APC for the backend:
Influences of quality-relevant manual adjustments in aluminum wire bonding equipment

Felix Klingert[1], Georg Roeder[1], Martin Schellenberger[1], Anton Bauer[1], Klaus Pressel[2], Michael Brueggemann[2]

[1] Fraunhofer IISB, Schottkystraße 10, 91058 Erlangen

[2] Infineon Technology AG, Wernerwerkstraße 2, 93049 Regensburg

Presenter: Felix Klingert

E-Mail: felix.klingert@iisb.fraunhofer.de

Agenda

Introduction

Motivation: APC for the backend

Fabrication stages	Cost	Challenges in semiconductor fabrication	Typical process conditions	Typical process control
Frontend (Device construction on wafers)	½	- Smaller devices (Moore's law over decades) - Yield optimization - New technologies (3D-integration)	- Smallest structure sizes: nm, process workflow: parallel/ cycle, in- and output tolerances controlled	- Control by equipment - Advanced Process Control [1]
Backend (Assembly and packaging of devices)	½		- Smallest structure sizes: µm, process workflow: in series, production windows in tolerance control of in- and output parameters, manual adjustments	- Control by human and offline tests - Advanced Process Control not used

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Introduction

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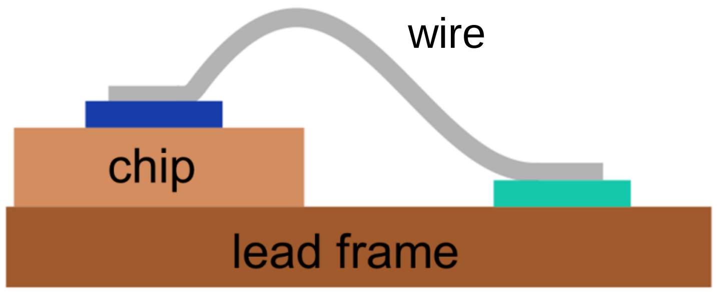
Introduction

EPPL project: APC in aluminum wire bonding

Wire bonding process in mass manufacturing:

- Wide process windows
- Several manual adjustments connected to component installation
- High amounts of devices affected

Wire bonding on a lead frame application



Our work on wire bonding in the European project EPPL (Enhanced Power Pilot Line):

- Investigations on bonding tool wear out [2, 3]
- Investigations on process influences of manual equipment adjustments
- Investigations on correlations between manual equipment adjustments and monitored equipment parameters

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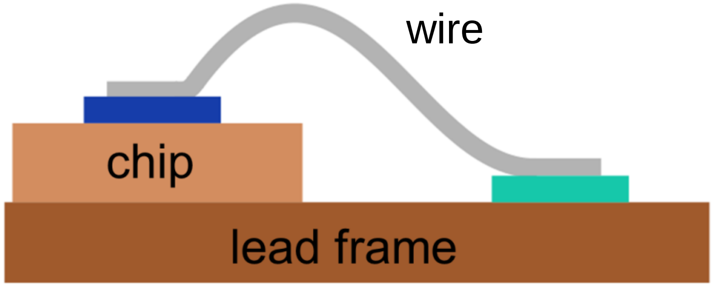

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Aluminum wire bonding

Overview

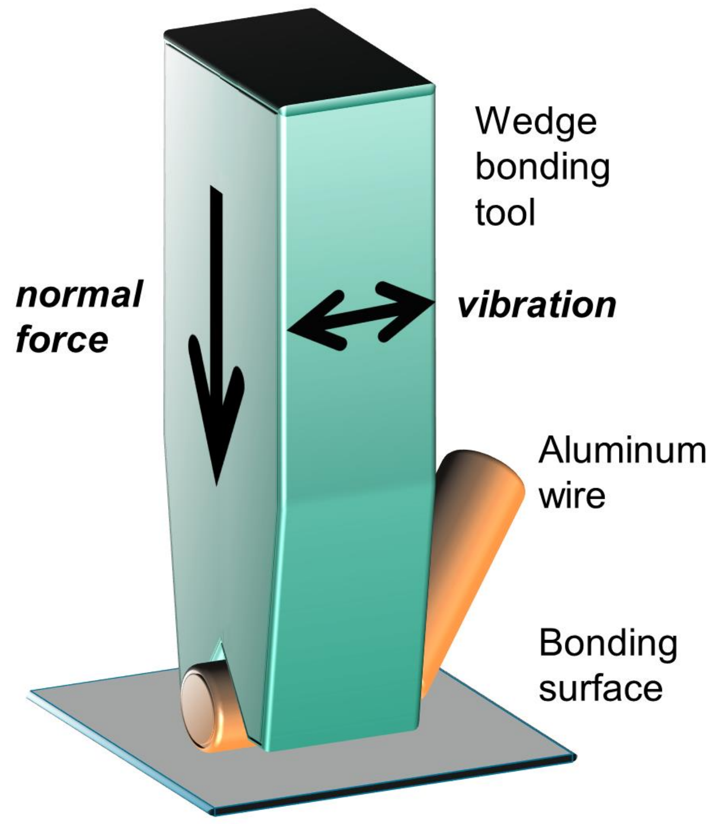
Wedge-wedge wire bonding:

- Thick Aluminum wire (100-500µm diameter)
- Metal bonding surface
- Bonding time ~ 200ms

Controlled input parameters:

- Horizontal ultrasonic ***vibration*** of 60kHz
- Vertical ***normal force***
- Theoretically process is not fully understood [4]

Sketch of wire bonding process



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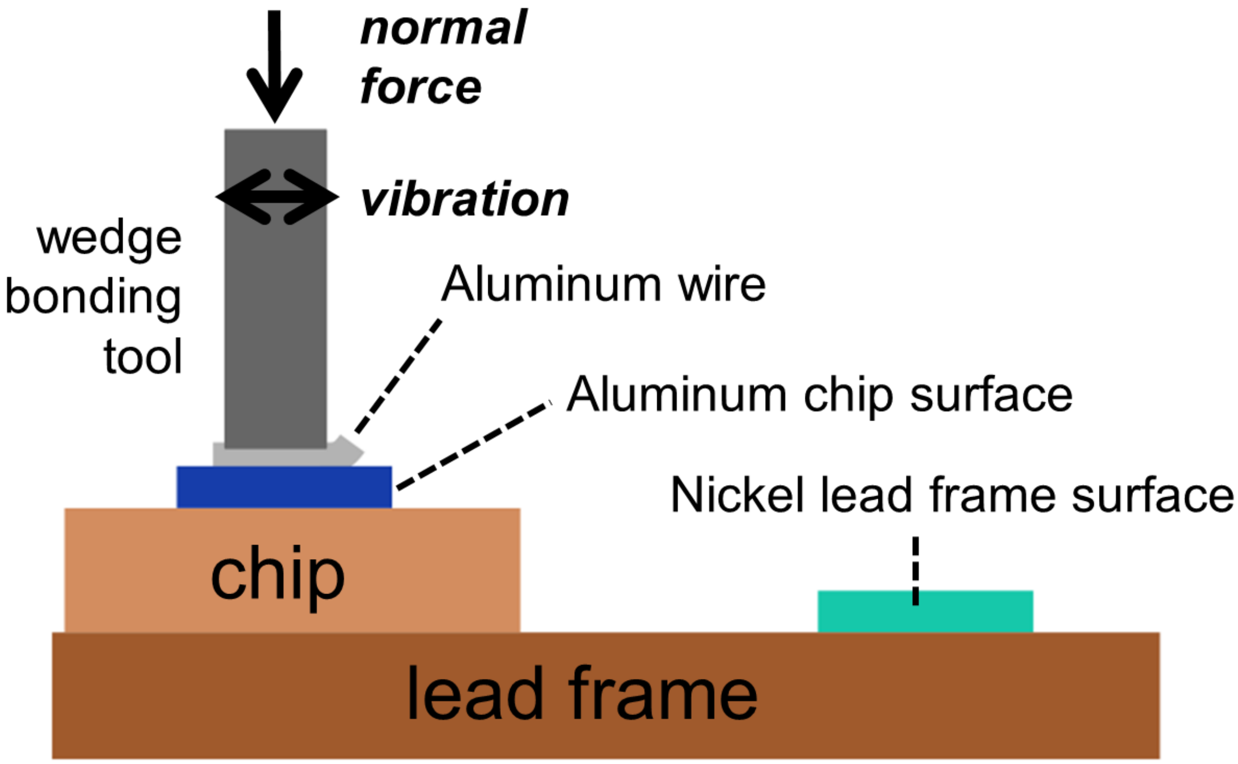
Aluminum wire bonding

Aluminum wire bonding on lead frame applications

First step: Bonding on the chip



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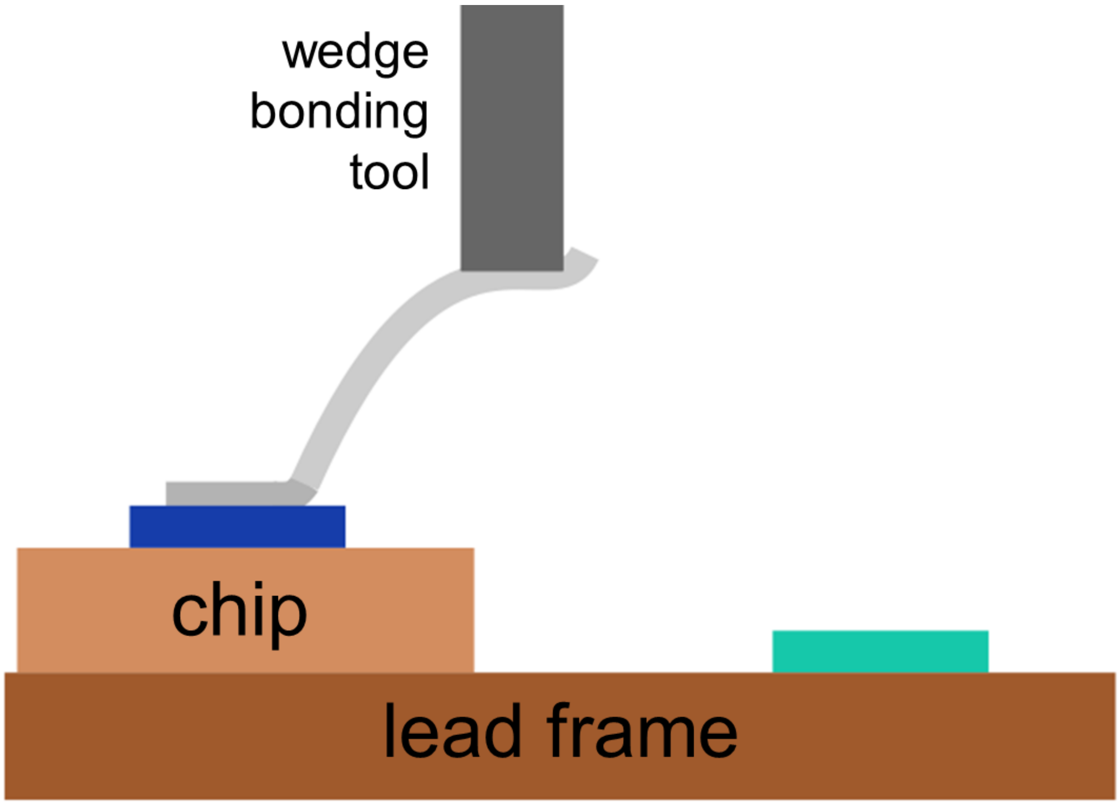
Aluminum wire bonding

Aluminum wire bonding on lead frame applications

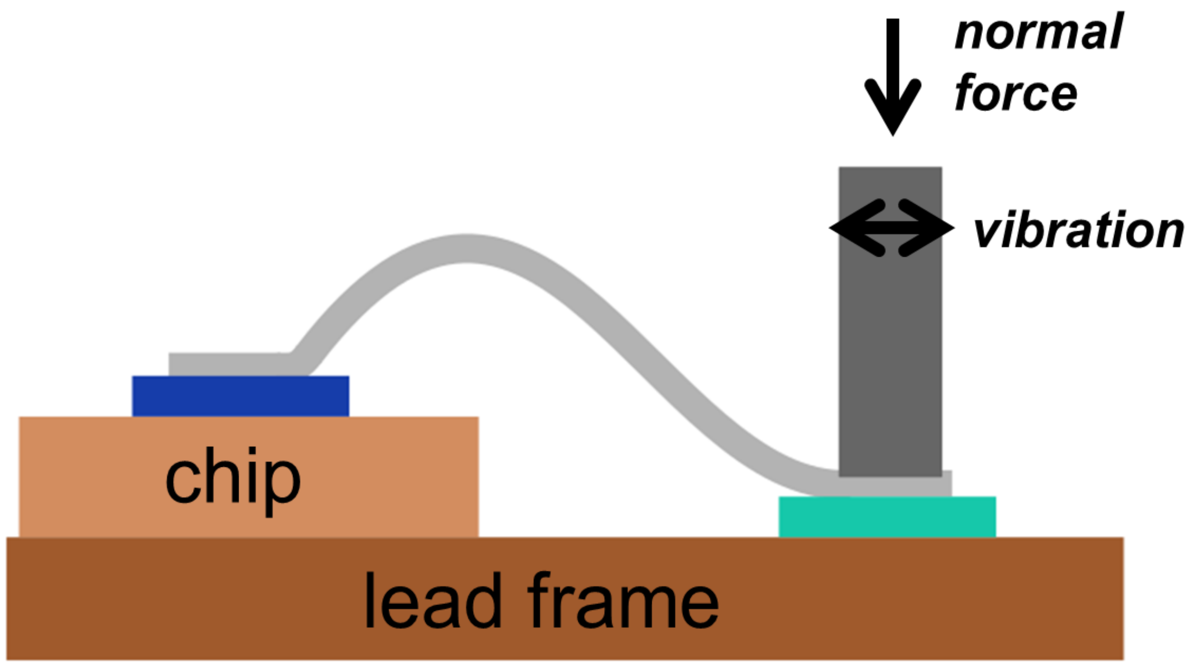
Second step: Wire loop formation



Aluminum wire bonding

Aluminum wire bonding on lead frame applications

Third step: Bonding on the lead frame



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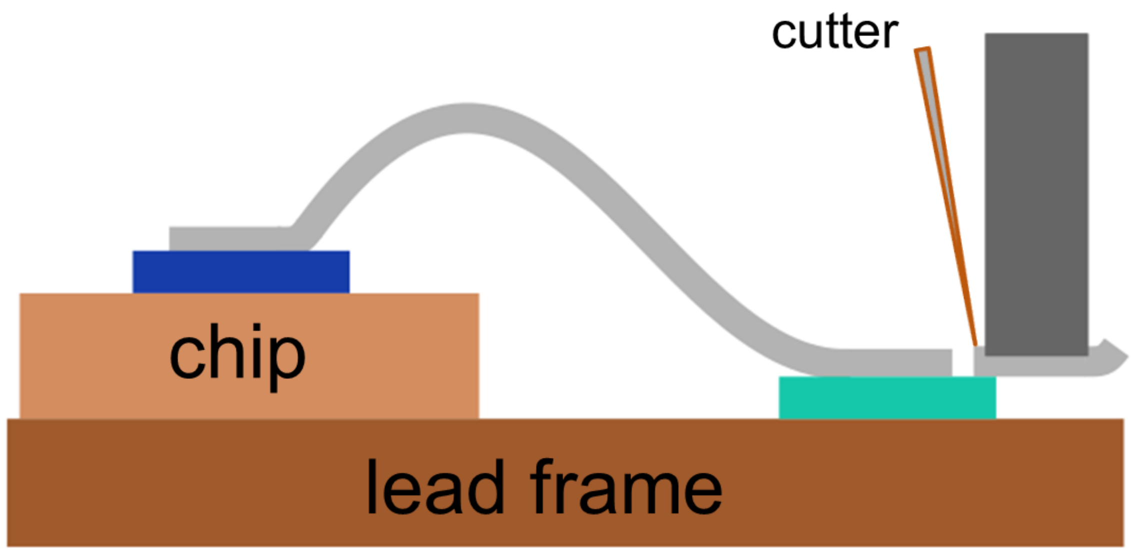
Aluminum wire bonding

Aluminum wire bonding on lead frame applications

Fourth step: Wire separation by cutter tool



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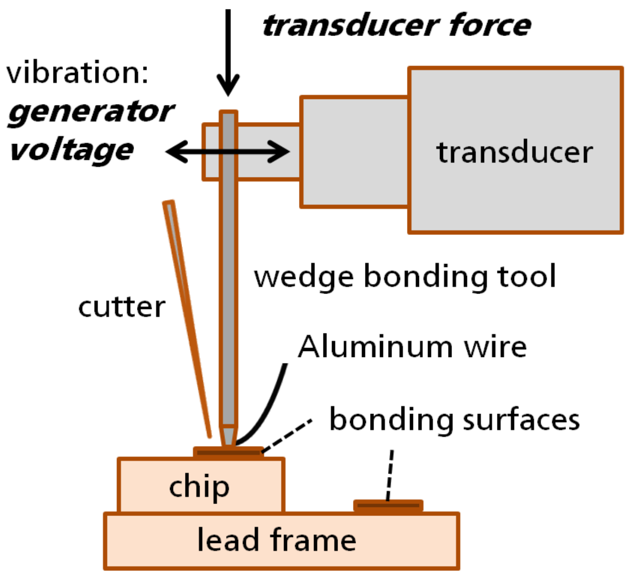
Aluminum wire bonding

Controlled parameters

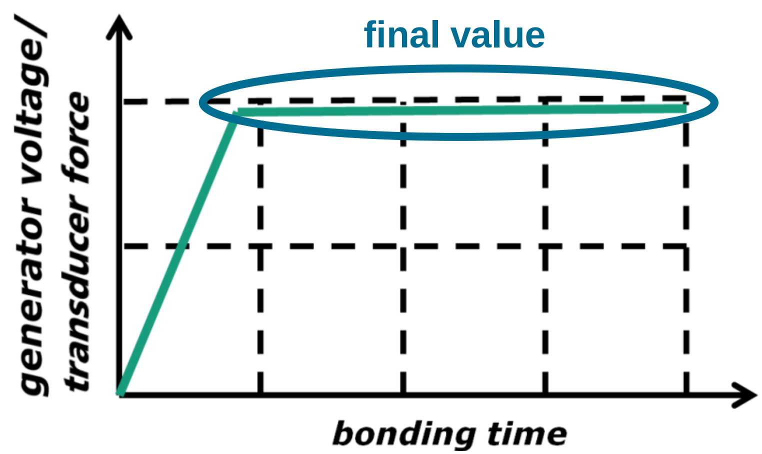
The following controlled parameters are stated to have the highest influence on bonding [5, 6]:

- ***generator voltage*** induces horizontal ultrasonic vibration
- ***transducer force*** induces vertical normal force

Generator voltage and transducer force



Controlled parameters over bonding time



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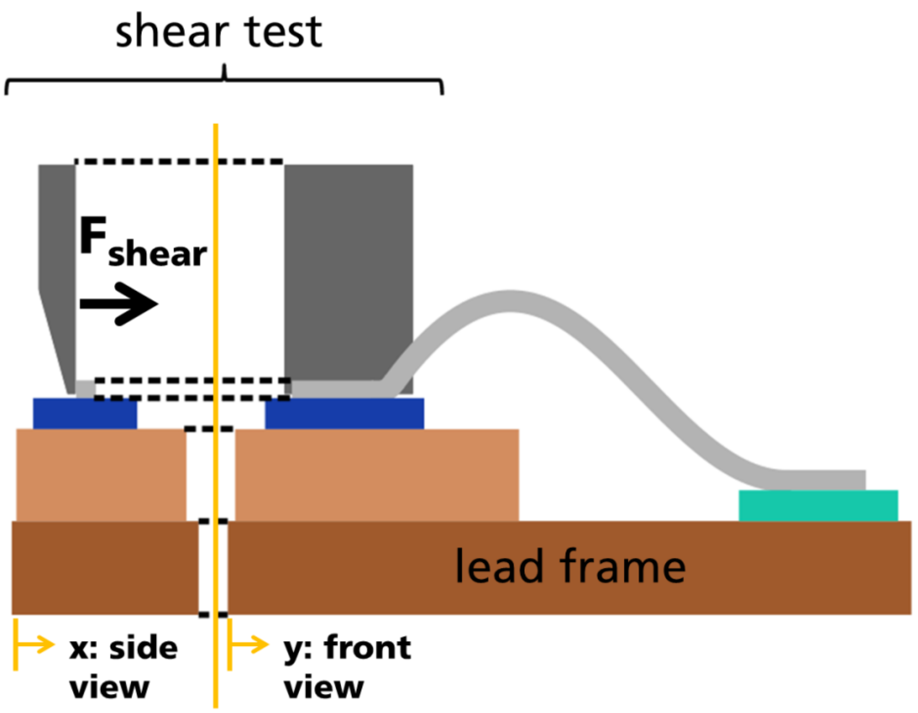
Process influences

Quality parameter: Shear force

Shear test:

- Shear test is usually used to rate bonding quality in mass manufacturing [5].
- Definition: Measure of shear force to destroy the wire in x-direction orthogonal to the wire alignment.

The quality parameter: Shear force



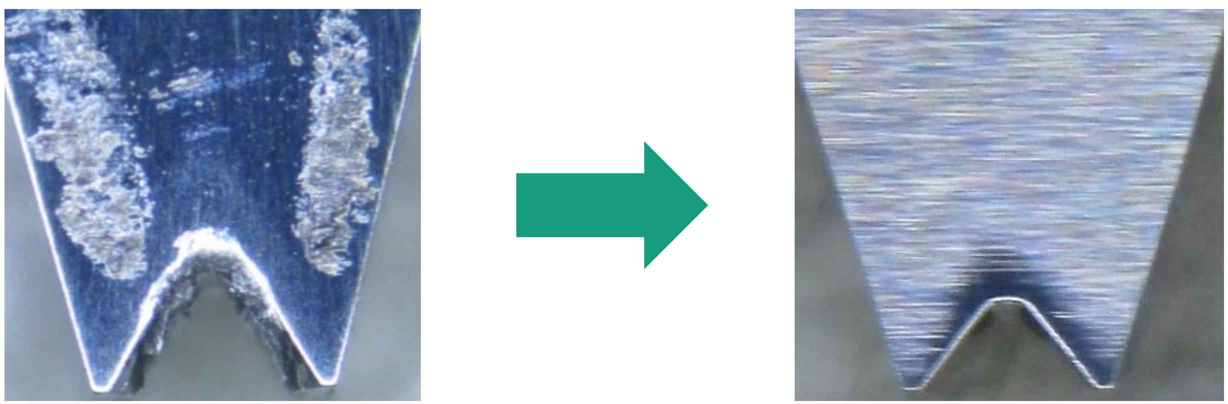
Study on manual adjustments in production

Wedge tool cleaning with manual adjusted installation

Wedge tool cleaning:

- Wedge bonding tools are cleaned after a fixed number of bonds usually several times per day to remove build-up of aluminum oxide at the tool tip.
- The reinstallation after cleaning requires manual equipment adjustment!

Wedge bonding tool before and after cleaning

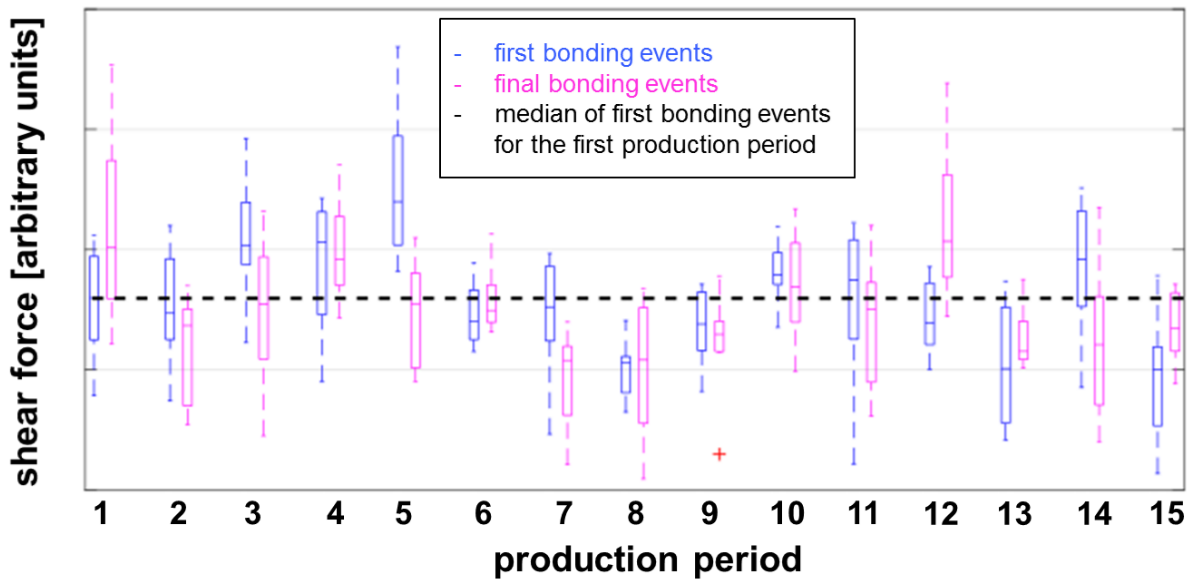


Study on manual adjustments in production

Shear force variations after bonding tool installation

Shear force studies of 10 wedges at the beginning and the end of 15 cleanings.

Shear forces on the chip surface for one wedge over production periods (8 samples per boxplot)



- Results of the wedge tool cleaning are tested separately.

→ Manual tool installation adjustments could be responsible for the variations inside the production window.

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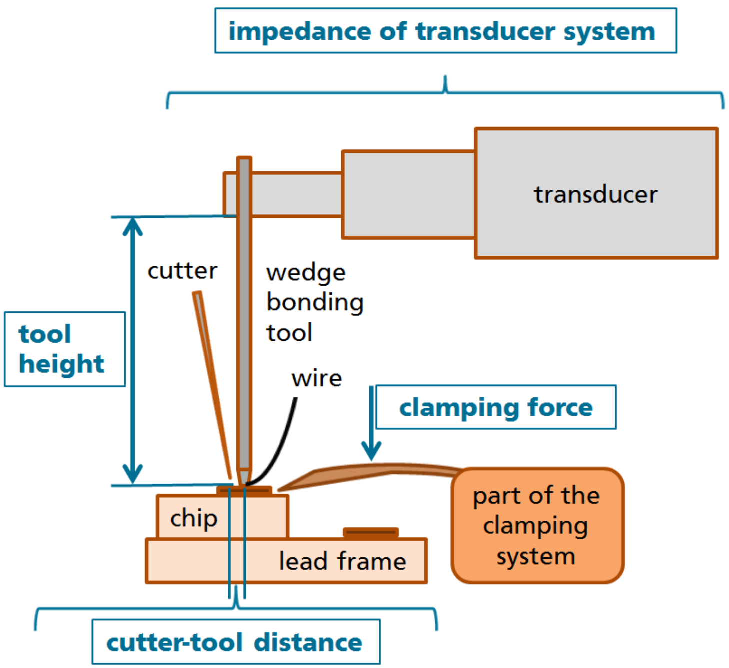
Experimental approach

Overview

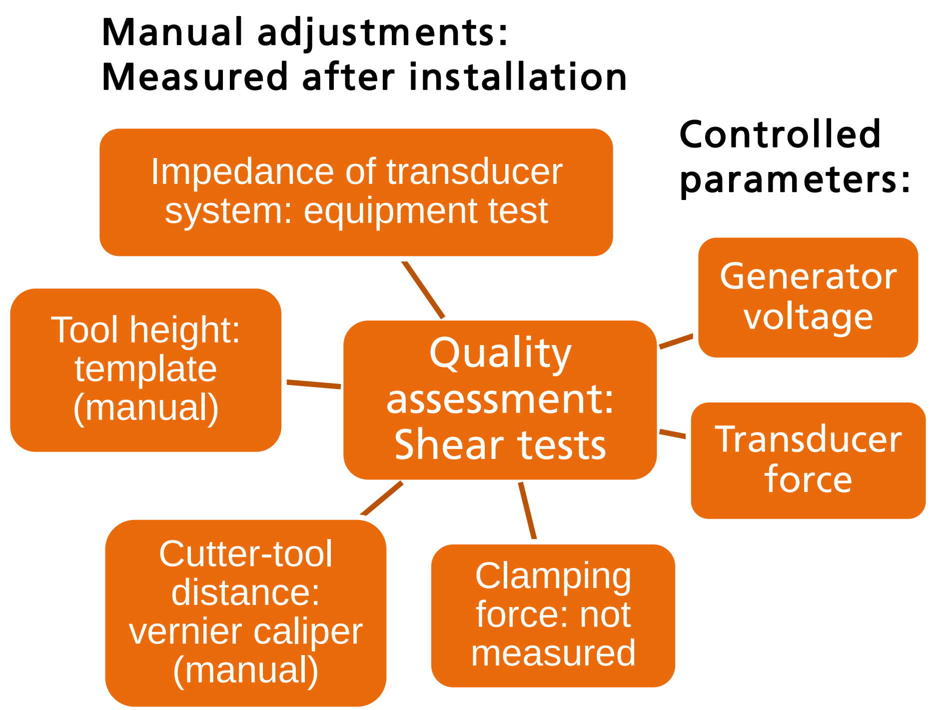
Manual adjustments impedance [7, 8] and clamping [9, 10] are assumed to have minor influence on the bonding process, but are not systematically investigated.

Systematic investigation of manual adjustments:

Selected manual adjustments



Investigations of experimental approach



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Experimental approach

Definition of manual adjustment states

Manual equipment adjustments:

- Reference state A
- Undesired manual adjustment states B-G

Sketch of the manual adjustments

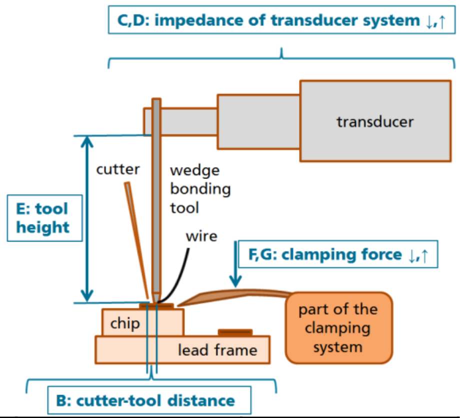


Table 1: Specifications of manual adjustment states

Label	Manual adjustment states	Reduced cutter-tool distance	Setup impedance	Shorter tool height	Device clamping
A	Controlled adjustment state	specified	specified	specified	specified
B	Reduced cutter-tool distance	LOW	specified	specified	specified
C	Setup impedance: Lower production limit	specified	LOW	specified	specified
D	Setup impedance: Upper production limit	specified	HIGH	specified	specified
E	Shorter tool height	specified	specified	LOW	specified
F	Weak device clamping	specified	specified	specified	LOW
G	Strong device clamping	specified	specified	specified	HIGH

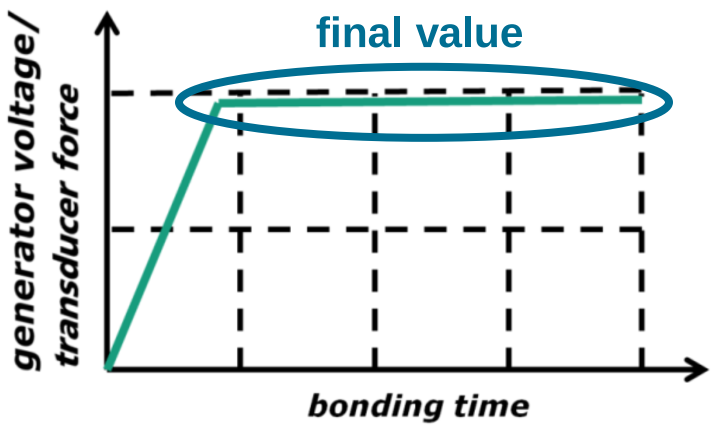
Experimental approach

Manual adjustment states vs. controlled parameters

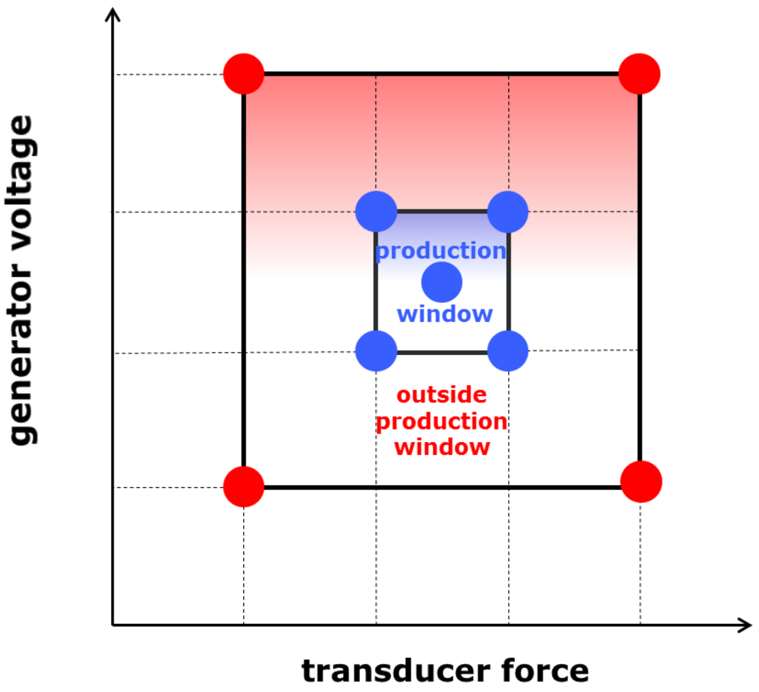
Experimental approach 1:
Shear force measurements for

- all manual adjustment states
- and a variation of the final values of the *controlled parameters,* generator voltage and transducer force in and outside the production window

Final values of the controlled parameters



Variation of the final values of the controlled parameters in and outside the production window



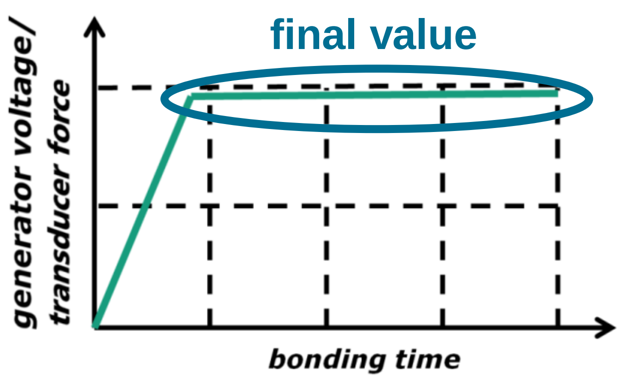
Experimental approach

Manual adjustment states at two different transducers

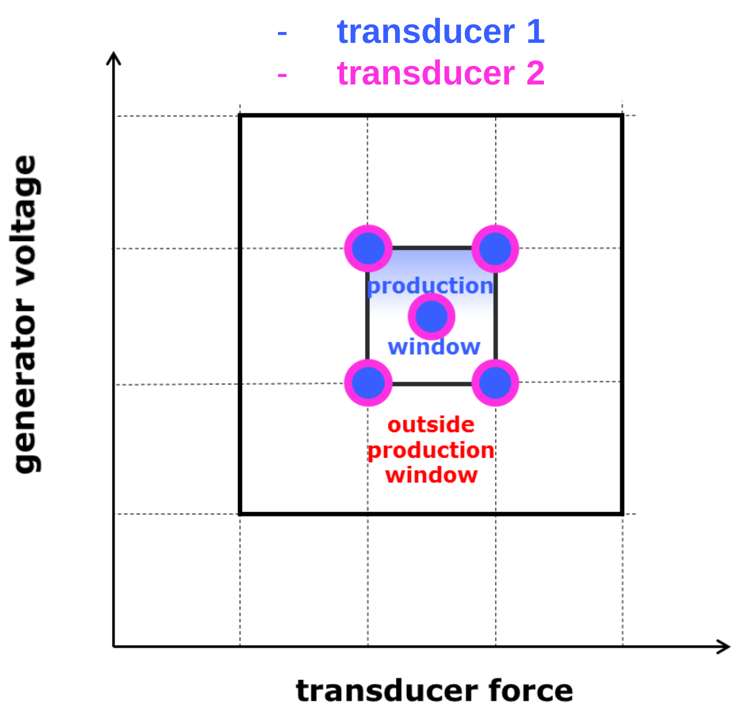
Experimental approach 2:
Shear force measurements :

- at two different transducers
- for all manual adjustment states with the final values of the *controlled parameters,* generator voltage and transducer force inside the production window

Final values of the controlled parameters



Variation of the final values of the controlled parameters inside the production window for two transducers



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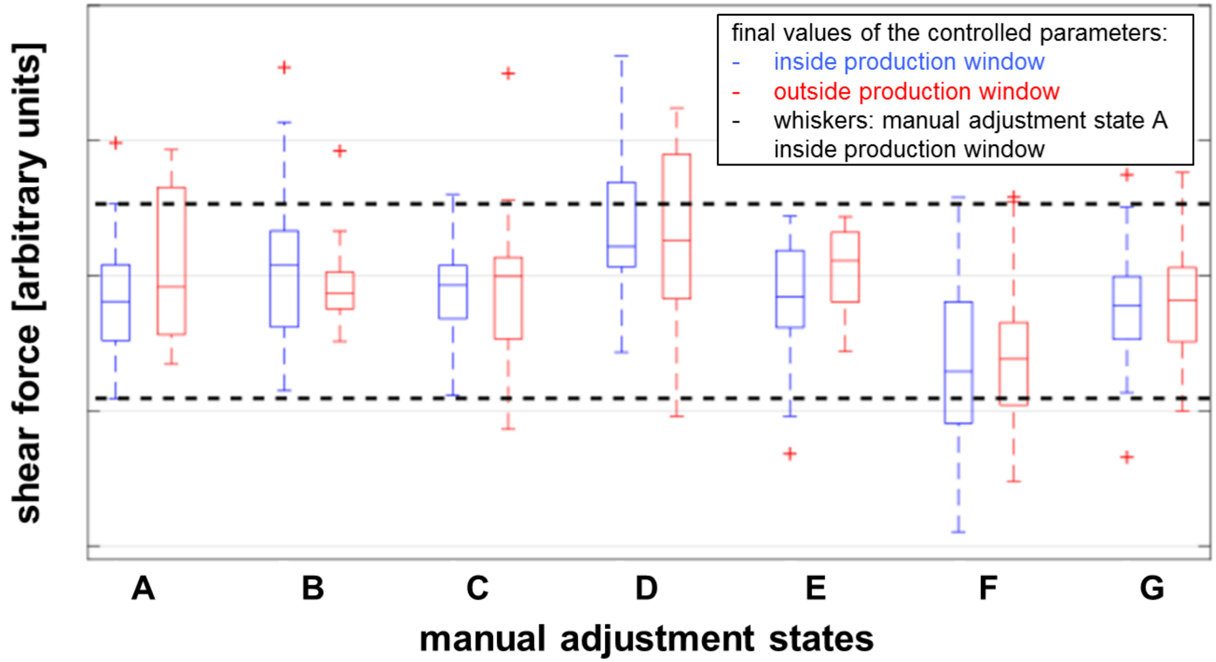
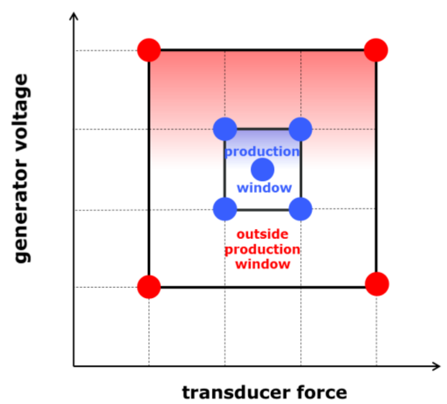
Results

Manual adjustment states vs. controlled parameters

Shear forces on the chip surface for manual adjustments states A-G with controlled parameters in and outside production window (8 samples per boxplot)





→ Shear forces of the adjustment states, high impedance D / low clamping F are increased (D) / reduced (F) in comparison with the reference state A.

→ Controlled parameters outside production window influence shear forces less.

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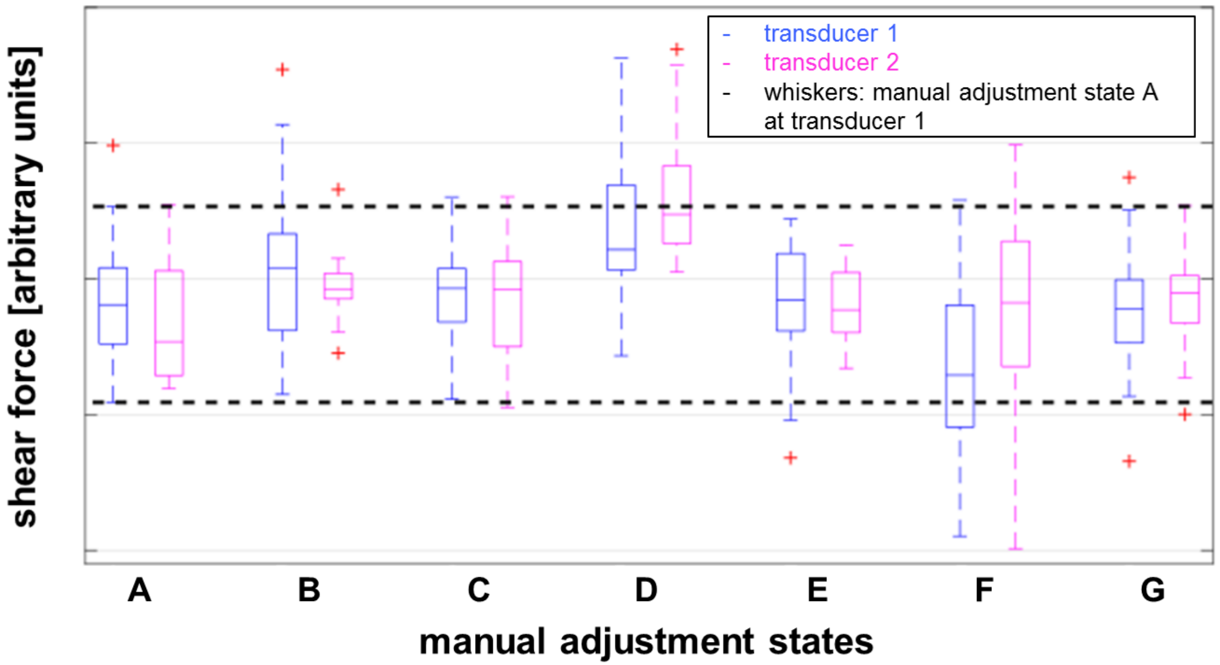
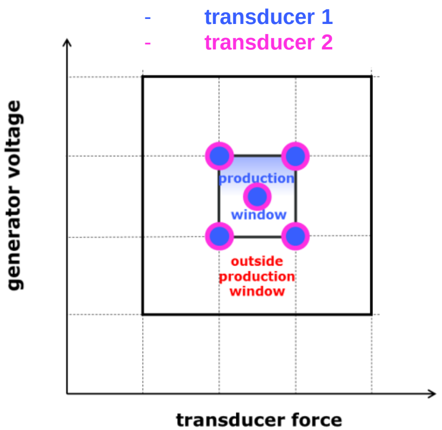
Results

Manual adjustment states for two different transducers

Shear forces on the chip surface for manual adjustments states A-G for two different transducers (8 samples per boxplot)





→ The influences of the manual adjustment states D and F at the production stability can be demonstrated for two different transducers.

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Results

Implementation of results

Specification improvements:

- Reduction of upper production limit of setup impedance
- Raise of clamping force
- More frequent control of clamping force

The manual adjustment states

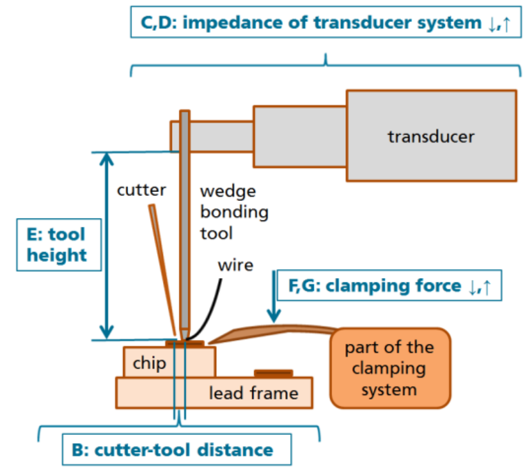

Table 2: Impedance and clamping adjustment states

Label	Manual adjustment states	Reduced cutter-tool distance	Setup impedance	Shorter tool height	Device clamping
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Conclusion

Innovations

Systematic approach to analyze influences of manual adjustments for process improvement

- Definition of typical manual adjustments related to component installations
- Detection of influence on production stability by manual adjustments with shear test measurements
- Comparison of influences from *manual adjustments* with *controlled parameters*
- Optimization of specifications to increase production stability
- Verification of results at two transducers

Conclusion

Outlook

- In further investigations we demonstrate manual adjustment conditions to be detectable by data mining on monitored machine parameters (to be published at the ASMC Conference 2017).
- The further studies show condition-based maintenance to enable detection of manual adjustment conditions for every bonding event with equipment stops including detailed adjustment instructions (to be published at the ASMC Conference 2017).
- With an implementation of all findings a condition-based maintenance system can partially substitute manual readjustments, test measures, pull and shear tests.
- The concepts are transferable to other back end equipment with manual adjustments in mechanical component installation.

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→ **Thank you for your attention!**

→ **Questions?**

More details: felix.klingert@iisb.fraunhofer.de

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Literature

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