Potentials of Advanced Process Control in Backend Applications
on the Example of Wire Bonding

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Agenda

I. Introduction

II. Data Collection and Analysis

III. Results of the Investigations

IV. Conclusion

Introduction
Infineon Regensburg and Fraunhofer IISB in EPPL

„Advanced process control" (APC) in the backend

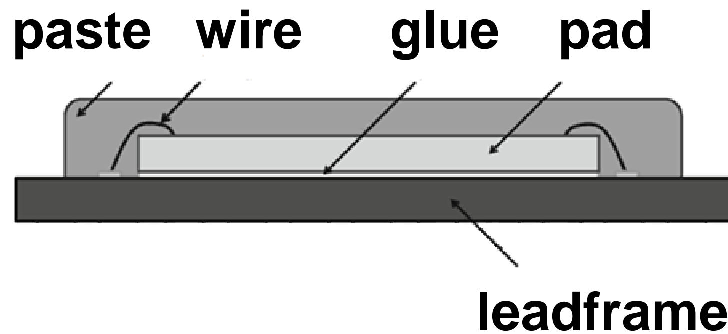
→ Cooperation in the European project:

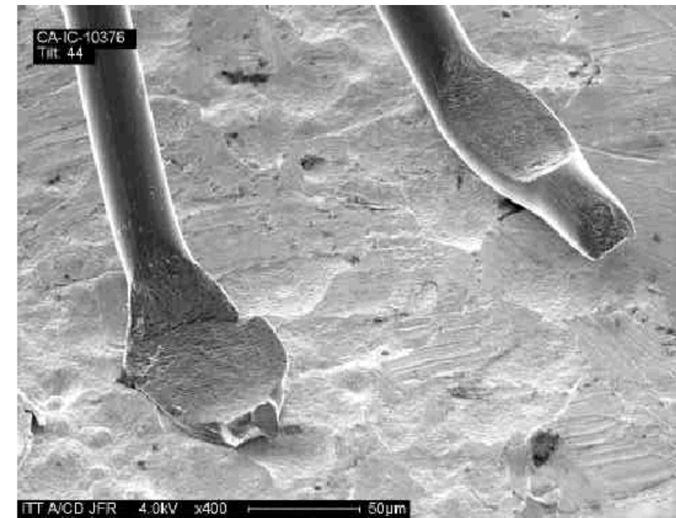
"Enhanced Power Pilot Line" (EPPL)

Introduction
Backend process: Wedge-wedge wire bonding

Wedge-wedge wire bonding:

- Ultrasonic welding process
- Wire: Aluminum with 500 µm diameter
- Pad contact area: Aluminum
- Leadframe contact area: Copper
- Process time: ~ 200 ms





Top: SEM picture of a bond with good and poor pull strength. [Reference 2]

Left: Electrically interconnected chip. [Ref. 1]

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Introduction
Aluminum wedge-wedge wire bonding

Left: Bonding process. [Ref. 3]

Introduction
Project objective 1

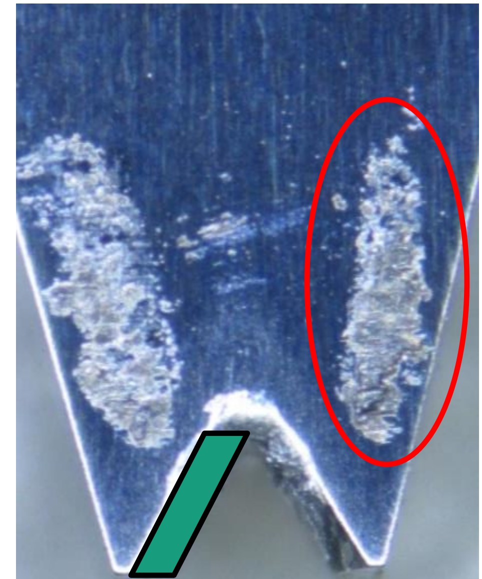
Develop Predictive Maintenance (PdM) system for wedge tool usage

Status quo:

- Disposal of tool after fixed number of cleaning cycles and fixed number of bonds per cycle (Preventive Maintenance)
- Tool change after each cleaning cycle
- Calibration more than once a day

Approach:

- Correlate wear status with quality parameters and equipment parameters



Cutter contamination

Bonding contamination

Tool tip with contamination. [Ref. 4]

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Introduction
Project objective 2

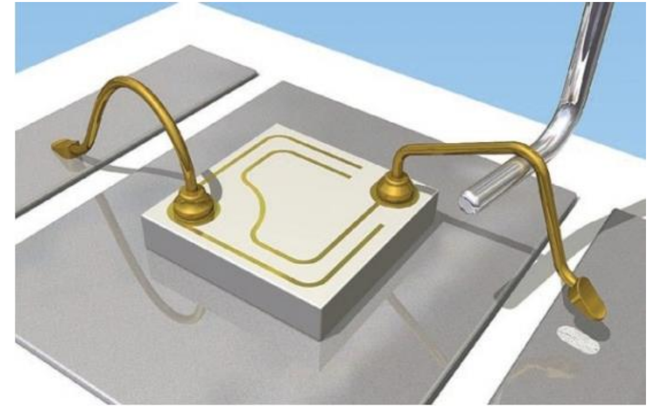
Develop Virtual metrology (VM) system to predict bonding quality

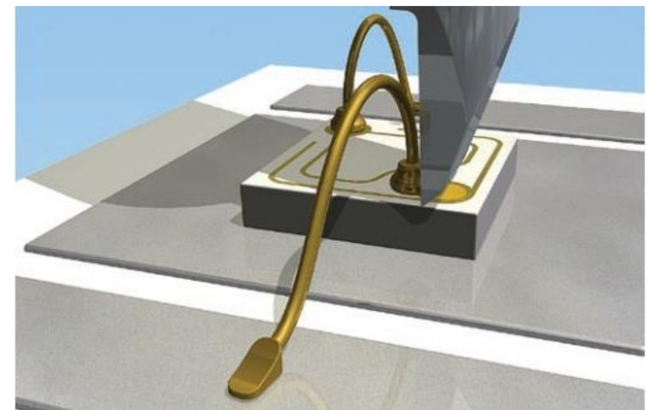
Status quo:

- Wedge-wedge bonding process not yet completely understood
- Input parameters are changed regularly
- Variation of output parameters
- Quality control by visual inspection, pull and shear tests

Approach:

- Understand influences of input parameters
- Assess the potentials of used quality control





Sketch of pull test and of shear test. [Ref. 6]

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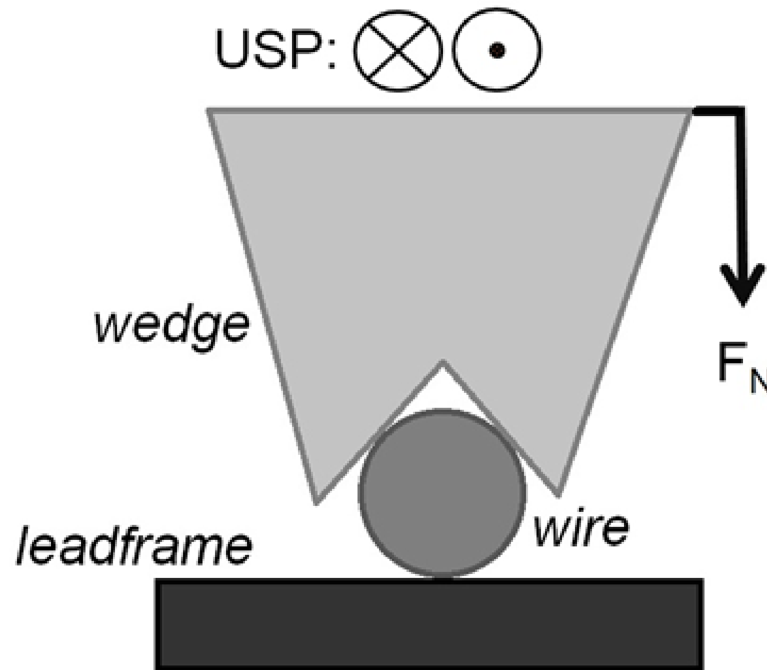
Data Collection and Analysis
Input parameters

Equipment:
- Bond force: F_N
- Bond power: USP
- Bond time

Process:
- Device material
- Wire material
- Device clamping
- Bondhead impedance
- Cutter gap
- Contamination



Sketch of ultrasonic wedge-wedge bonding.

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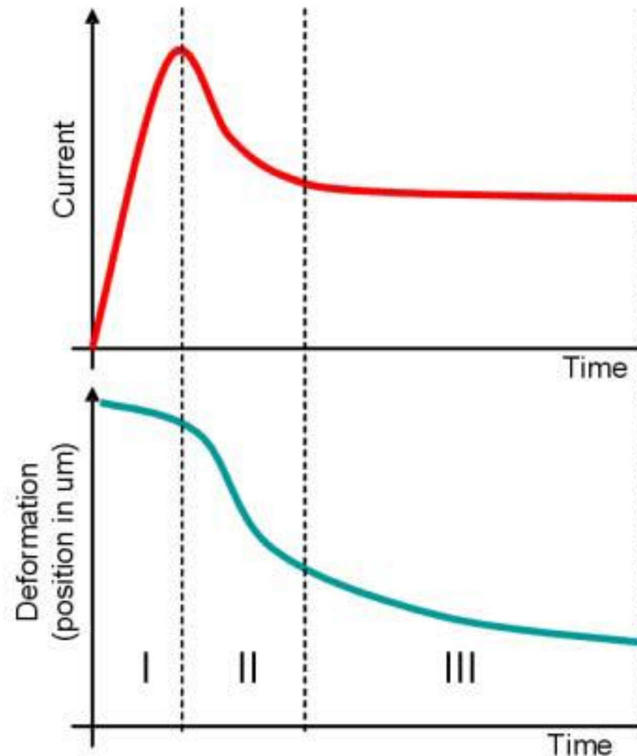
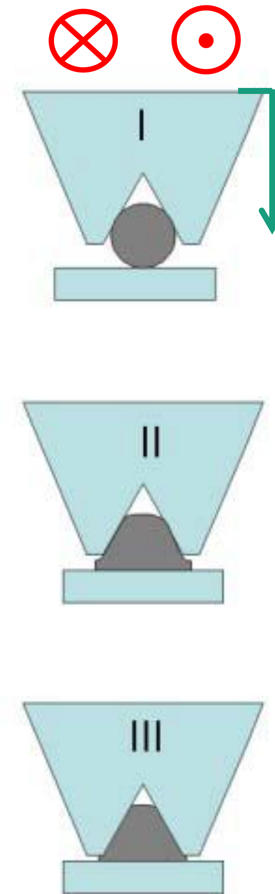
Data Collection and Analysis
Output parameter

Equipment:
- Generator current
- Wire deformation
- Transducer frequency
- Generator phase error

Process:
- Visual control (Microscope)
- Pull test
- Shear test





Typical current and deformation curve for three different phases of the ultrasonic wedge-wedge bonding process. [Ref. 5]

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Data Collection and Analysis
Life cycle and DoE measurements

Life cycle measurements:

- 12 wedges throughout their lifespan (approximately 500.000 bonds).
- Documentation of input parameter changes and bonding failures.

DoE measurements:

- Design of experiment (DoE) for the parameters: bond power and force.
- All equipment and process parameters have been collected.
- Pull and Shear tests have been performed.

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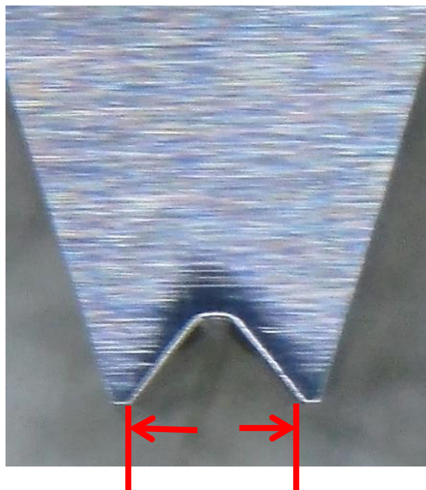
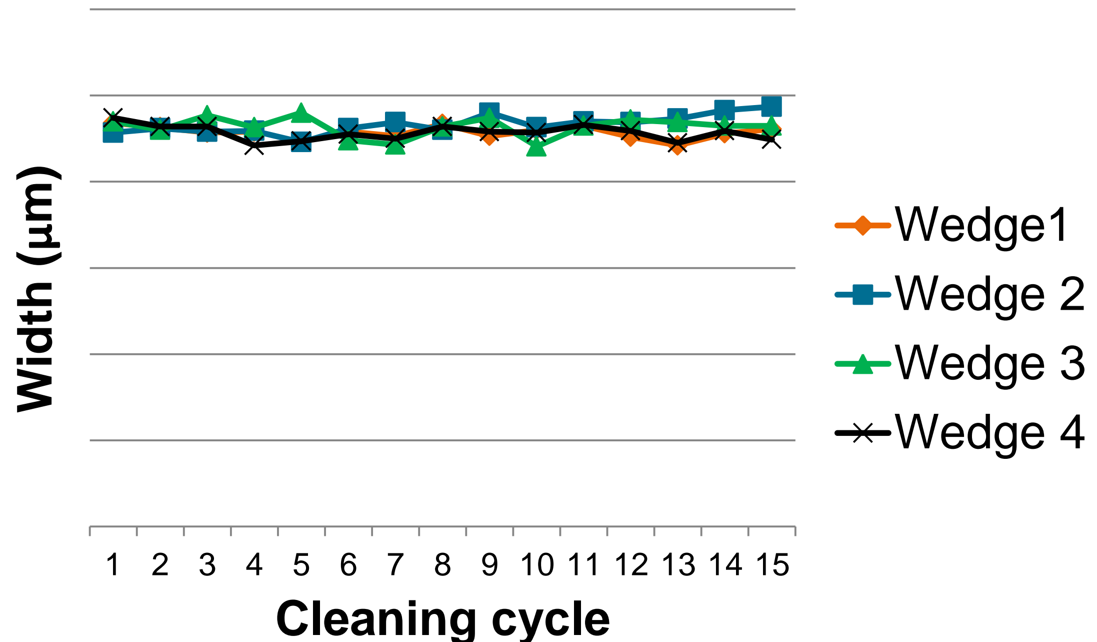
Results of the Investigations
Objective 1: PdM system for tool usage

1. Contamination removed after cleaning
2. Tool utilization can be increased





The diagram shows the evolution of the tool width (left) for 15 cleaning cycles. [Ref. 4]

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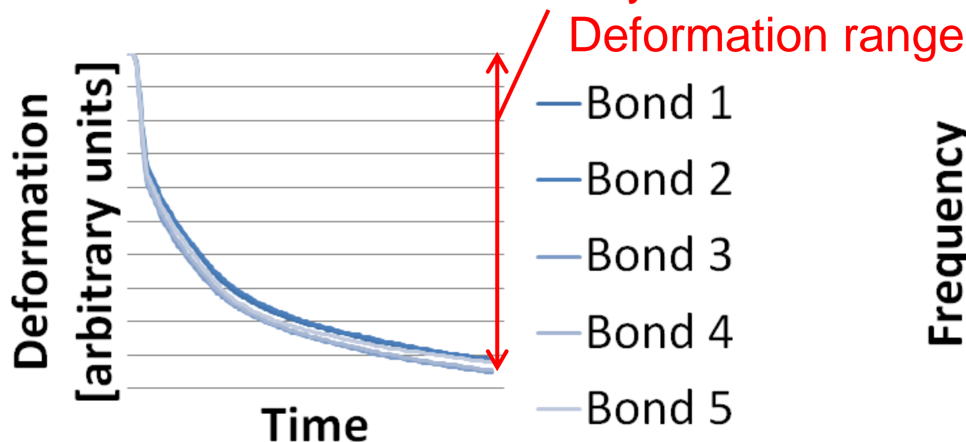
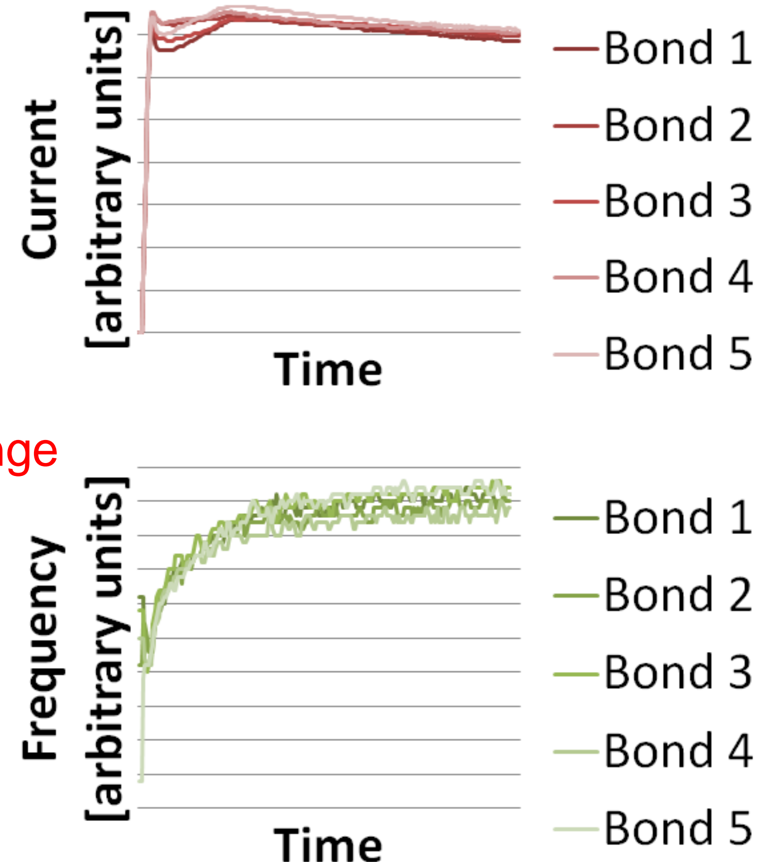
Results of the Investigations

Objective 1: PdM system for tool usage

1. Contamination removed after cleaning
2. High effort for process calibration
3. Calibration process imprecise
4. Tool utilization can be increased
5. Expected equipment predictors do not indicate tool wear





Data of the parameters current, deformation and frequency are shown. [Ref. 4]

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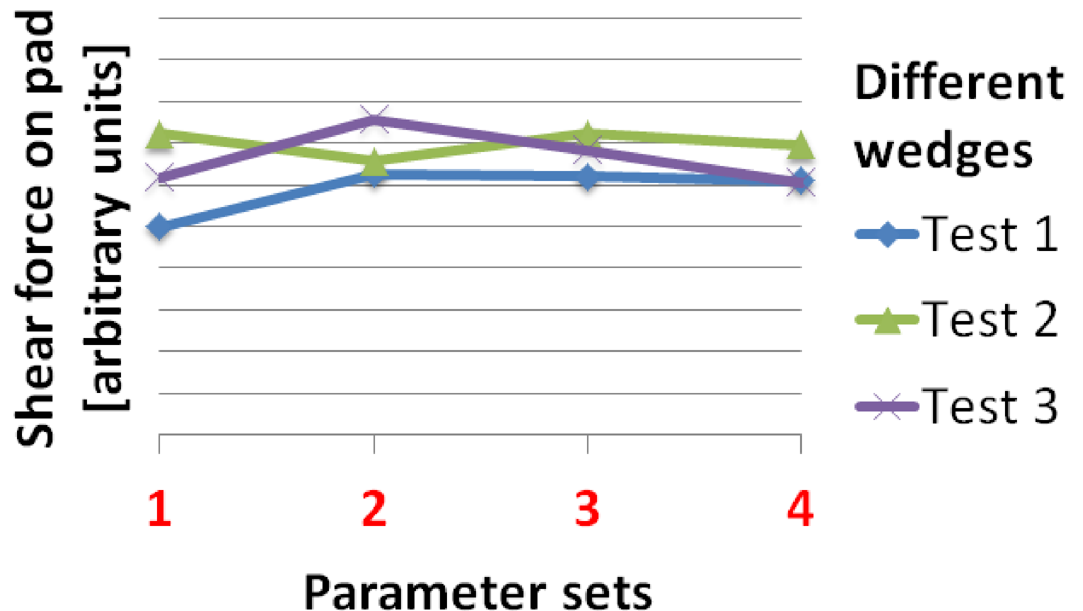
Results of the Investigations

Objective 2: VM system to control bonding quality

1. Quality control cannot quantify defined parameter changes.
2. Reliable quality parameter from equipment data not identified.

1	Pad	Lead
Force	x	w
Power	y	z
2	Pad	Lead
Force	x	w
Power	y+a	z+b
3	Pad	Lead
Force	x+c	w+d
Power	y	z
4	Pad	Lead
Force	x+c	w+d
Power	y+a	z+b



Shear force for different parameter sets. [Ref. 4]

Conclusion

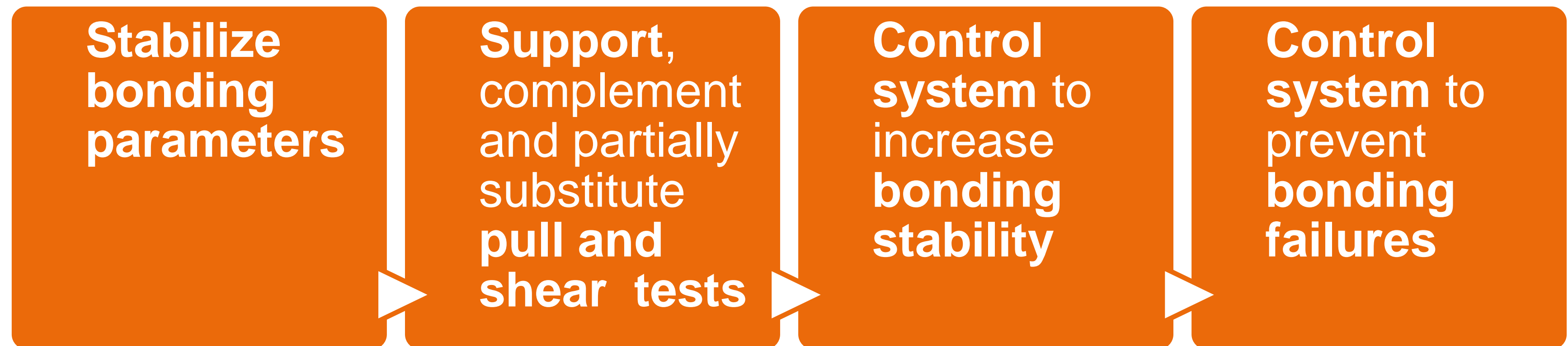
Potentials for APC in wire bonding process

Summary:

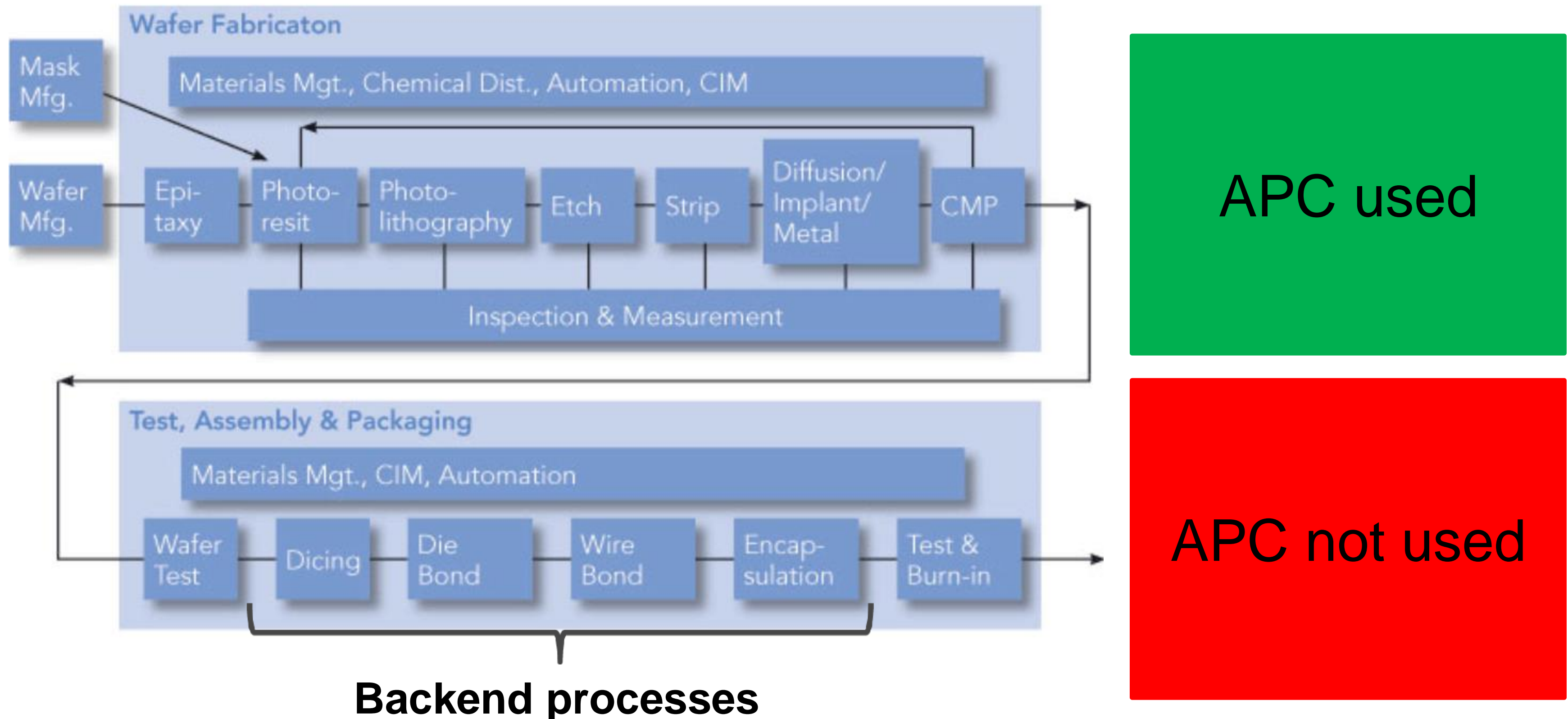
1. The tool utilization and calibration process can be optimized significantly by a PdM system.
2. More approaches are necessary to find reliable quality parameters from equipment data and implement the results of the investigation.

Outlook:

1. The investigations indicate potentials for APC in the topics:



Conclusion
Potentials for APC in backend processes



The integrated circuit fabrication steps from the silicon wafer to the chip. [Ref.8]

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→ **Thank you for your attention!**

→ **Questions?**

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Literature 1

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