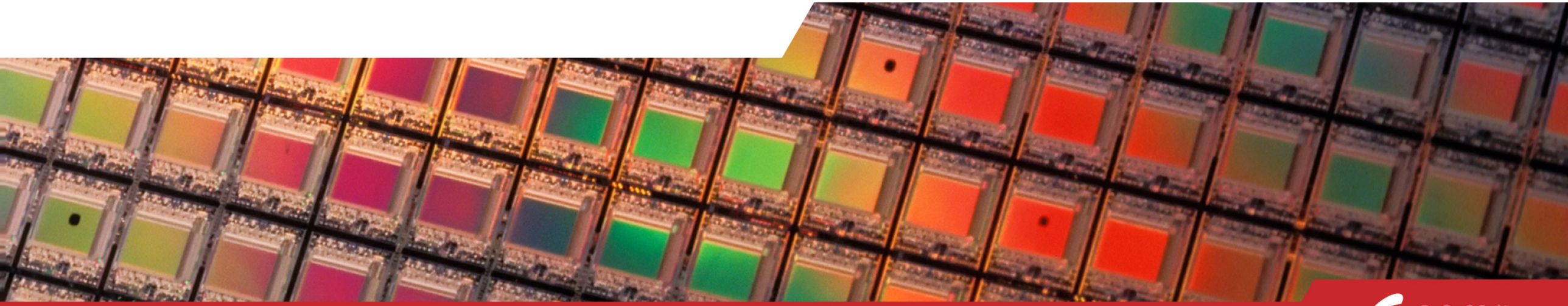
Productivity Innovations for Automotive IC Wafer Test

Amy Leong (CMO, FormFactor Inc.)

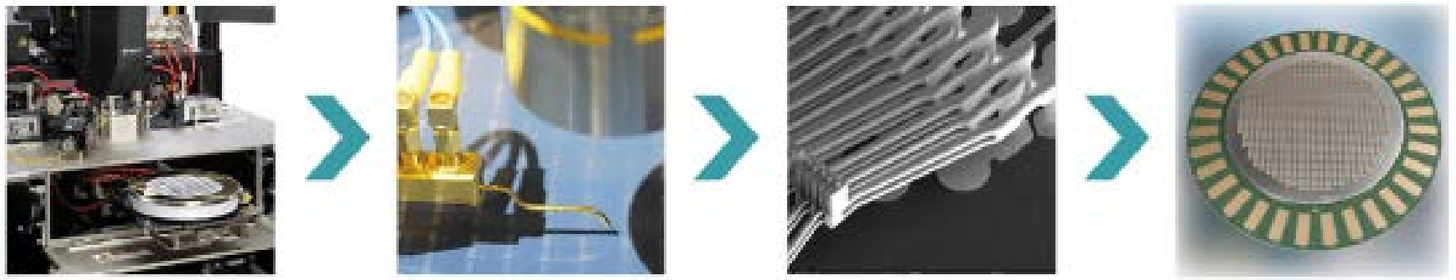


FormFactor – Leading in Electrical Test and Measurement

- Founded in 1993 (Nasdaq: FORM); headquarters in California, USA
- 2017 Revenue $548M
- ~1600 employees, about 1/3 directly support customers

- #1 supplier in advanced probe cards and engineering probe systems
- VLSIResearch's THE BEST Suppliers customer satisfaction survey for the 5th consecutive year
- Largest R&D spend in served markets, ~14% of revenue, on customer-guided technology and product development

Test Insight from Lab to Fab



Engineering/ Development | First Silicon | Ramp | Production

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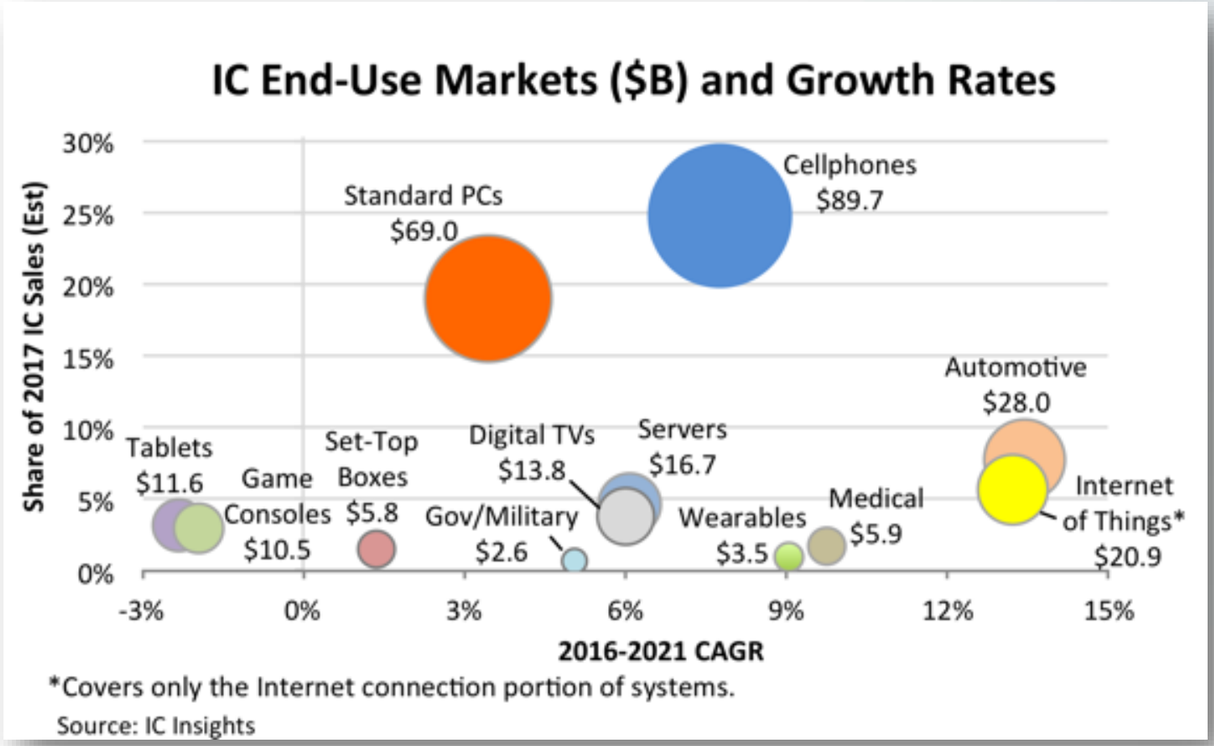
Automotive IC Market Growth

- Automotive semiconductor industry is forecasted to reach $43B by 2021
  - 14% CAGR (2016-2021)

- Average semiconductor content in a car ranges between $338 - $704
  - Autonomous driving will increase the above numbers



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Smart Cars with Increasing Autonomy to Save Lives

- 1.2 million people die on roads per year globally
- 94% of serious crashes are due to human error

2015
ASSIST
- Sensor
- Driver Active
- Fail Safe

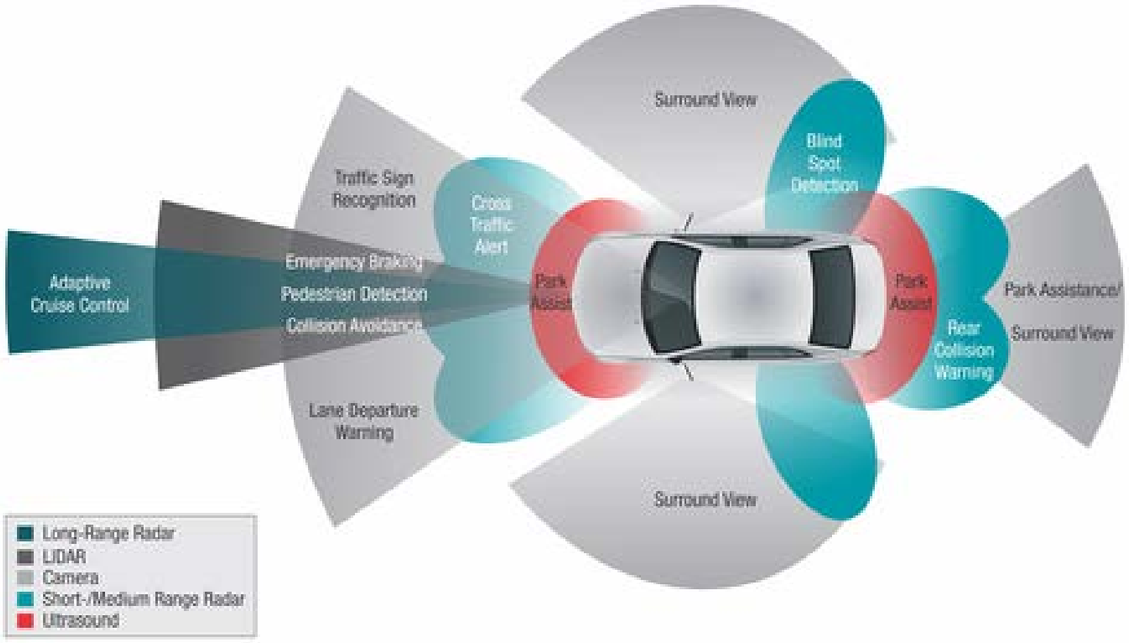
2020
AUTOMATE
- Sensor Fusion
- Co-pilot
- Dependable

2030
AUTONOMOUS
- High Accuracy Maps
- Driverless
- Safety Cocoon

Source: NHTSA

Smart Chips to Help Cars “See” Better

- Sensor Fusion For Car Safety -- $10B Collision Avoidance ICs by 2020
  - LIDAR* and Camera: Not high frequency but LOTs of data
  - Collision avoidance radar @77GHz
  - Low latency V2V and V2I communications, which is offered by 5G @ potentially 60GHz



*LIDAR - Light Detection and Ranging

Sensing growth

Global sales of collision-avoidance sensors are rising rapidly. Here are sales forecasts.

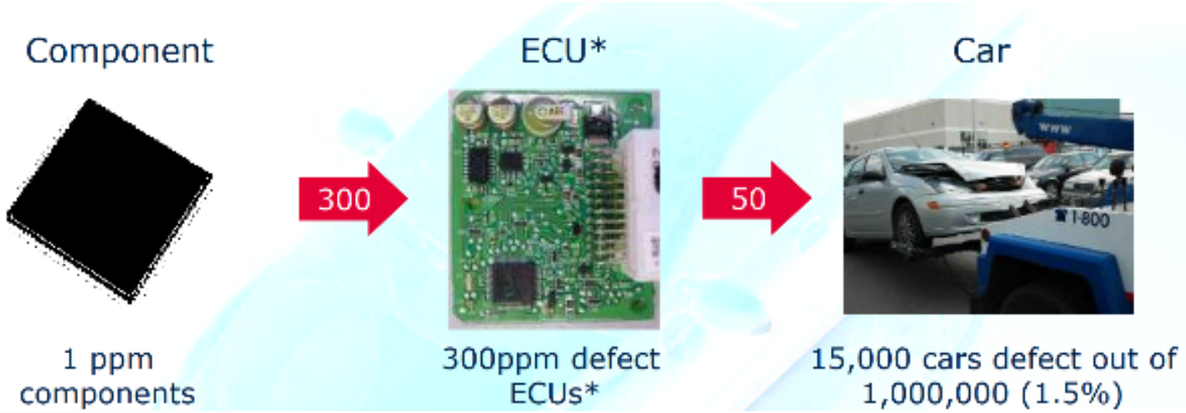
	2014	2020
Radar	$1.62 billion	$4.38 billion
Camera	$1.28 billion	$3.93 billion
Ultrasound	$990 million	$1.41 billion
Lidar	$52 million	$185 million
Total	$3.94 billion	$9.90 billion

Source: Strategy Analytics; McKinsey 2017; IHS Automotive

Smart Chips With Zero Defect

Why Zero Defect?

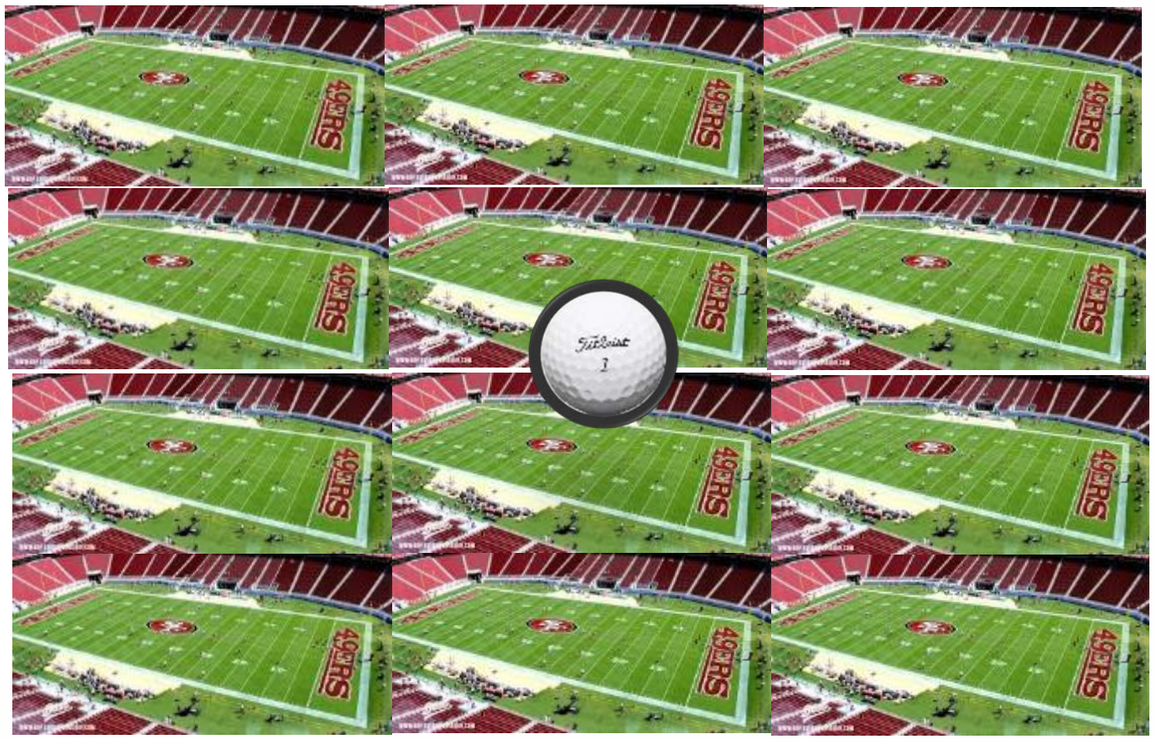
Because 1 defect part per million is not good enough!



Source: Infineon

Try to Visualize 1 Defect Part Per Billion

It’s like finding a golf ball in a field with the size of 12 American football stadiums (110 x 49m)



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Automotive ICs: Rapidly-Growing Semiconductor End Market with Stringent Quality and Test Requirements

THE MARKET OPPORTUNITY

- ICs & sensors improve both performance & safety on the path to autonomous vehicles
- Highest major end market growth in semiconductors at 14% CAGR 2016-2020*
- Proliferation and integration of digital ICs, RF (mmWave radar) and MEMS sensors

THE CUSTOMER NEED

- Required defect levels is at least 10x more stringent than mobile and consumer applications**
- Extreme test conditions—high power/ current, high + low temperatures, etc.
- Supplier scale and sustainability important

What FORMFACTOR Brings to Automotive Supply Chain?

- Best-in-class electrical performance over broad range of wafer test conditions
- Productivity innovations to accelerate automotive IC profitability
- Long history as key supplier to top companies in automotive supply chain

* IC Market Drivers 2017 Update, IC Insights
** Spotlight on Automotive, PwC Semiconductor Report 2013

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FormFactor Automotive Products Offering From Lab to Fab

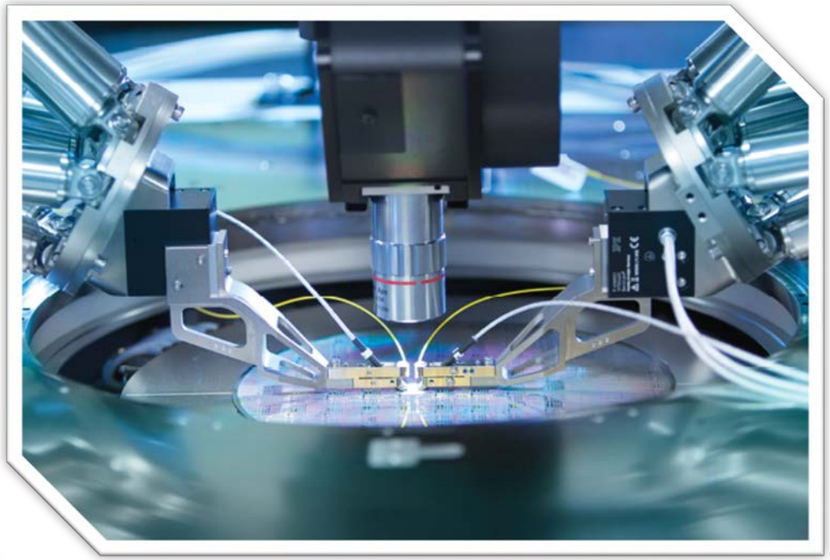
Announced @ SEMICON CHINA 2018

SUMMIT200 Power IC Semi Auto Prober

Full triaxial capability @ 600A pulse and 10kV

Fast time-to-volume data **Lab Characterization**

Announced @ SEMICON West 2018

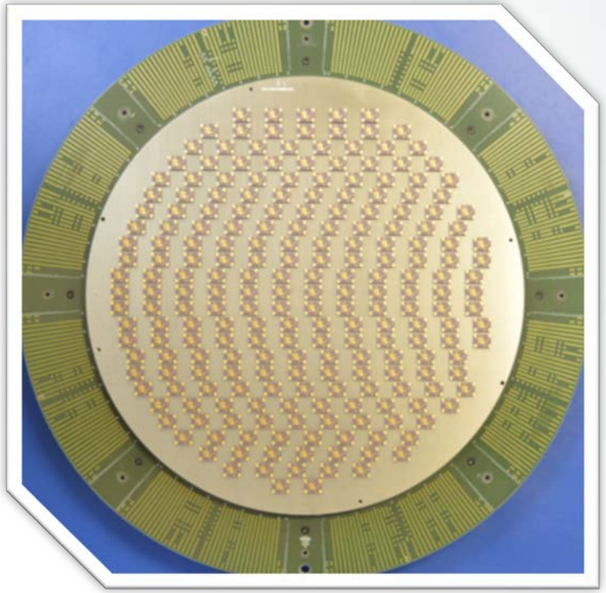


CM300 300mm LIDAR Auto Prober

6-Axis high speed, high precision piezo control

Taking Si Photonic **From the Lab Into Production**

Coming Soon



TrueScale Matrix for Microcontroller

300mm MEMS Probe Card (-40 to 165C) Lower **Production Test** Cost by 15% through multi-DUT

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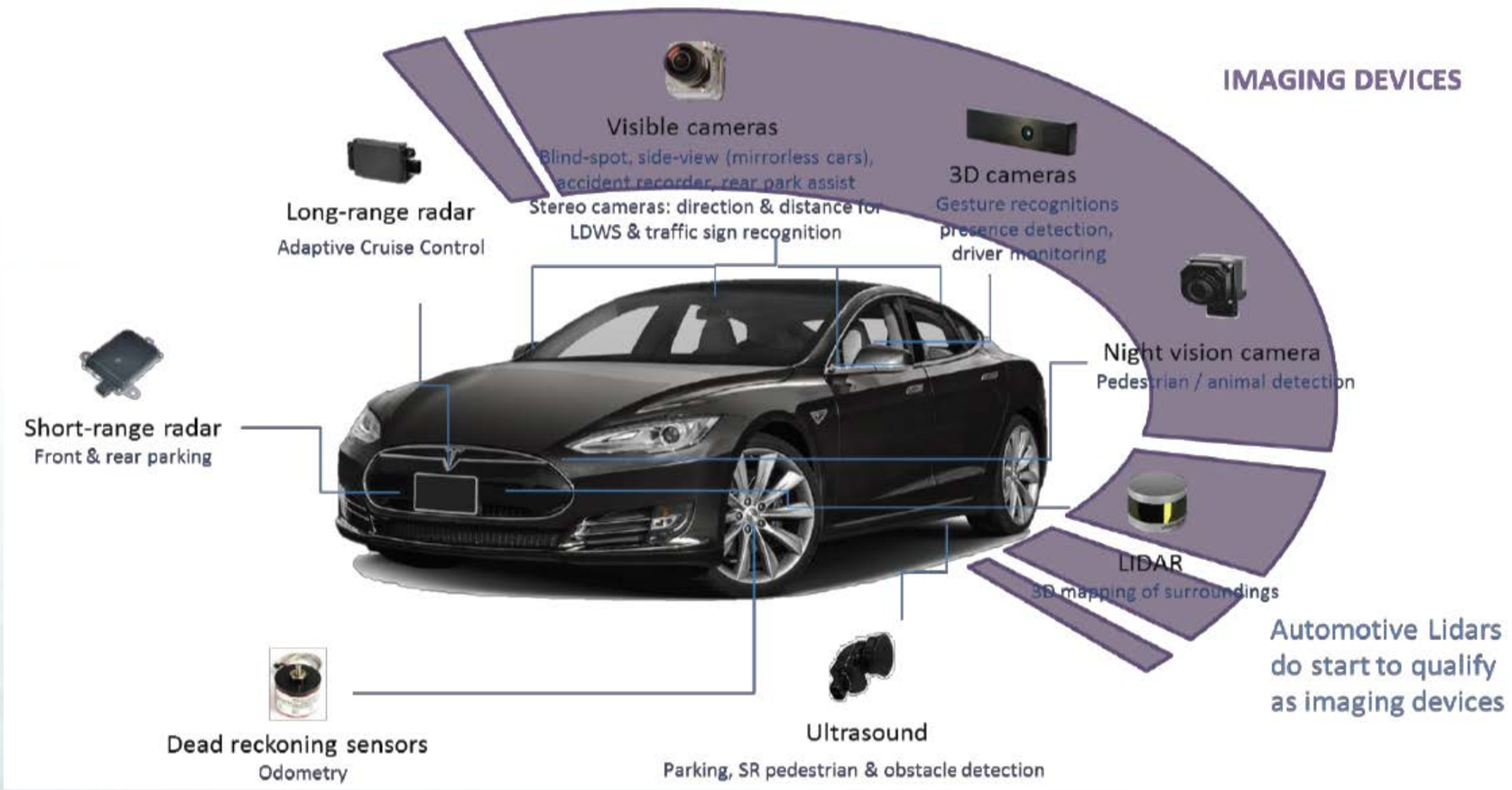
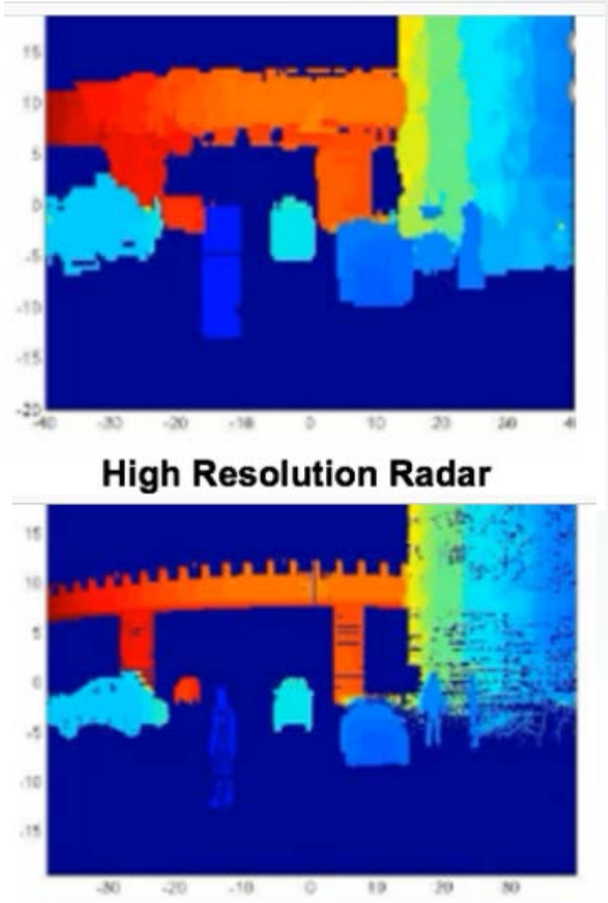
Case Study 1: Emerging LIDAR Wafer Test
LIDAR will become key sensors for autonomous vehicles





High Resolution Radar vs LIDAR
(Source: NXP)

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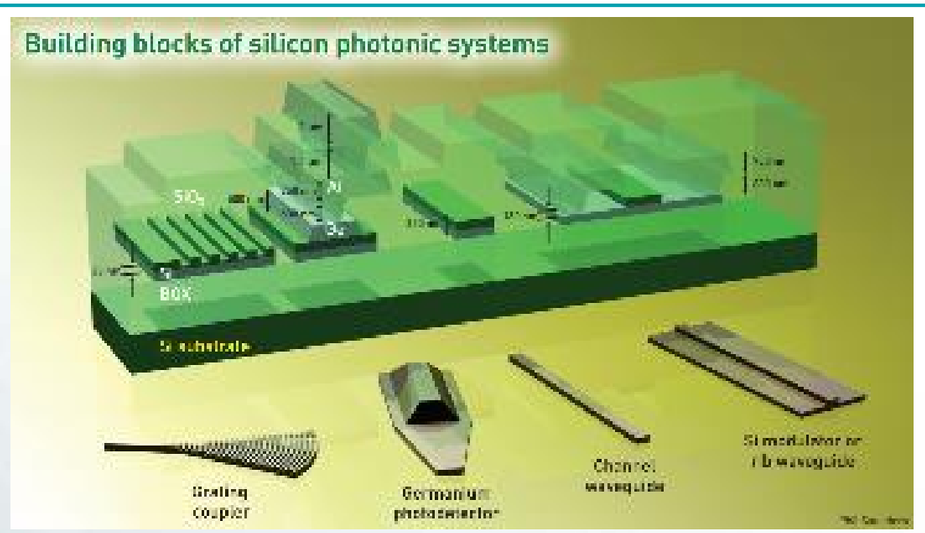
Case Study 1: Emerging LIDAR Wafer Test
Why Silicon Photonics (SiPh) for LIDAR?

- Leverage Complementary Metal-Oxide Semiconductor (CMOS) manufacturing capabilities to fabricate photonic devices
- SiPh Key Applications
  - Big Data requirement for fast transmission and low power consumption
  - LIDAR for automotive imaging, 3D mapping, robotics, industrial applications



Advantages of Using Silicon

- Low cost: leverage existing CMOS fabs
- High integration: Devices that modulate, detect, route and filter light are co-located on the same wafer

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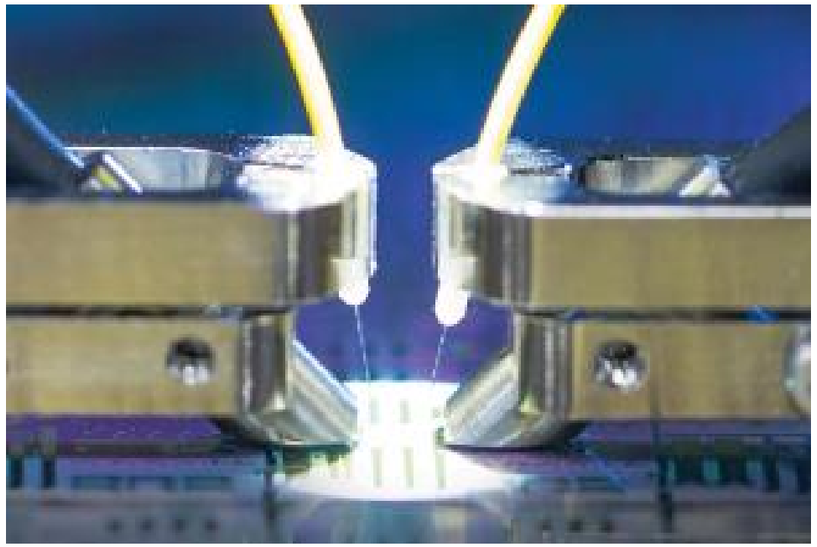
Case Study 1: Emerging LIDAR Wafer Test
SiPh Wafer Test Challenges

- Align optical fibers to couple light to a wafer, without physical contact
  - Traditional electrical testing uses Probes-To-Pad-Alignment (PTPA) to touch the wafer
  - For SiPh, in addition to the electrical probes, we need to precisely align the optical fibers above the wafer, at nano-scale, to deliver maximum power to the device
- Integrated measurement system for fast time to data
  - Optical-to-Optical (O-O) and Optical-to-Electrical (O-E) Measurements



Case Study 1: Emerging LIDAR Wafer Test
Collaboration to Deliver Integrated SiPh Wafer Test Solution

Nasdaq

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FormFactor Collaborates with Keysight Technologies and GLOBALFOUNDRIES to Deliver Silicon Photonics Test and Measurement Solution

By GlobeNewswire, June 18, 2018, 09:00:00 AM EDT

Vote up AAA

Proven, integrated solution features FormFactor's Cascade CM300xi Probe System and Keysight's Photonics Application Suite

LIVERMORE, Calif., June 18, 2018 (GLOBE NEWSWIRE) -- FormFactor, Inc. (NASDAQ:FORM), a leading electrical test and measurement supplier to the semiconductor industry, announced today the company has deployed an integrated CM300xi probing solution for wafer-level testing of silicon photonics (SiPh) devices. Teams from GLOBALFOUNDRIES, FormFactor and Keysight worked together to ensure the system is flexible to meet engineering needs and to deliver high throughput in volume production.

See headlines for FORM

View Print Version

More from GlobeNewswire

- **FormFactor to Participate in the 10th Annual CEO Investor Summit 2018**
- **FormFactor Collaborates with Keysight Technologies and GLOBALFOUNDRIES to Deliver Silicon Photonics Test and Measurement Solution**
- **FormFactor Announces Breakthrough Improvements in Productivity for RF Probe Systems**

Referenced Stocks

- **FORM** 75% **Rate It**

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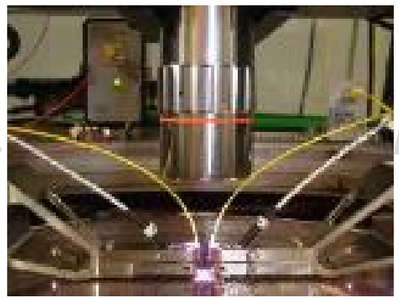
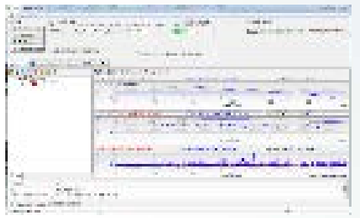
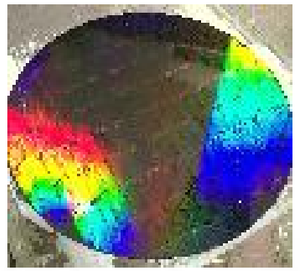
KEYSIGHT TECHNOLOGIES

Integrated Optical Probing Solution





Auto SiPh Solution enables customers to be **measuring** photonics devices **in days** instead of months or years.



GLOBALFOUNDRIES

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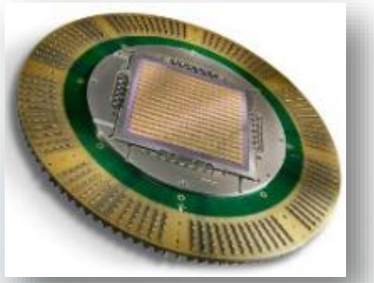
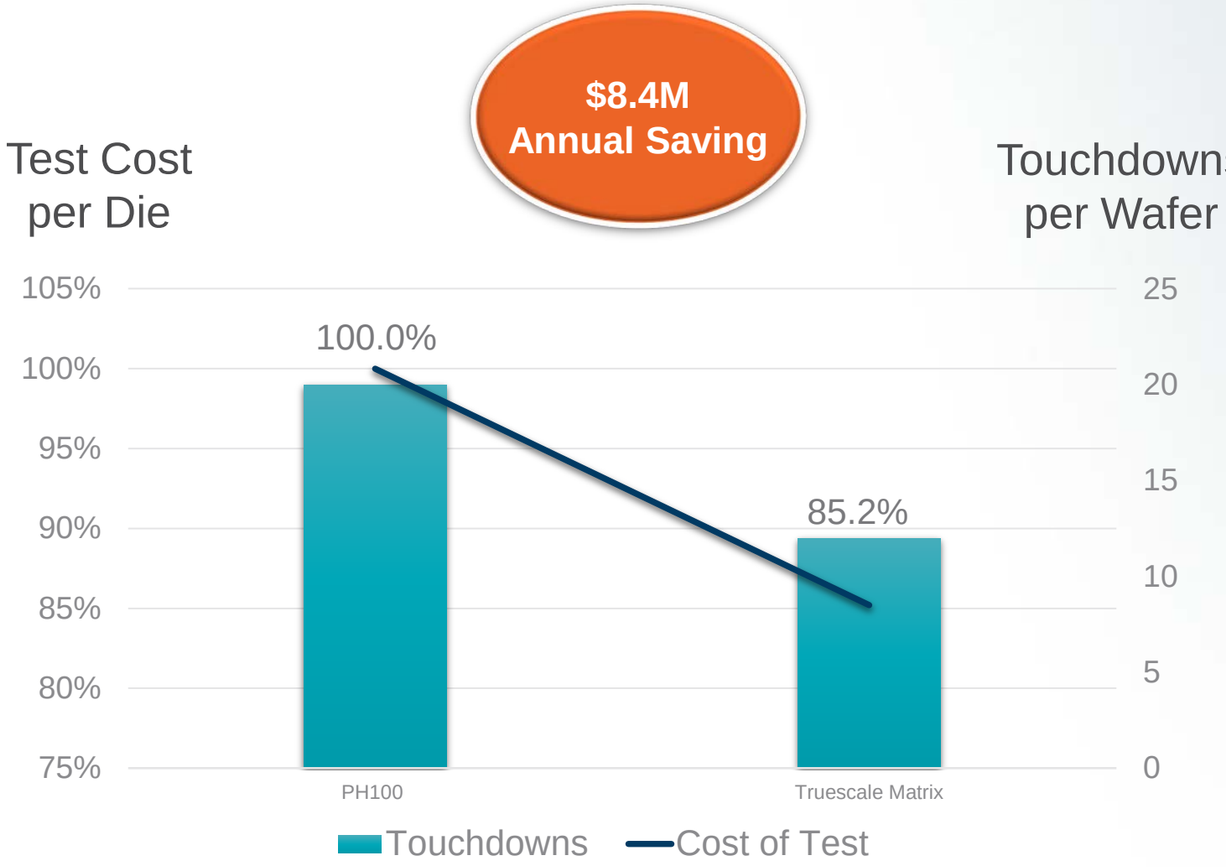
Case Study 2: Automotive Microcontroller Production Probing
Productivity Improvement and Test Cost Reduction

- **Challenge:** Reduce Test Cost Per Die
- **Solution:**
  - Increase test parallelism to reduce test cell investment
  - Same probe card for hot (160C) and cold (-40C) testing
- **Results**: $8.4M Annual Test Cost Saving



64-DUT Parallel Test
PH100 Probe Card
100mm Testing Area

95-DUT Parallel Test
TrueScale Matrix Probe Card
300mm Test Area



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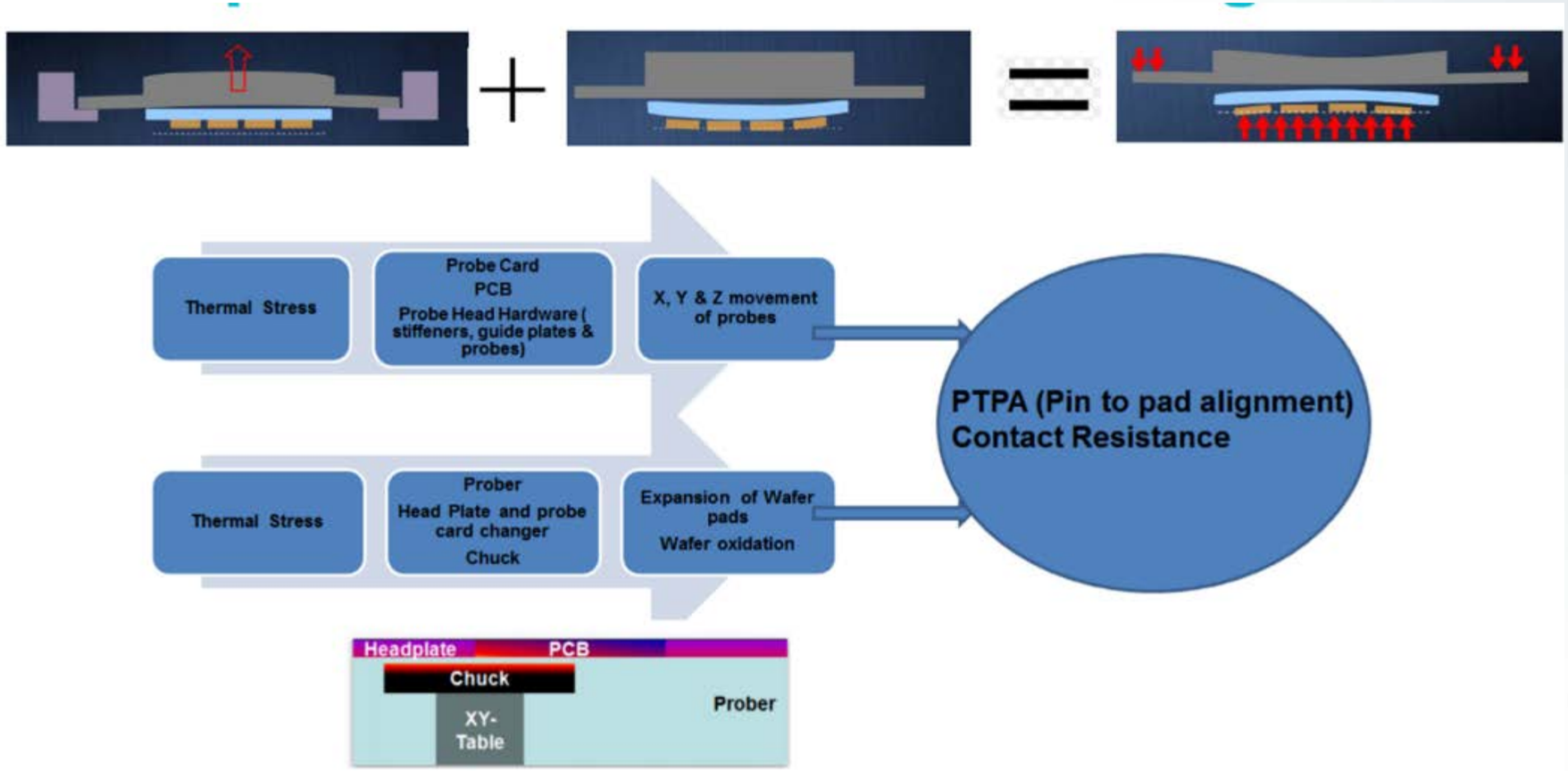
Case Study 2: Automotive Microcontroller Production Probing
Wide-Temperature-Range Wafer Test Challenges

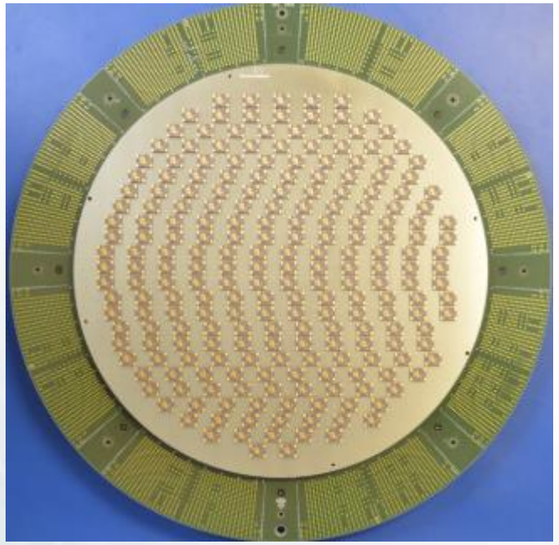
- Long test time
  - High test cost per die
- Wide temperature range
  - -40 to 160ºC
- Small pad size
  - 55um x 45um



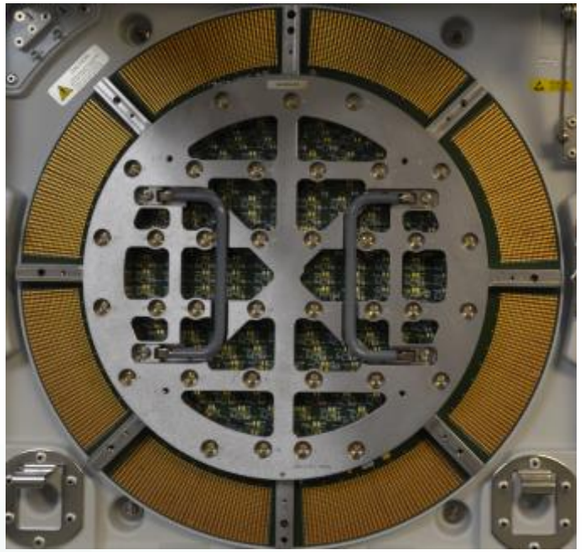
Temperature Effect on Probe Card During Wafer Test

Case Study 2: Automotive Microcontroller Production Probing
FFI Solutions

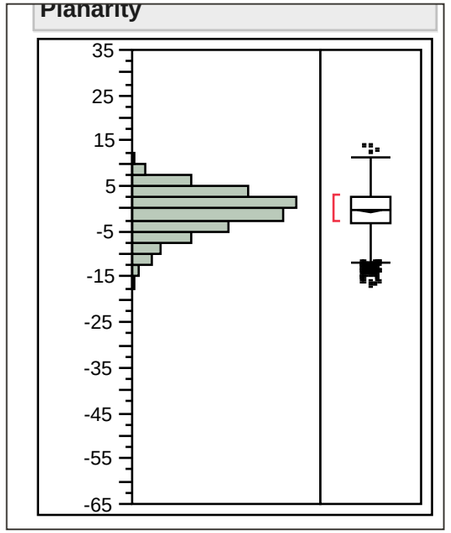
- TrueScale Matrix Product Design Considerations
  - 300mm active area probing for most efficient touchdown pattern
  - Custom Wafer Side Stiffener to Match probe card CTE (Coefficient of Thermal Expansion) to Silicon wafer to allow wide temperature range probing, up to 200C
  - Modified Tester Side Stiffener to improve planarity

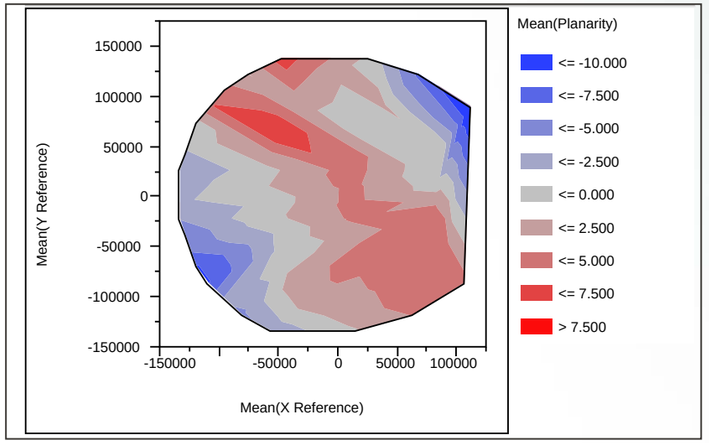


Custom Wafer Side Stiffener for wide temp range operation



Modified Tester Side Stiffener
To Improve System Level Planarity





25um Planarity @ Factory Outgoing

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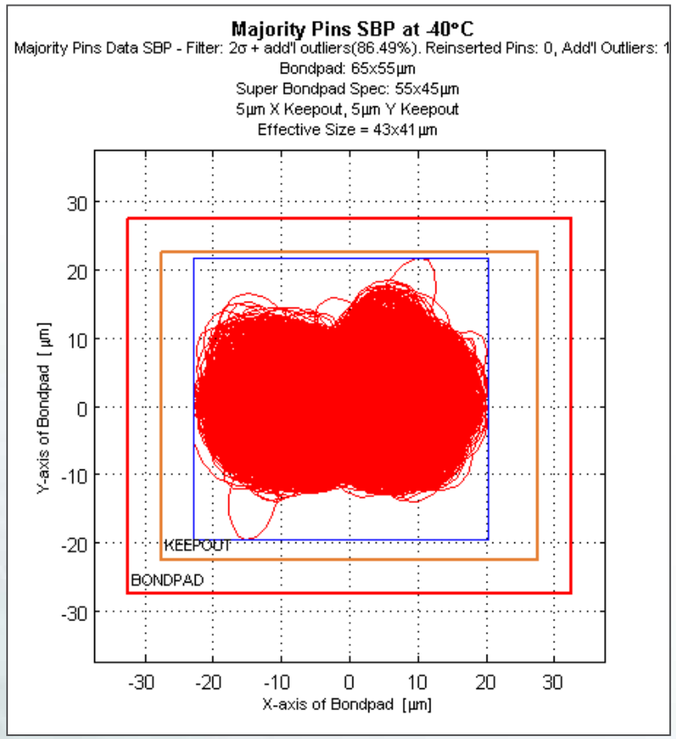
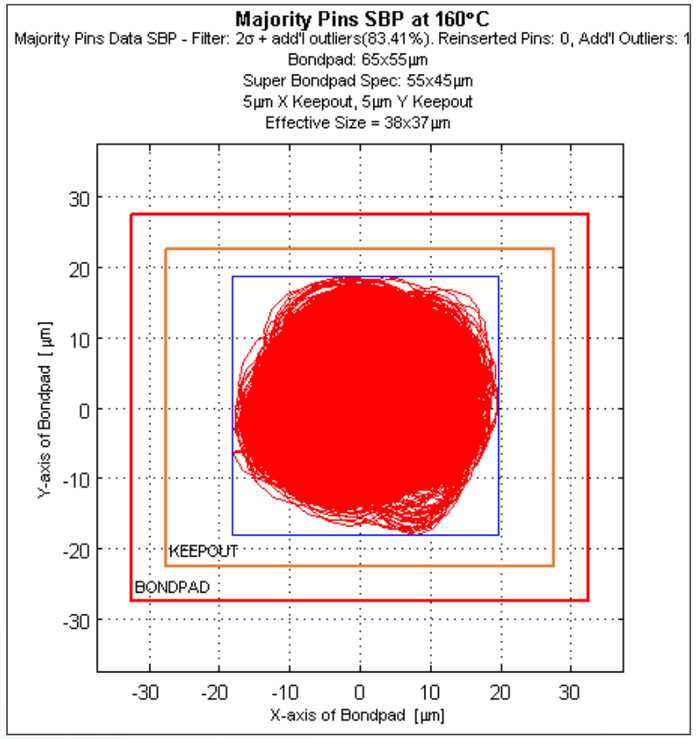
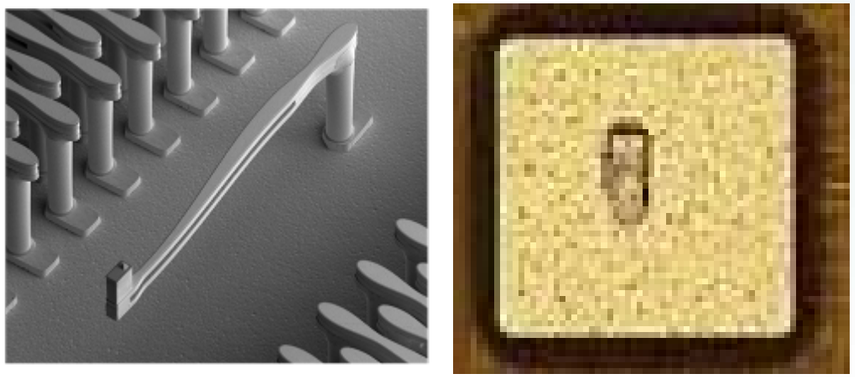
Case Study 2: Automotive Microcontroller Production Probing
Probe Mark Margin Performance Analysis

- Target customer specs -- 55um x 45um
- Results show Cold (-40C) at 43um x 41um, Hot (160C) at 38um x 37um







Super-Bond-Pad (SBP) analysis overlays all the probe mark positional errors in one chart

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Summary

- Automotive sector is expected to grow substantially over the next 5 years
- Nearly every type of semiconductor devices is included
- Safety devices will play the dominant role in this growth
  - They will require higher standards of test
- FormFactor has extensive test products and expertise to help automotive customers enhance productivity and reduce test cost

Together,
Accelerate IC Innovation to
Profitability From Lab To Fab

Thank You