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# Analysis of wedge tool wear-out by machine data

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IMAPS Advanced Technology Workshop & Tabletop Exhibition on Wire Bonding

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# Agenda

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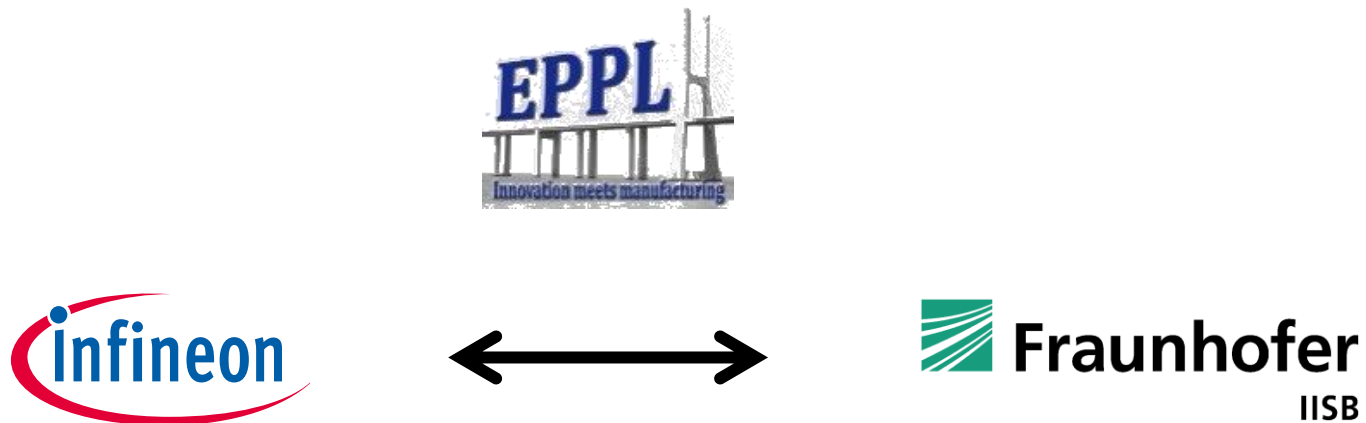
- I. Introduction: Bonding and statistics
- II. Analysis: Wedge wear-out
- III. Summary and outlook

# Introduction

## Infineon Regensburg and Fraunhofer IISB in EPPL

### „Advanced process control” (APC) in the backend

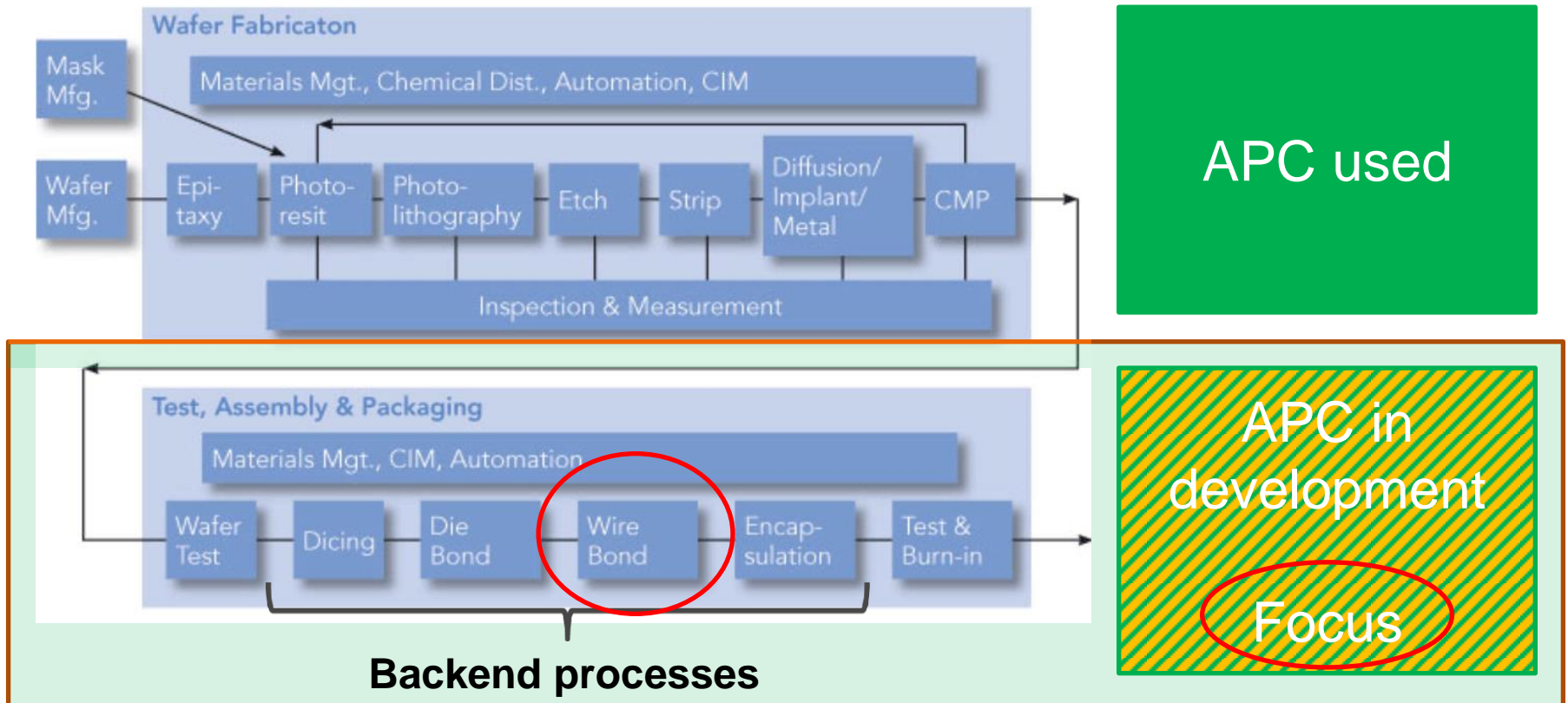
- Cooperation in the European project:  
“Enhanced Power Pilot Line” (EPPL)



# Introduction

## Potentials for APC in backend processes

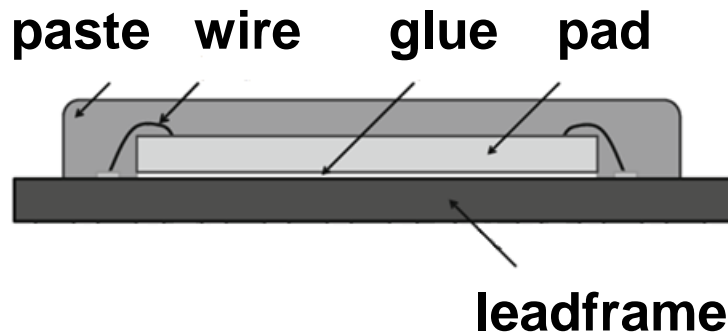
The chip-making Process



[Ref.1]

# Introduction

## Wedge-wedge wire bonding

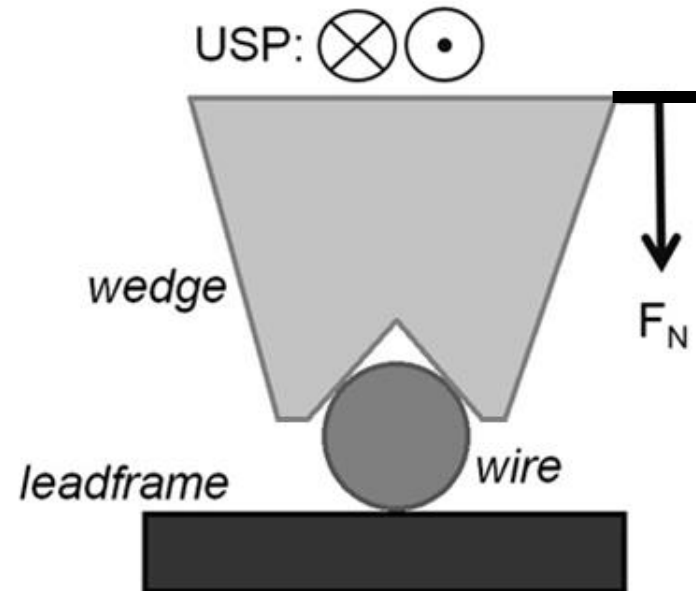
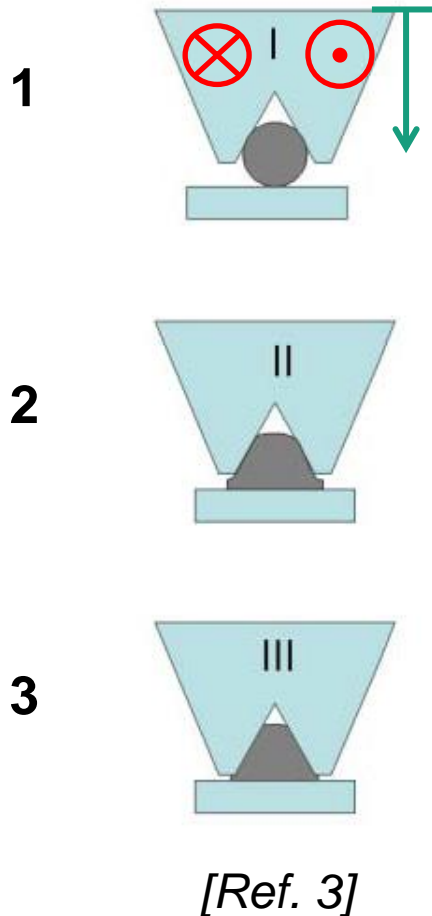


[Ref. 2]

- **Ultrasonic welding process**
- **Wire:** Aluminum, 500  $\mu\text{m}$  diameter
- **Pad:** Aluminum
- **Leadframe:** Copper
- **Bonding time:** ~ 200 ms

# Introduction

## Wedge tool



### Main parameters:

- Bond force:  $F_N$
- Bond power: USP (Ultrasonic power)
- Bond time

# Introduction

## Bonding quality by trace parameters

- Process parameters:
  - Maximal current [mA]
  - Mean End Current avg. [mA]
  - Deformation [ $\mu\text{m}$ ]



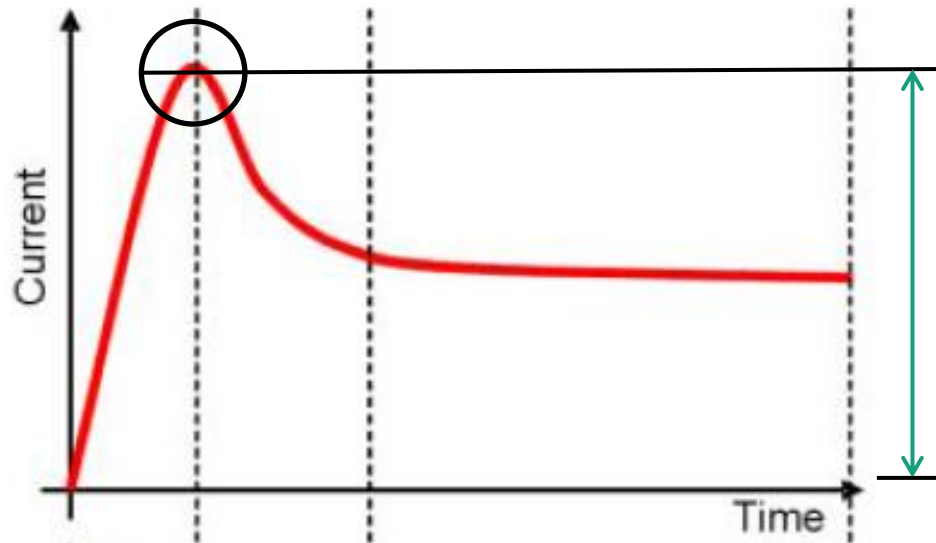
**Relate to each other!**

- Quality parameters
  - Pull test [N]
  - Shear test [N]
  - Wedge height [ $\mu\text{m}$ ]
  - Wedge width [ $\mu\text{m}$ ]

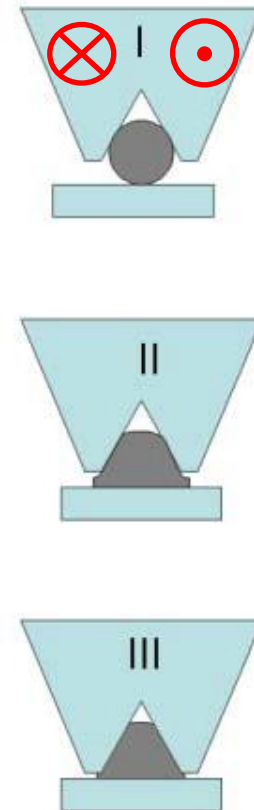
# Introduction

## Bonding quality by trace parameters

- Keynumber: Maximal current



[Ref. 3]





# Introduction

## Box plot Statistics

[Ref. 4]

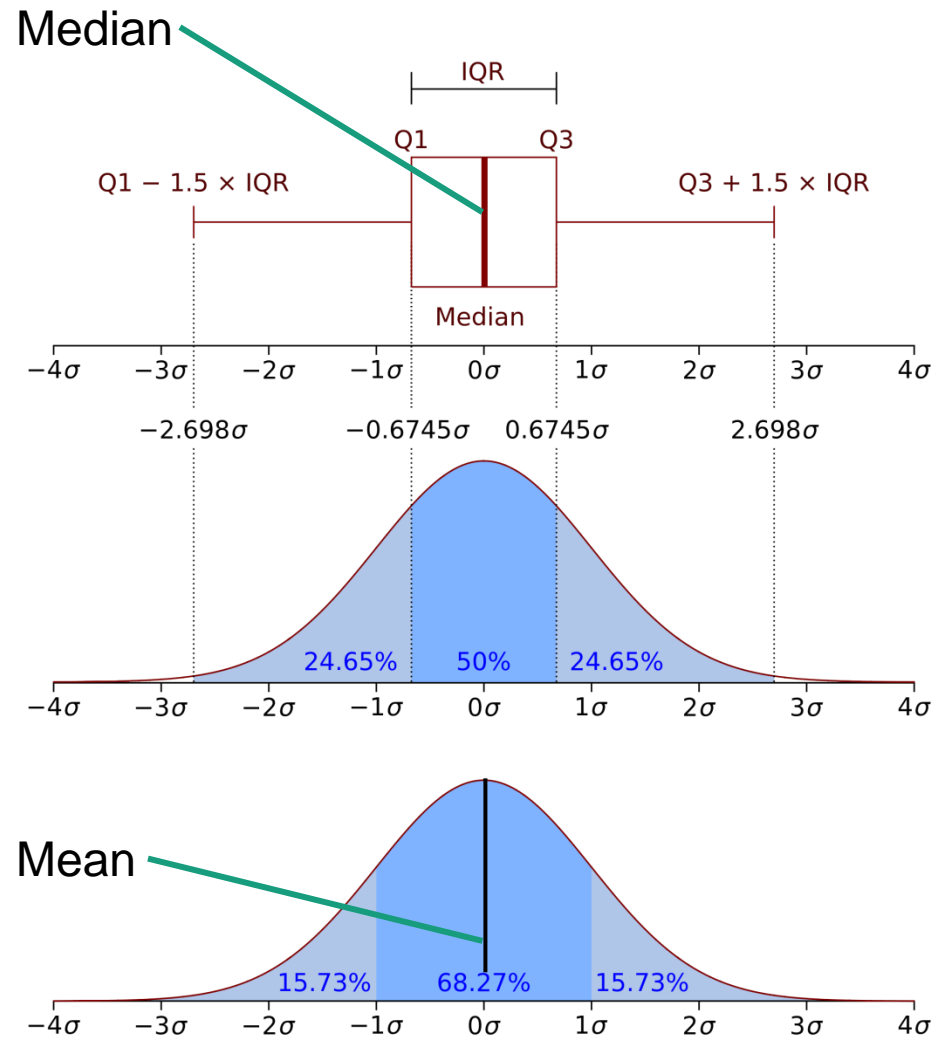
- Box plot

Median  
Quantiles (Q1 and Q3)  
IQR

- Statistics:  
Box plot

- Statistics:  
Standard deviation  $\sigma$

Mean



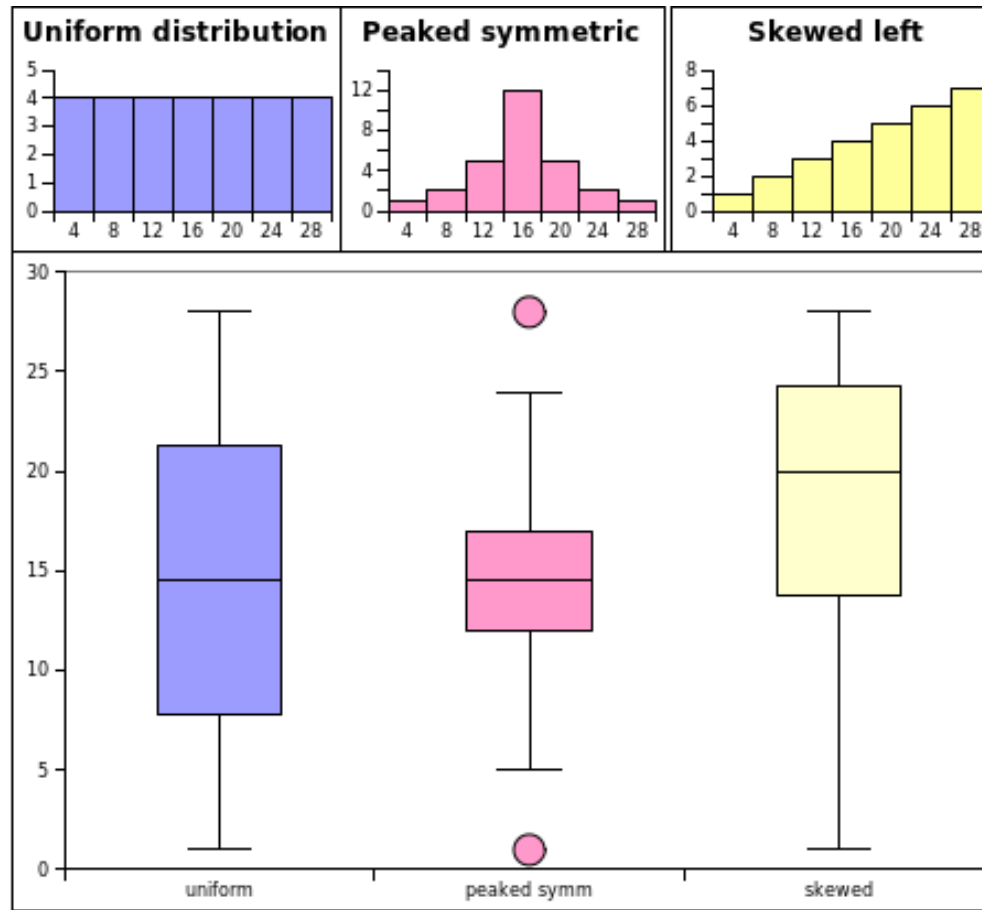
# Introduction

## Boxplot Statistics

(1)

(2)

(3)



[Ref. 5]

# Analysis: Wedge wear-out

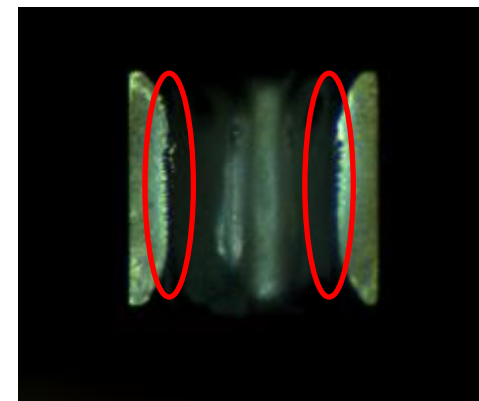
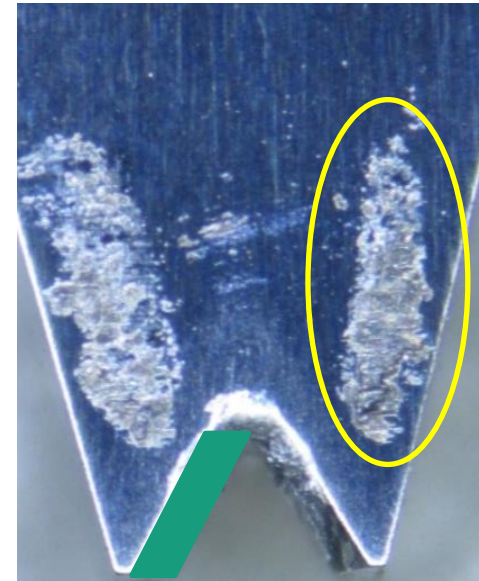
## Project objective

Detect and predict wedge wear-out to establish a controlled maintenance (Predictive Maintenance (PdM))

### Status quo:

- Cleaning cycles: Cleaning after fixed number of bonds
- Disposal of tool after fixed number of cleaning cycles (Preventive Maintenance (PM))

[Ref. 6]



# Analysis: Wedge wear-out

## Project idea by trace parameter observation

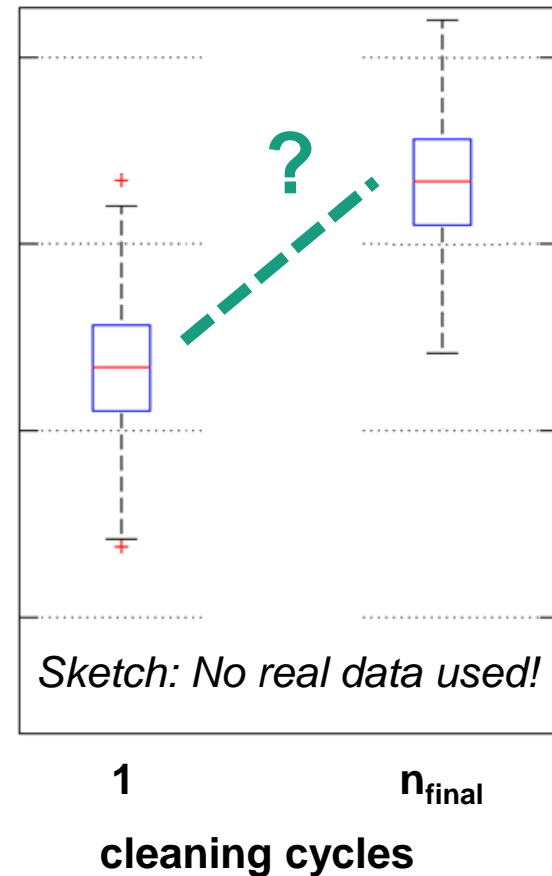
### Project idea:

- Measurement indicated strong statistical increase between cleaning cycle:

1 vs.  $n_{\text{final}}$

- Is this an indication of wedge wear-out?
- Do we exchange wedges too late? (Detection: Quality parameters?)
- Can a systematic trend be determined?

Maximum Current (mA)



# Analysis: Wedge wear-out Deployment

- 12 wedges from cleaning cycle:

1, 2, ...  $n_{\text{final}}$

- Process parameters:

Maximum Current

Mean End Current

Wedge deformation

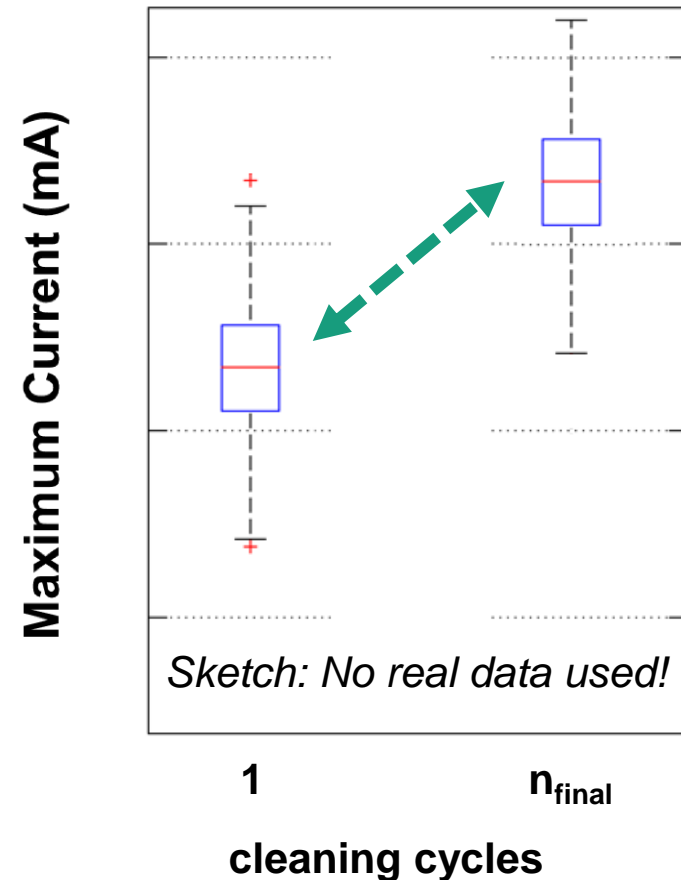
- Quality parameters:

Pull test

Shear test

Wedge height

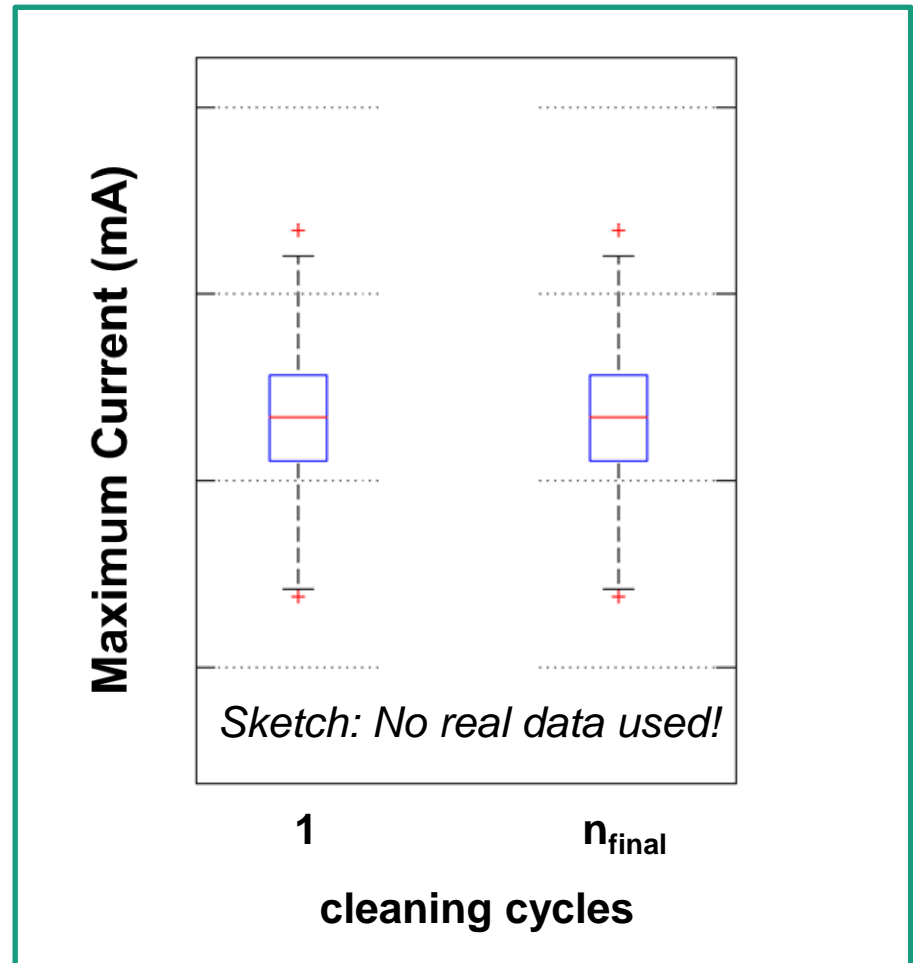
Wedge width



# Analysis: Wedge wear-out

## Result for Maximum current

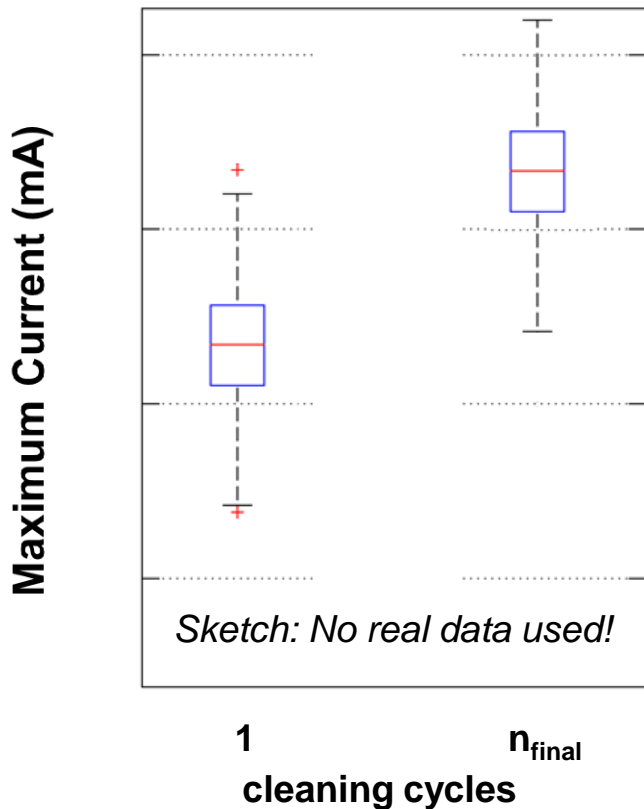
- No **statistical** average increase for 12 wedges
- No indication of wear-out
- Wedges are not exchanged too late



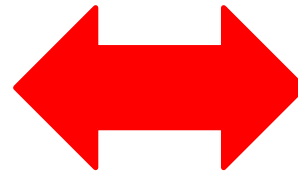
# Analysis: Wedge wear-out

## Result for Maximum current

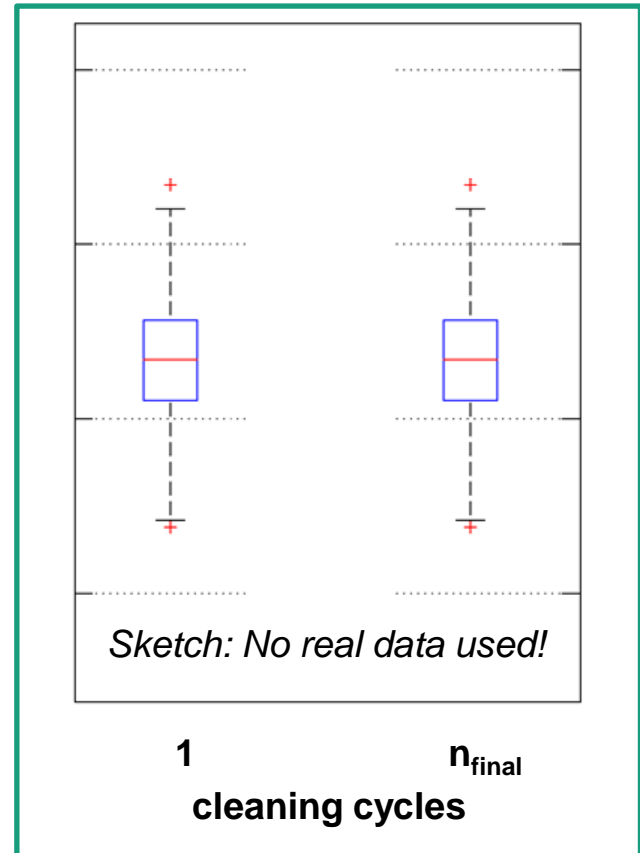
### Pre-project observation



Why?



### Project observation



# Analysis: Wedge wear-out

## Basic statistical analysis

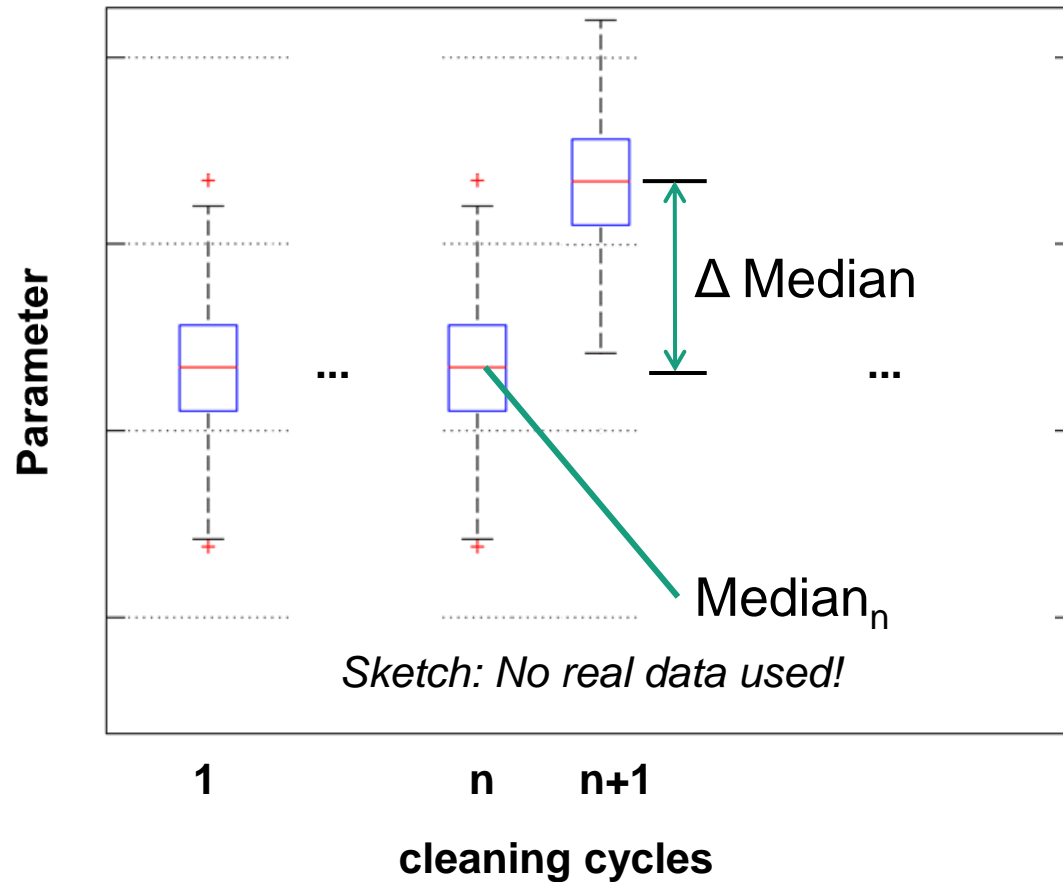
- Strong value variations between cleaning cycles

- Mathematics:

$\Delta$  Median

- $\Delta \text{Median}_{\max} = \text{Median}_{n,\max} - \text{Median}_{n,\min}$

with  $n=[1, n_{\text{final}}]$

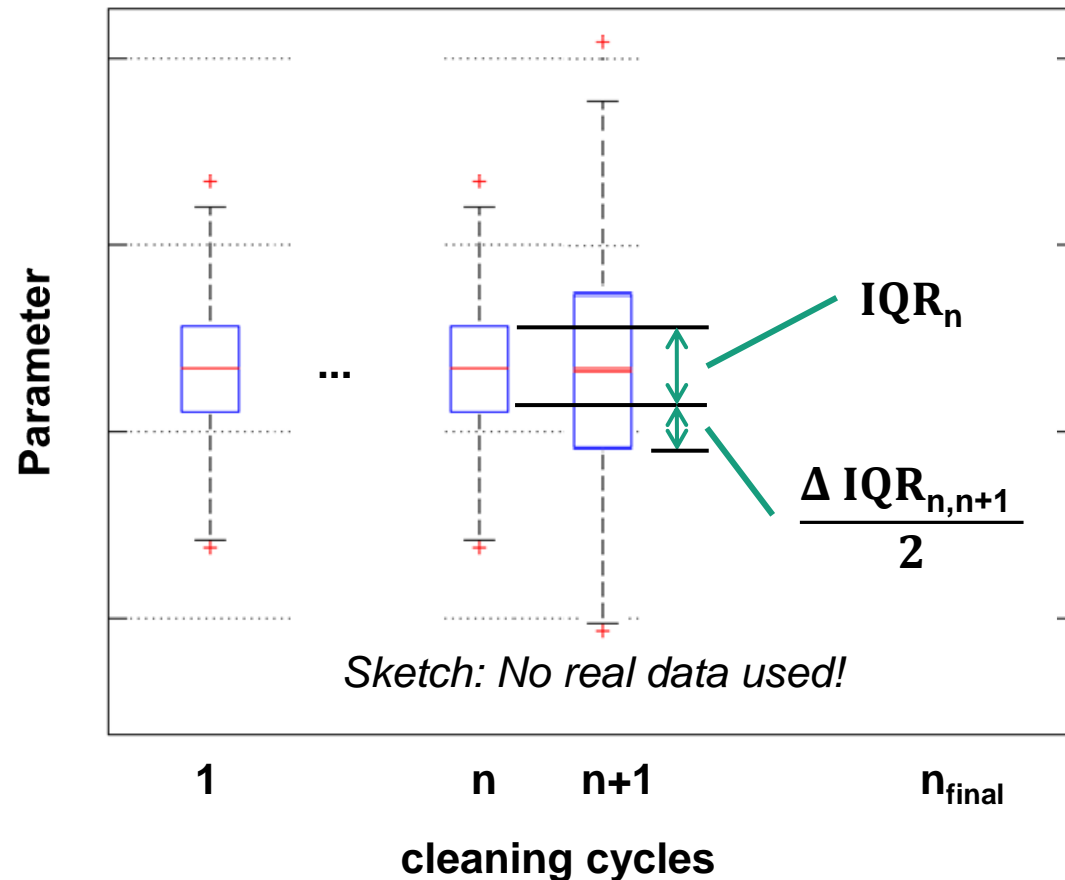




# Analysis: Wedge wear-out

## Basic statistical analysis

- Strong value variations within cleaning cycles
- Mathematics:  
 $\Delta IQR_{n,n+1}$
- $\Delta IQR_{\max} = IQR_{n,\max} - IQR_{n,\min}$   
 with  $n=[1, n_{\text{final}}]$



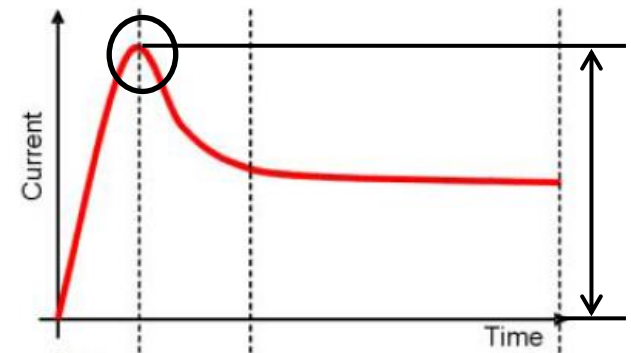
# Analysis: Wedge wear-out

## Process parameters: Maximum Current

Parameter	Statistical keynumber	[%]
Maximum current	$\Delta \text{Median}_{\text{max}} / \text{Median}$	
Maximum current	$\Delta \text{IQR}_{\text{max}} / \text{Median}$	

Unit: **Percent** of the statistic value on the absolute value (Median)

All values from one representative wedge. All values rounded.



[Ref. 3]

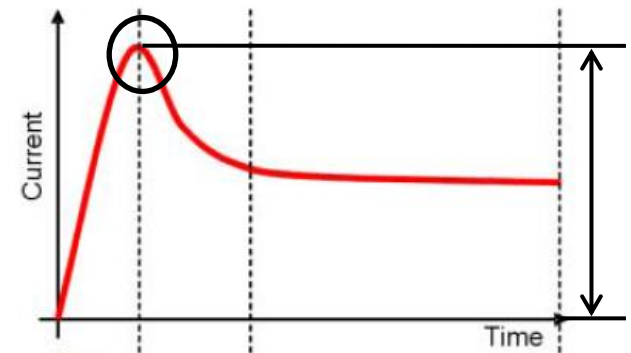
# Analysis: Wedge wear-out

## Process parameters: Maximum Current

Keynumber	Statistic description	[%]
Maximum current	$\Delta \text{Median}_{\text{max}} / \text{Median}$	31.6
Maximum current	$\Delta \text{IQR}_{\text{max}} / \text{Median}$	5.5

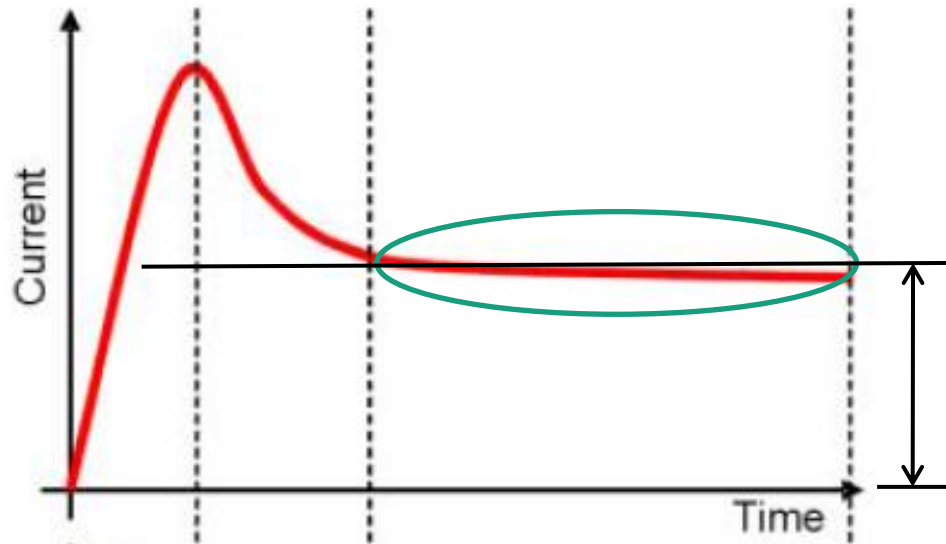
All values from one representative wedge. All values rounded.

[Ref. 3]

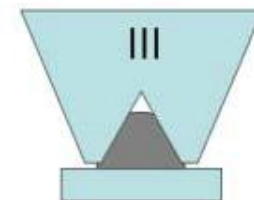
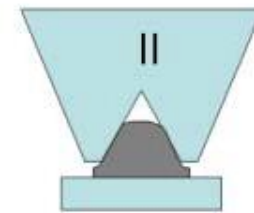
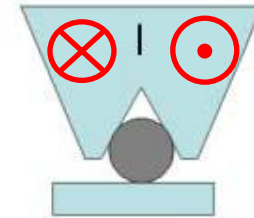


# Analysis: Wedge wear-out

Process parameters: Mean End Current



[Ref. 3]



# Analysis: Wedge wear-out

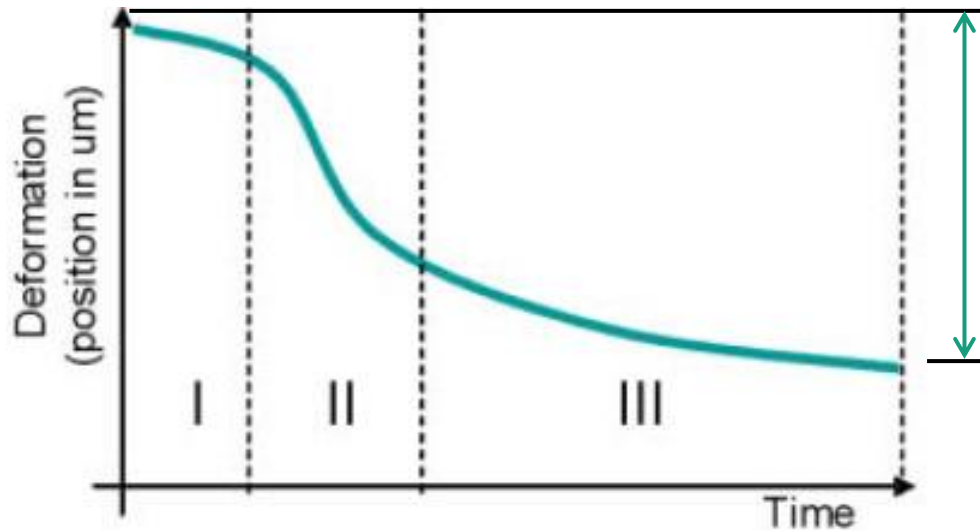
## Process parameters: Mean end Current

Parameter	Statistical keynumber	[%]
Maximum current	$\Delta \text{Median}_{\text{max}} / \text{Median}$	31.6
Maximum current	$\Delta \text{IQR}_{\text{max}} / \text{Median}$	5.5
Mean End current	$\Delta \text{Median}_{\text{max}} / \text{Median}$	17.4
Mean End current	$\Delta \text{IQR}_{\text{max}} / \text{Median}$	7.1

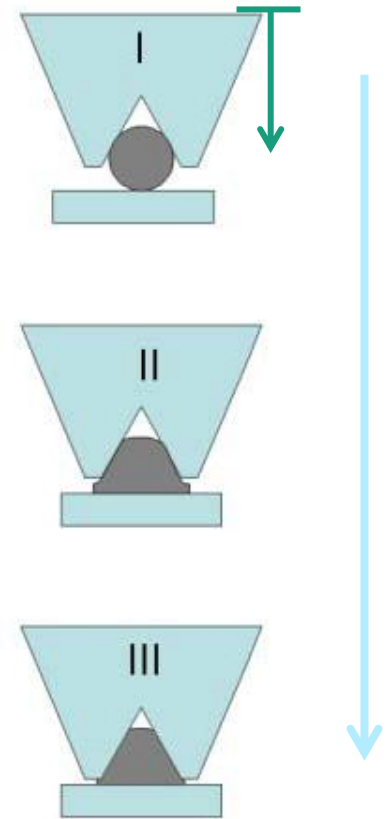
All values from one representative wedge. All values rounded.

# Analysis: Wedge wear-out

Process parameters: Deformation



[Ref. 3]



# Analysis: Wedge wear-out

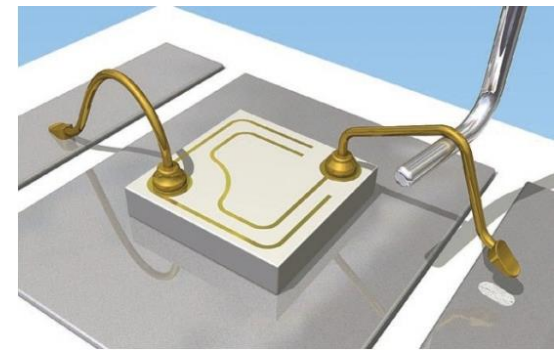
## Process parameters: Deformation

Parameter	Statistical keynumber	[%]
Maximum current	$\Delta \text{Median}_{\text{max}} / \text{Median}$	31.6
Maximum current	$\Delta \text{IQR}_{\text{max}} / \text{Median}$	5.5
Mean End current	$\Delta \text{Median}_{\text{max}} / \text{Median}$	17.4
Mean End current	$\Delta \text{IQR}_{\text{max}} / \text{Median}$	7.1
Deformation	$\Delta \text{Median}_{\text{max}} / \text{Median}$	18.8
Deformation	$\Delta \text{IQR}_{\text{max}} / \text{Median}$	6.9

All values from one representative wedge. All values rounded.

# Analysis: Wedge wear-out

## Quality parameters: Pull test



[Ref. 7]

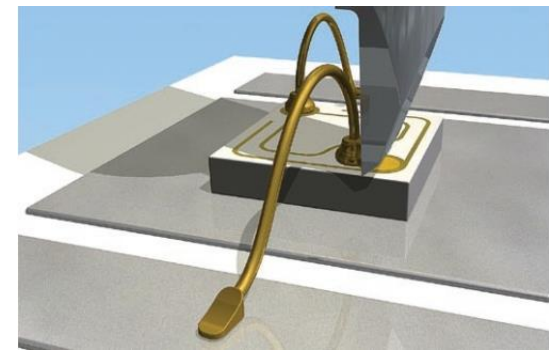
Parameter	Statistical keynumber	[%]
Pull test	$\Delta \text{Median}_{\text{max}} / \text{Median}$	7.1
Pull test	$\Delta \text{IQR}_{\text{max}} / \text{Median}$	9.6

All values from one representative wedge. All values rounded.



# Analysis: Wedge wear-out

## Quality parameters: Shear test



[Ref. 7]

Parameter	Statistical keynumber	[%]
Pull test	$\Delta \text{Median}_{\text{max}} / \text{Median}$	7.1
Pull test	$\Delta \text{IQR}_{\text{max}} / \text{Median}$	9.6
Shear test	$\Delta \text{Median}_{\text{max}} / \text{Median}$	37.5
Shear test	$\Delta \text{IQR}_{\text{max}} / \text{Median}$	23.6

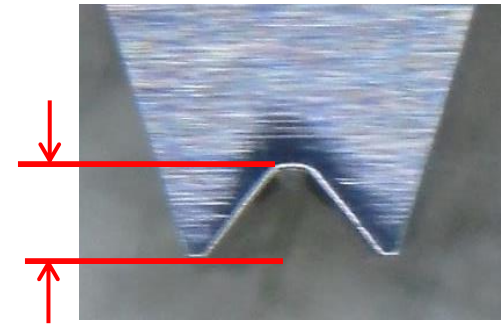
All values from one representative wedge. All values rounded.

# Analysis: Wedge wear-out

Quality parameters:

Wedge height

*Wedge height*



[Ref. 6]

Parameter	Statistical keynumber	[%]
Pull test	$\Delta \text{Median}_{\text{max}} / \text{Median}$	7.1
Pull test	$\Delta \text{IQR}_{\text{max}} / \text{Median}$	9.6
Shear test	$\Delta \text{Median}_{\text{max}} / \text{Median}$	37.5
Shear test	$\Delta \text{IQR}_{\text{max}} / \text{Median}$	23.6
Wedge height	$\Delta \text{Median}_{\text{max}} / \text{Median}$	10.8
Wedge height	$\Delta \text{IQR}_{\text{max}} / \text{Median}$	-

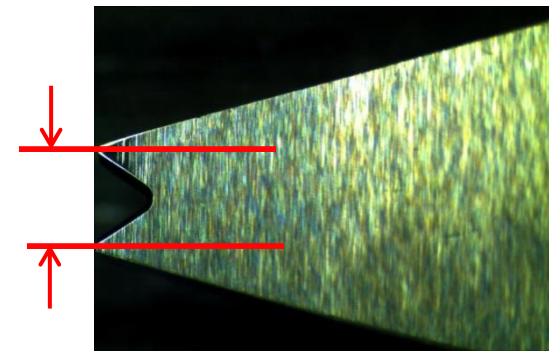
All values from one representative wedge. All values rounded.

# Analysis: Wedge wear-out

Quality parameters:

Wedge width

Wedge width



[Ref. 6]

Parameter	Statistical keynumber	[%]
Pull test	$\Delta \text{Median}_{\text{max}} / \text{Median}$	7.1
Pull test	$\Delta \text{IQR}_{\text{max}} / \text{Median}$	9.6
Shear test	$\Delta \text{Median}_{\text{max}} / \text{Median}$	37.5
Shear test	$\Delta \text{IQR}_{\text{max}} / \text{Median}$	23.6
Wedge height	$\Delta \text{Median}_{\text{max}} / \text{Median}$	10.8
Wedge height	$\Delta \text{IQR}_{\text{max}} / \text{Median}$	-
Wedge width	$\Delta \text{Median}_{\text{max}} / \text{Median}$	4.0
Wedge width	$\Delta \text{IQR}_{\text{max}} / \text{Median}$	-

All values from one representative wedge. All values rounded.

# Summary and outlook

## Summary - Wedge Wear-out

### Results:

- Wedge wear-out not significant factor in available measurements
- Indication of different important factors
- Wedge change and cleaning has significant influence
- Wedges can be used longer
  - Test measurements with longer cycles have started (Aluminum plates and leadframes are used!)

# Summary and outlook

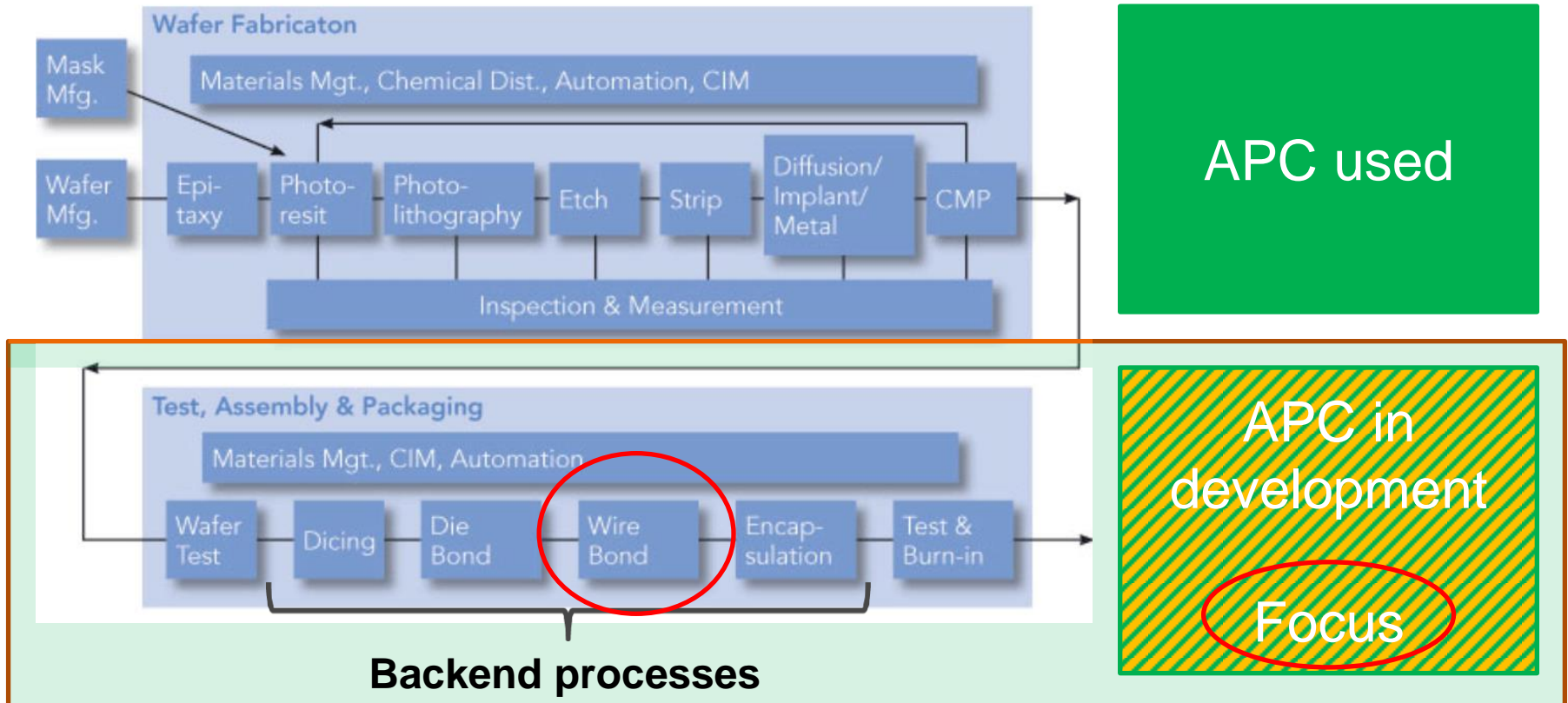
## Summary - Connected topics

- Finding correlations between process parameters and the main influences on bonding system (for example clamping)
- Choosing the right bonding parameters (power, force and time) to achieve the optimal performance
- Exploring further methods to generate quality parameters in a manufacturing environment

# Summary and outlook

## Outlook - Potentials for APC in backend processes

The chip-making Process



The integrated circuit fabrication steps from the silicon wafer to the chip. [Ref.1]

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# Analysis of wedge tool wear-out by machine data

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→ **Thank you for your attention!**

→ **Questions?**

# Literature

1. Integrated circuit fabrication steps; NXP Semiconductors N.V.; Titel: “How we make semiconductors” (2014)
2. Interconnected chip; A. Klemmt; Dissertation: “ Ablaufplanung in der Halbleiter- und Elektronikproduktion”; ISBN 978-3-8348-1993-2
3. Bonding process of equipment output parameters; Kulicke & Soffa Industries; Manual: 7200 Wire Bonder Programmer Guide (Document Number: D-95295, Version 6.7)
4. Sketch: Sketch: <http://www.comfsm.fm/~dleeling/statistics/text5.html>
5. Measurement and analysis data; Infineon Technologies AG and Fraunhofer IISB
6. Sketch of pull and shear test; Nordson DAGE; Website: <http://www.azom.com/article.aspx?ArticleID=11678>