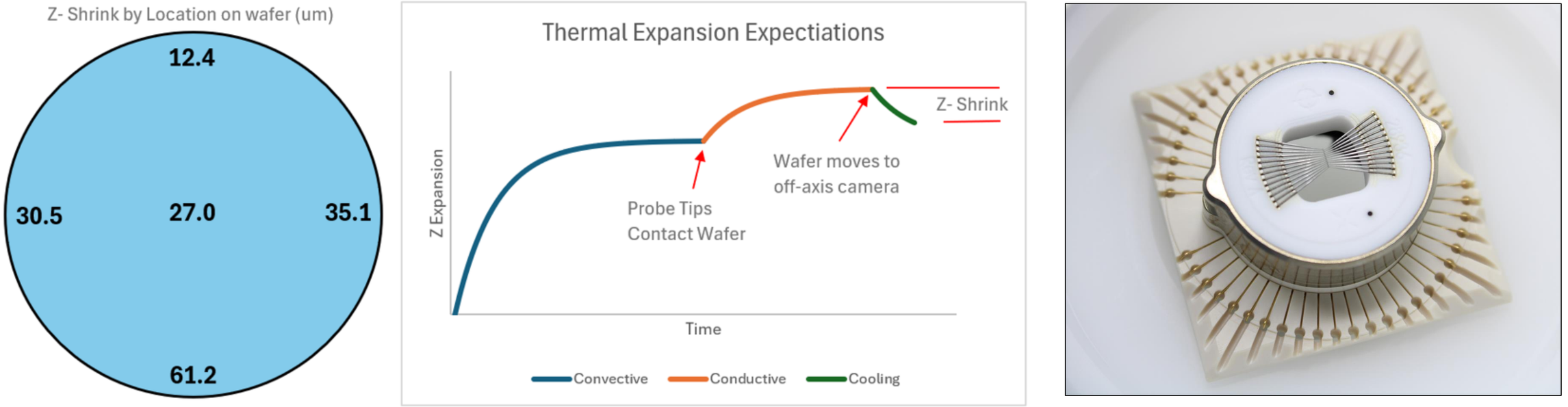


Figure: Measured Z-shrink of the probe tips. (Left) Expectation of Z expansion on a wafer (Right)

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THANKS

For Your Attention

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March 21, 2025

Sophisticated piezo MEMS wafer-level testing technologies that meet the semiconductor industry's demanding requirements

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schmitz@aixacct.com

Community of
On-Wafer Test &
Reliability
Experts

Overview

- Introduction
- Groundbreaking wafer-level reliability solution
- Displacement measurements on piezoelectric materials
- Memory Testing solutions
- Summary

Community of
On-Wafer Test &
Reliability
Experts

Introduction

- **aixACCT** systems GmbH, founded in 1999 in Aachen, Germany

from **aix** la chapelle (“city with a chapel”, French for Aachen)

ACCT – **A**dvanced **C**ustomized **C**haracterization **T**echnologies

- Over 40 employees serving over 500 worldwide customers

with more than 2600 units sold

http://www.aixacct.com

Piezoelectric
Pyroelectric
Ferroelectric
Multiferroics
Resistive
Thermoelectrics

Thin films
MEMS
Bulk materials
Multilayer
Single crystals
Polymers

Academia
National Labs
R&D Centers
Industry

Community of On-Wafer Test & Reliability Experts

Introduction

aixACCT

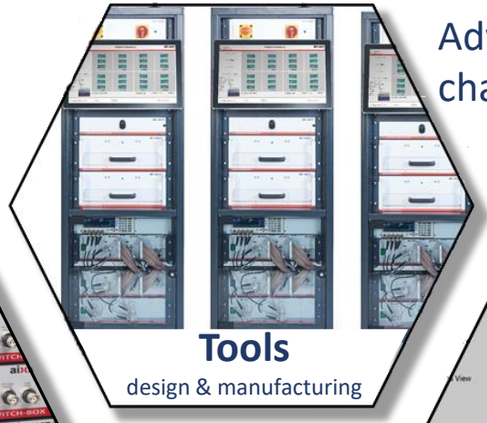
25 years

Specialized testers,
amplifiers and controllers

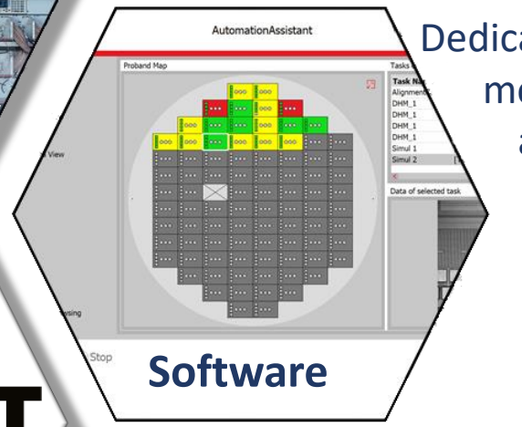
Advanced tools for
characterization

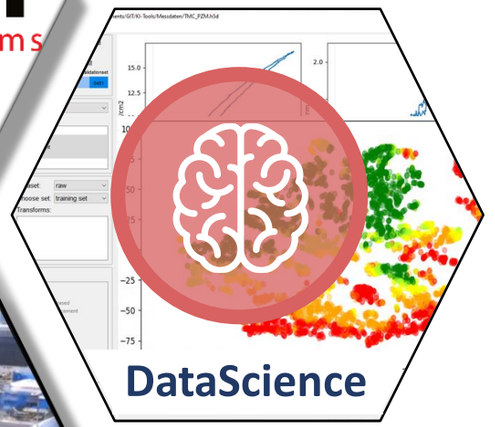
Dedicated software for
measurements and
automation tasks

installed about **35000**
charging controllers



aixACCT
systems





Enhanced data analytics for
process optimization and
lifetime prediction

QA and production support in
semiconductor and piezo industry

Test Measurement
Consulting
Supporting tech giants

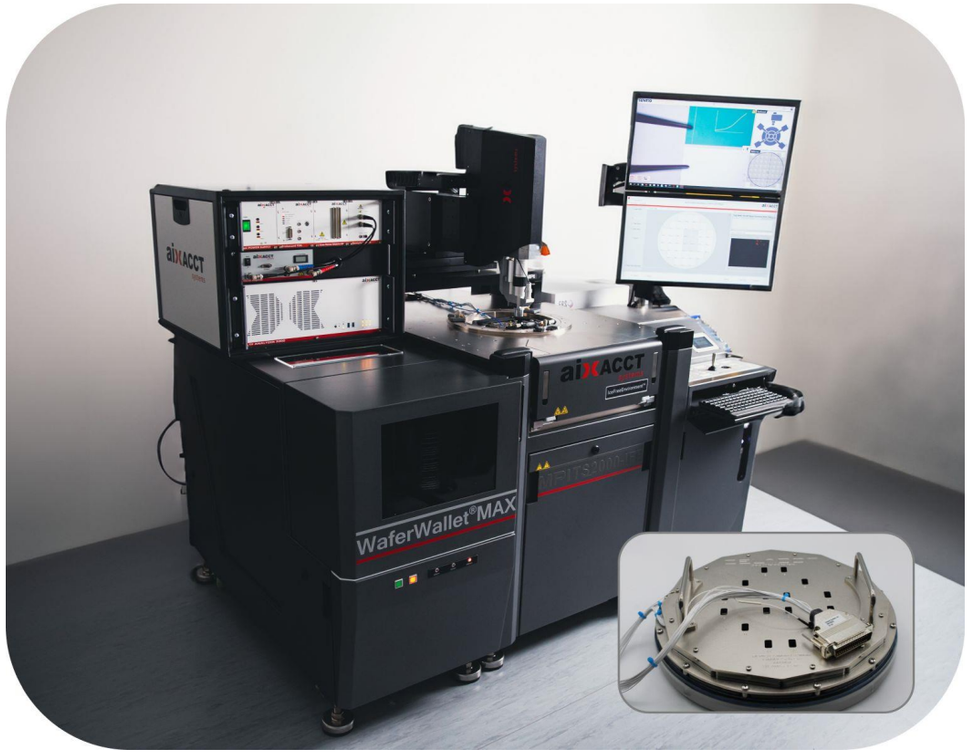
*C*ommunity of
*O*n-Wafer Test &
*R*eliability
*E*xperts

Wafer-level reliability test solution

Wafer-level Durability Analyzer measurement system
aixWDA

Key Specs

- Temperature ranges: from -60C to 350C
- Sample dimensions: full wafer, up to 200mm
- Parallel measurements up to 64 channels using specialized probe card
- Heating rate > 8K/min over the full temperature range
- **maintaining constant contact over temperature**
- Automatic wafer loader available for fast turnaround



Community of
On-Wafer Test &
Reliability
Experts

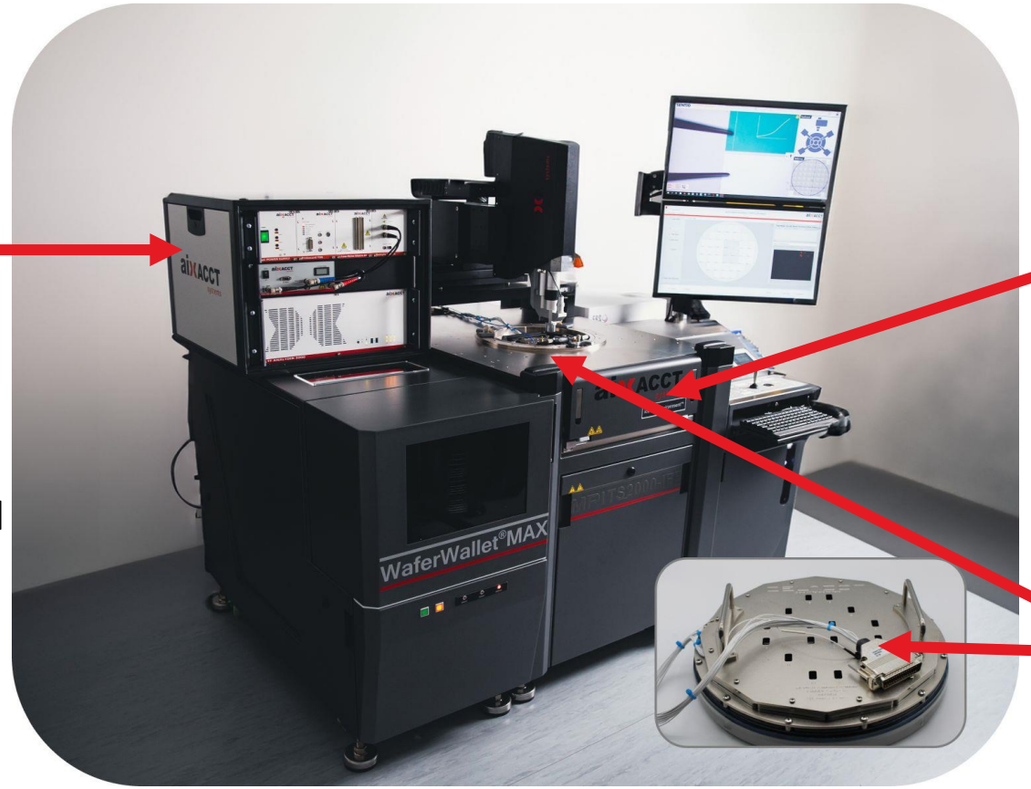
Wafer-level reliability test solution

aixWDA measurement system

aixACCT measurement system controls the overall function

aixACCT is responsible for overall functionality and performance

aixACCT has selected strong cooperation partners for successful project result: MPI, Celadon



MPI TS2000IFE Prober and Loader including ERS temperature chuck (-60C to 350C, constant ramp function) with integration support by ATV

Celadon high temperature Probecard with TDS

Dedicated parallel TSDC and Q-DLTS test electronics

Full Automation

Thermal drift compensation

Overtravel protection

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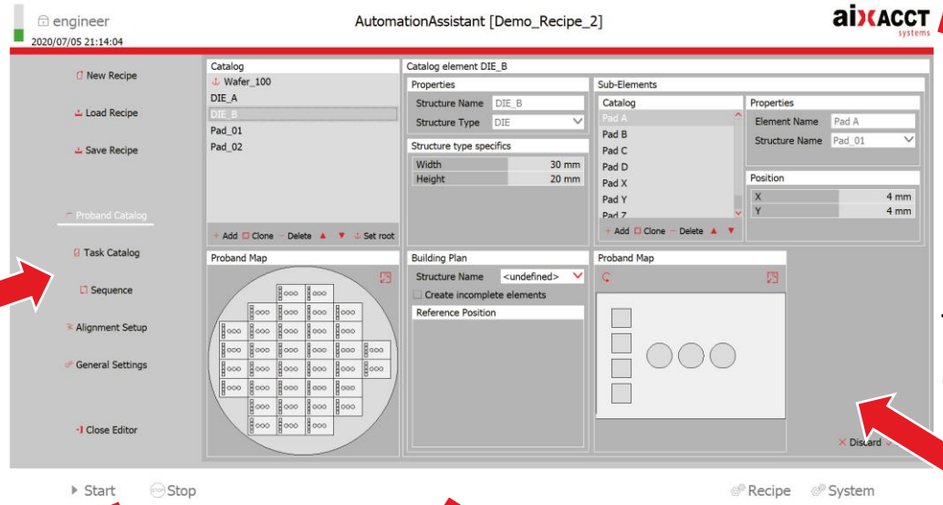
Automation Assistant control software

aixACCT

Automation Assistant

SECS/GEM host interface

Test System Control

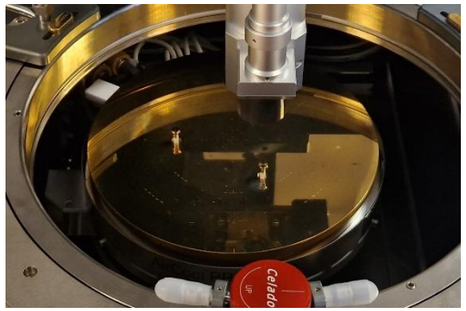


Temperature Control

aixACCT dedicated Test System

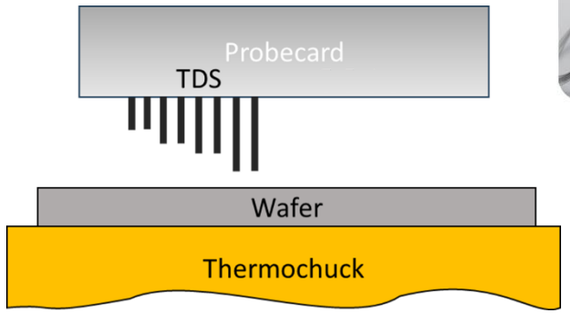
Probe System and Loader Control

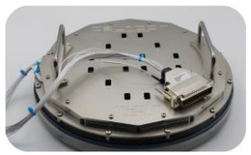
Continuous Contact Control



MPI integrated ERS Thermochuck

MPI TS2000-IFE with WWMAX





Celadon T300 probecard

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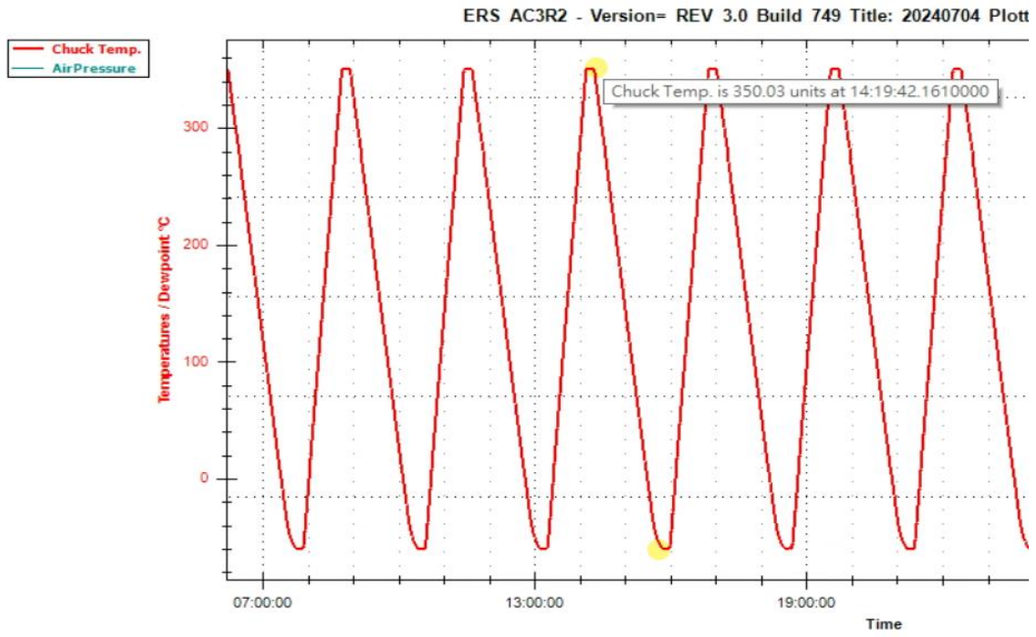
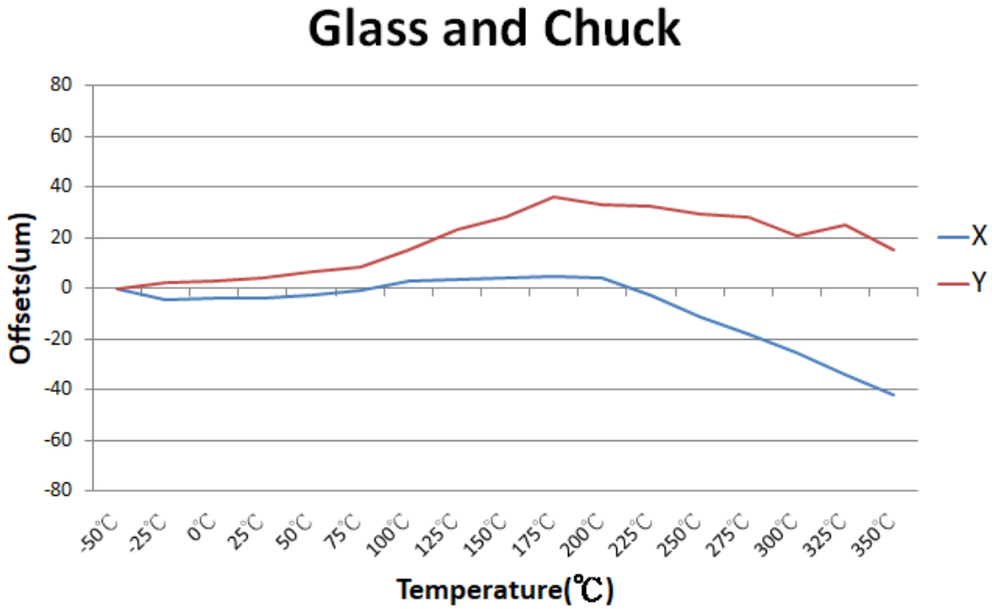
Wafer-level reliability test solution

- New MPI/ERS Thermochuck with extended temperature range -60…350°C with fast ramp function
- >8K/min heating
- >5K/min cooling



- Minimized XY chuck drift verified by MPI

The relative offsets between the glass and the chuck from -50°C to 350°C (center)



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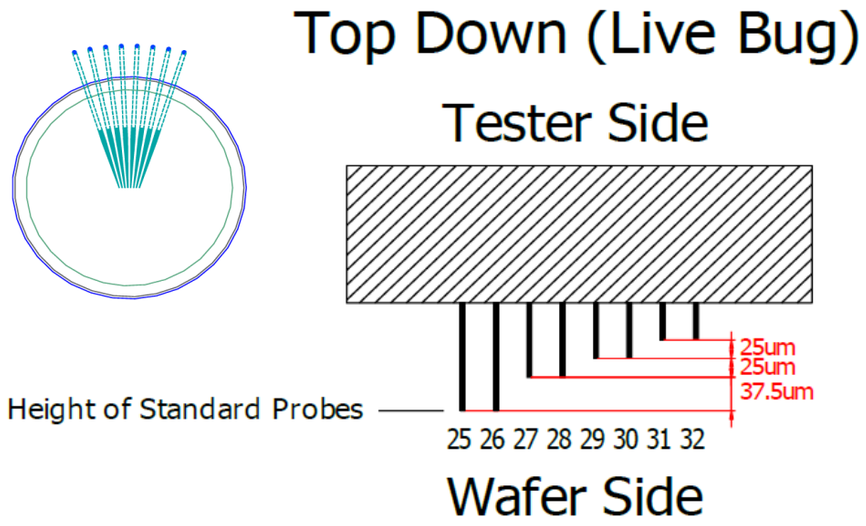
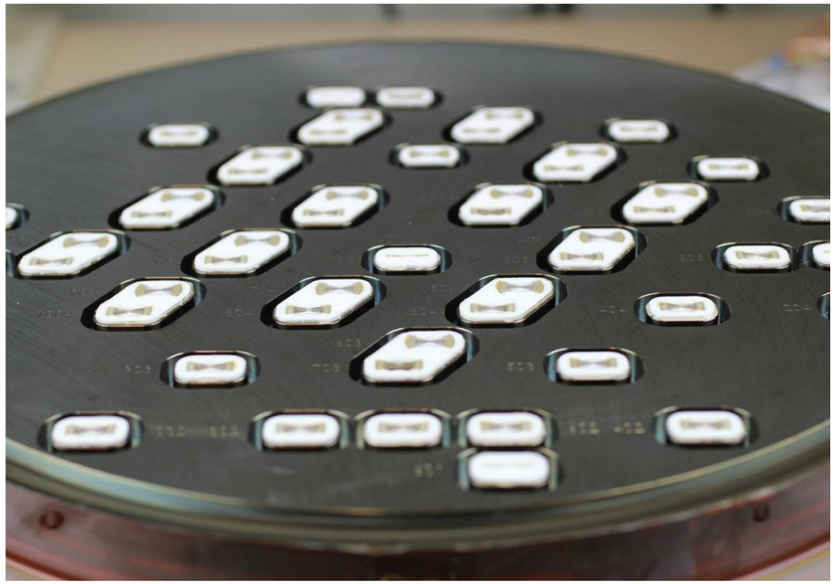
Wafer-level reliability test solution

- New Celadon Probecard TDS



- Integrated into Celadon T300 probecard



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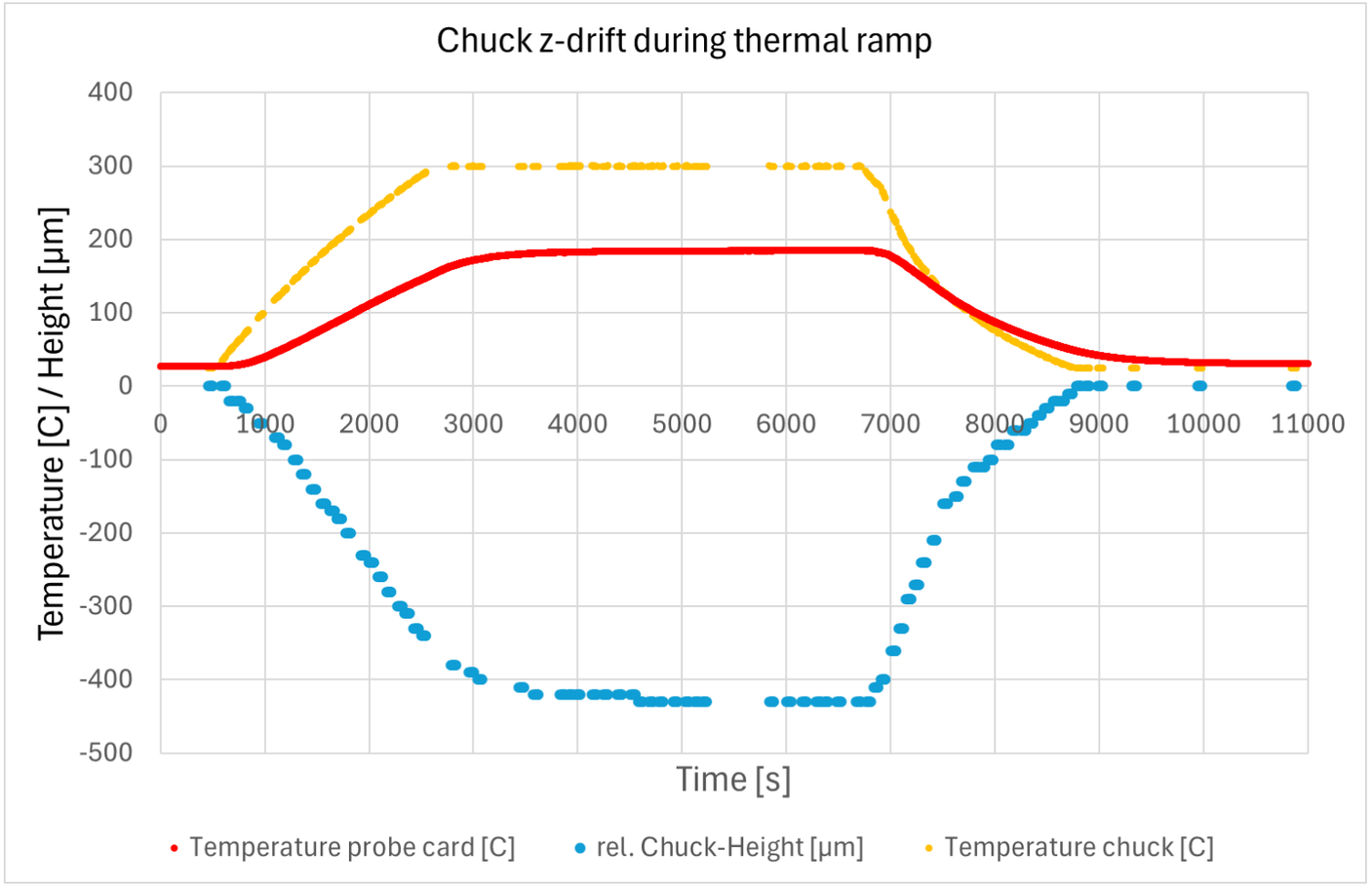
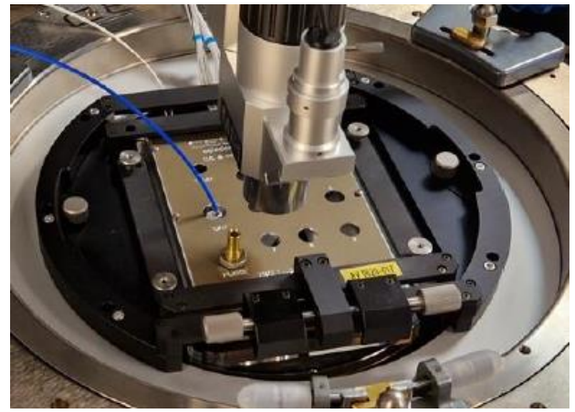
Wafer-level reliability test solution

- Pre-Experiments carried out by ATV





- Celadon T90 test probecard
- Heating chuck to 300C
- Contact maintained manually (stepwise) and drift of more than 400um to be compensated

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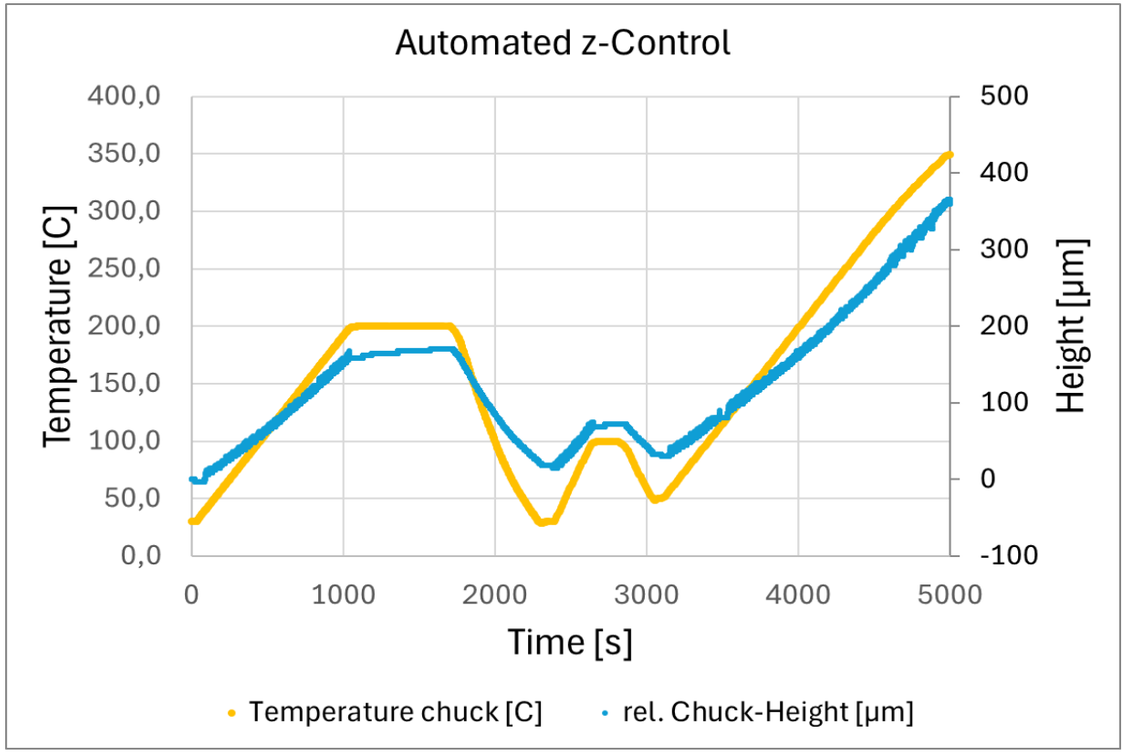
Wafer-level reliability test solution

- Joined into fully automated control solution by aixACCT
  - in-situ z-drift compensation
  - fully automated overtravel detection and failure handling avoids damage
  - measurements across entire wafer from -60C to 350C possible with highly stable electrical contact for continuous measurements at 8K/min without recontacting



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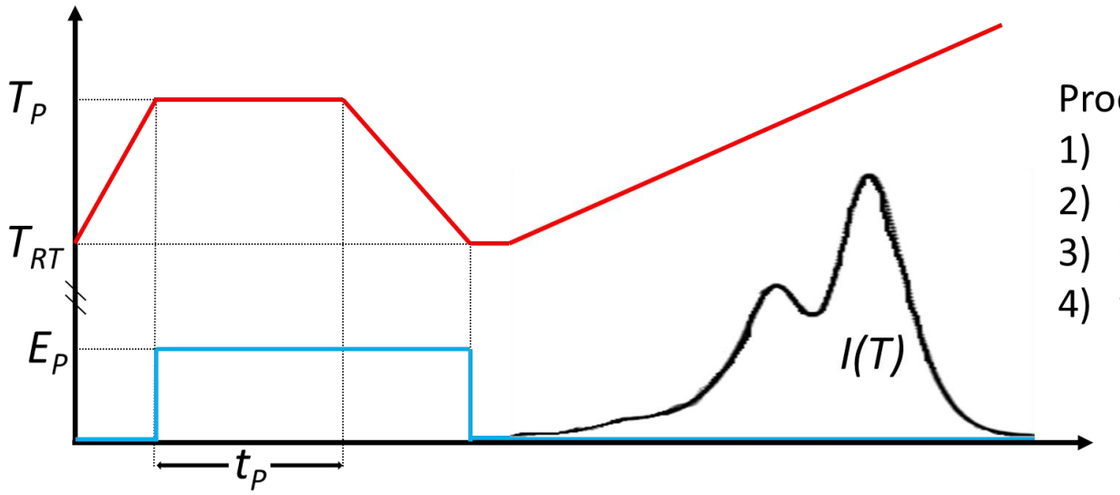
Wafer-level reliability test solution

- Application in Piezo for a world leading MEMS foundry
  - TSDC = **T**hermally **S**timulated **D**epolarization **C**urrent

Call it: **T**ime **S**aving **D**efect **C**haracterization ?

Why? Let me explain in a minute!



Process of TSDC measurement:
1) heating up
2) degradation
3) quenching
4) thermal depolarization

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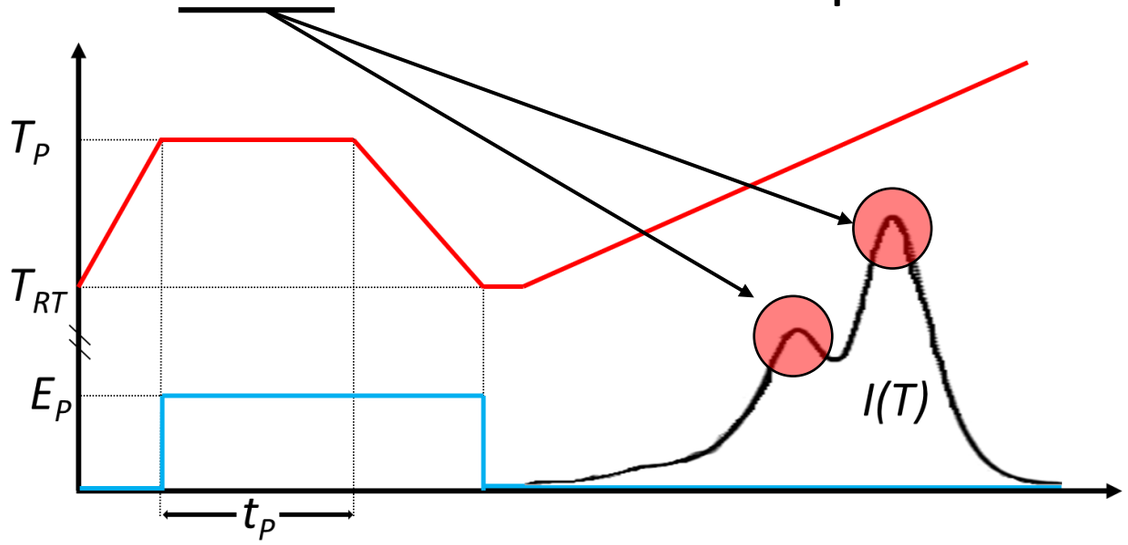
Wafer-level reliability test solution

- Material defects, such as oxygen vacancies in PZT ($PbZrTiO_3$), lead to unreliable device performance
- Usually: HALT (highly accelerated lifetime testing) for 1000hrs is carried out under harsh conditions to predict lifetime
- TSDC obtains information about vacancies or other defects
  - Peaks in the current response correlate to vacancies



Lifetime prediction possible without time consuming HALT

CDP , Center of Dielectrics and Piezoelectrics at Pennstate university
https://cdp.ncsu.edu/

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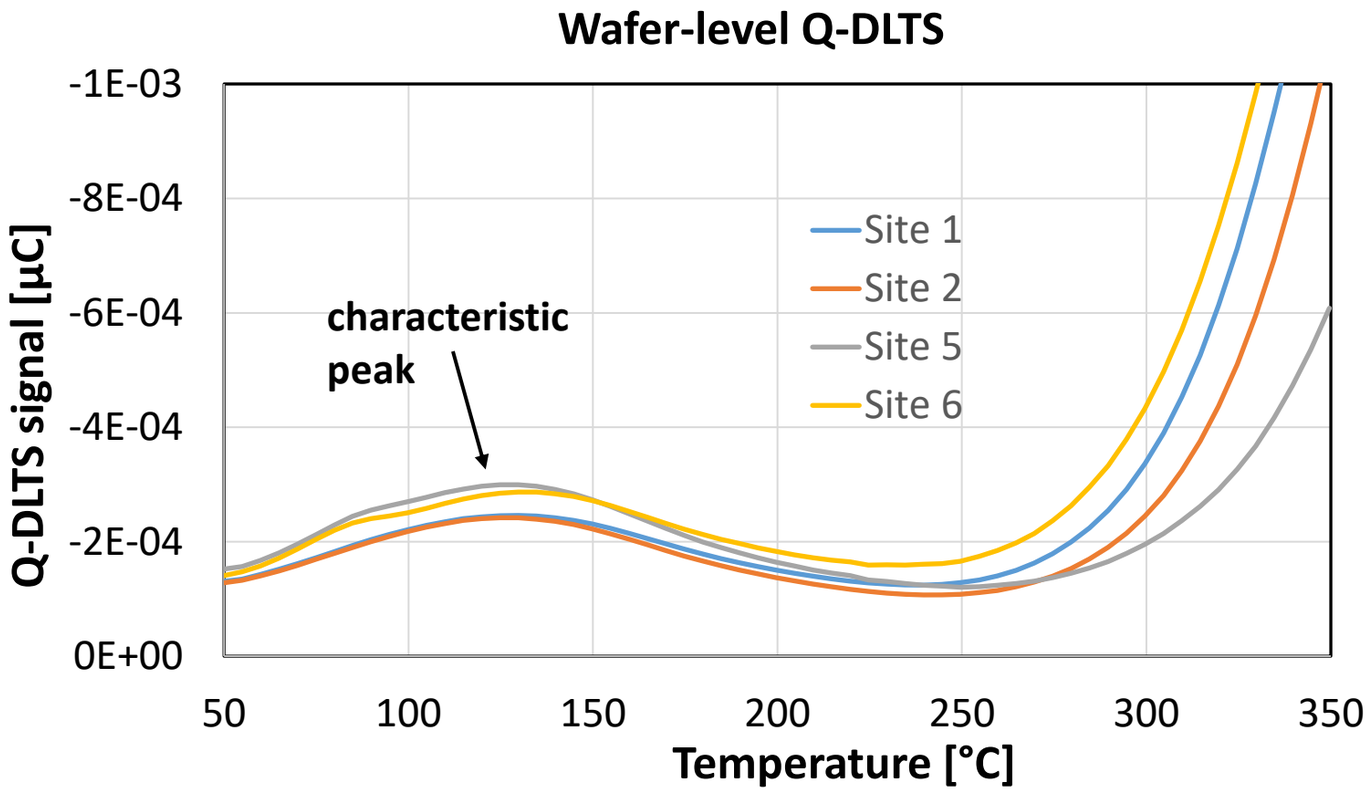
Wafer-level reliability test solution

Q-DLTS (charge based Deep Level Transient Spectroscopy)

Q-DLTS measures the transient current decrease at a range of temperatures after an electrical voltage pulse was applied to the sample.



- DLTS signal characteristic for material defects in thin film
- Temperature stepping required for peak resolution

High test speed by temperature stepping without recontacting

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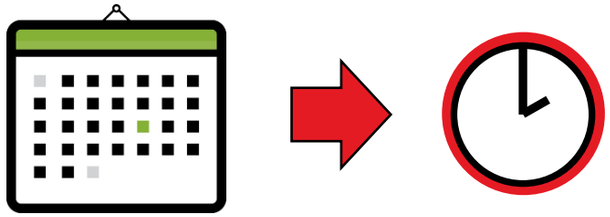
Wafer-level reliability test solution

- Electrical contact during thermal ramp enables outstanding possibilities in terms of device and material characterization
  - High throughput measurements possible
  - No need of separating probe card and wafer
  - No need of realignment process

Gamechanger: Testing time reduced from weeks to hours



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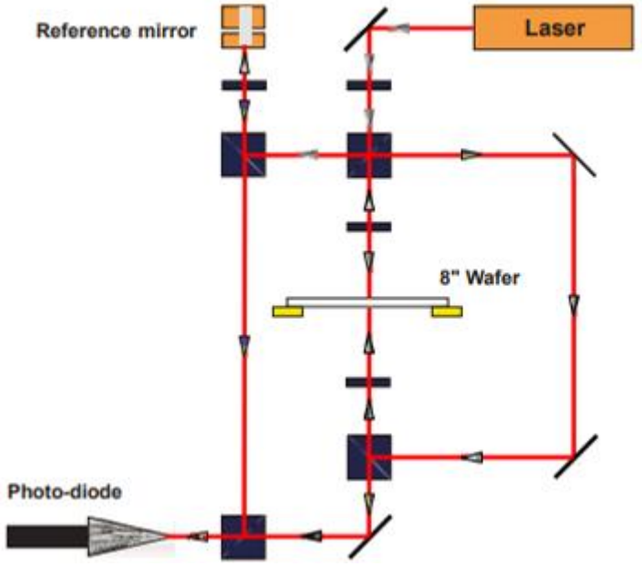
Displacement measurements

- Double-Beam Laser Interferometer (DBLI)

- determine d33 (displacement) with laser on wafer-level
- Laser beam guided onto backside and sample using the same beam path
- Influence of substrate bending can be eliminated and only piezo response of the sample is measured



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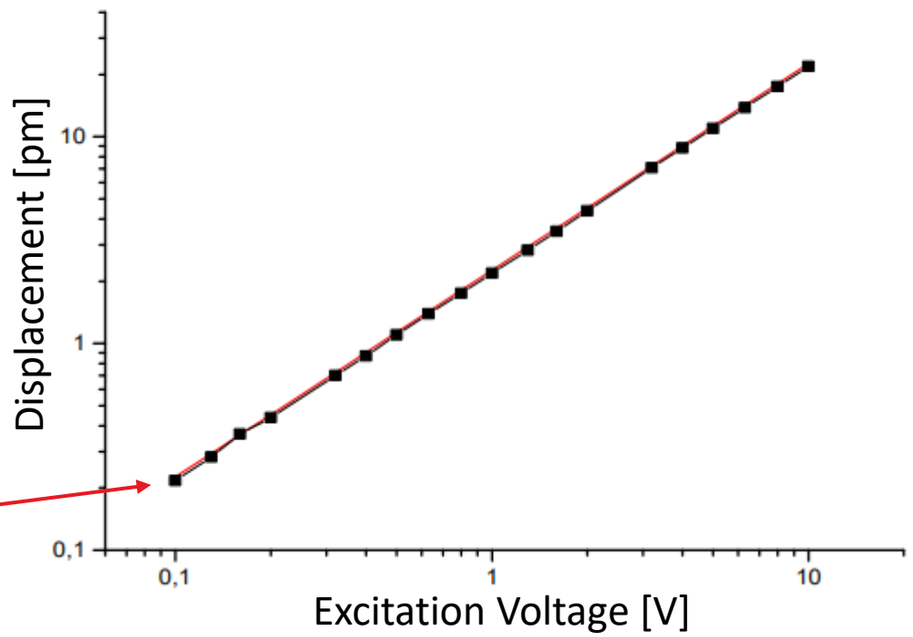
Displacement measurements

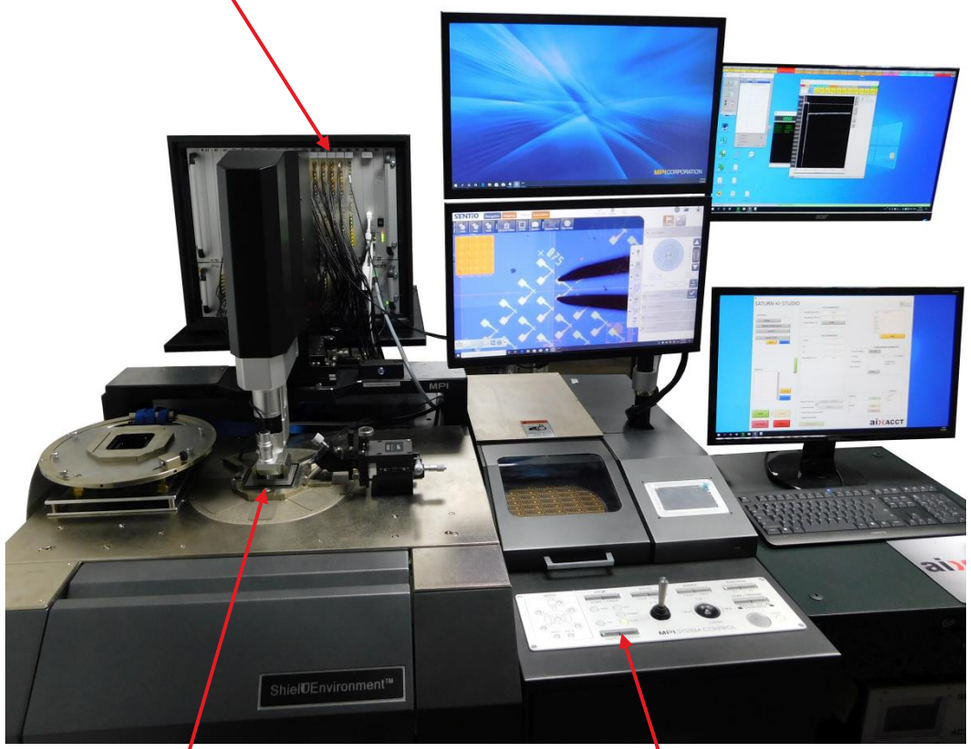
- Outstanding precision
- **Gold Standard** for piezoelectric film characterization
- Piezoelectric coefficient d_{33} obtained for x-cut quartz
  - Well known d_{33}=2.3pm/V
- Linear response for different excitation voltages obtained by DBLI
  - Achieves **200fm** resolution
  - No readjustment of optics required



Memory Testing solutions

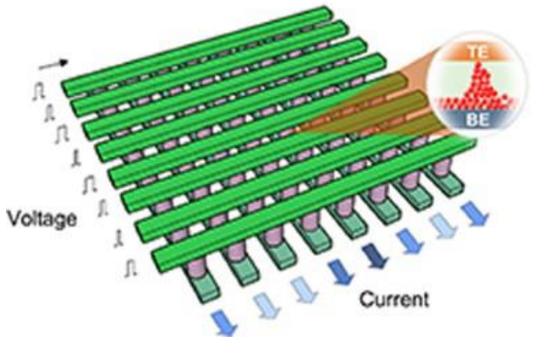
- Resistive Memory Testing
  - 64 Output Channels, 32 Input Channels
  - Individually addressable & individual waveform each channel
  - Characterizes resistive switching in 16x16 matrix
  - Import demand: Ultra-fast current compliance to avoid device failure
    - Programable current limit with response down to 5ns and minimal overshoot

aixACCT measurement equipment controls the overall function of the system



Multisite probe card

MPI TS2000 Prober



NEUROSYS & NEUROTEC PROJECTS

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Summary

- New Test System for high throughput lifetime testing was developed
  - We thank MPI, ATV, and Celadon for their cooperation in realizing this first-of-its-kind aixWDA system!
  - Wafer-level TSDC and Q-DLTS in one system
  - Measurement of electrical current in parallel on wafer-level under thermal ramp in contact!
- Standardized Piezo testing
- Emerging technologies testing
- aixACCT is complete solution provider

Visit us on https://www.aixacct.com/

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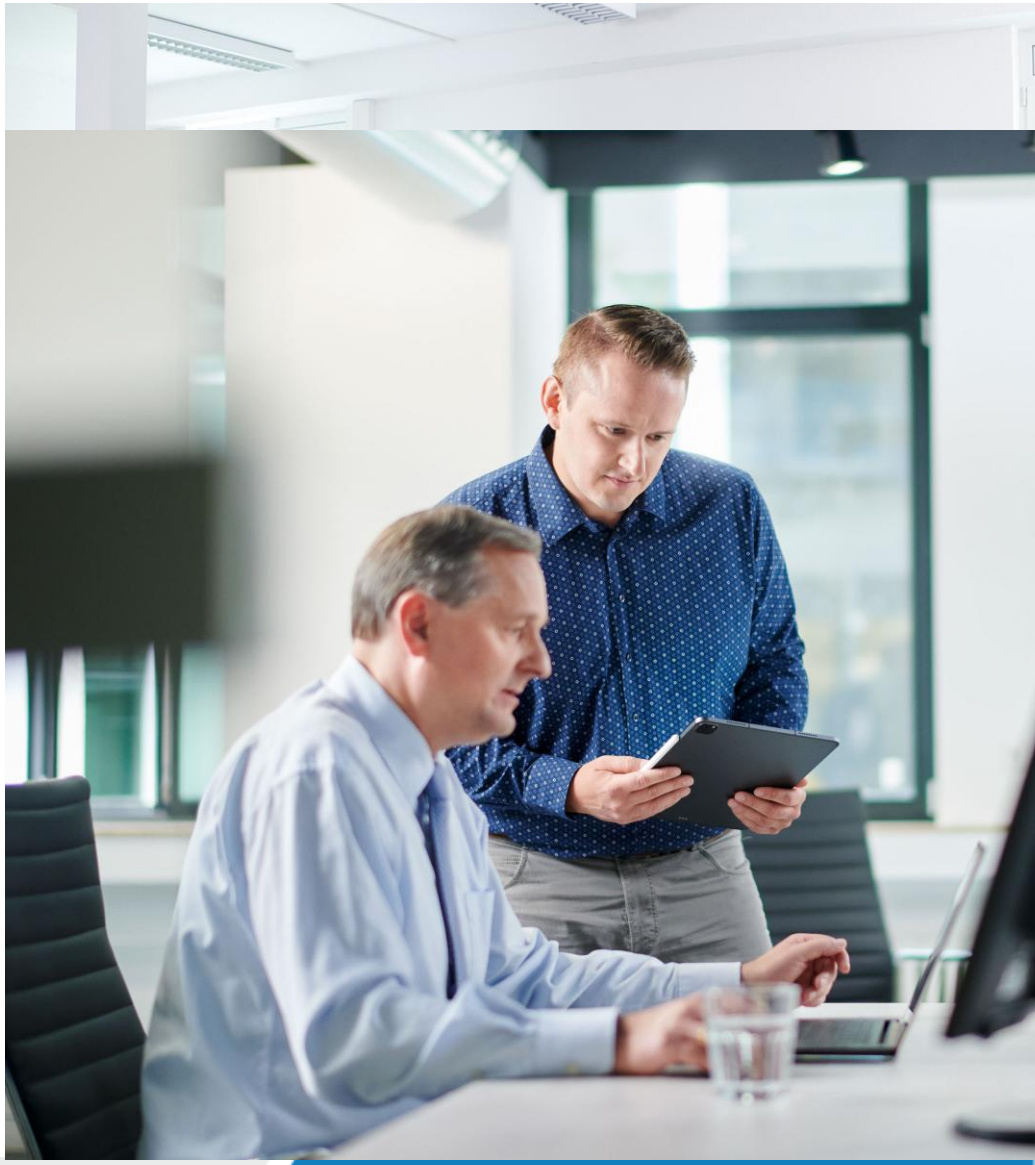
An integrated system to Enable Highly Stable Full Wafer Reliability Testing of MicroLEDS

Ian Cheng
AutomatisierungsTechnik Voigt GmbH

ATV Introduction

- June 2000 – founded in Germany
- 2009 Keithley distribution partner
- 2014 MPI & Celadon distribution partner for on-wafer test

- 2022 building extension with demo & training center
- 30 employees, software experts, hardware, application & service engineers



ATV System

ATV fill in where the su

- Software / Hardware engi
- Measurement Instrument
- Prober systems / Probe ca
- Service team

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Custom solutions

- POWER – 3kV / 2000A
- LED / LASER
- MEMS

WLR MicroLED Challenges

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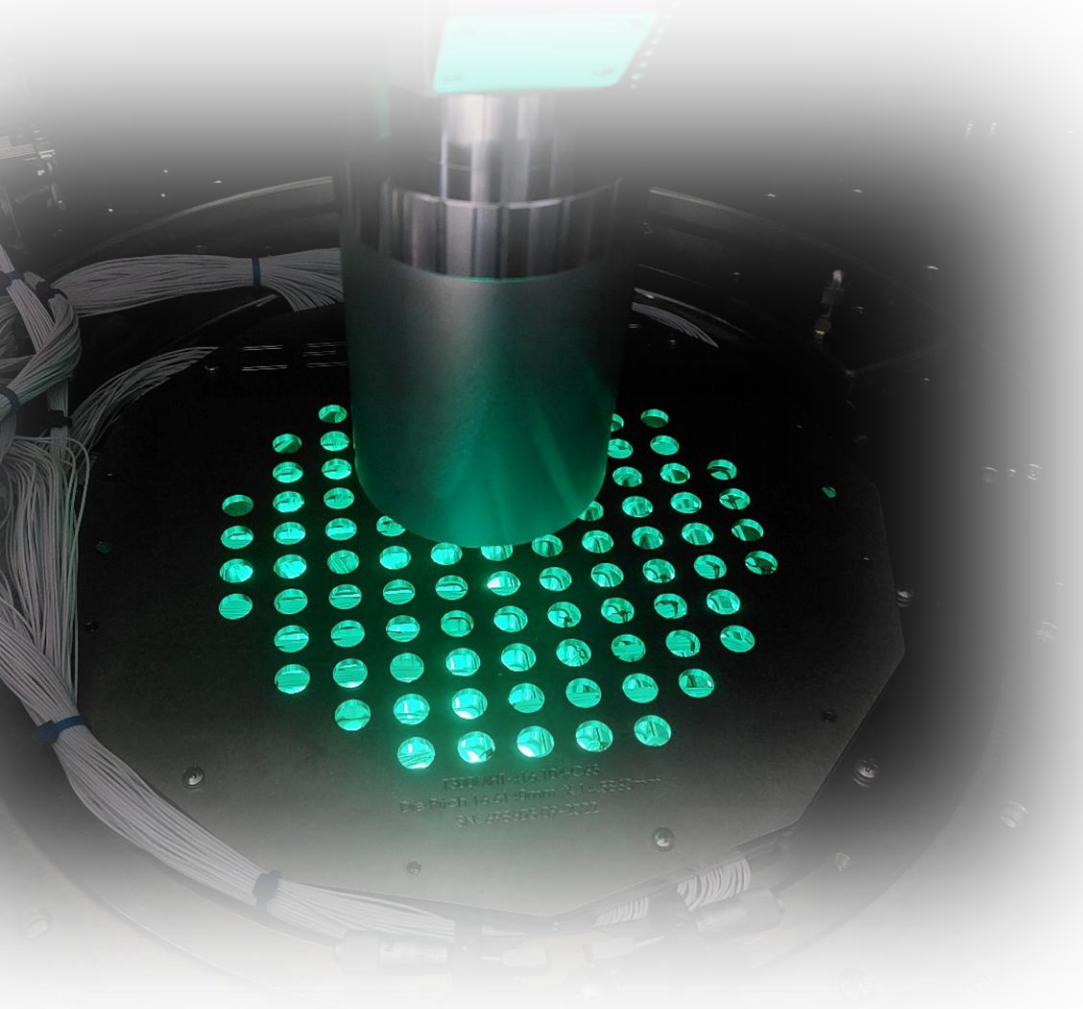


Time-intensive

- Time intensive full wafer measurement to 3 days
- Ultra-stable optical and electrical measurement

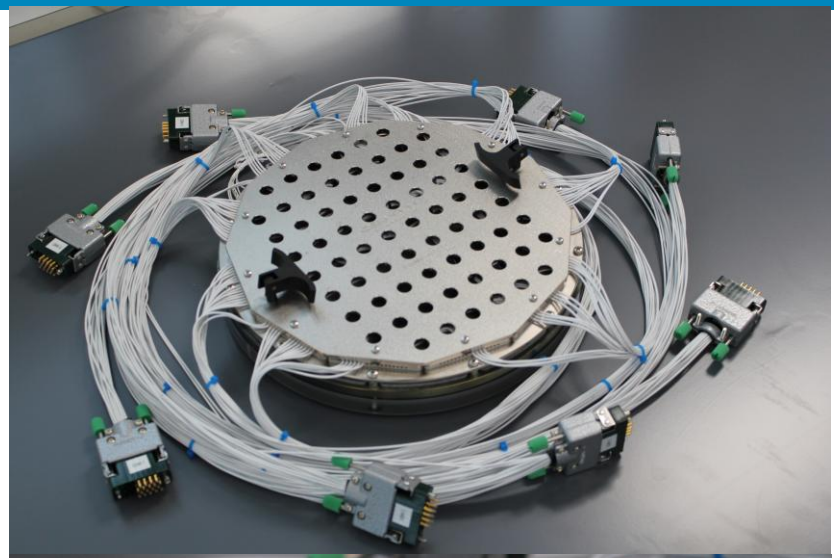
Test equipment challenges

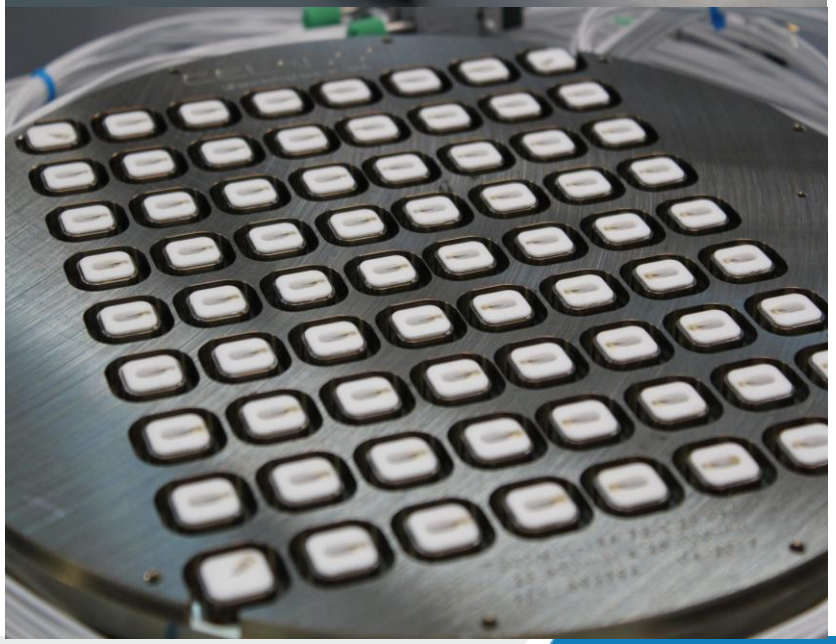
- Parallel high current, continuous measurement setup
- Precise contact over full wafer

Complex data processing

- Massive optical and electrical data collection
- Difficult failure mode analysis

Case Study





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T300 ButtonTile™

Case Study

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TS2000-SE

ATV, MPI, Celadon

atv AutomatisierungsTechnik Voigt GmbH

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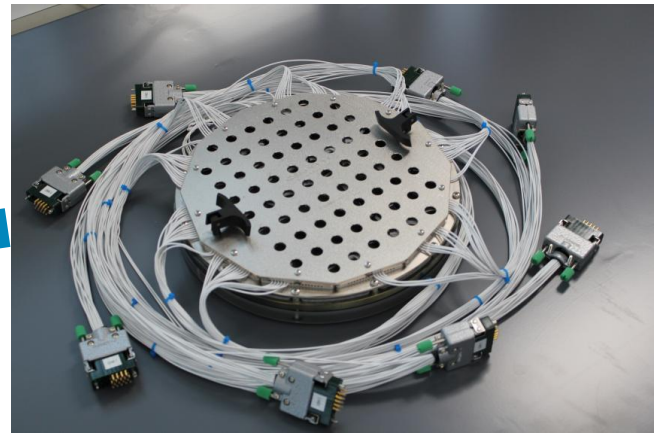
Measmatic

Probertool



CELADON™

About ATV integrations…

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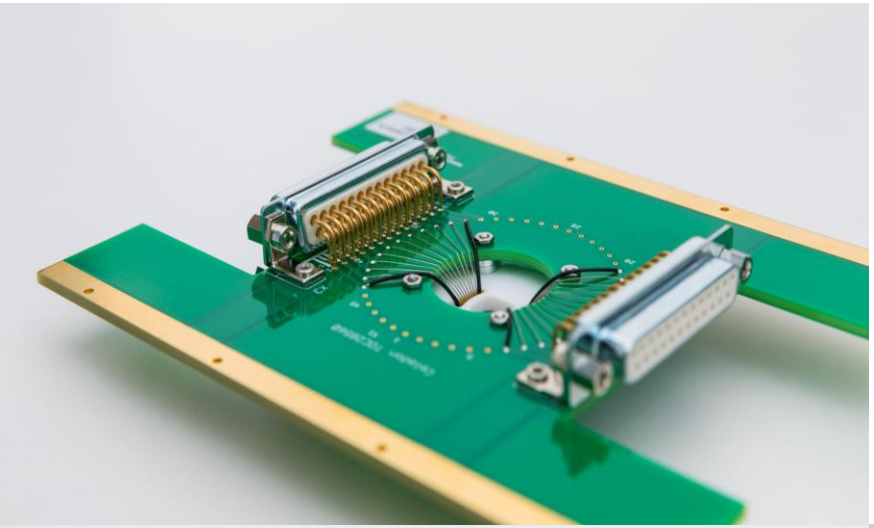

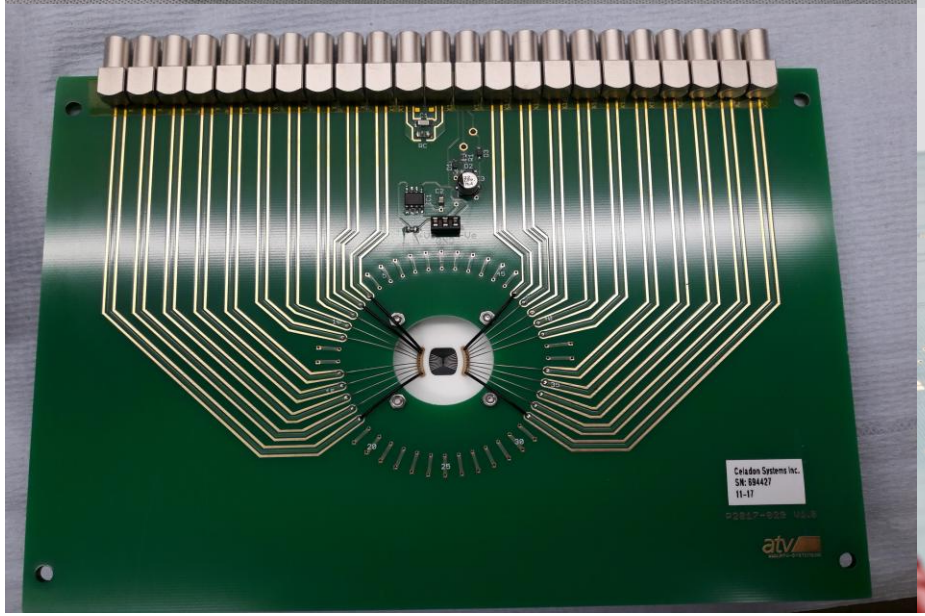

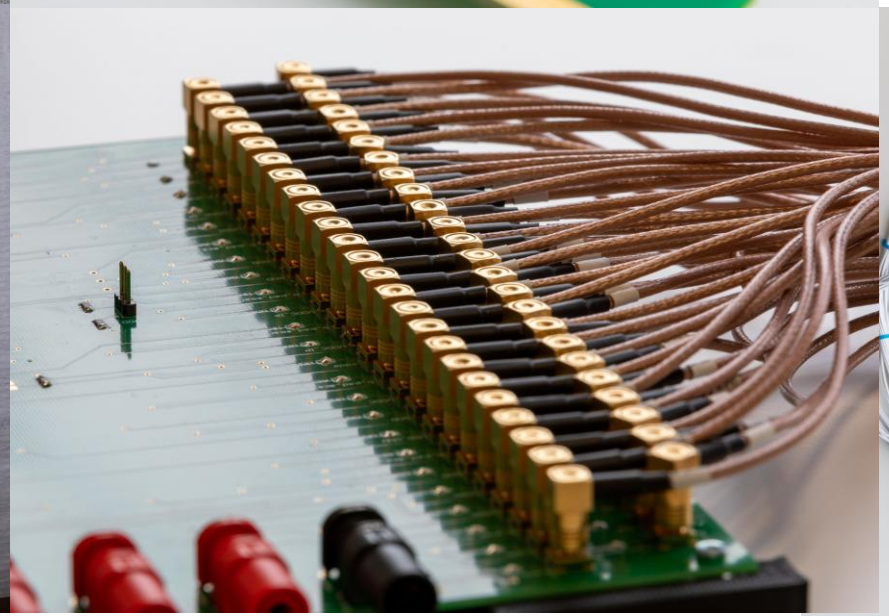

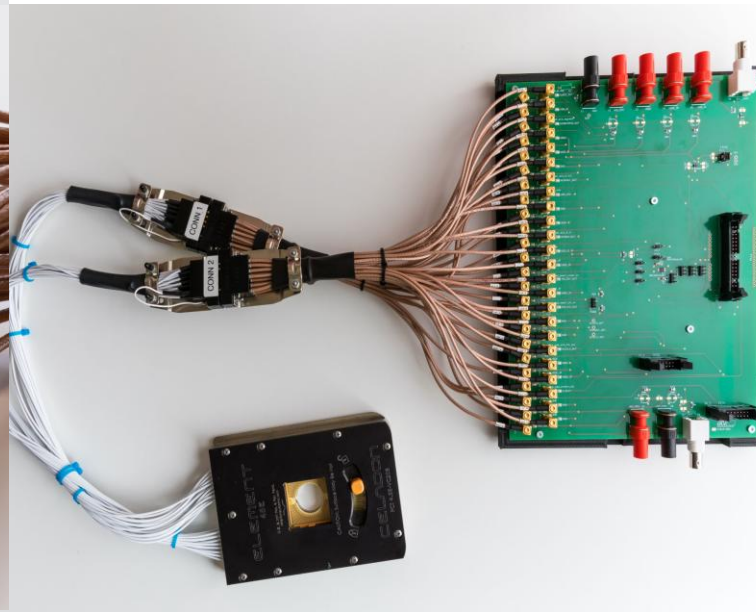

Thank you! Questions?

https://www.atv-systems.de/

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cheng@atv-systems.de

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