SW Test Workshop
Semiconductor Wafer Test Workshop

A Probe Card Inspection Process Enabling Fast Feedback Loops

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nanofocus®
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Overview

- NanoFocus AG
- Motivation, Background, Targets
- Objectives, Specifications
- Approach, Material
- Characterization, Results
- Summary, Perspectives

NanoFocus AG

- Optical 3D metrology supplier for QA, process control, zero defect strategies
- Integrated value chain from R&D over production to customer support & service

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Motivation

- Why did we want to create such a probecard inspection process?

„Make sure an **intact wafer condition after test**“

„**To control test** is to control the mechanical contact and the electrical contact between the probes and the DUT.“

J. Broz, S. Khavandi ITWS7 2015

„… while the electrical contact not least depends on the mechanical contact…“

Background

- How exactly could we contribute to such process?

„Continuous observation of head & clearance conditions avoids damage and loss”

„Continuous observation of wear & tear allows tight control of probe (tip) conditions”

„Fast feedback of the process allows shorter and more focused repair & maintenance cycles”

„Fast feedback of the process allows closed loop of observation”

Target

Wafer Test

Probe Card Storage

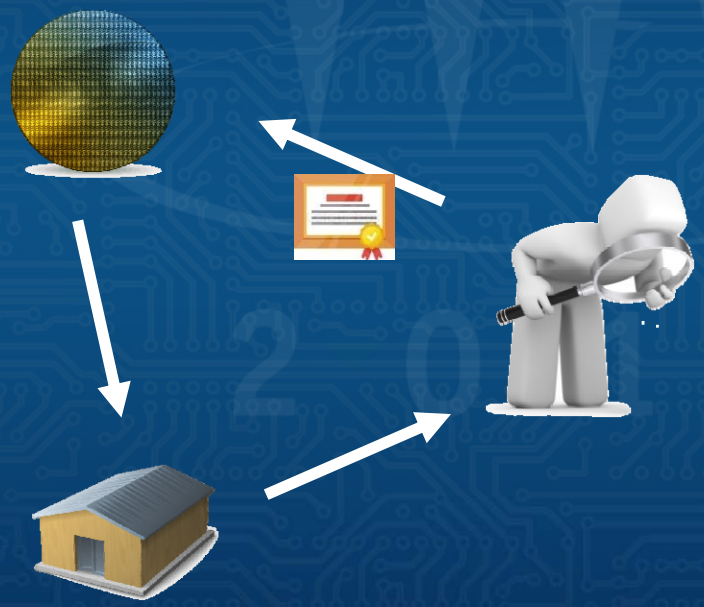
Target

Wafer Test

Inspector

Probe Card Storage

Target



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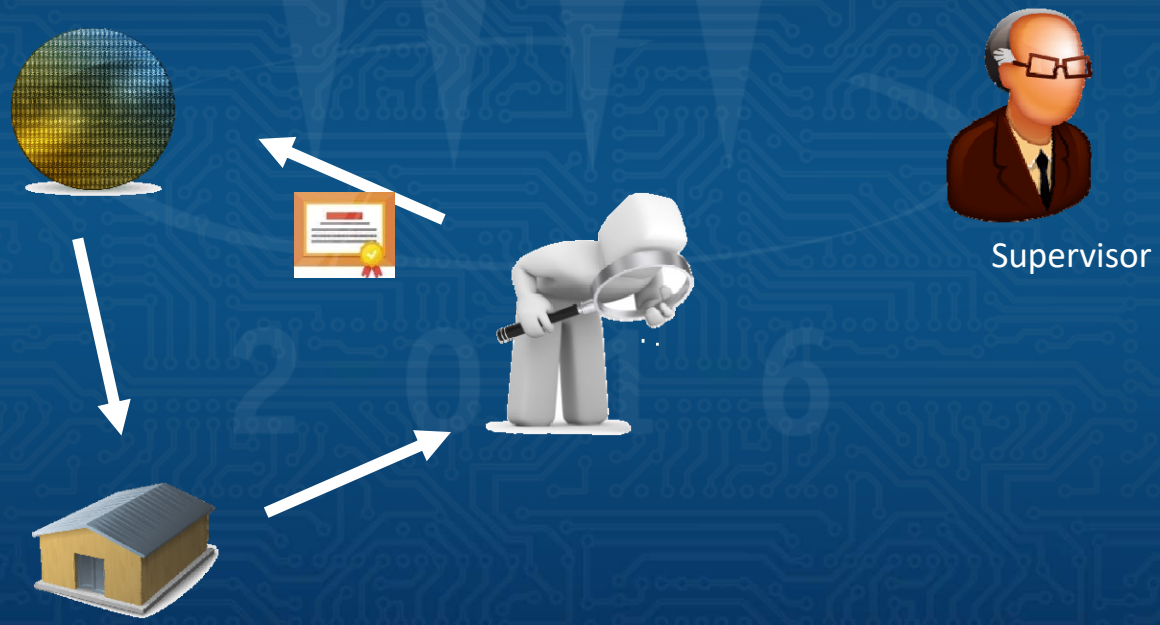

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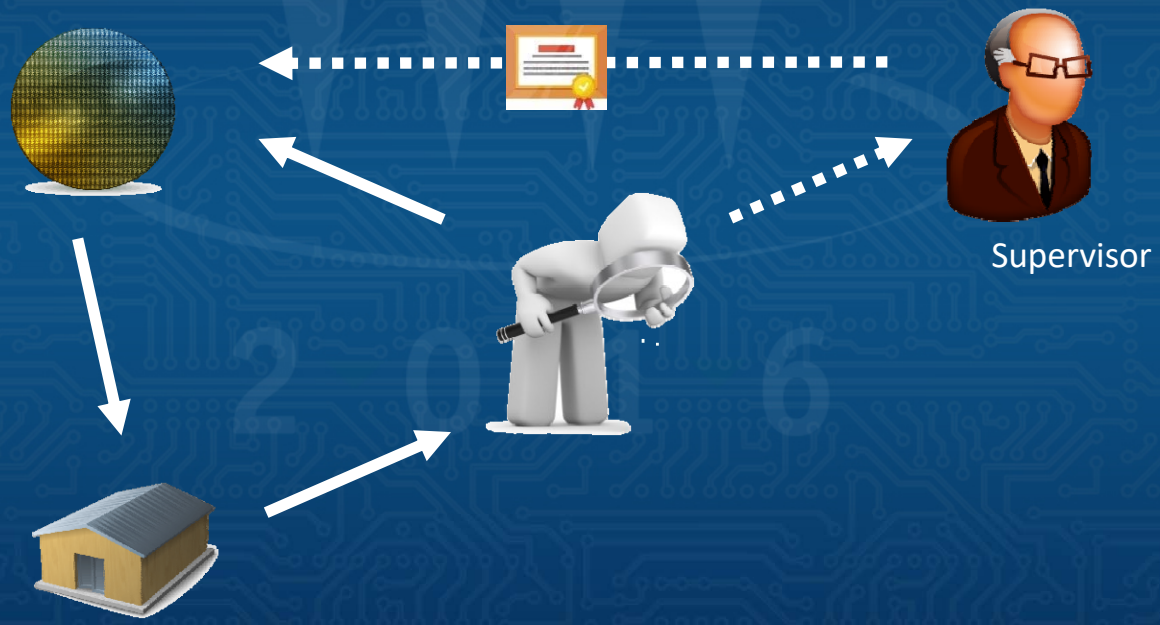
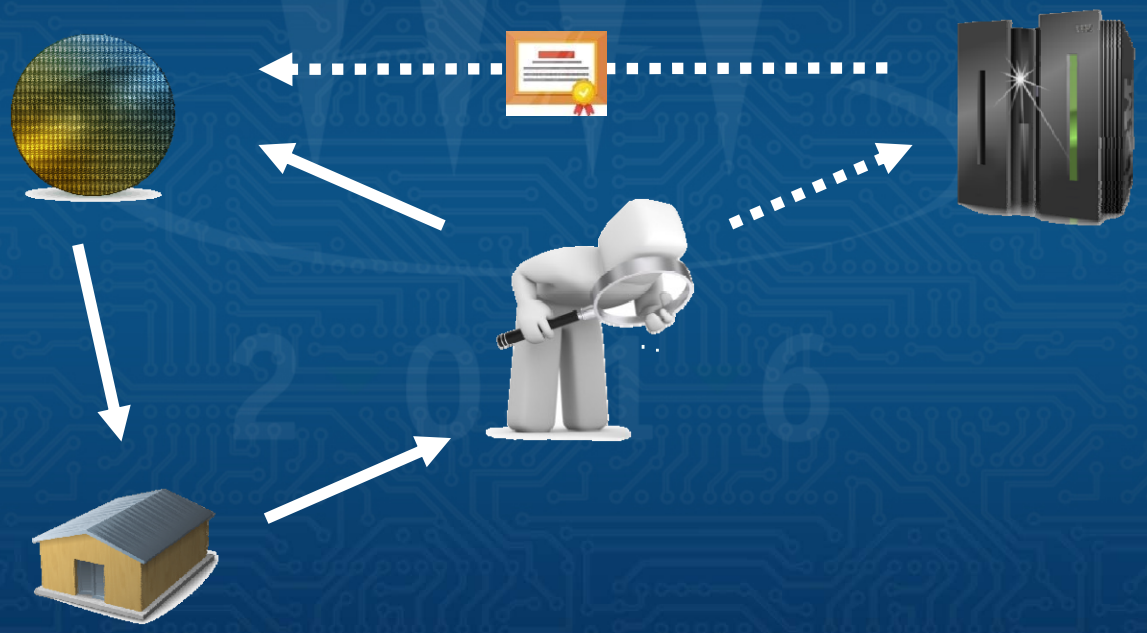
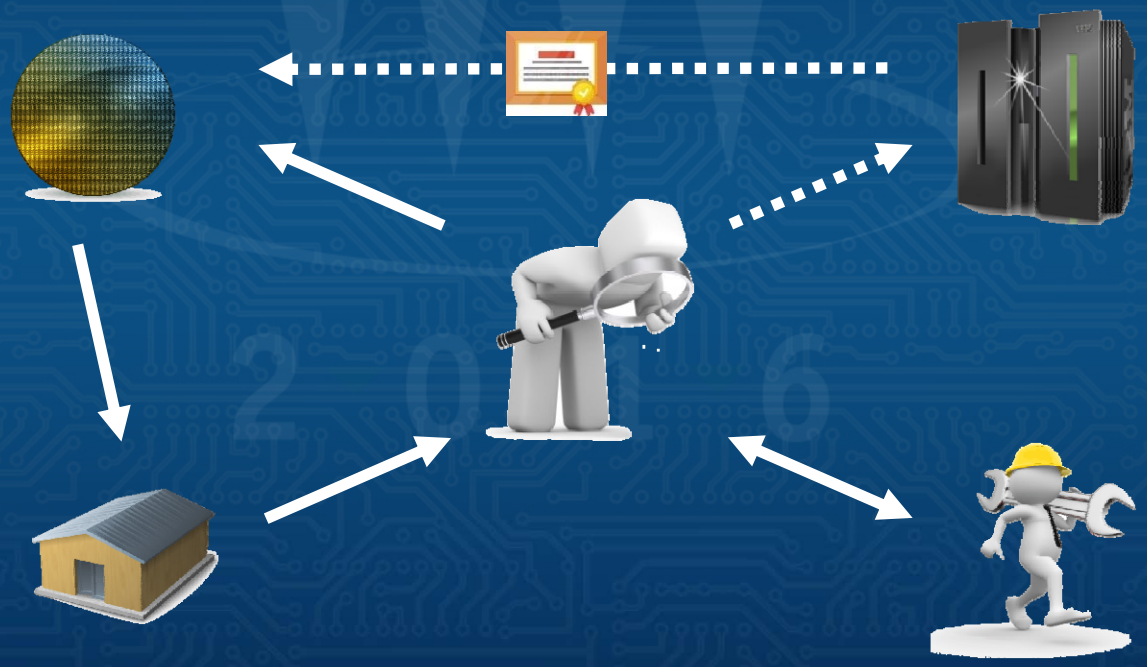


Target

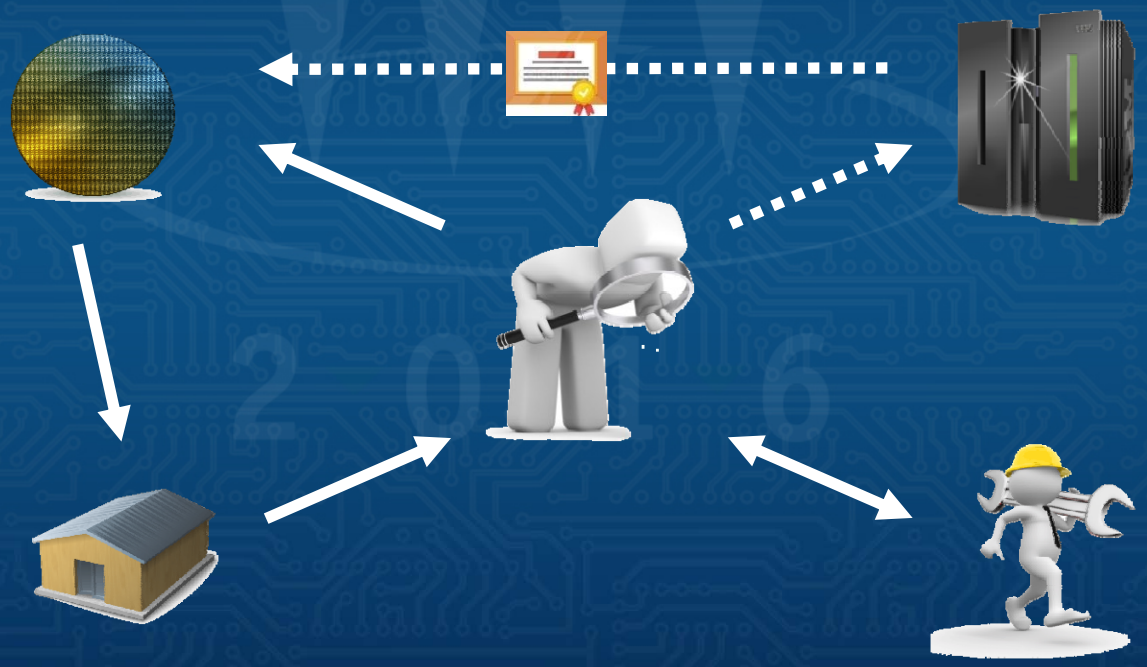


Target



Target

„A fast probe card inspection enabling a clear and resilient decision about if a probe card is OK for testing or not.”



Objectives

- Which specifications do the acquired tip parameters have to meet?

Inspection	Parameter	Specification
Probe Tip	Misplacement	Precision: 2 µm @ 3σ Rel. Accuracy: 2 µm
	Diameter (min./maj.)	
	Height / Planarity	
	Tip Area [1)]	Precision: $\Delta A_i / \Delta A_{max,i} < 1$ Rel. Accuracy: n/a
	Tip Types	Verticals, MEMS, Cantilever, POGO

[1)] The factor stated for precision is resultuing from the error propagation of the diameters measured. The factor must result < 1 for the measurements to be in spec.

Objectives

- Which specifications do the other acquired parameters have to meet?

Inspection	Parameter	Specification
Probe Head	Planarity / Tilt	Precision: 2 µm @ 3σ Rel. Accuracy: n/a
Clearance	Object Detection[2)]	False Positives: < 2% Detection: > 98% Min. Object: 625 µm²
Time	Average UPH	Approx. 4 cards per Hour

[2)] The minimum detectable object size is depending on the lateral resolution settings. It can be reduced using higher lateral resolutions. It is possible with no HW changes but comes along with increased inspection time.

Approach

Feasibility Study
„Proving precision & accuracy targets.“

Tool Implementation
„Realizing a tool fitting site requirements.“

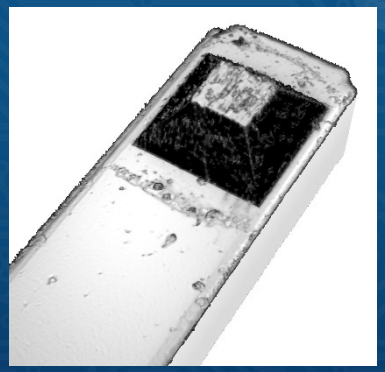
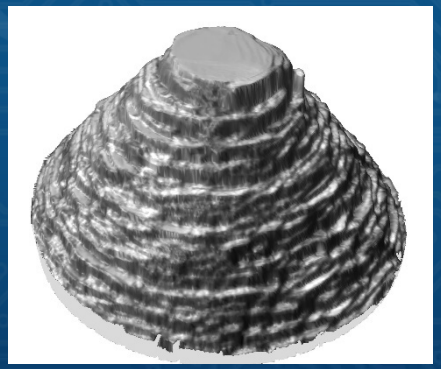
Tool Assessment
„Qualifying the tool for measurement ability and environmental effects.“

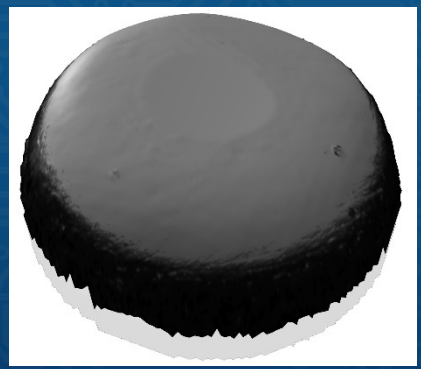
Tool Automation
„Enabling the tool for the process, SECS/GEM hook up.“

Approach - Material

- Selected material for feasibility study and AFAT

- MEMS Card
  ~13x 13 µm^2
- Vertical Card
  ~Ø 10 µm
- POGO Card
  ~Ø 30 µm
- Cantilever Card
  ~Ø 80 µm



Characterization

- Statistical results, precision & accuracy assessment tips

Inspection	Parameter	Specification	
Probe Tip	Misplacement	Precision: 2 µm @ 3σ Rel. Accuracy: 2 µm	
	Diameter (min. / maj.)		
	Height / Planarity		
	Tip Area [1)]	Precision: $\Delta A_i/\Delta A_{max,i} < 1$ Rel. Accuracy: n/a	
	Tip Types	Verticals, MEMS, Cantilever, POGO	

Characterization

- Statistical results, precision & accuracy assessment head, clearance

Inspection	Parameter	Specification	
Probe Head	Planarity / Tilt	Precision: 2 µm @ 3σ Accuracy: n/a	
Clearance	Object Detection[2)]	False Positives: < 2% Detection: > 98% Min. Object: 625 µm²	
Time	Average UPH	Approx. 4 cards per Hour	

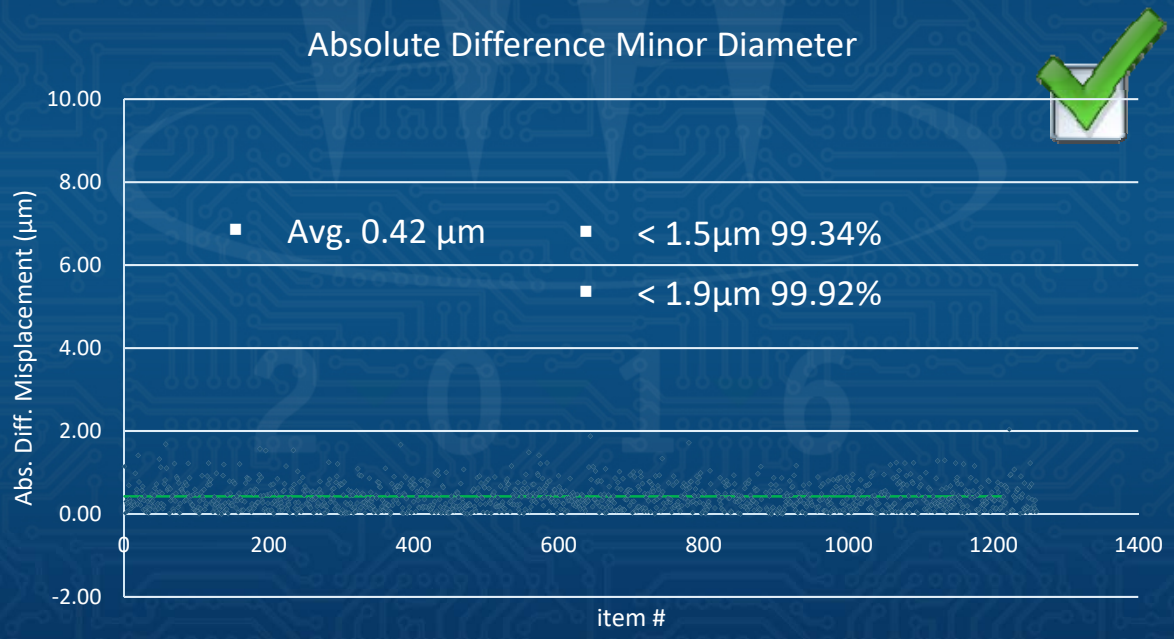
Characterization - Precision

- Precision assessment, example data on MEMS card

MEMS	Mean Stdev @ 3σ [µm]
Height	**0.781**
Area (DA / DAmax)	0.449
Minor Diameter	**1.245**
Major Diameter	1.323
Misplacement	0.806
Dist. to best plane fit	0.241
Planarity Error	**0.298**
Tilt Angle	0.001
No. of items	*2072.00*

Characterization - Comparison

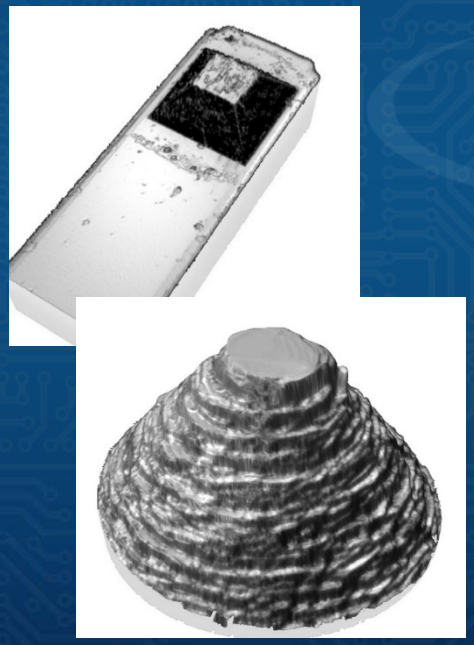
- Relative accuracy assessment, example data on vertical card



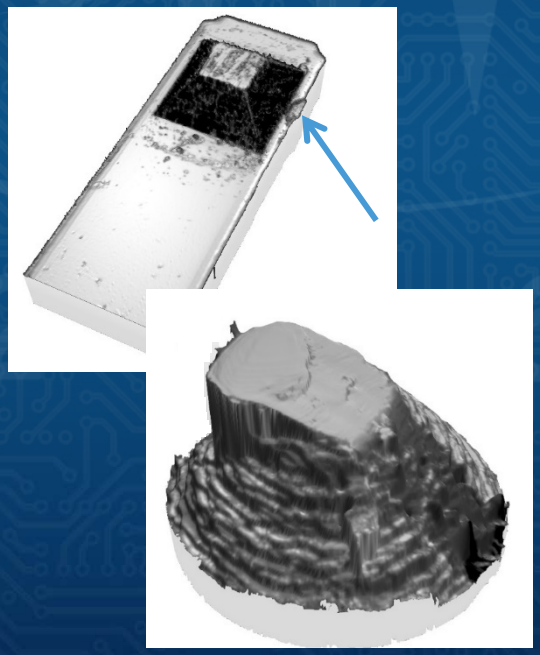
Characterization - Comparison

- Typical tip imperfections as found on reference cards

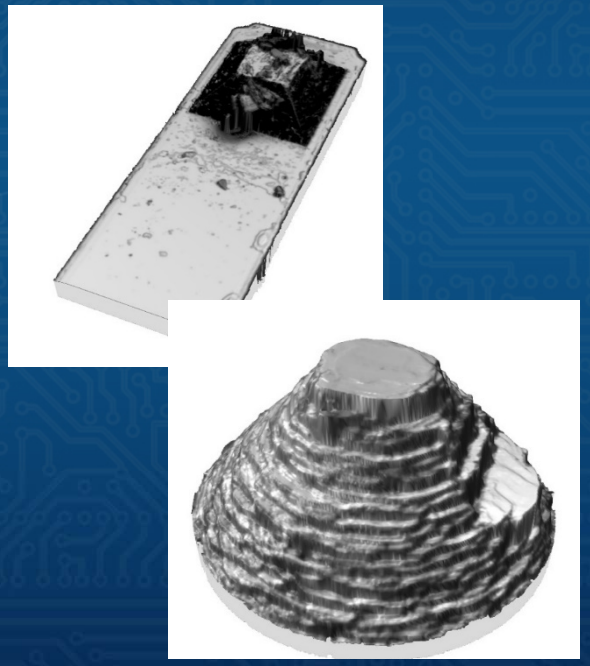
- OK Condition



- Scratches, Dents, Abrasion

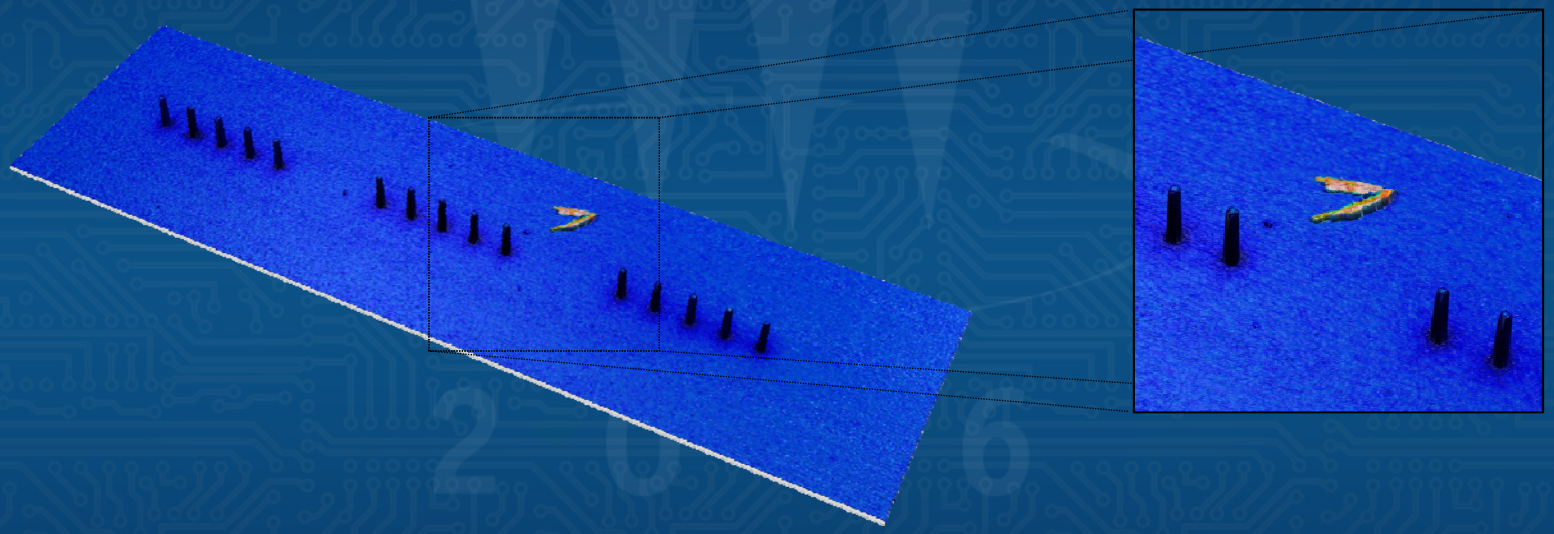


- Adhesions, Damages



Characterization - Clearance

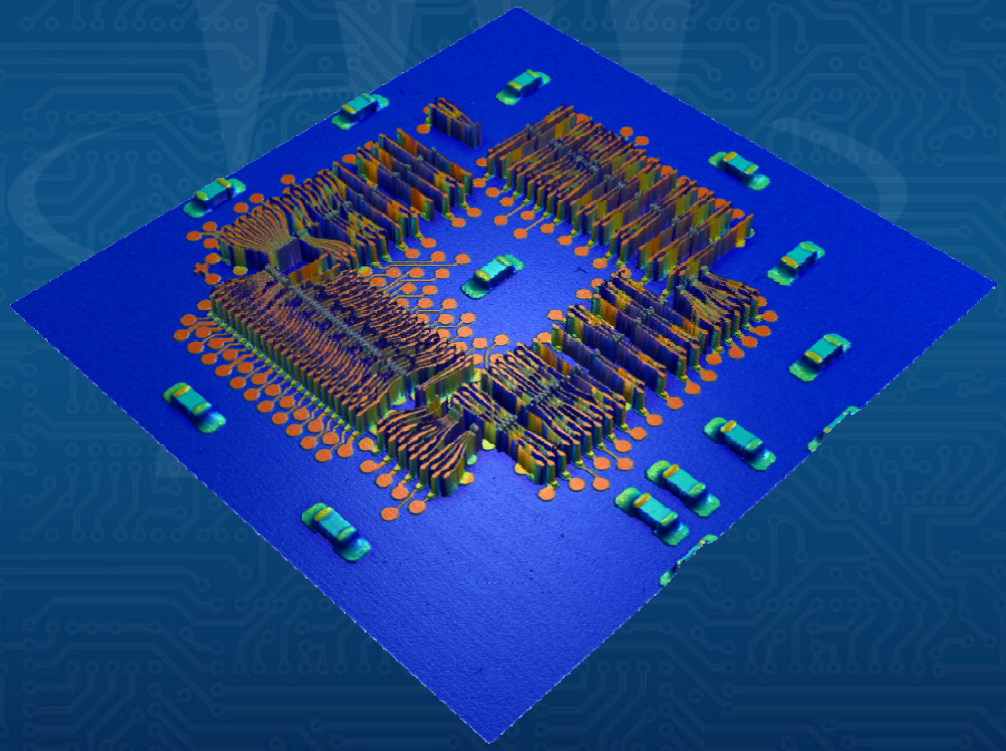
- Clearance inspection, capability on vertical card



- Particle & object detection in the clearance area is possible repeatedly & reliable
- „False positives“ and „slip“ are under long term surveillance

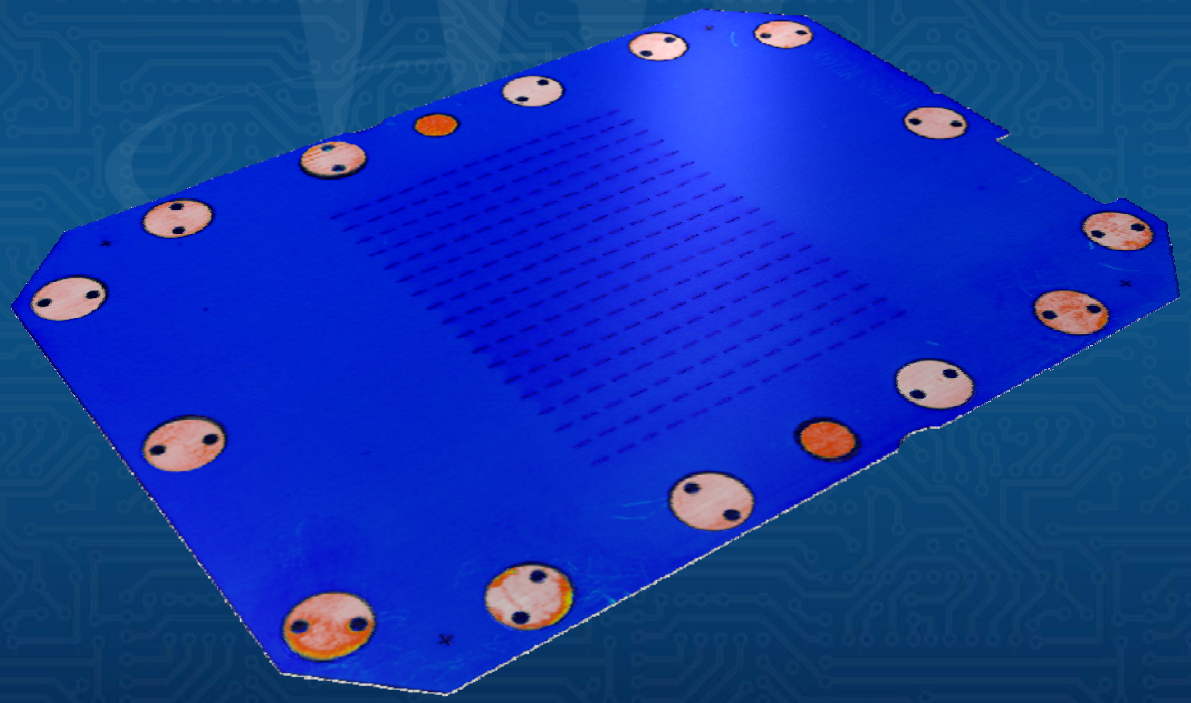
Characterization - Clearance

- Clearance inspection, capability on MEMS card



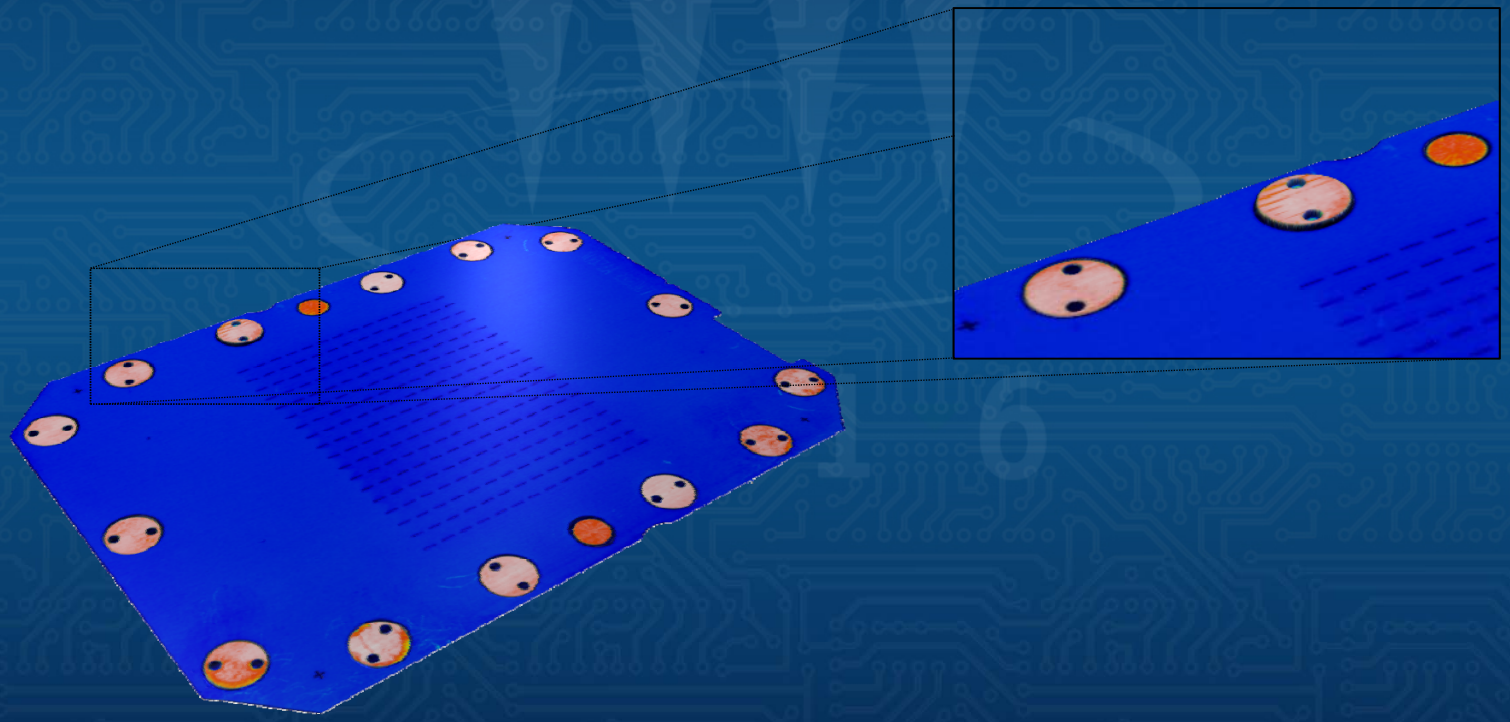
Characterization - Head

- Probe head inspection, capability on vertical card



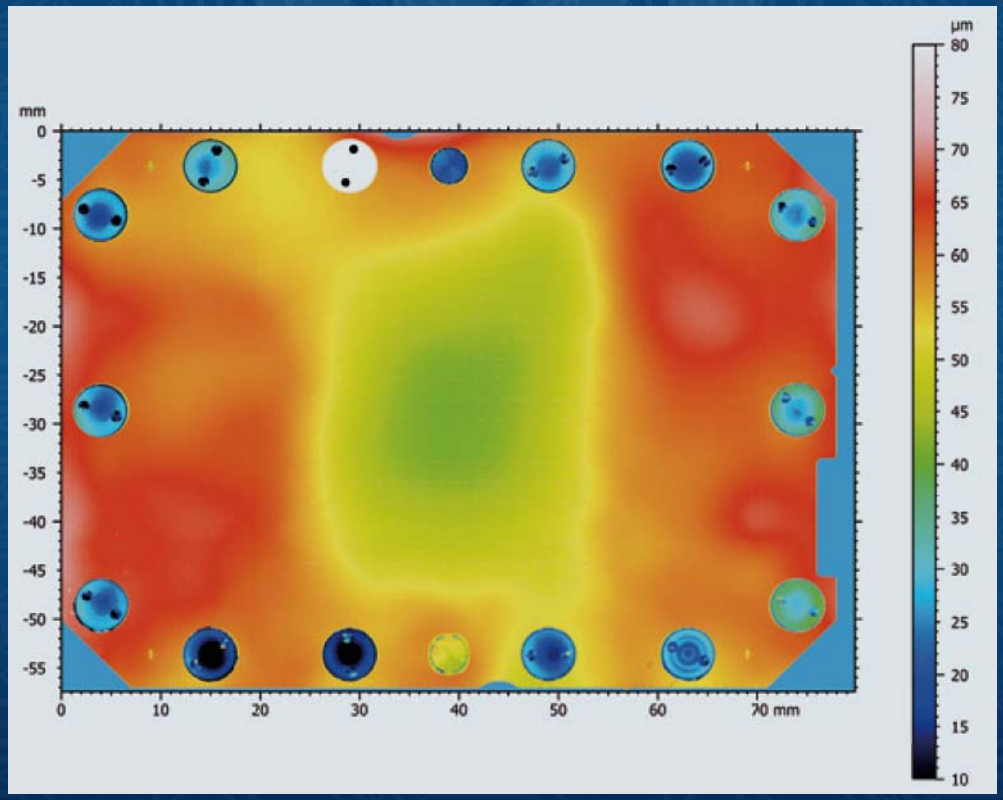
Characterization - Head

- Probe head inspection, capability on vertical card



Characterization - Head

- Probe head inspection, capability on vertical card



Characterization Time

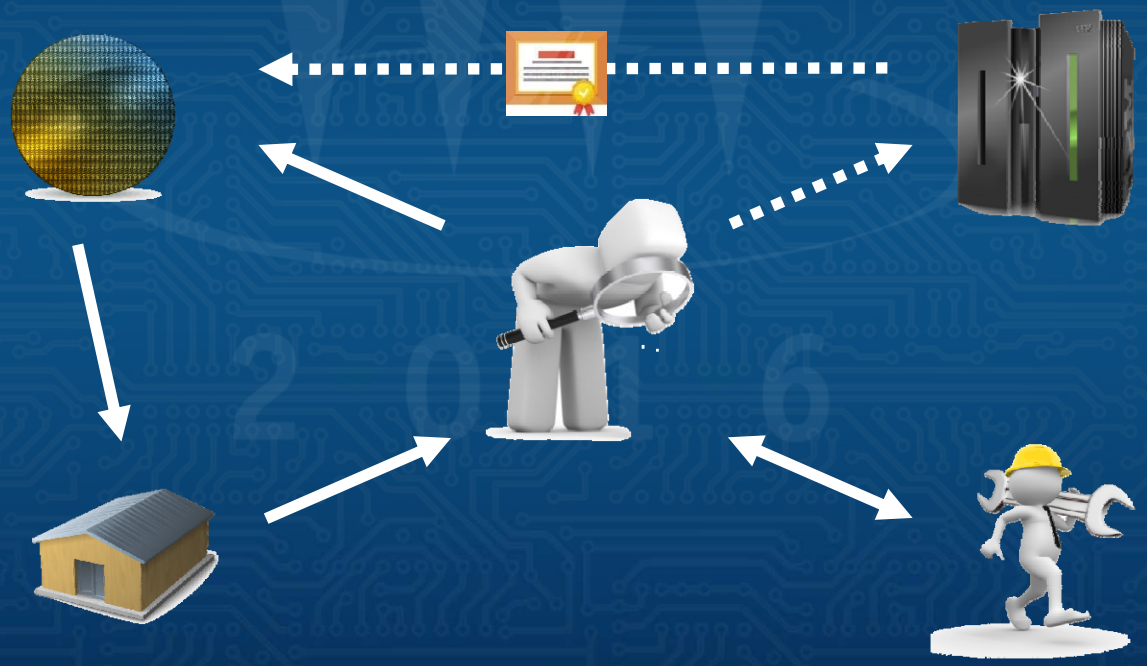
- Probe card inspection process, summary of acquisition times

Type & Task	Time	# Tips	Time / Tip
Verticals			
ProbeHead	01:55.0		
TipInspection	05:33.0	1260	**00:00.264**
Clearance Inspection	05:35.0		
Time saved by factor	4.9		
MEMS			
ProbeHead	02:48.0		
TipInspection	06:15.0	2072	**00:00.181**
Clearance Inspection	02:17.0		
Time saved by factor	2.7		

Type & Task	Time	# Tips	Time / Tip
Cantilever (Smoophy)			
ProbeHead	00:43.0		
TipInspection	01:03.0	104	00:00.606
Clearance Inspection	00:39.0		
Cantilever (LUPO)			
ProbeHead	00:38.0		
TipInspection	00:51.0	26	00:01.962
Clearance Inspection	01:24.0		

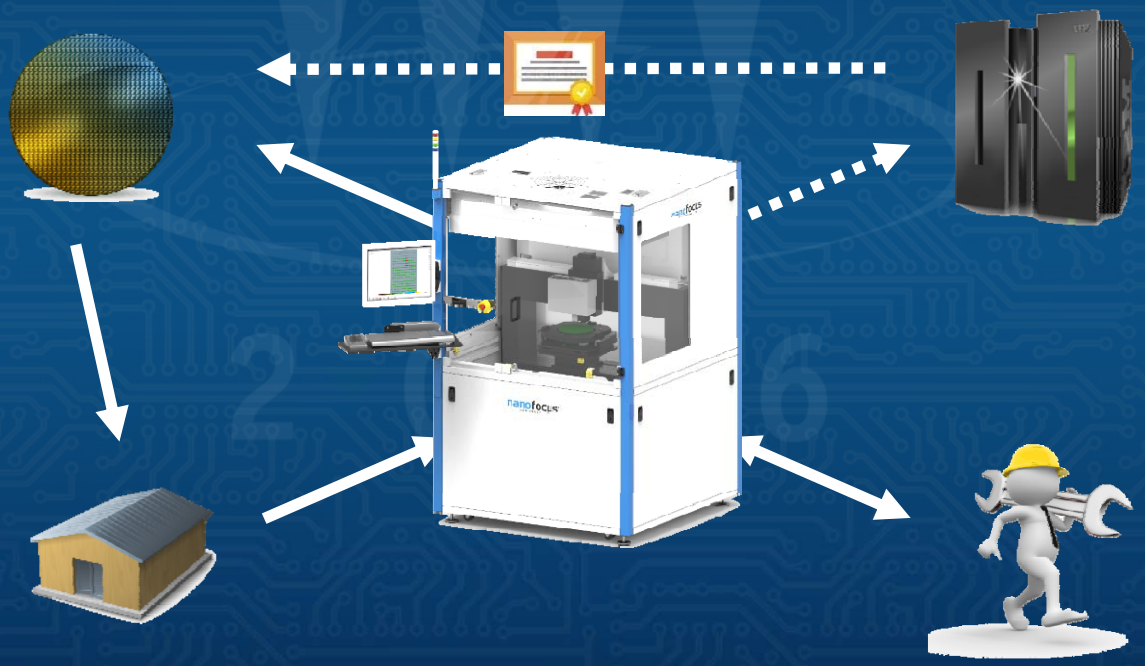
Target

„A fast probe card inspection enabling a clear and resilient decision about if a probe card is OK for testing or not.”

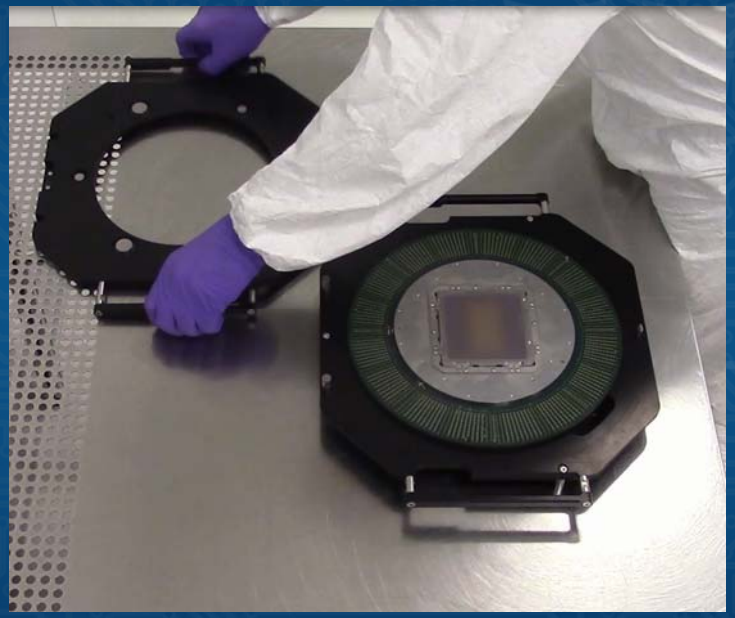


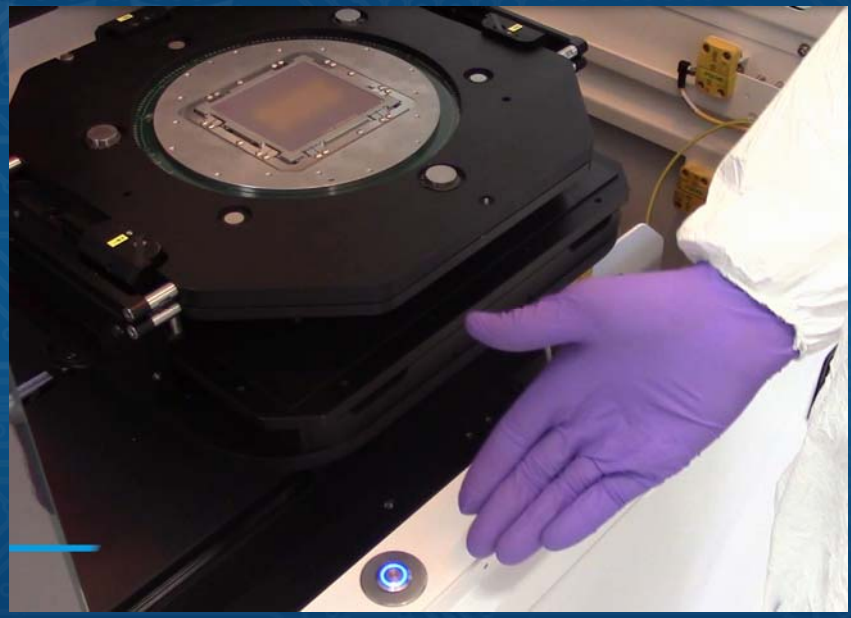
Result

„A **load & go** probe card inspection enabling a clear and resilient decision about if a **probe card is OK for testing or not.**"



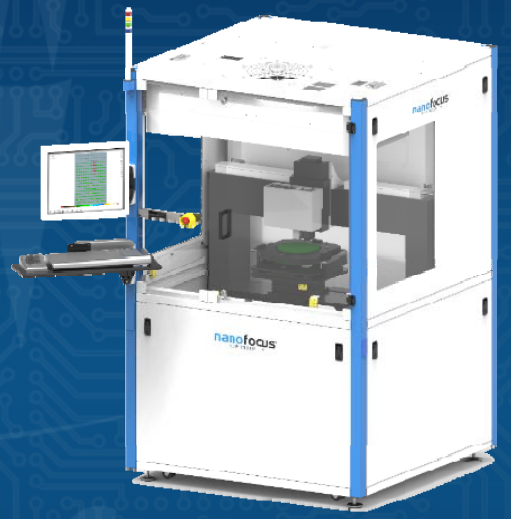
Load & Go





Summary, Benefits, Perspectives

- Objectives of development were met
- **Process enables Load & Go tool**
- **Clear OK or NOK decision possible**
- Tool can be run as capacity tool
- Optical / contact less inspection



- Evaluate correlation between scrubs and tip / head conditions
- Probe mark / scrub analysis in high resolution 3D

Thank You!

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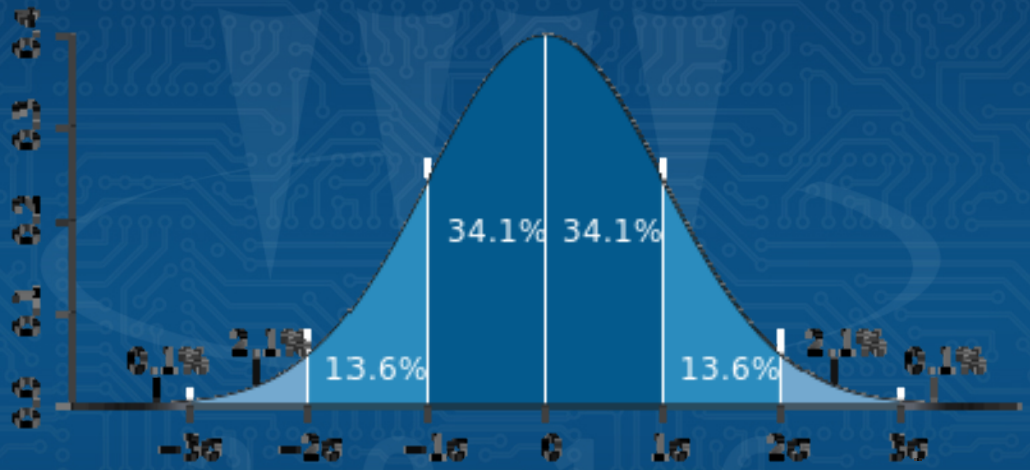
Backup

3 sigma - confidence at normal distribution



@1σ – 68.3 % of the results are within ± 2µm from the „truth“
@2σ – 95.4 % …
@3σ – 99.7 % …

Backup

Limit criteria for areas / error propagation (1)

The standard deviation σy of a value $y = f(x_i \dots x_n)$ is caculated, accordingly to the error propagation rules, as follwos:

$$(\sigma y)^2 = \sum_{i=1}^{n} \left(\frac{\partial f}{\partial x_i} \right)^2 \cdot \sigma {x_i}^2$$

For the MEMS tips with $A = d_{min} \cdot d_{maj}$ this means in particular:

$$\sigma A = \sqrt{d_{maj}^2 \cdot \sigma d_{min}^2 + d_{min}^2 \cdot \sigma d_{maj}^2}$$

For the elliptic structures with $A = {}^{\pi}/_{4}\, d_{min} \cdot d_{maj}$ this means:

$$\sigma A = {}^{\pi}/_{4} \sqrt{d_{maj}^2 \cdot \sigma d_{min}^2 + d_{min}^2 \cdot \sigma d_{maj}^2}$$

Backup

Limit criteria for areas / error propagation (2)

The acceptable standard deviation for the area thus is depending on the actual values of the diameters measured and the according standard deviations. For this reason for every single tip the maximum acceptable standard deviation ΔA_{max} is calculated based on the actual values. However, the emerging dynamic acceptance criteria for the areas is capped by the nominal standard deviation of the diamaters of 2/3µm, which means for the upper limit:

$$\sigma A_{max,i} = \sqrt{d_{maj,i}^2 \cdot MIN\left(\sigma d_{min,i}; \frac{2}{3}\mu m\right)^2 + d_{min,i}^2 \cdot MIN\left(\sigma d_{maj,i}; \frac{2}{3}\mu m\right)^2}$$

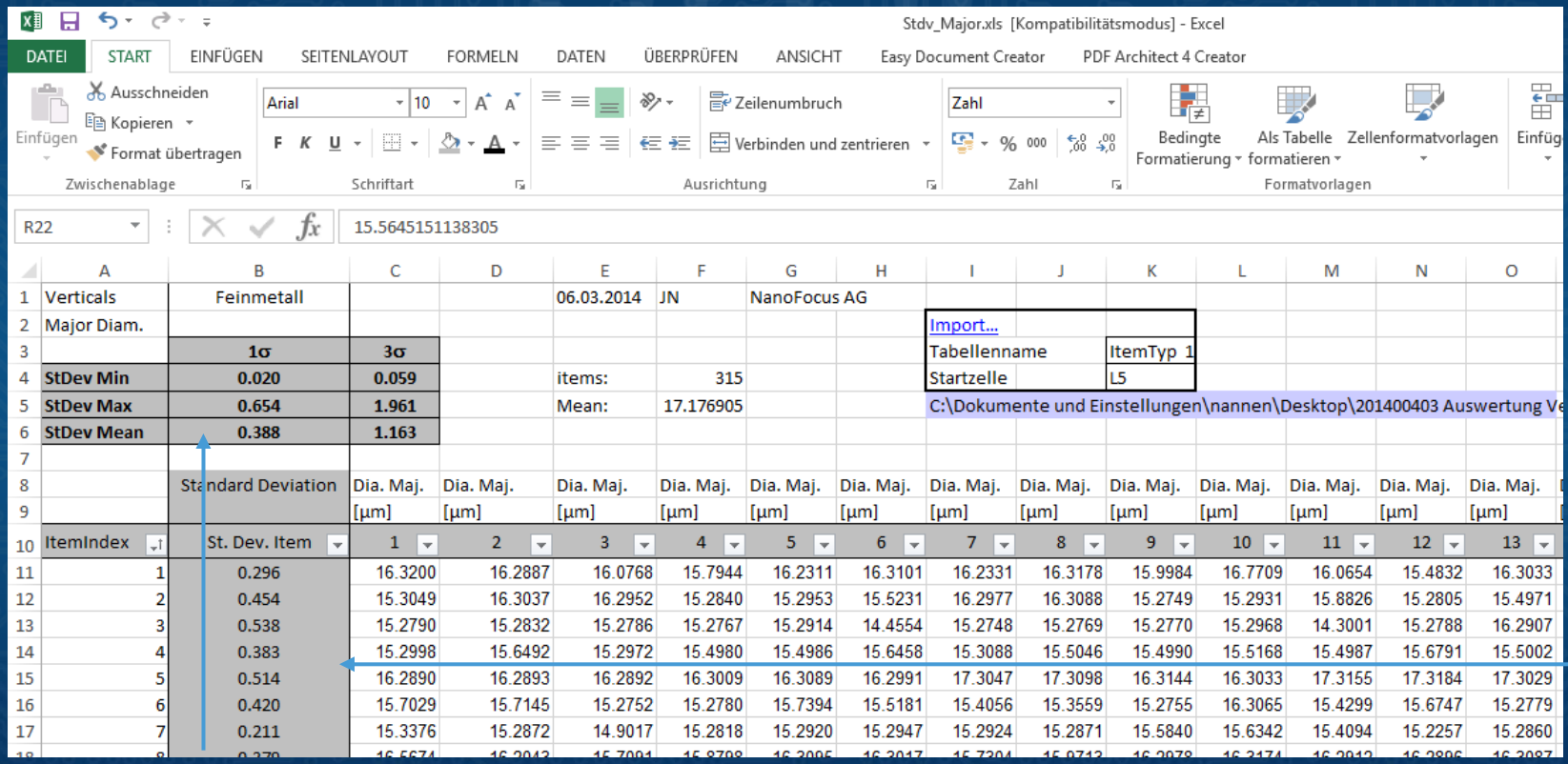
The pass / fail status of each single tip area measurement finally is qualified by the factor $\frac{\Delta A_i}{\Delta A_{max,i}}$. In case this „precision factor“ is > 1 the measurement is out of specification.

Backup

Tool at customer site

Backup

Calculation of standard deviation



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	Verticals	Feinmetall			06.03.2014	JN	NanoFocus AG								
2	Major Diam.								Import...						
3		1σ	3σ						Tabellenname		ItemTyp 1				
4	StDev Min	0.020	0.059		items:	315			Startzelle		L5				
5	StDev Max	0.654	1.961		Mean:	17.176905			C:\Dokumente und Einstellungen\nannen\Desktop\201400403 Auswertung Ve						
6	StDev Mean	0.388	1.163												
7															
8		Standard Deviation	Dia. Maj.	Dia. Maj.	Dia. Maj.	Dia. Maj.	Dia. Maj.	Dia. Maj.	Dia. Maj.	Dia. Maj.	Dia. Maj.	Dia. Maj.	Dia. Maj.	Dia. Maj.	Dia. Maj.
9			[µm]	[µm]	[µm]	[µm]	[µm]	[µm]	[µm]	[µm]	[µm]	[µm]	[µm]	[µm]	[µm]
10	ItemIndex	St. Dev. Item	1	2	3	4	5	6	7	8	9	10	11	12	13
11	1	0.296	16.3200	16.2887	16.0768	15.7944	16.2311	16.3101	16.2331	16.3178	15.9984	16.7709	16.0654	15.4832	16.3033
12	2	0.454	15.3049	16.3037	16.2952	15.2840	15.2953	15.5231	16.2977	16.3088	15.2749	15.2931	15.8826	15.2805	15.4971
13	3	0.538	15.2790	15.2832	15.2786	15.2767	15.2914	14.4554	15.2748	15.2769	15.2770	15.2968	14.3001	15.2788	16.2907
14	4	0.383	15.2998	15.6492	15.2972	15.4980	15.4986	15.6458	15.3088	15.5046	15.4990	15.5168	15.4987	15.6791	15.5002
15	5	0.514	16.2890	16.2893	16.2892	16.3009	16.3089	16.2991	17.3047	17.3098	16.3144	16.3033	17.3155	17.3184	17.3029
16	6	0.420	15.7029	15.7145	15.2752	15.2780	15.7394	15.5181	15.4056	15.3559	15.2755	16.3065	15.4299	15.6747	15.2779
17	7	0.211	15.3376	15.2872	14.9017	15.2818	15.2920	15.2947	15.2924	15.2871	15.5840	15.6342	15.4094	15.2257	15.2860

Backup

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