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Parametric Test Structures and Probing Process Attributes

TECHNOPROBE

Wafer Probing Technologies

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Parametric Test Structures and Probing Process Attributes

Presentation Overview

- **Background of parametric test**
- **What is the function of parametric test?**
- **Test structure locations and challenges**
- **Comparison of different probe technologies**
- **Data review of Technoprobe's new parametric probe**
- **Next Steps and Summary**
- **Question & Answer: 5 minutes**

Parametric Test Structures and Probing Process Attributes

Parametric Test Background

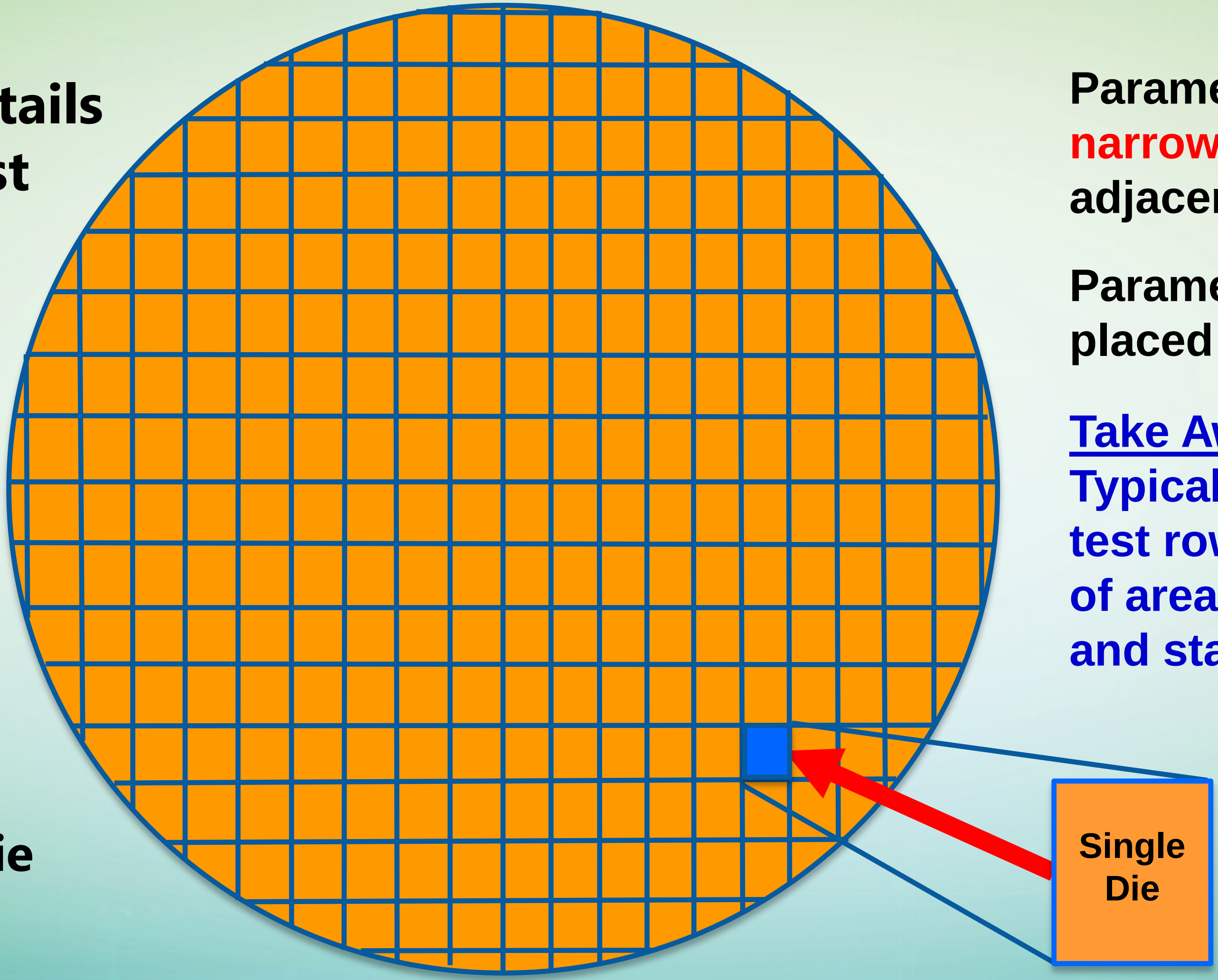
What is parametric test?

- **Direct Current (DC) test application measuring basic Silicon (Si) structures**
- **Appearing simple and unsophisticated at first observation**
- **Key to understanding the basis statistics of semiconductor devices**
- **Critical for monitoring the health of a semiconductor wafer factory**
- **Heavily utilizes the principles of Statistical Process Control (SPC)**
- **From the beginning wire probe technology has been the workhorse**
- **Currently customers use various forms of tapered probe technologies**
- **Whose tips are subject to changing dimensions over their Life-Time**
- **More than a half century later there is a new probe technology**

Take Away: Parametric test is simple, but a very critical part of fab monitoring

Parametric Test Structures and Probing Process Attributes

Exploring the details of Parametric test



Note: View of wafer with Full Die

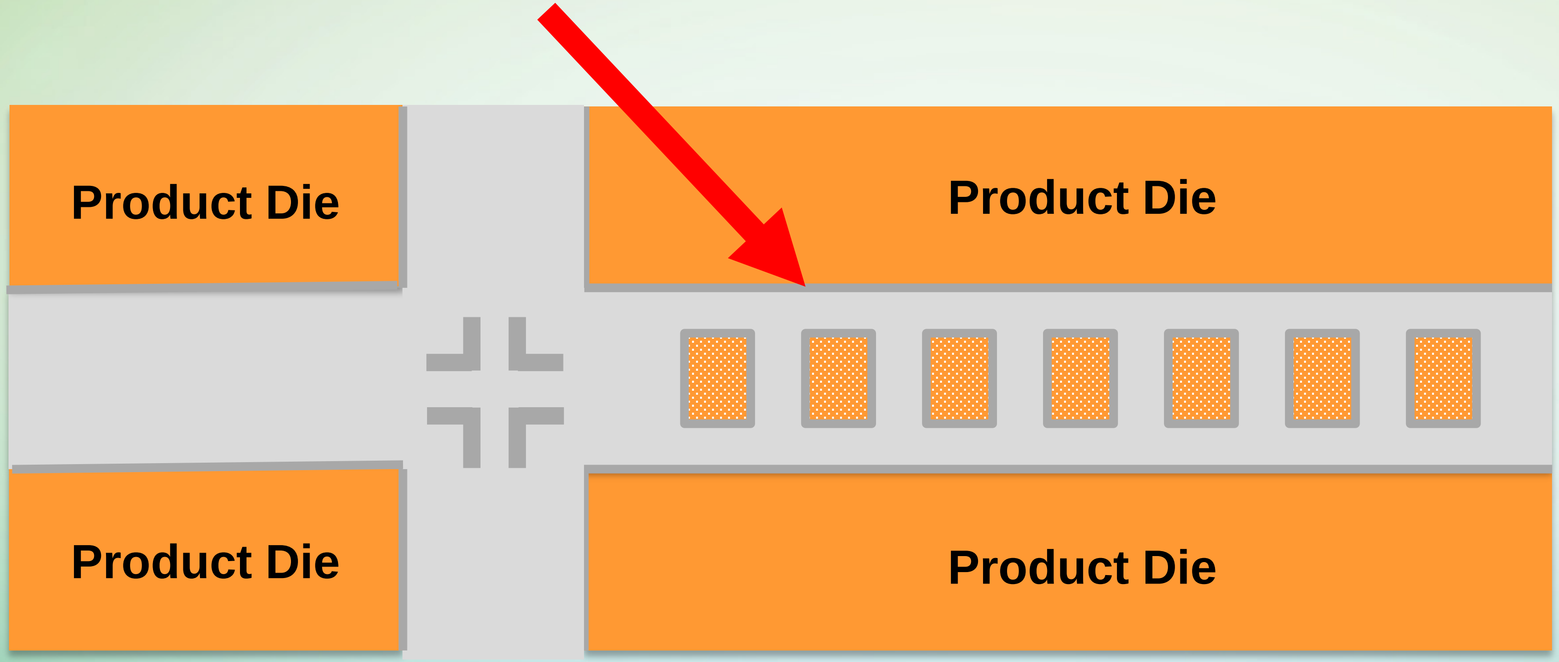
Parametric test occurs in the narrow regions between the adjacent Full Die locations

Parametric test structures are placed in these narrow regions.

Take Away:
Typically the amount of Parametric test rows varies by the availability of area within the narrow regions and stability of the silicon process.

Parametric Test Structures and Probing Process Attributes

Narrow regions with the parametric pads are located between full die locations and going by various names like frame, kerf and scribe

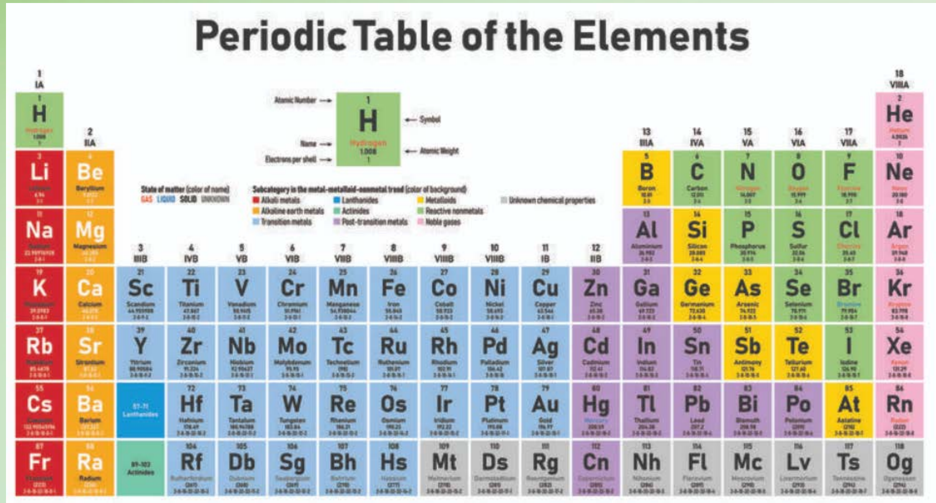


Notes:

1) Ideally the pads are arranged in only one axis.
2) Test structures and wiring must all fit between adjacent die.
3) Test structures are completely isolated from the Full Die circuitry.

Take Away: Parametric pads are located in the region between adjacent die

Parametric Test Structures and Probing Process Attributes



Elements used to build matter found in universe

Table of Parametric Elements

Probe to Probe Leakage						Probe to Probe Capacitance
Resistors	Diodes	Transistors	Oxides	Diffusions	Wells	Gates
Contact Chains	Parasitic Leakage	Electrical Breakdown	Via Chains	Capacitors	Off Current	Drive Current
Etch Structures	Lithographic Structures	Wafer polish Structures	Inter-Layer Oxides	Tx to Tx Isolation	Intra-Layer Oxides	Reliability Structures

Elements used to build complex computer chips

Parametric Test Monitors:

Critical silicon fab process parameters

Disposition of test data vs spec limits

Identifies wafer(s) with fab mis-processing

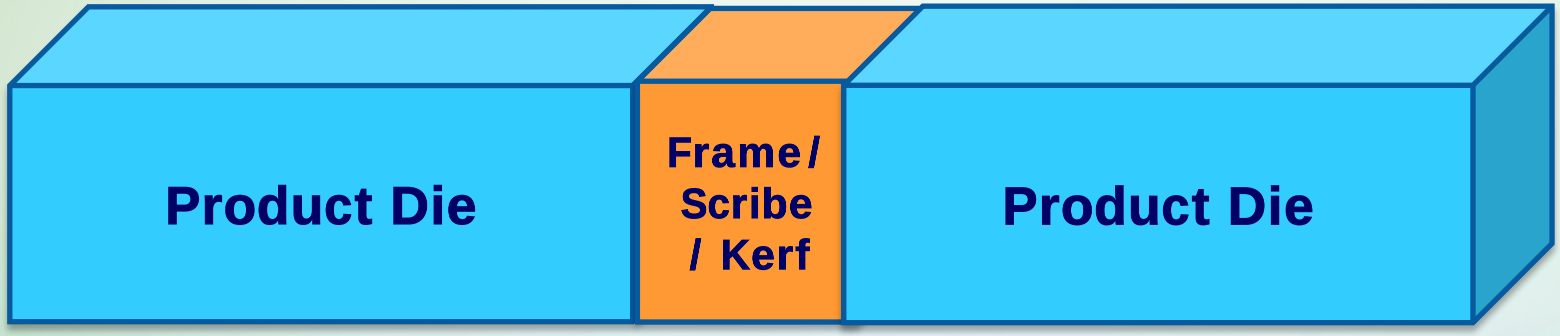
Data doesn't directly correlatedly to Full Die

Take Away: Parametric test provides the data necessary to judge whether silicon process is in control

Parametric Test Structures and Probing Process Attributes

Elements from the Product Die are placed into the Frame/Scribe/Kerf area

Objective: To test basic elements used to fabricate complex circuitry in product die



Wafer surface types:
- Grown semi-flat
- Polished flat

Die attach methods:
- Wire Bond pads
- C4 bumped die

Parametric test structures are based on silicon technology design rules

Take Away: No 1:1 correlation between Product Die and Parametric test results

Parametric Test Structures and Probing Process Attributes

Where do our customers need our help?

Parametric test evaluates the wafer fab's process capability of yielding product die and monitors health of factory as a function of time and material.

- **Parametric testers can obtain outstanding measurement accuracy**
  - **where 3σ accuracy = 1µA / 1000µA = 0.1%**
- **Wafer probers have stepping precision down in single micron level**
  - **where 3σ accuracy = 3um / 2mm Die Size = 0.15%**
- **However, Contact Resistance (CRes) numbers are not as accurate**
  - **where typical 3σ accuracy 0.5 ohm / 1.5 Ohms = 33%**

Take Away: Obtaining the best possible parametric test data is a function of uniform probe tip performance throughout its' lifetime.

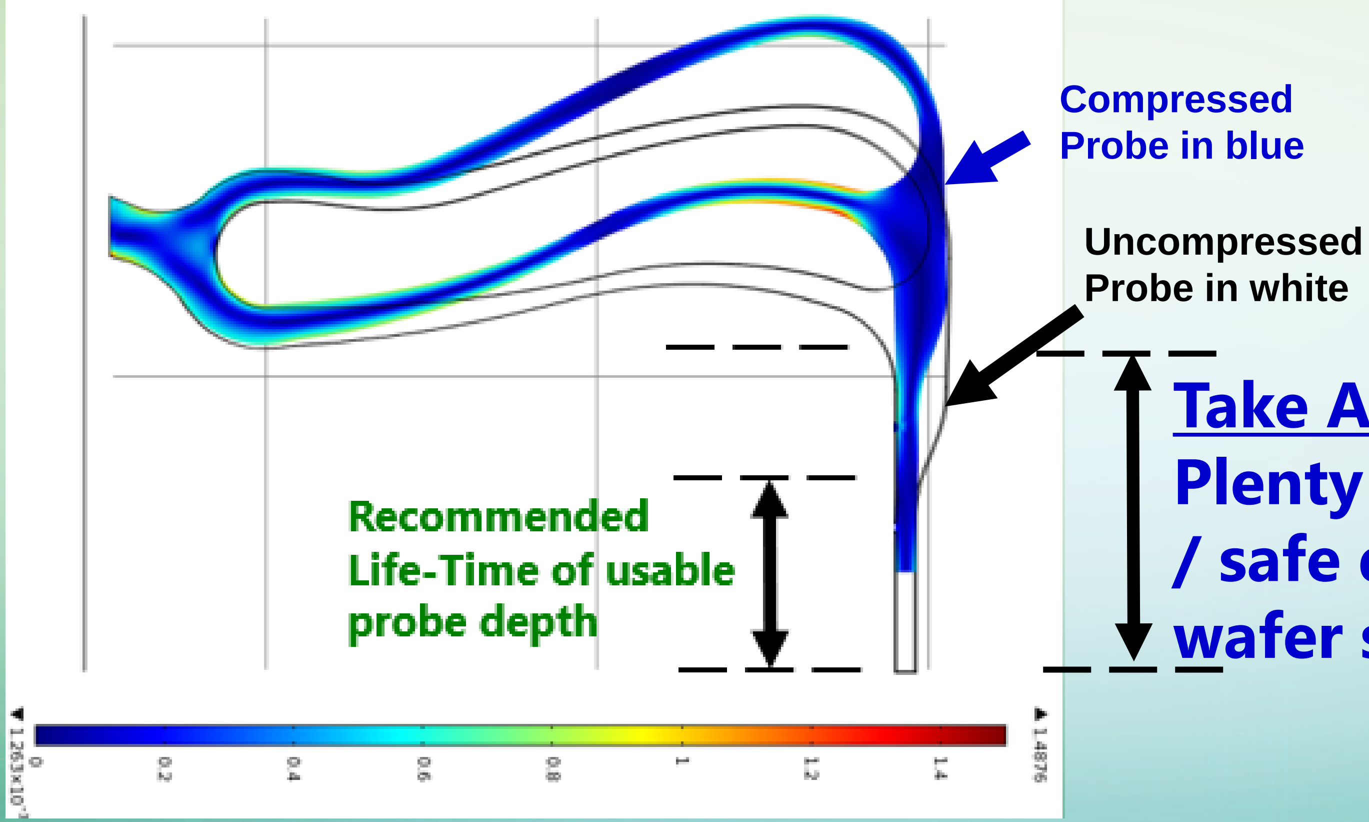
Parametric Test Structures and Probing Process Attributes

- **Comparison of various physical probe attributes across different probe technologies**

Parametric Test Structures and Probing Process Attributes

TPEG™ MEMs New eMantis Probe Technology

Simulation results using 200µm OT (100% over max value)



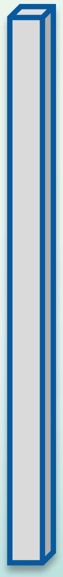
- **Uniform and controlled mechanical stress across needle**
- **Vertical movement lowers X-axis scrub motion to about 10µm**

Take Away:
Plenty of clearance / safe distance to wafer surface

Parametric Test Structures and Probing Process Attributes

Aspect Compared	Long Arm Cantilever	MEMS Trapezoid Shaped Probes	MEMS eMantis Probes with Long Tip Length
Probe Shape	Tapers from knee of wire to tip	Tapers from base of probe to tip	Zero taper, as probe has uniform shape over entire life-time

Probe Technologies:
- Blade / Tungsten
- Epoxy / Cantilever
- MEMS

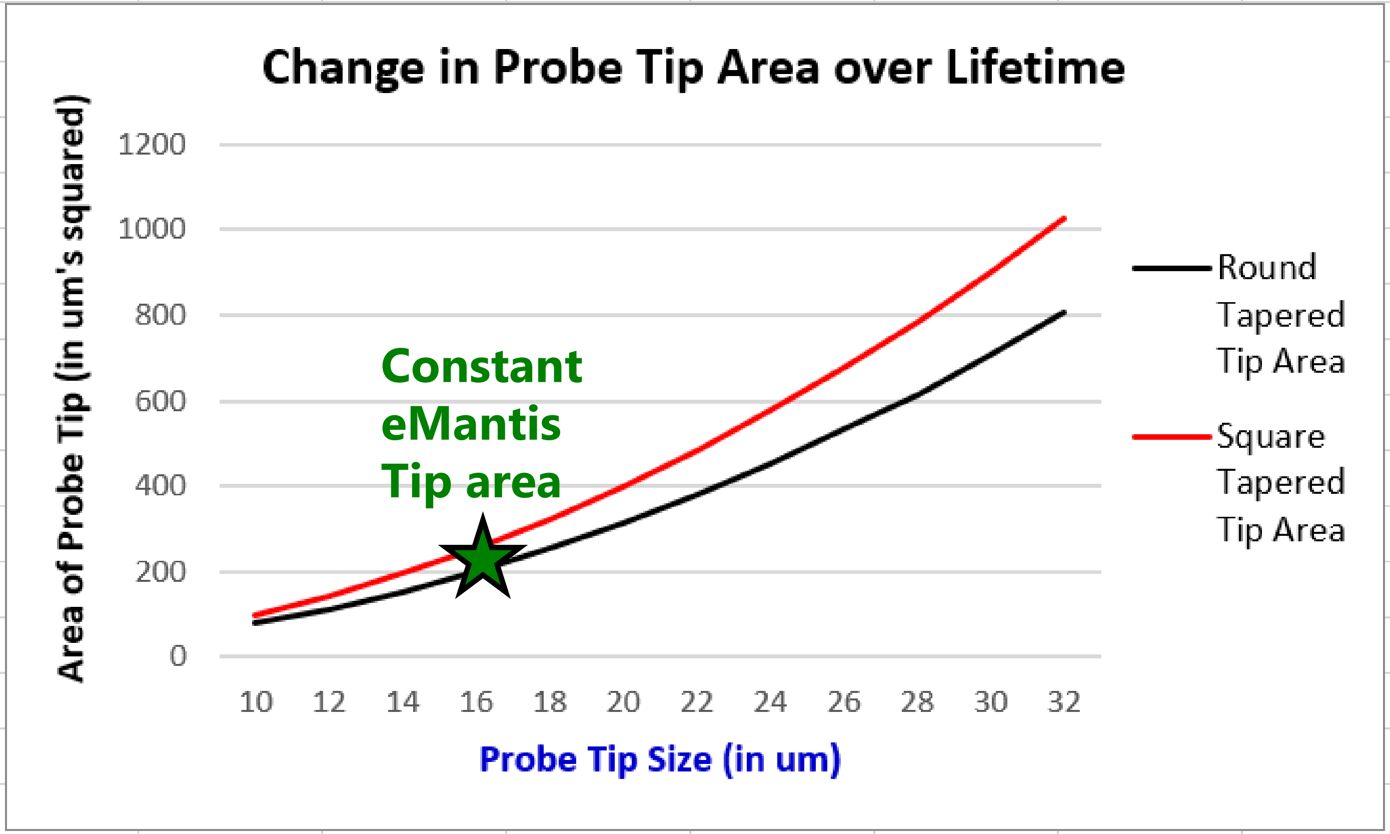


Note:
Parametric probe technologies come in several different shapes

Take Away: Tapered probe tips constantly increase in size over their Life-Time

Parametric Test Structures and Probing Process Attributes

Aspect Compared	Long Arm Cantilever	MEMS Trapezoid Shaped Probe	MEMS eMantis Probes with Long Tip Length
Growth of probe tip	Increases with usage	Increases with usage	Constant eMantis dimensions (see star below) provides uniform tip size & scrub effectiveness

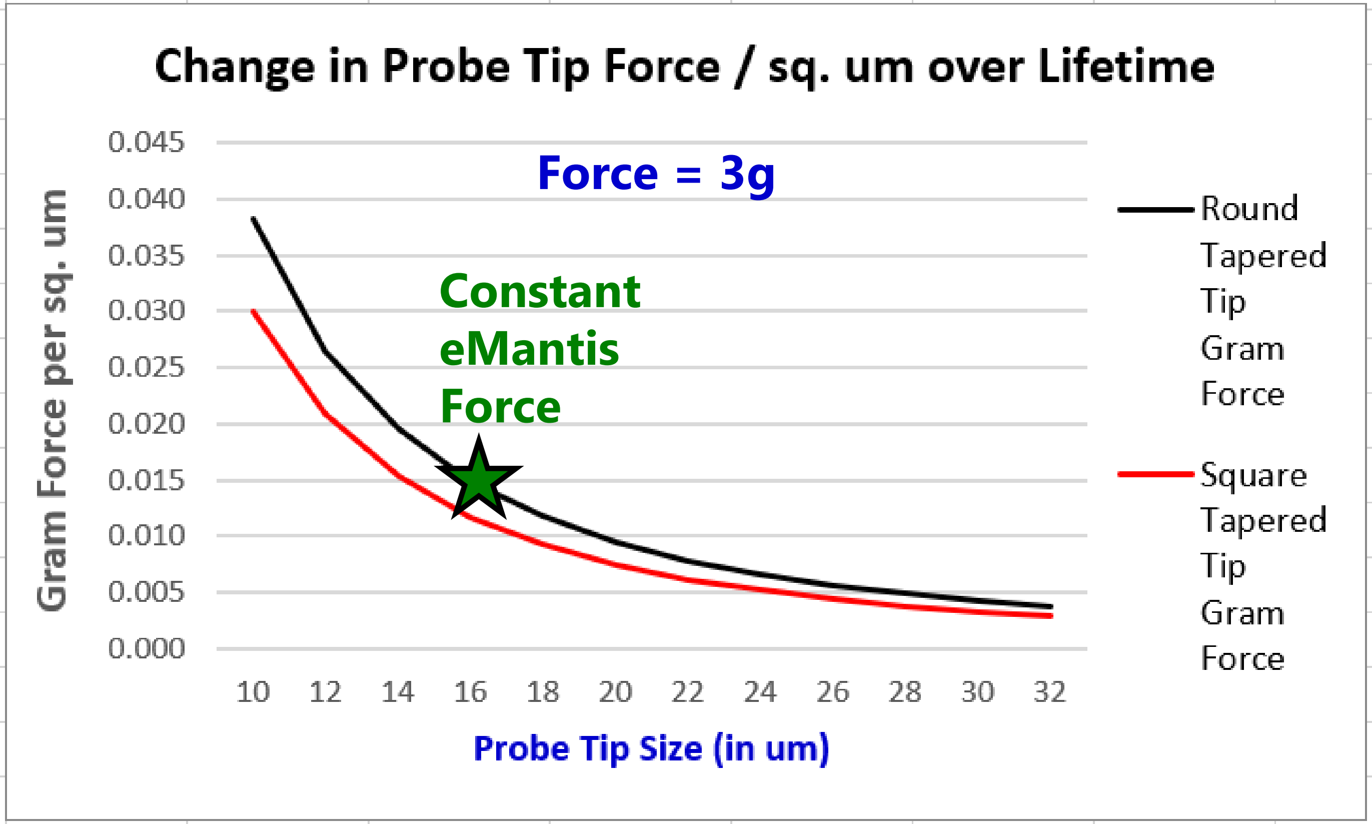


Tips initially starting at 10um and growing to 32um increase in area by 1000%

Take Away: Increasing tip size of tapered probe degrades scrub depth / effectiveness

Parametric Test Structures and Probing Process Attributes

Aspect Compared	Long Arm Cantilever	MEMS Trapezoid Shaped Probe	MEMS eMantis Probes with Long Tip Length
Gram Force per sq µm	Decreases as tip diameter increases	Decreases as tip size increases	Force remains constant (see star below) over Life-Time of the probe

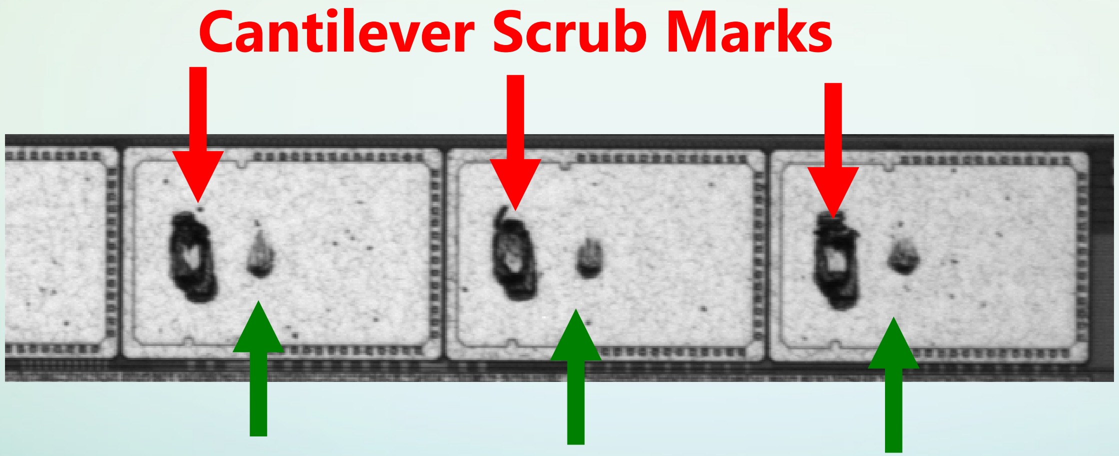


Tips initially starting at 10um and growing to 32um decrease the Force / sq µm by 1000%

Take Away: Increasing tip size of tapered probe decreases Gram Force / sq µm on pad

Parametric Test Structures and Probing Process Attributes

Aspect Compared	Long Arm Cantilever	MEMS Trapezoid Shaped Probe	MEMS eMantis Probes with Long Tip Length
Scrub Length	Long, around 20um	Short to medium in length	Short length uses less pad area, is less likely to hit passivation and has greater probing process margin

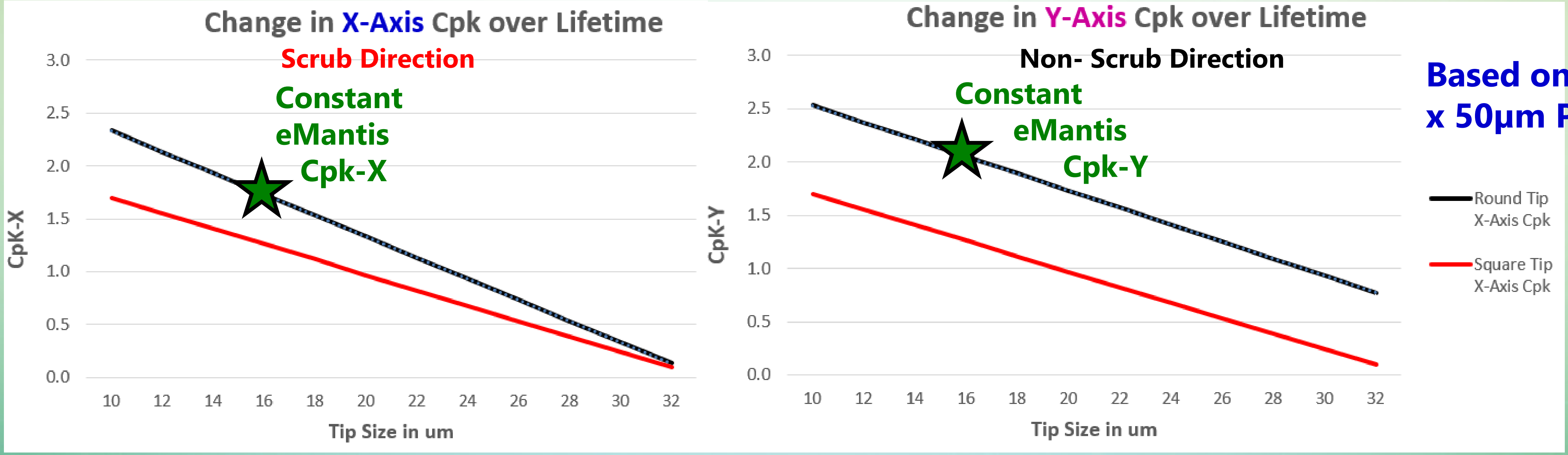


OT = 75µm T = 25°C

Take Away: eMantis has shorter scrubs, less debris and greater probing process margin

Parametric Test Structures and Probing Process Attributes

Aspect Compared	Long Arm Cantilever	MEMS Trapezoid Shaped Probe	MEMS eMantis Probes with Long Tip Length
Cpk	Degrades with wear	Degrades with wear	Uniform shape (see star below) yields constant probing process Cpk over lifetime of probe



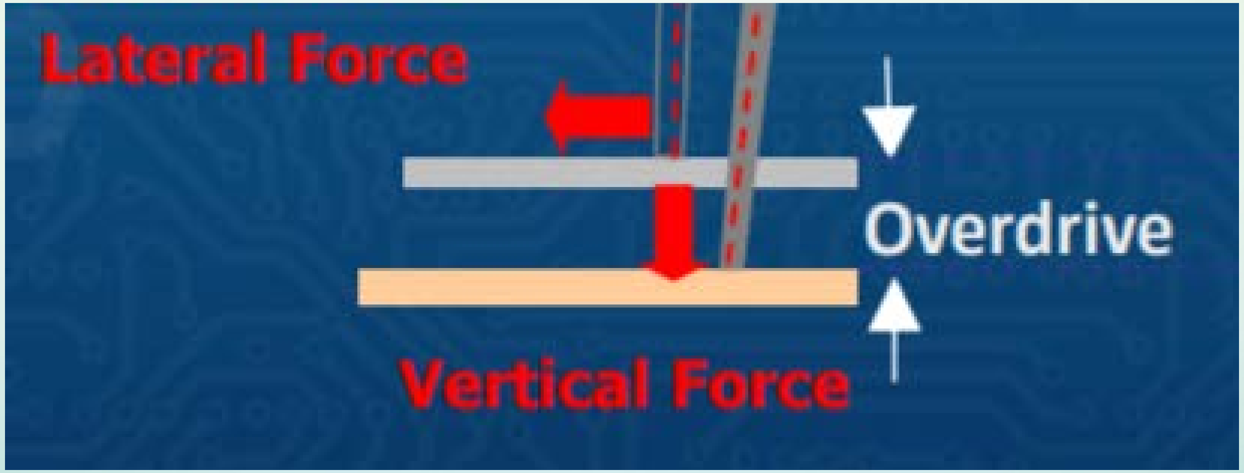
Based on 50µm x 50µm Pad Size

Take Away: eMantis probes yield constant Cpk over their Life-Time

Parametric Test Structures and Probing Process Attributes

Aspect Compared	Long Arm Cantilever	MEMS Trapezoid Shaped Probe	MEMS eMantis Probes with Long Tip Length
Probe Forces	Heavy	Medium to Heavy	Light, which results in an increased wafer die yield which lowers Cost of Ownership

Medium/Heavy Lateral compresses Si circuits adjacent to probed pads

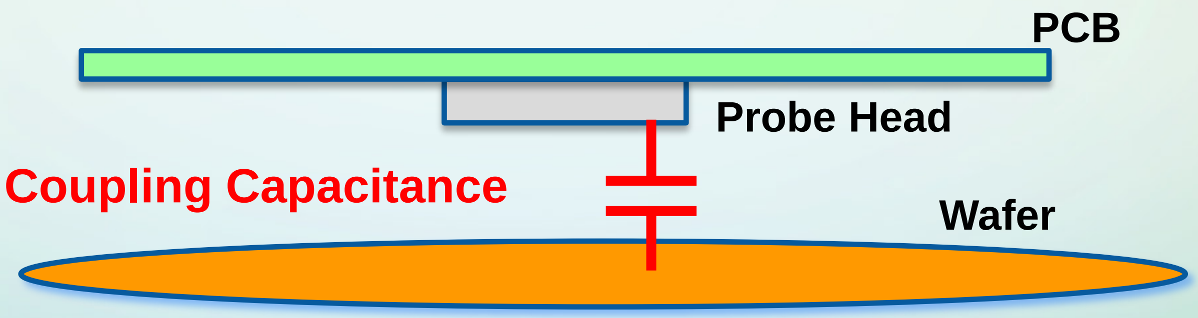


Heavy Vertical Force can crack the Inter-Layer-Dielectric (ILD)

Take Away: Less lateral / vertical forces minimizes the amount of die / wafer damage

Parametric Test Structures and Probing Process Attributes

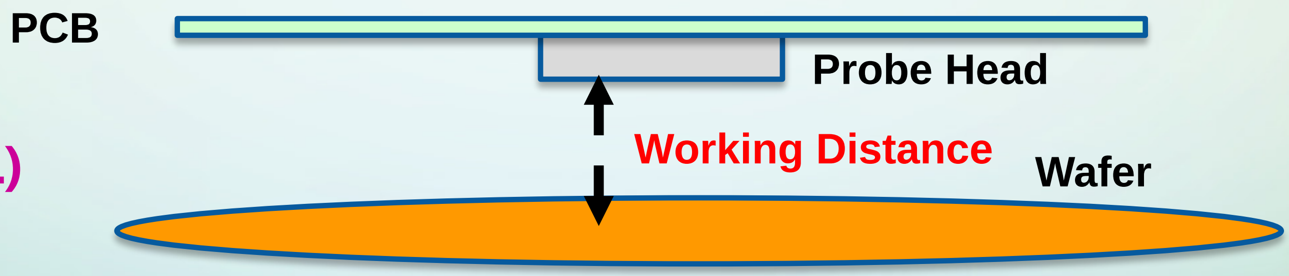
Aspect Compared	Long Arm Cantilever	MEMS Trapezoid Shaped Probe	MEMS eMantis Probes with Long Tip Length
Measurement coupling to wafer surface	Ok, as good separation of probes and wafer	High, as short height, very close to or even touching wafer surface	Minimum. Excellent separation between probes and wafer due to large distance from probe head to wafer surface.



Take Away: eMantis probes lower coupling to wafer, which yields a truer data signature

Parametric Test Structures and Probing Process Attributes

Aspect Compared	Long Arm Cantilever	MEMS Trapezoid Shaped Probe	MEMS eMantis Probes with Long Tip Length
EoL distance from probe beam to wafer surface	Reasonably good	Extremely close to wafer surface	Best in class. Even at EoL the probe array still has excellent clearance from probe tip to the horizontal surface of probe body.



Note: End-of-Life (EoL)

Take Away: eMantis provides the best protection against scratching die / wafers

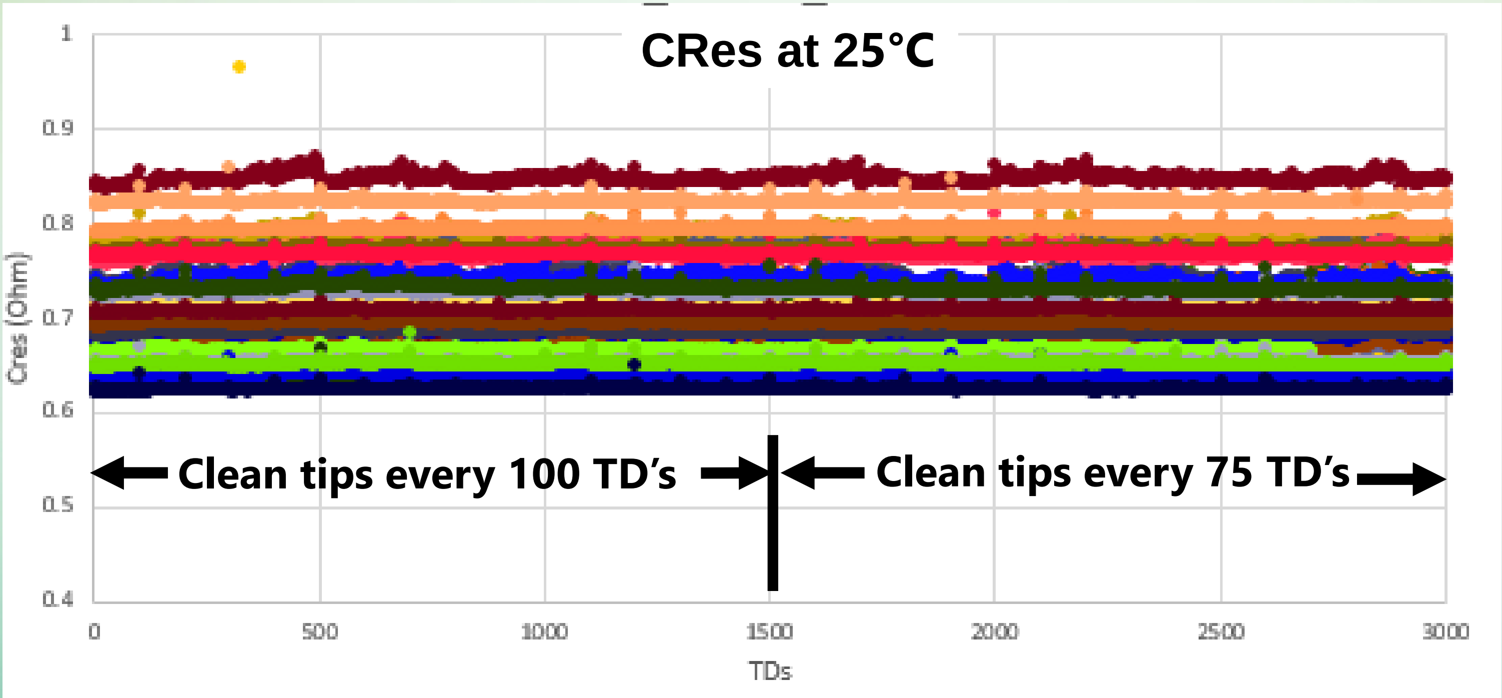
Parametric Test Structures and Probing Process Attributes

- **Data review of Technoprobe's new eMantis parametric probe technology**

Parametric Test Structures and Probing Process Attributes

<u>**25°C CRes test conditions:**</u>

- 1→1500 TDs @ 90μm OT (blank Al wafer) cleaning w/5TD's @50μm OT on MIPOX every 100 TD's
- 1501→3000 TDs @ 90μm OT (blank Al wafer) cleaning w/5TD's @50μm OT on MIPOX every 75 TD's



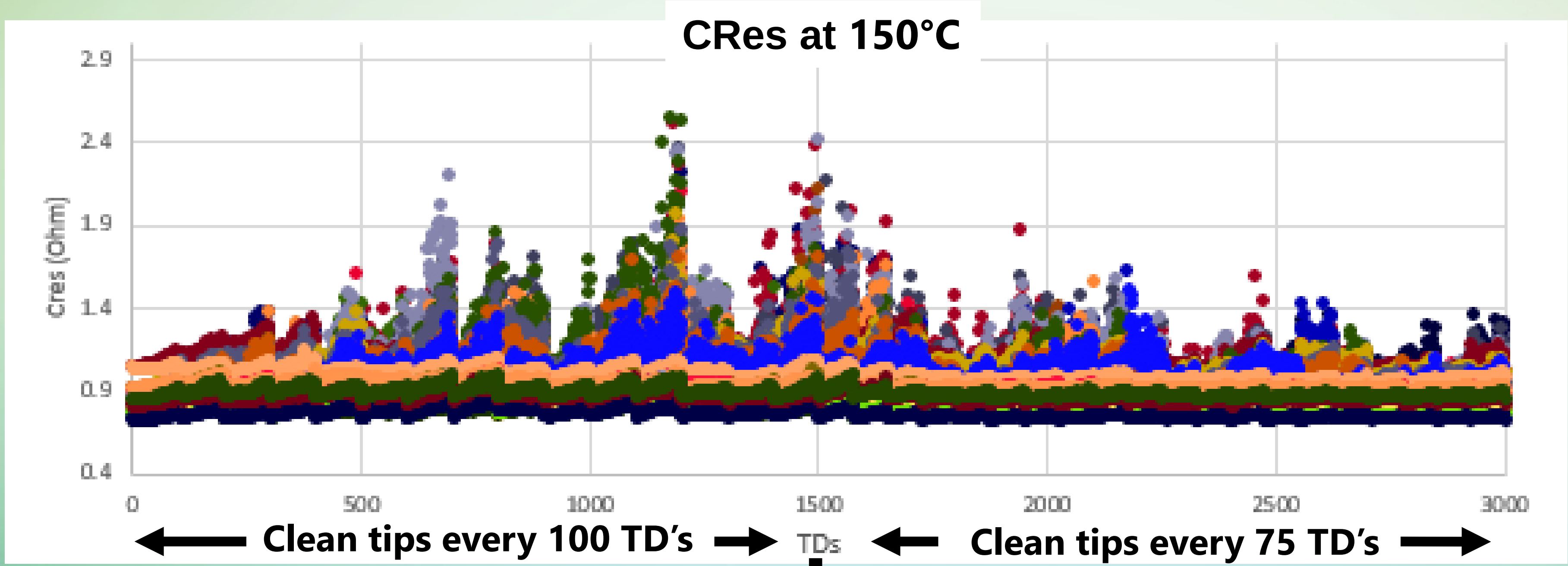
No CRes change between cleaning rates, therefore suggest using 100 TD's

<u>Take Away:</u> Test results show outstanding CRes, which is stable, repeatable and has a very low 3σ value

Parametric Test Structures and Probing Process Attributes

150°C CRes test conditions:

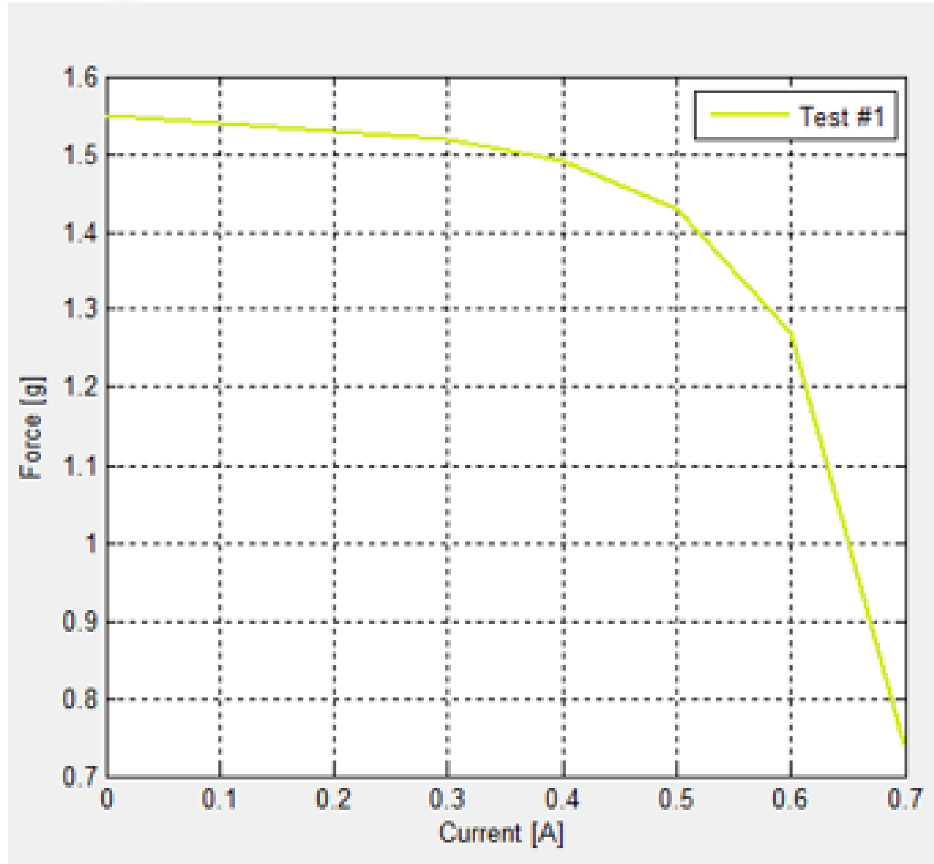
- 1→1500 TDs @ 90µm OT (blank Al wafer) cleaning w/5TD's @50µm OT on MIPOX every 100 TD's
- 1501→3000 TDs @ 90µm OT (blank Al wafer) cleaning w/5TD's @50µm OT on MIPOX every 75 TD's



Note:
Higher cleaning rate at 75 TD's reduces CRes variation

Take Away: Results show good CRes data, which is impacted by oxide growth on wafer surface

Parametric Test Structures and Probing Process Attributes

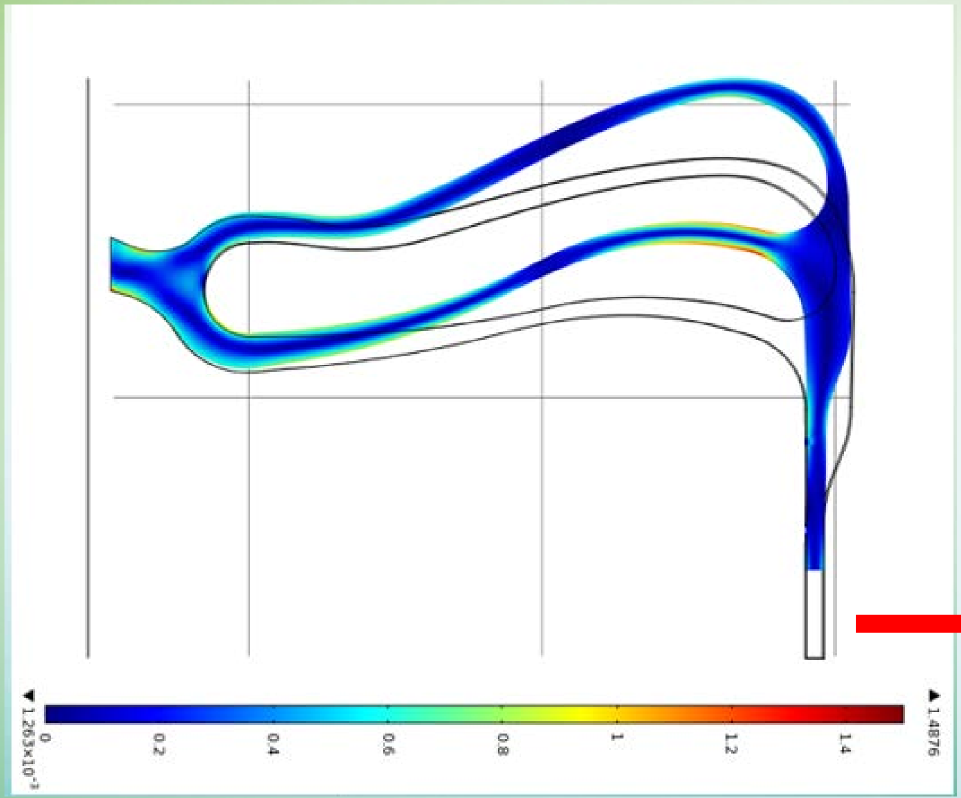


- **The Current Carrying Capability (CCC) is defined as the maximum direct current that can be carried by a probe without any damage or burning for an indefinite time.**
- **Whenever the force is reduced by 10% from its original measurement that corresponding value of current is the maximum CCC.**
- **Force reduction is due to probe heating that leads to a drop in the probe stiffness.**

CCC Results @ 10% = 532mA @ 20% = 610mA

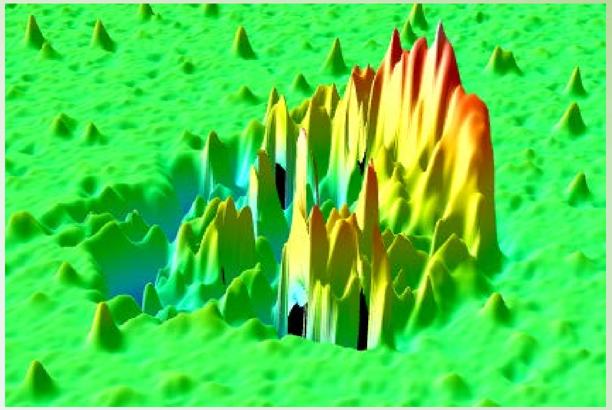
Take Away: eMantis probes provide excellent CCC for parametric test application

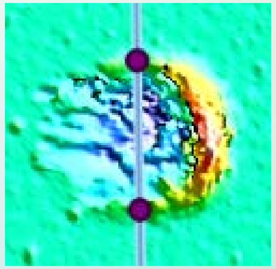
Parametric Test Structures and Probing Process Attributes

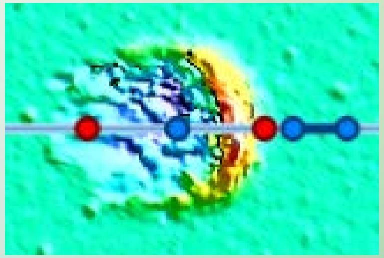


- **L = Length [µm]**
- **D = Depth [nm]**
- **W =Width [µm]**

Scrub Mark Direction







<u>Take Away:</u> eMantis probes have short scrubs, which minimizes damage to pads

Parametric Test Structures and Probing Process Attributes

25°C scrub results using TD's = 1, 3, 6 and OT = 75µm, 100µm

OT = 75µm

TD=1	OT=75 µm
	MIN - MAX
L [µm]	11.8 – 17.9
D [nm]	123.6 – 441.8
W [µm]	10.7 – 13.3

TD=3	OT=75 µm
	MIN - MAX
L [µm]	15.3 – 19.3
D [nm]	297.8 – 588.8
W [µm]	13.1 – 15.1

TD=6	OT=75 µm
	MIN - MAX
L [µm]	16.8 – 21.5
D [nm]	186.1 – 553.8
W [µm]	14.4 – 18.1

OT = 100µm

TD=1	OT=100 µm
	MIN - MAX
L [µm]	12.2 – 18.3
D [nm]	259.9 – 408.6
W [µm]	13.1 – 15.3

TD=3	OT=100 µm
	MIN - MAX
L [µm]	14.5 – 20.5
D [nm]	255.0 – 492.2
W [µm]	14.3 – 15.8

TD=6	OT=100 µm
	MIN - MAX
L [µm]	15.1 – 19.8
D [nm]	316.1 – 633.8
W [µm]	14.2 – 16.5

Take Away: eMantis stat's remain relatively constant across # of TD's and OT

Parametric Test Structures and Probing Process Attributes

150°C scrub results using TD's = 1, 3, 6 and OT = 75µm, 100µm

TD=1 OT=75 µm	MIN - MAX	TD=3 OT=75 µm	MIN - MAX	TD=6 OT=75 µm	MIN - MAX	
L [µm]	18.2 – 18.3	L [µm]	16.8 – 19.9	L [µm]	17.5 – 21.1	
D [nm]	142.0 – 277.9	D [nm]	132.1 – 471.0	D [nm]	187.5 – 461.8	OT = 75µm
W [µm]	12.9 – 16.3	W [µm]	12.8 – 17.3	W [µm]	12.8 – 16.7	
TD=1 OT=100 µm	**MIN - MAX**	**TD=3 OT=100 µm**	**MIN - MAX**	**TD=6 OT=100 µm**	**MIN - MAX**	
L [µm]	18.4 – 19.5	L [µm]	17.7 – 23.5	L [µm]	18.9 – 20.4	
D [nm]	183.0 – 424.5	D [nm]	189.4 – 314.8	D [nm]	164.4 – 400.4	OT = 100µm
W [µm]	13.5 – 17.8	W [µm]	13.2 – 16.7	W [µm]	15.1 – 19.6	

Take Away: eMantis stat's remain relatively constant across # of TD's and OT

Parametric Test Structures and Probing Process Attributes

Conclusion of temp study comparing TD's = 6 at Temp = 25°C & 150°C

	Temp = 25°C		Temp = 150°C	
OT = 75μm	L [μm]	19.12μm	L [μm]	19.29μm
	D [nm]	369.95nm	D [nm]	324.66nm
	W [μm]	16.21μm	W [μm]	14.71μm
OT = 100μm	L [μm]	17.43μm	L [μm]	19.66μm
	D [nm]	474.94nm	D [nm]	282.42nm
	W [μm]	15.35μm	W [μm]	17.39μm

Take Away: No significant difference between results at 25°C and 150°C

Parametric Test Structures and Probing Process Attributes

1M TD Life-Time Probe Tip Wear Rate Study

- **Cleaning recipe:**
  - **Frequency: 100 TD's**
  - **Material: Mipox WA6000**
  - **Pattern/OT: 5 Up/Down cycles at 50µm**
- **Tip wear results:**
  - **At 500K TD's = 15 µm**
  - **At 1M TD's = 32 µm**
- **Life-Time expectation is 5M TD's**
- **Scrub movement on pad has radius of 6 µm**

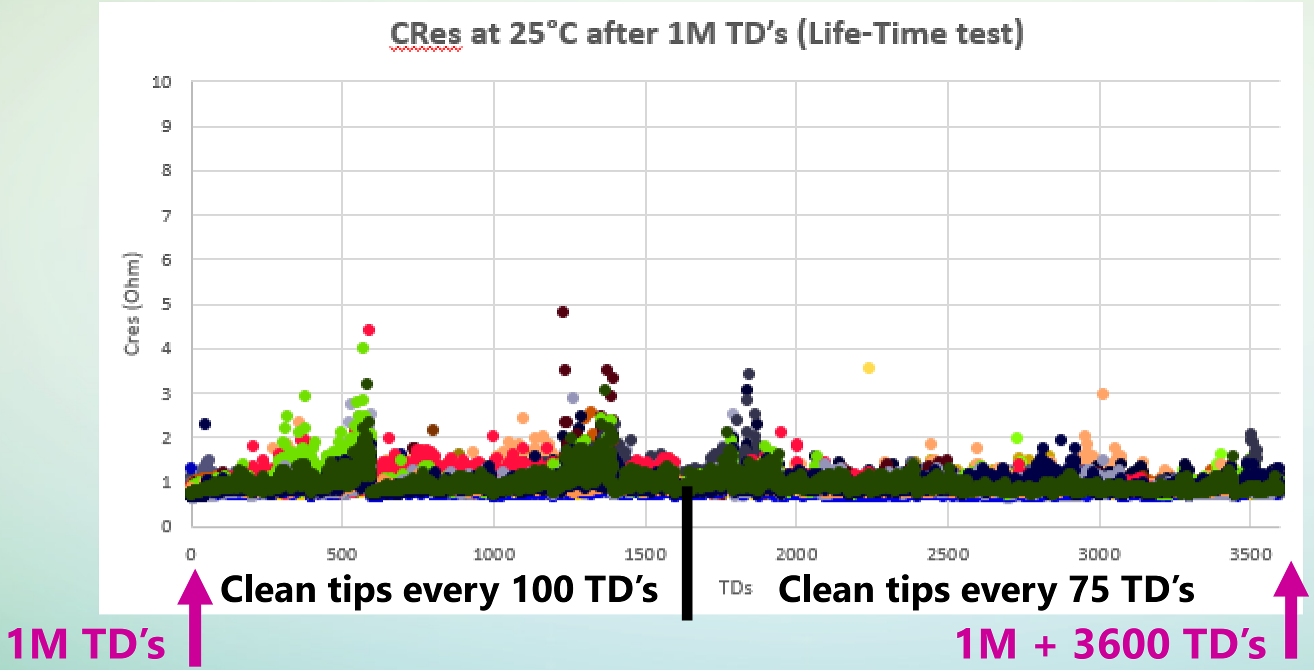
Take Away: Tip Wear Rate study shows that eMantis probes have a very long Life-Time

Parametric Test Structures and Probing Process Attributes

<u>25°C Test conditions:</u>

- 1→1600 TD's @ 90µm OT (blank Al wafer) cleaning w/5TD's @50µm OT on MIPOX every 100 TD's
- 1601→3600 TD's @ 90µm OT (blank Al wafer) cleaning w/5TD's @50µm OT on MIPOX every 75 TD's

Data points on chart start after 1M TD's



CRes data results post 1M TD's on probe tips

<u>Take Away:</u> Test results show outstanding CRes, which is stable and has a very low 3σ value

Parametric Test Structures and Probing Process Attributes

Comparison of Initial Scrubs (TD's = 6) versus Wear Rate study at 1M TD's

	25°C (6 TD's)		25°C (1M TD's)	
OT = 75µm	L [µm]	19.12	L [µm]	12.66
	D [nm]	369.95	D [nnm]	252.75
	W [µm]	16.21	W [µm]	11.08
OT = 100µm	L [µm]	17.43	L [µm]	11.6
	D [nm]	474.94	D [nm]	377.5
	W [µm]	15.35	W [µm]	12.52

Take Away: scrubs after 1M TD's are smaller than initial because probe tip contact surface is becoming rougher

Parametric Test Structures and Probing Process Attributes

Thank You and Recognition

- **Riccardo Vettori – Technoprobe SPA Italy**
  - **R&D and Process Manager - Pathfinding**
- **Giulia Rottoli – Technoprobe SPA Italy**
  - **R&D and Process Engineer - Pathfinding**
- **Giorgia Delachi – Technoprobe SPA Italy**
  - **R&D and Process Engineer - Pathfinding**
- **SW Test Committee for this opportunity**

Parametric Test Structures and Probing Process Attributes

Next Steps

- Expand product application of eMantis technology
- Execute eMantis probe pitch shrink roadmap
- Return to SW Test in future with customer data

Parametric Test Structures and Probing Process Attributes

Summary

- Parametric test is small but steady part of probe card market
- Parametric data is critical for monitoring Si process health
- Test structures are building blocks of product die circuitry
- Constantly changing tip attributes degrades test results
- Lowering 3σ value of CRes is critical for collecting great data
- Customers require best test data & highest yield possible

Parametric Test Structures and Probing Process Attributes

Q&A