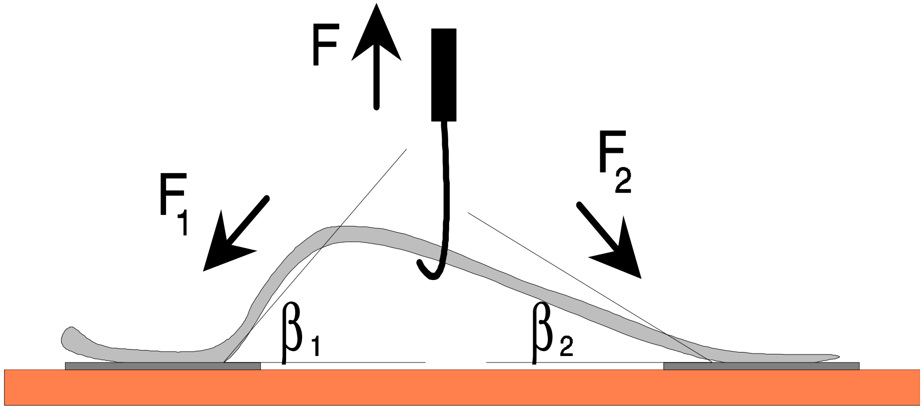
Wire Bonding Quality Assurance and Testing Methods

Visual and mechanical testing methods of wire bonds

- Light- and scanning electron microscopical examinations
- Pull test
- Shear test



$$F = F_1 = F_2 \quad \text{bei } \beta_1 = \beta_2 = 30°$$

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Wire Bonding Quality Assurance and Testing Methods

Wire bonding and quality assurance: General requirements

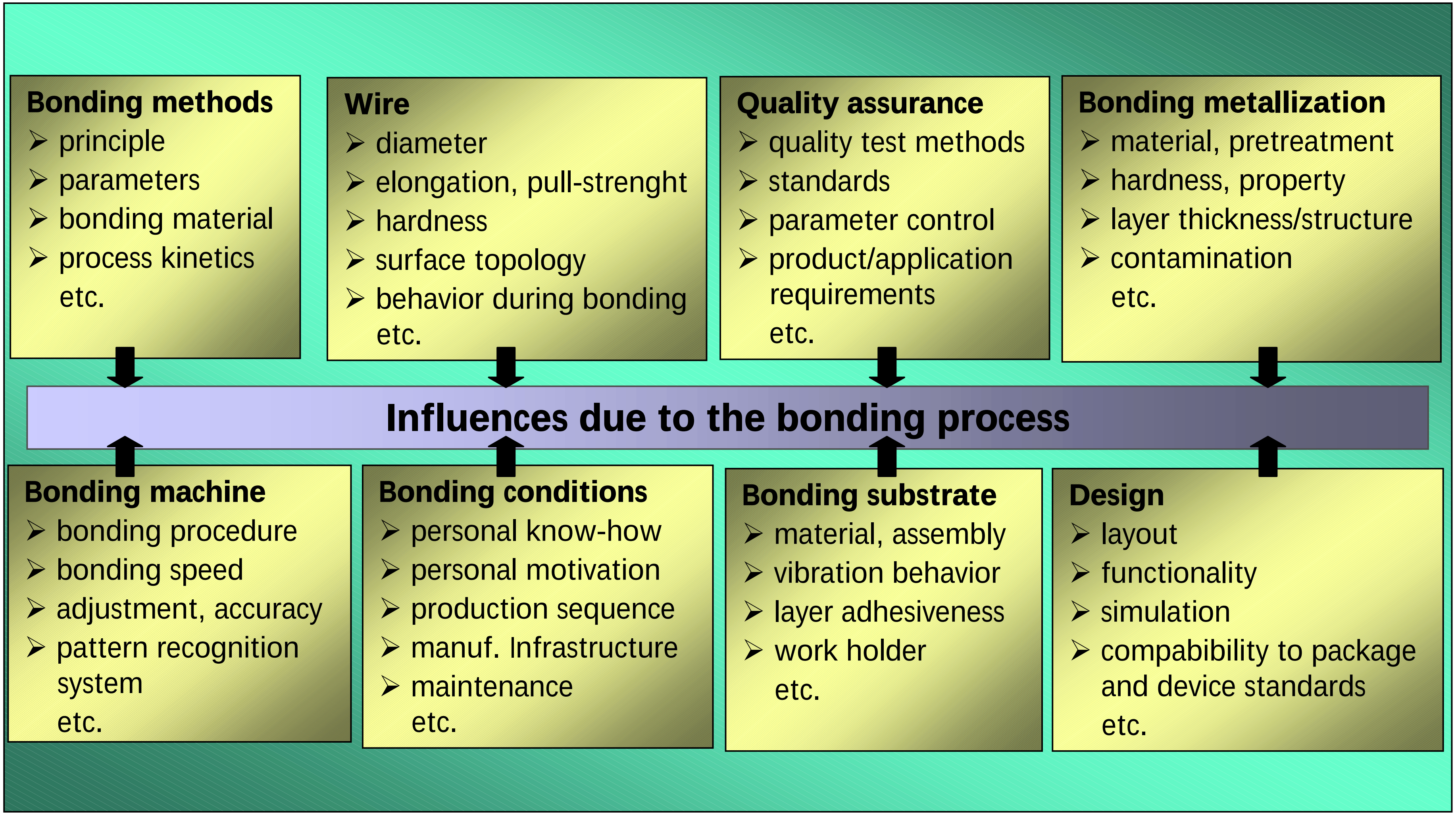
Global formulation:

- low cost technology
- easy to realize and flexible during application
- strong mechanical stability
- thermal stability (in regard to further processing steps) and
- good long term stability
- low contact resistance
- as much as possible great welding area between wire and metallization
- no physical and chemical interactions with other materials

Test methods:

- visual inspektion MIL-STD 883 method 2010, 2017
- pull test MIL-STD 883 methode 2011 (destructive), methode 2023 (non destructive)
- shear test ASTM F 1269-89

Wire Bonding Quality Assurance and Testing Methods



Bonding methods
- principle
- parameters
- bonding material
- process kinetics

etc.

Wire
- diameter
- elongation, pull-strenght
- hardness
- surface topology
- behavior during bonding

etc.

Quality assurance
- quality test methods
- standards
- parameter control
- product/application requirements

etc.

Bonding metallization
- material, pretreatment
- hardness, property
- layer thickness/structure
- contamination

etc.

Influences due to the bonding process

Bonding machine
- bonding procedure
- bonding speed
- adjustment, accuracy
- pattern recognition system

etc.

Bonding conditions
- personal know-how
- personal motivation
- production sequence
- manuf. Infrastructure
- maintenance

etc.

Bonding substrate
- material, assembly
- vibration behavior
- layer adhesiveness
- work holder

etc.

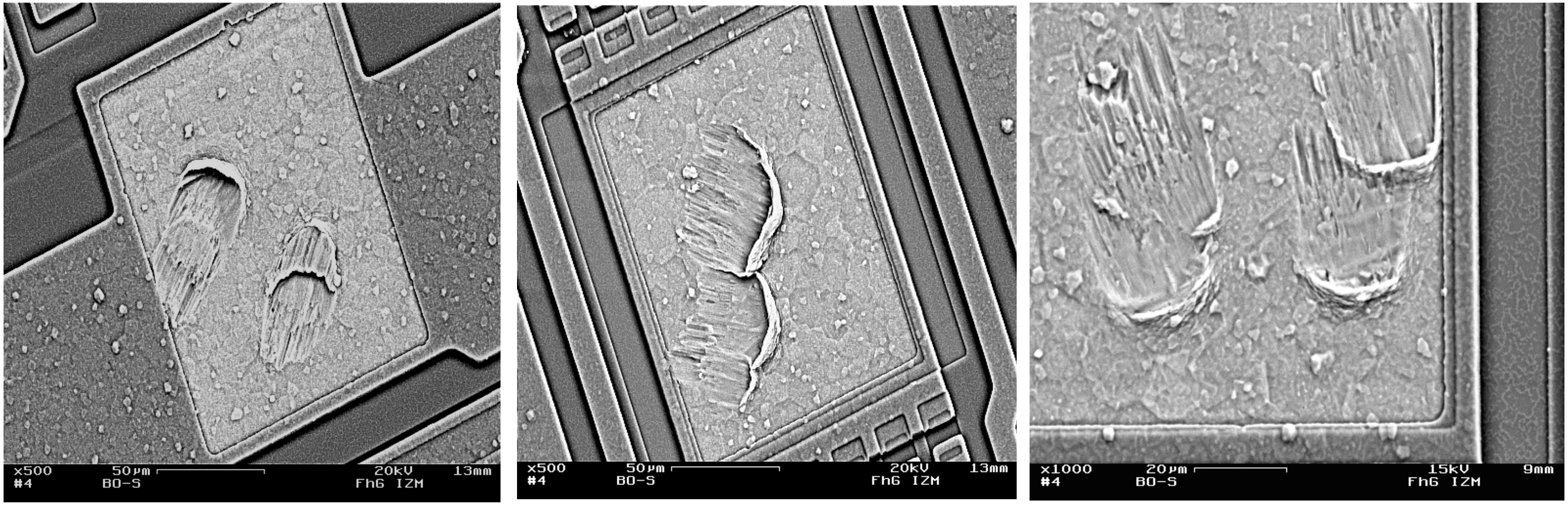
Design
- layout
- functionality
- simulation
- compability to package and device standards

etc.

Wire Bonding Quality Assurance and Testing Methods

<u>Bond pads on chip:</u>

- Multiple imprints of test probes or deep very imprints
- Strong adverse effects of surface quality
- Influence on bondability



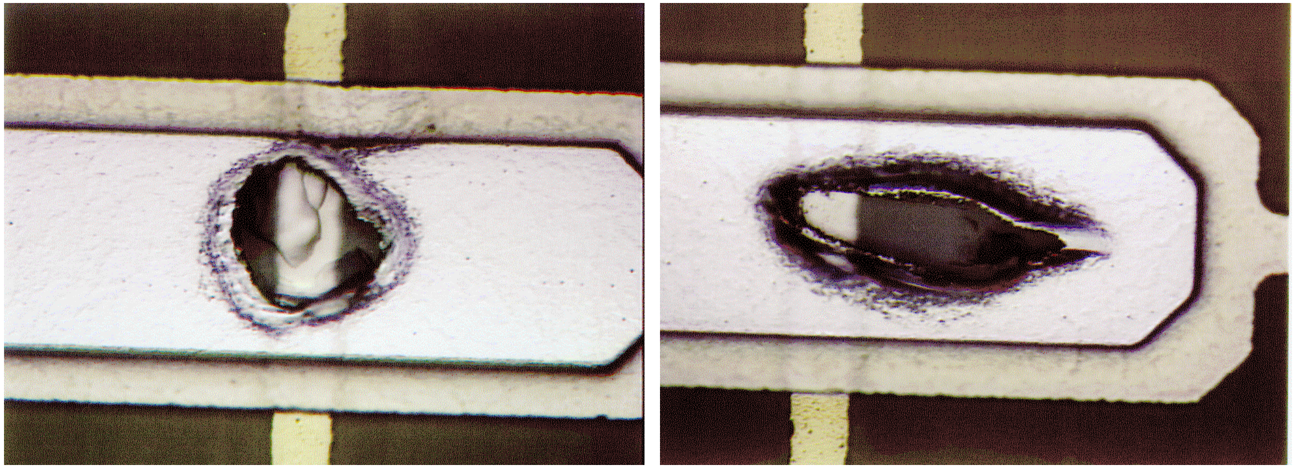
Wire Bonding Quality Assurance and Testing Methods

Visual inspection MIL-STD 883 method 2010, 2017

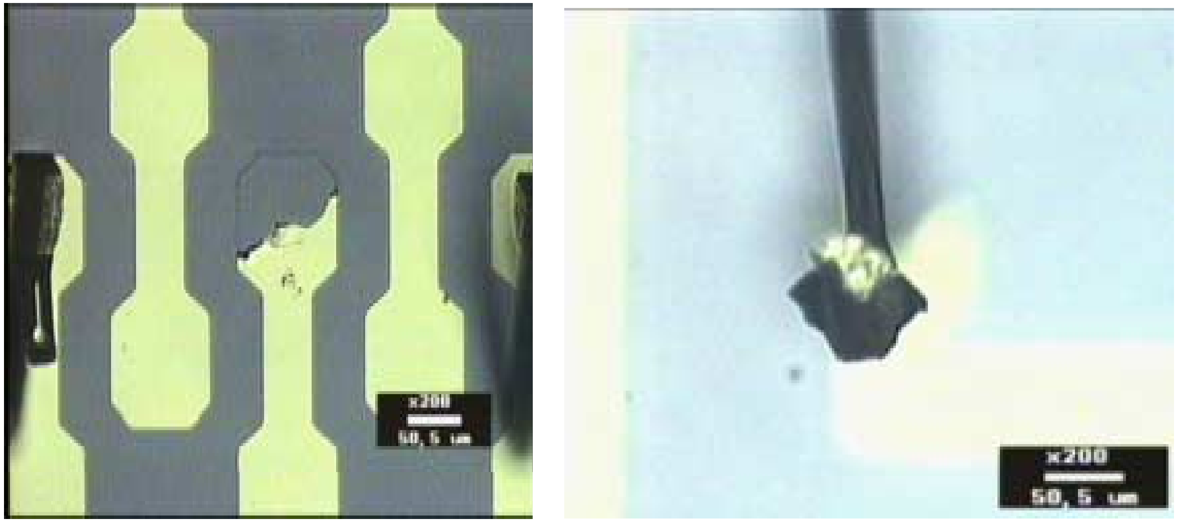
to proof:	selective parameters:
- geometry of bond contacts	- wire deformation
- loop geometry	- snap off behaviour
- placement of bond contacts	- position and welded area
- predetermined quantity of loops	- adhesion of metallization
- short circuits	- missing bonds or loops

Remark: Visual inspection of bondpads before wire bonding!

Wire Bonding Quality Assurance and Testing Methods



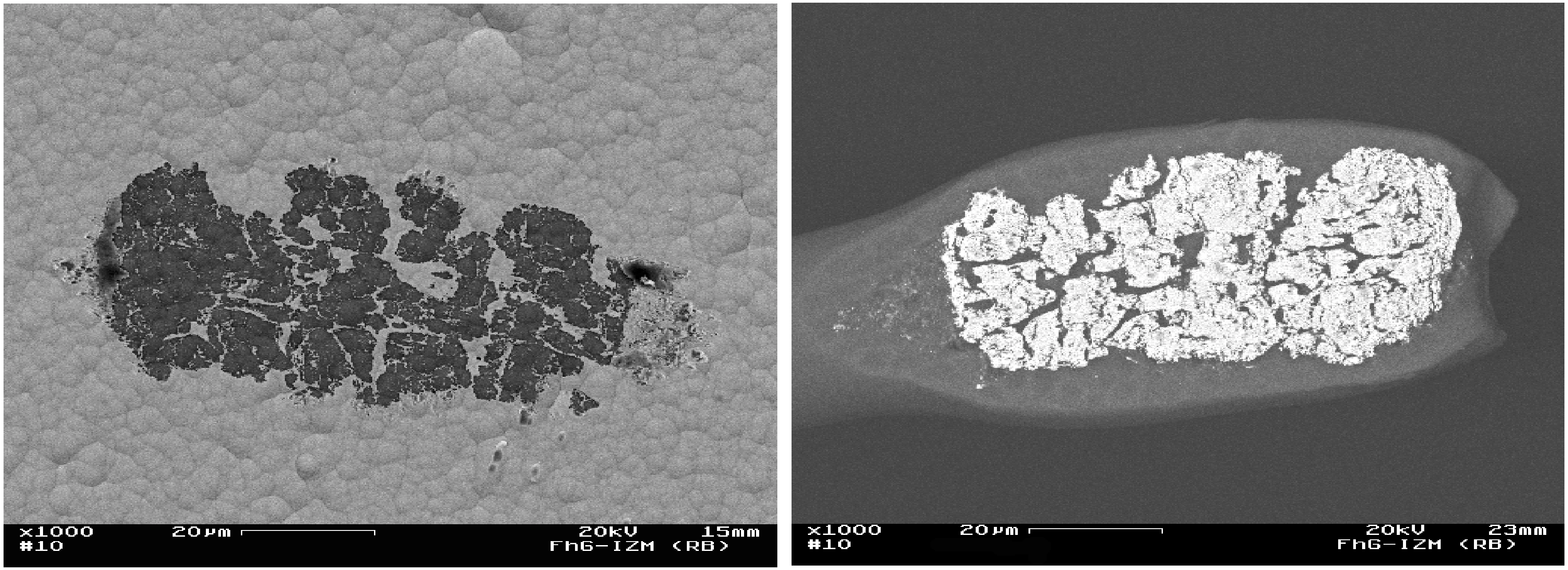
Ball and wedge bond lift offs of wafer metallizations while TS-Au-B/W-Bonding



Wafer metallization lift offs while TS-Au-W/W-Bonding

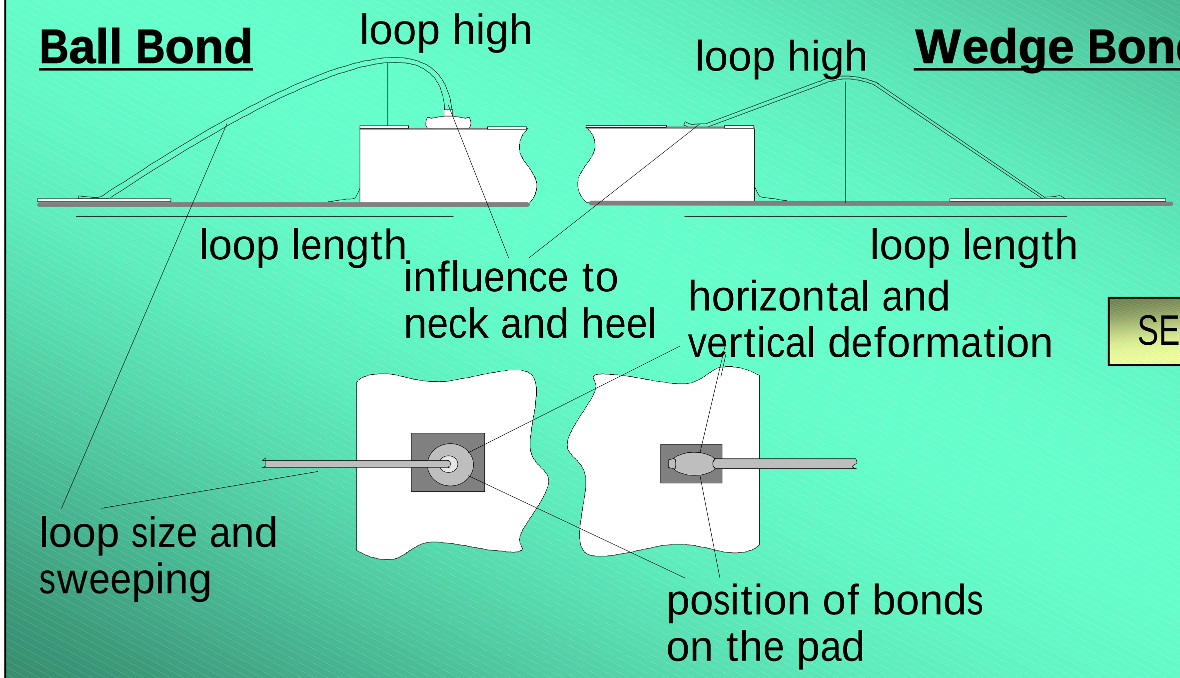
Wire Bonding Quality Assurance and Testing Methods

SEM-View (BSE): PCB metallization lift off and undersurface of a lift off bond (wedge)



Wire Bonding Quality Assurance and Testing Methods

Quality Tests (Visual Methods)



Ball Bond

loop high

loop length

influence to neck and heel

loop size and sweeping

loop high

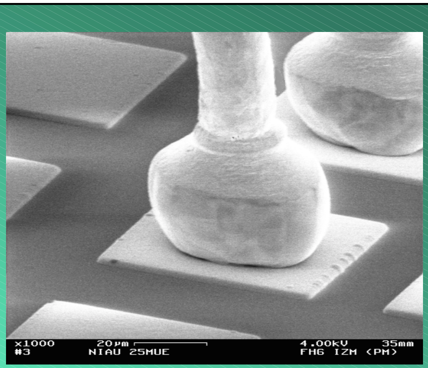
Wedge Bond

loop length

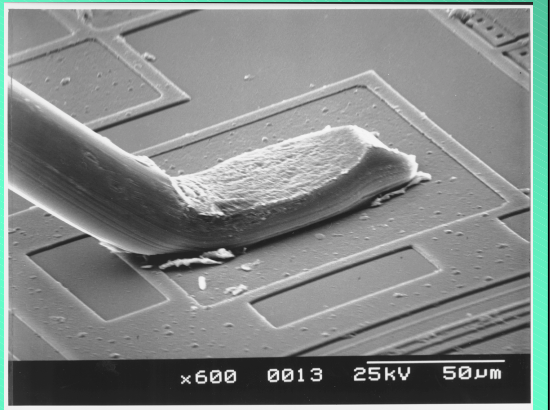
horizontal and vertical deformation

position of bonds on the pad

Geometrical Parameters during Wire Bond



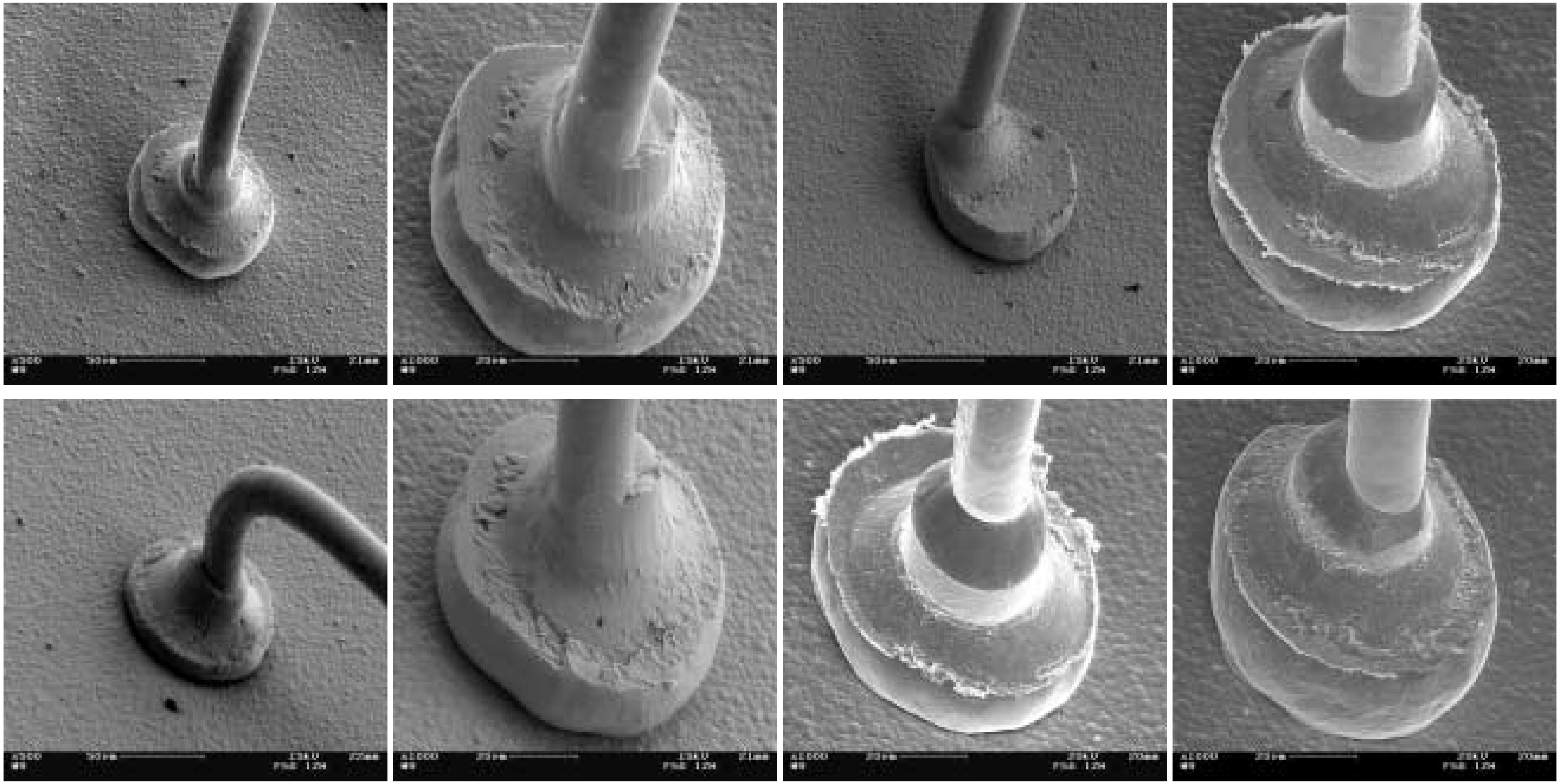
SEM – Figure of a typical Ball Bond



SEM – Figure of a typical Wedge Bond

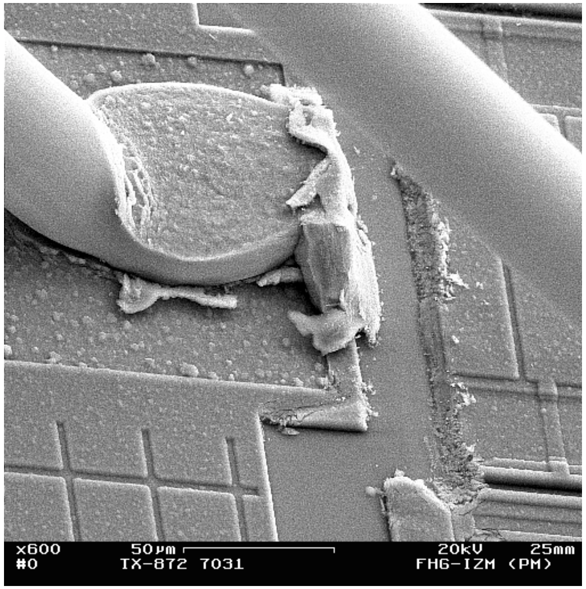
Wire Bonding Quality Assurance and Testing Methods

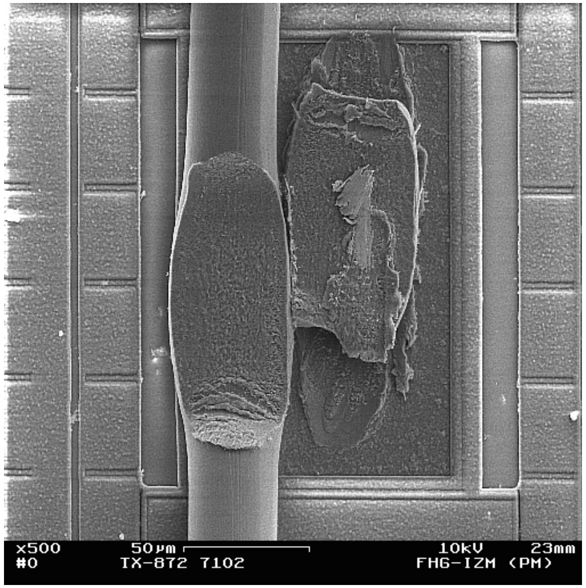
Ball bond failures

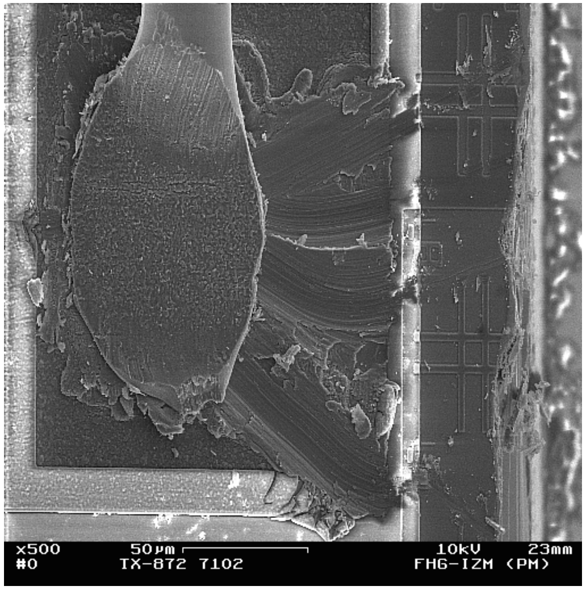


Wire Bonding Quality Assurance and Testing Methods

Visual inspection of wire bonds

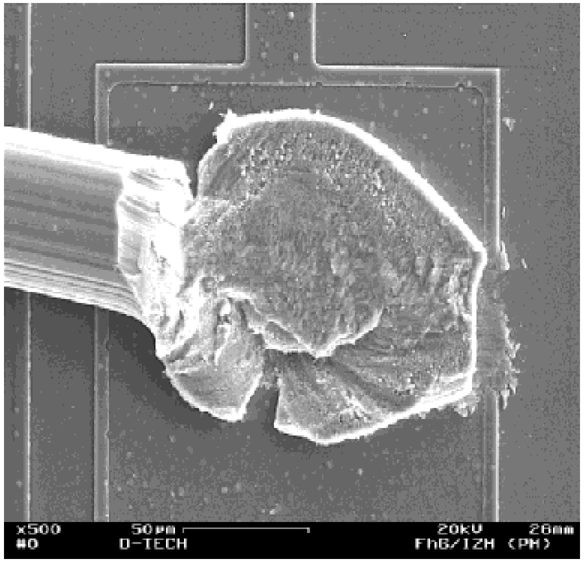


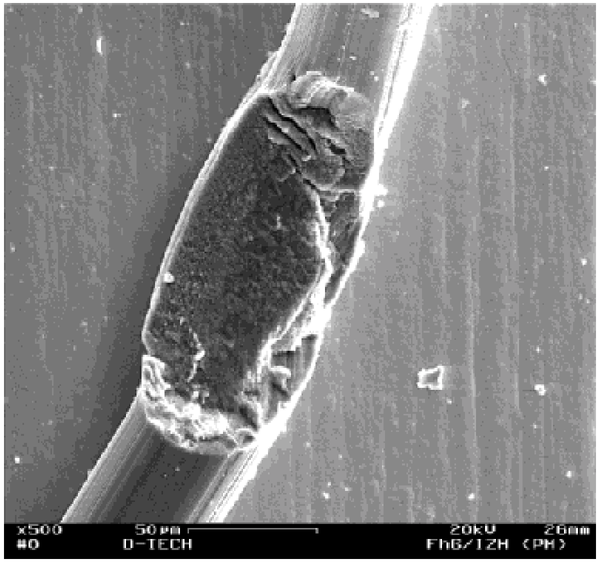


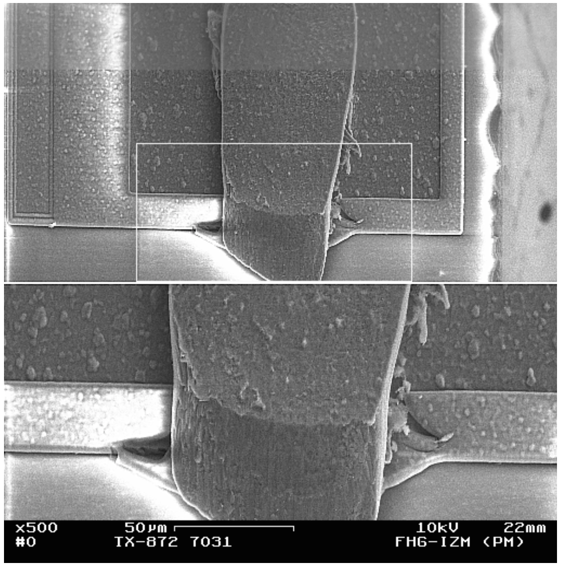


Wire Bonding Quality Assurance and Testing Methods

Visual inspection of wire bonds



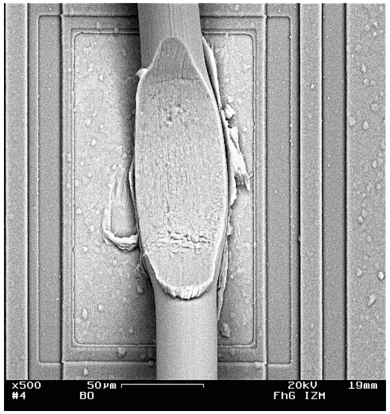


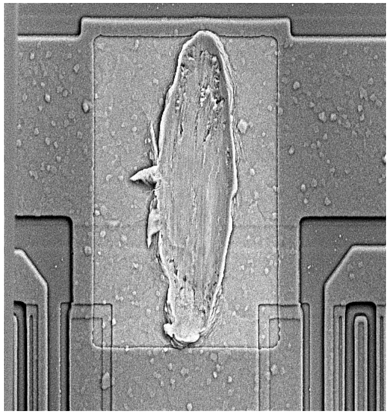


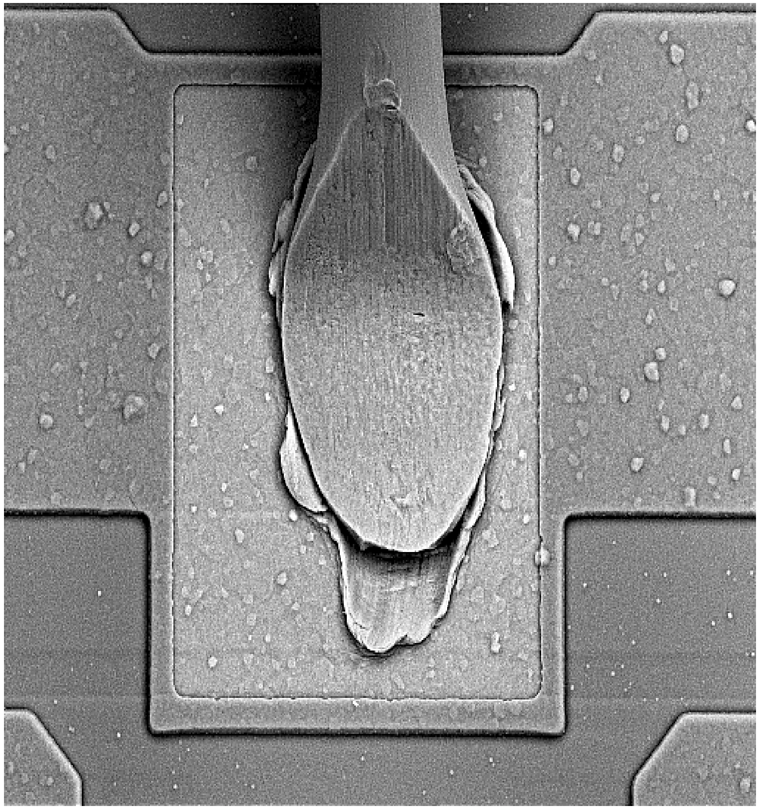
Wire Bonding Quality Assurance and Testing Methods

Wedges on chip

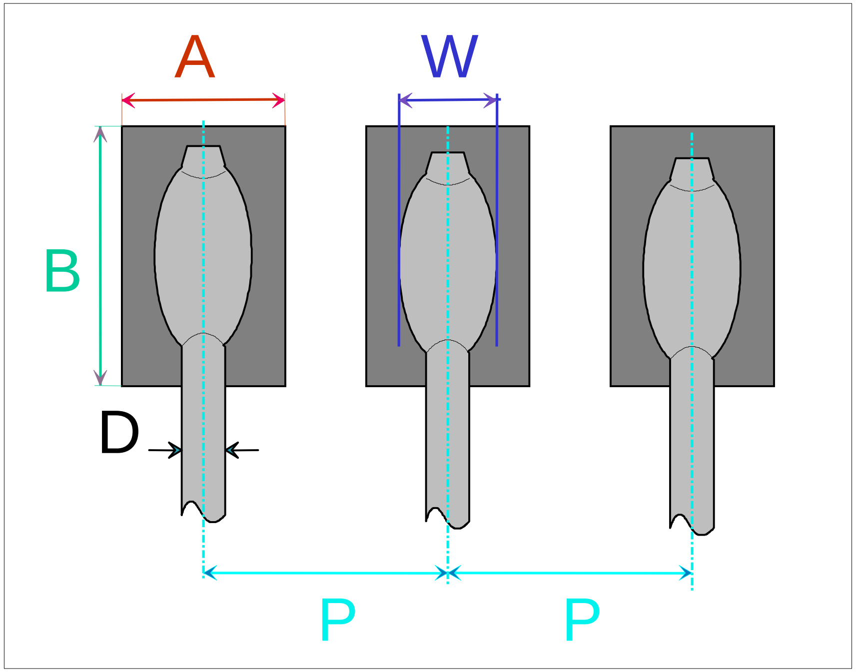
- strong squeezing out of chip metallization while bonding
- possible evidence of a too soften surface metallization







Wire Bonding Quality Assurance and Testing Methods



A pad width

B pad length

D wire diameter

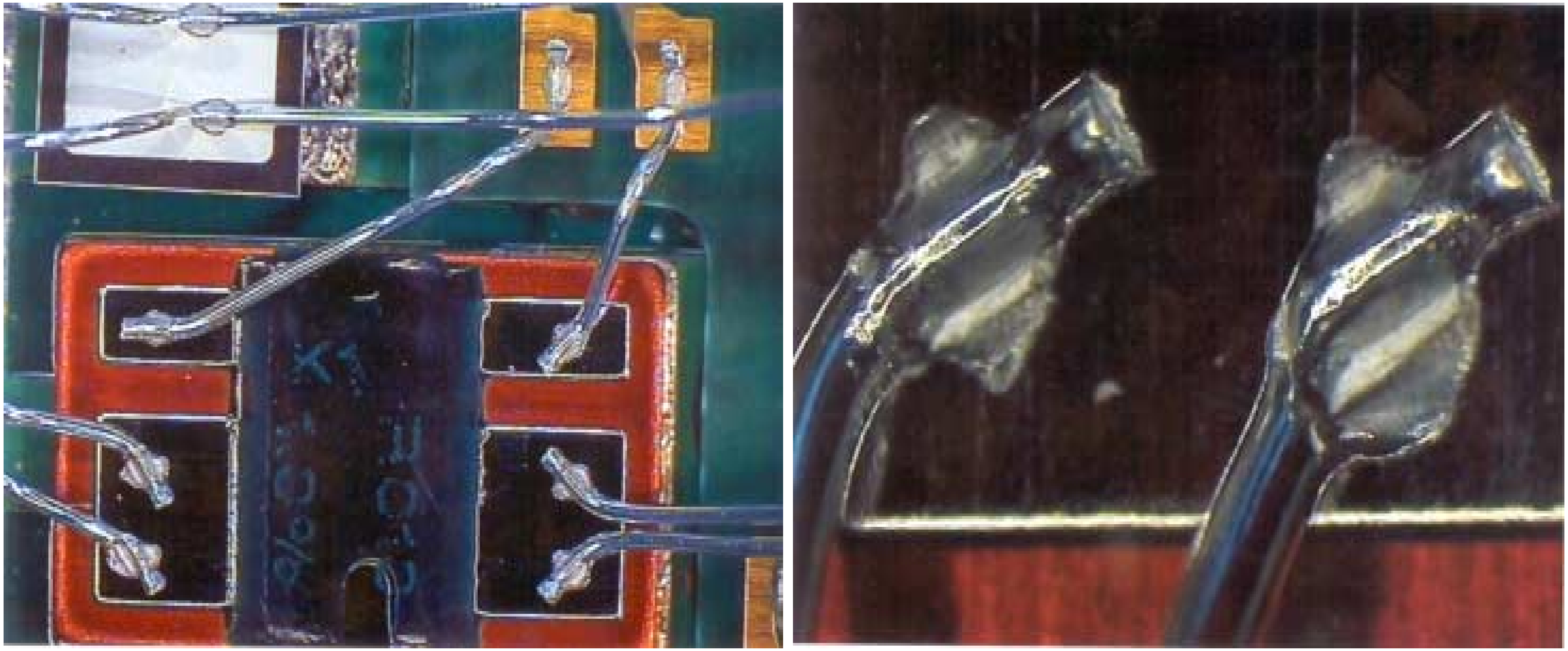
W bond width

P pitch

wire D	standard				cutting edge			
	A	B	P	W	A	B	P	W
1Mil	100µm .004in	125µm .005in	125µm .005in	45µm .0018in	50µm .002in	75µm .003in	75µm .003in	38µm .0015in
2Mil	125µm .005in	150µm .006in	200µm .008in	75µm .003in	90µm .0036in	125µm .005in	140µm .0056in	70µm .0028in
3Mil	180µm .0072in	200µm .008in	250µm .01in	125µm .005in	120µm .0048in	170µm .0064in	150µm .006in	112µm .0045in
4Mil	200µm .008in	280µm .0112in	280µm .0112in	130µm .0052in	150µm .006in	220µm .0088in	190µm .0076in	130µm .0052in

wire D	Heavy wire							
	A	B	P	W	A	B	P	W
5Mil	250µm .01in	300µm .012	350µm .014in	150µm .006in	175µm .007	250µm .01in	250µm .01in	150µm .006in
6Mil	250µm .01in	500µm .02in	400µm .016in	200µm .008in	230µm .0092in	320µm .0128in	250µm .01in	180µm .0072in
10Mil	400µm .016in	800µm .032in	600µm .024in	320µm .0128in	350µm .013in	500µm .02in	350µm .013in	300µm .012in
20Mil	800µm .032in	1300µm .052in	1150µm .046in	650µm .026in	660µm .0264in	950µm .038in	700µm .028in	600µm .024in

Wire Bonding Quality Assurance and Testing Methods

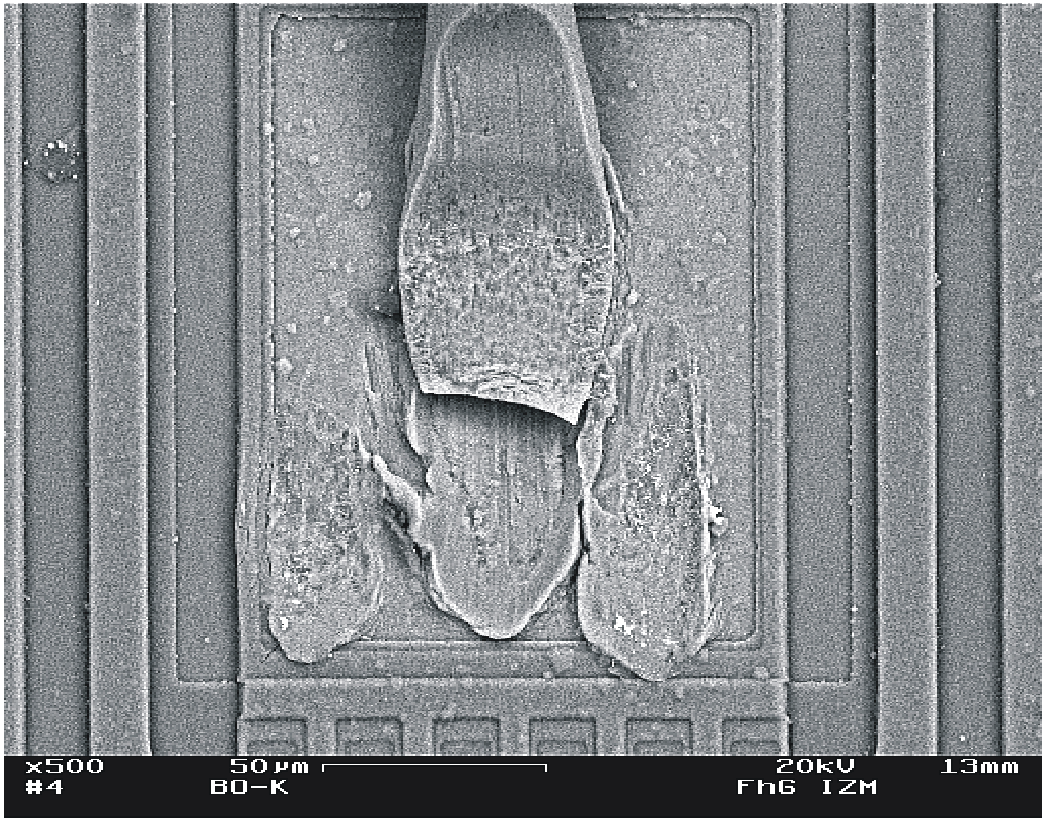


Overbonded wedges (too much deformation), right: Detail

Wire Bonding Quality Assurance and Testing Methods

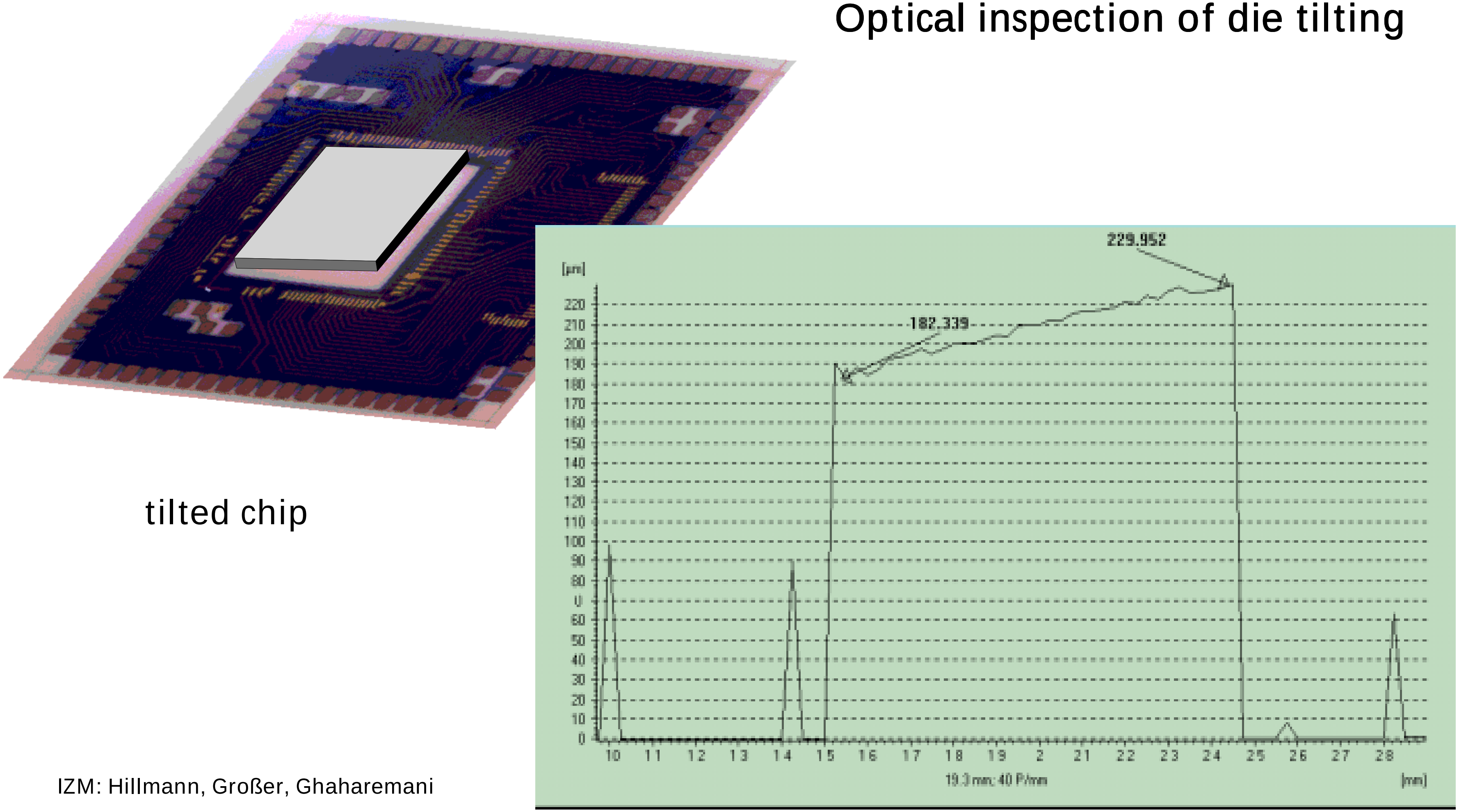
Results of a tilted glued or soldered chip on bonding process:

- Surfaces of chip pads aren´t horizontal
- Bonding tool is touched down tilted, too
- Wedge is deformed non-uniform
- Pad metallization or chip could be damaged



Wire Bonding Quality Assurance and Testing Methods

Optical inspection of die tilting

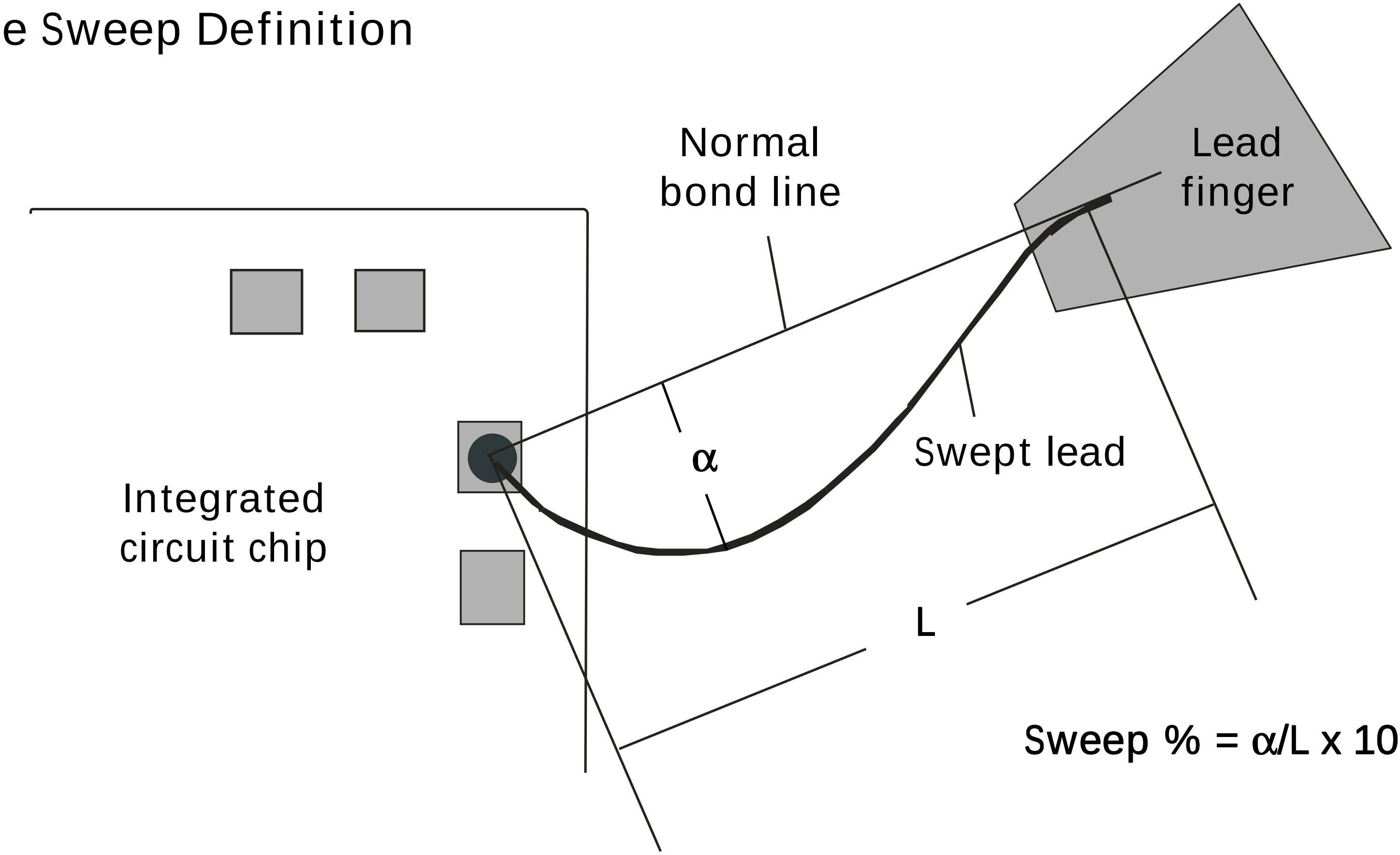


tilted chip

IZM: Hillmann, Großer, Ghaharemani

Wire Bonding Quality Assurance and Testing Methods

Wire Sweep Definition



Sweep % = α/L x 100%

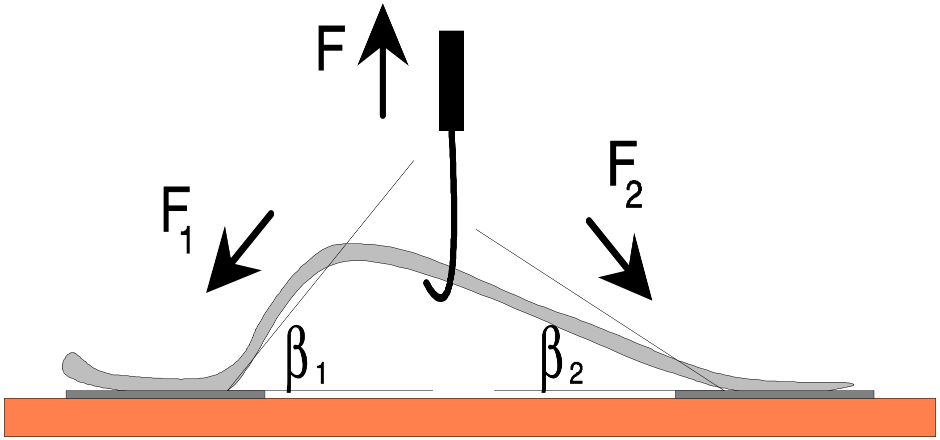
Wire Bonding Quality Assurance and Testing Methods

Mechanical bond contact inspection (tests)

to proof:	selected tests:
- mechanical stiffness of loops	- pull test
- ball bond strength	- shear test
- heavy wire wedge bond strength	- shear test
- simultaneous proofing of many bond contacts	- centrifugal test
- fatigue behaviour of loops	- vibration test
- crack initiation and growth	- mechanical shock test
- sweep off behaviour	- air jet test

Wire Bonding Quality Assurance and Testing Methods

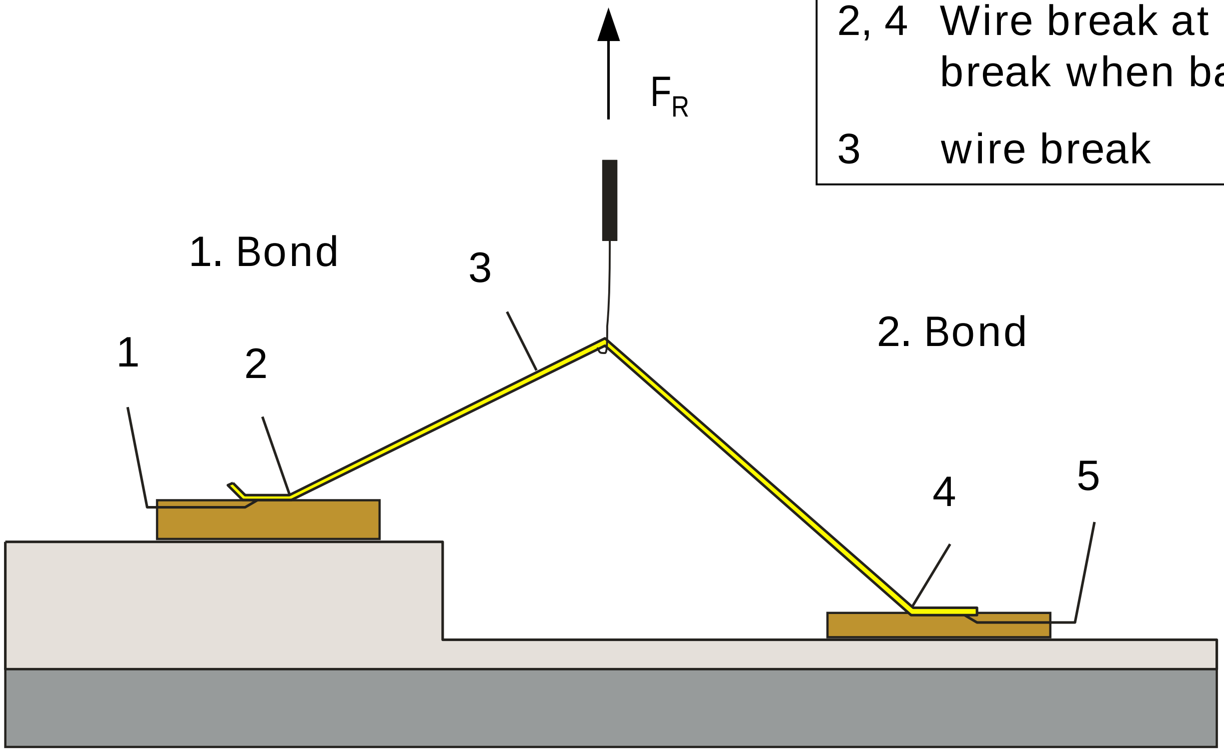
Principle of pull test



$$F = F_1 = F_2 \quad \text{bei } \beta_1 = \beta_2 = 30°$$

Quelle: Dage Firmenschrift

Wire Bonding Quality Assurance and Testing Methods



Failure modes:

1, 5 Bond lift off from pad metallization (lift off)

2, 4 Wire break at bond (heelcrack or neck break when ball/wedge bonding)

3 wire break

Wire Bonding Quality Assurance and Testing Methods

Load/Force distribution while bond pull test

$$F_1 = F_2 = \frac{F}{2 \sin \Theta} = \frac{F}{2}\left[1 + \left(\frac{d}{2\,h}\right)^2\right]^{1/2}$$

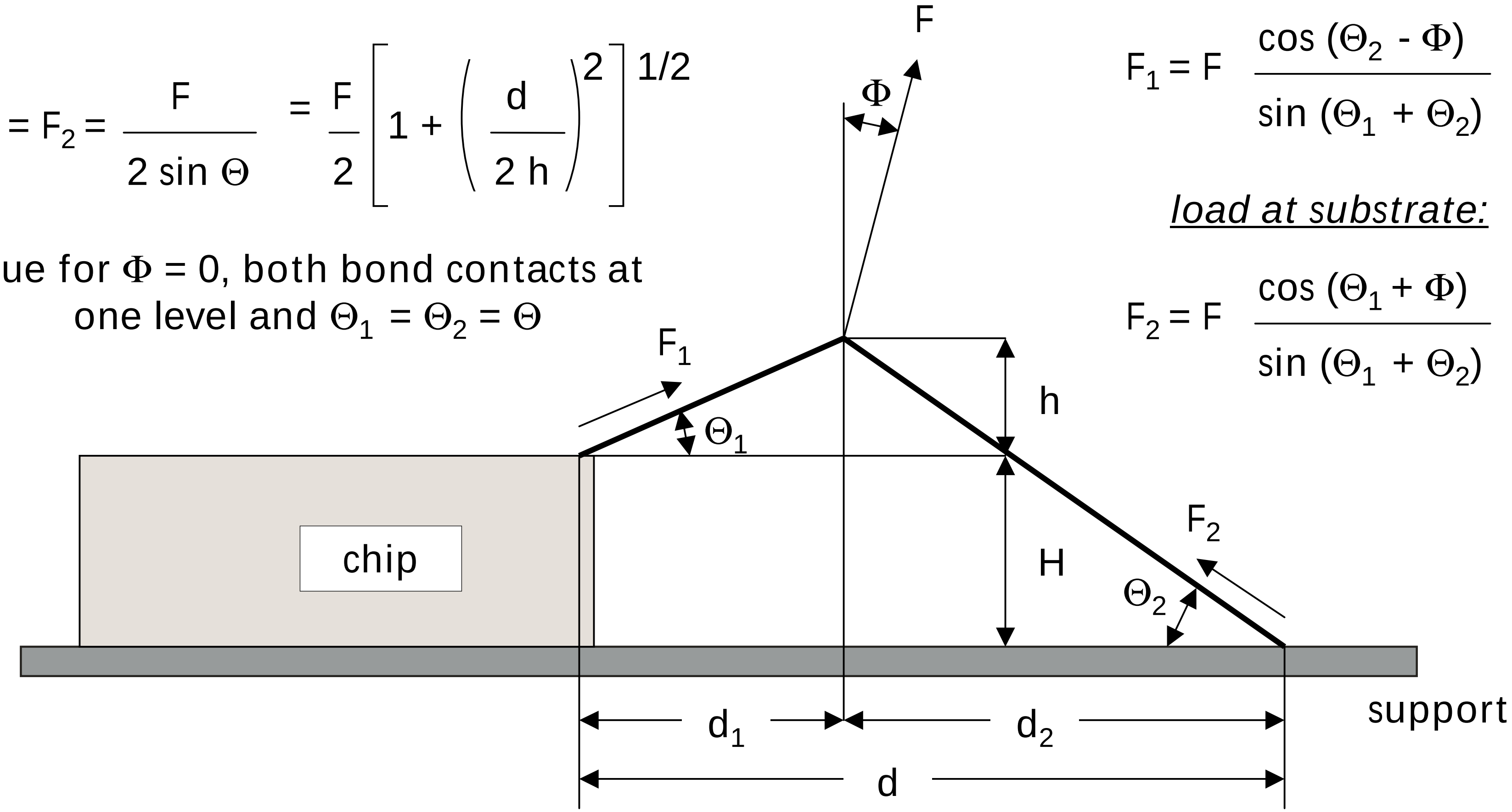
true for $\Phi = 0$, both bond contacts at one level and $\Theta_1 = \Theta_2 = \Theta$

load at chip:

$$F_1 = F \frac{\cos(\Theta_2 - \Phi)}{\sin(\Theta_1 + \Theta_2)}$$

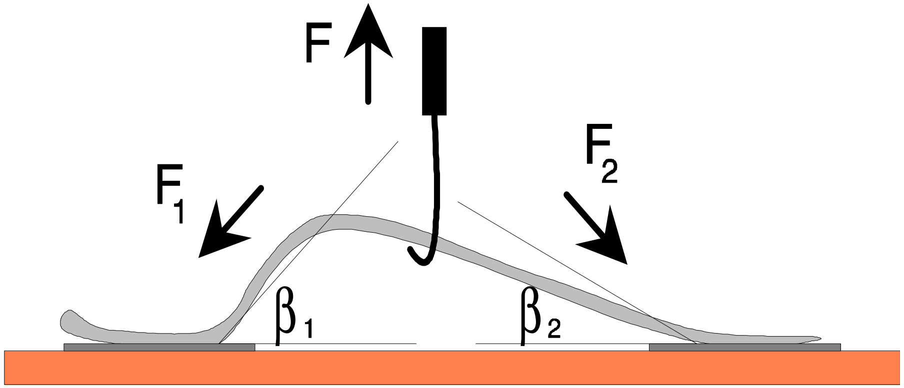
load at substrate:

$$F_2 = F \frac{\cos(\Theta_1 + \Phi)}{\sin(\Theta_1 + \Theta_2)}$$



Wire Bonding Quality Assurance and Testing Methods

Quality criteria for pull testing

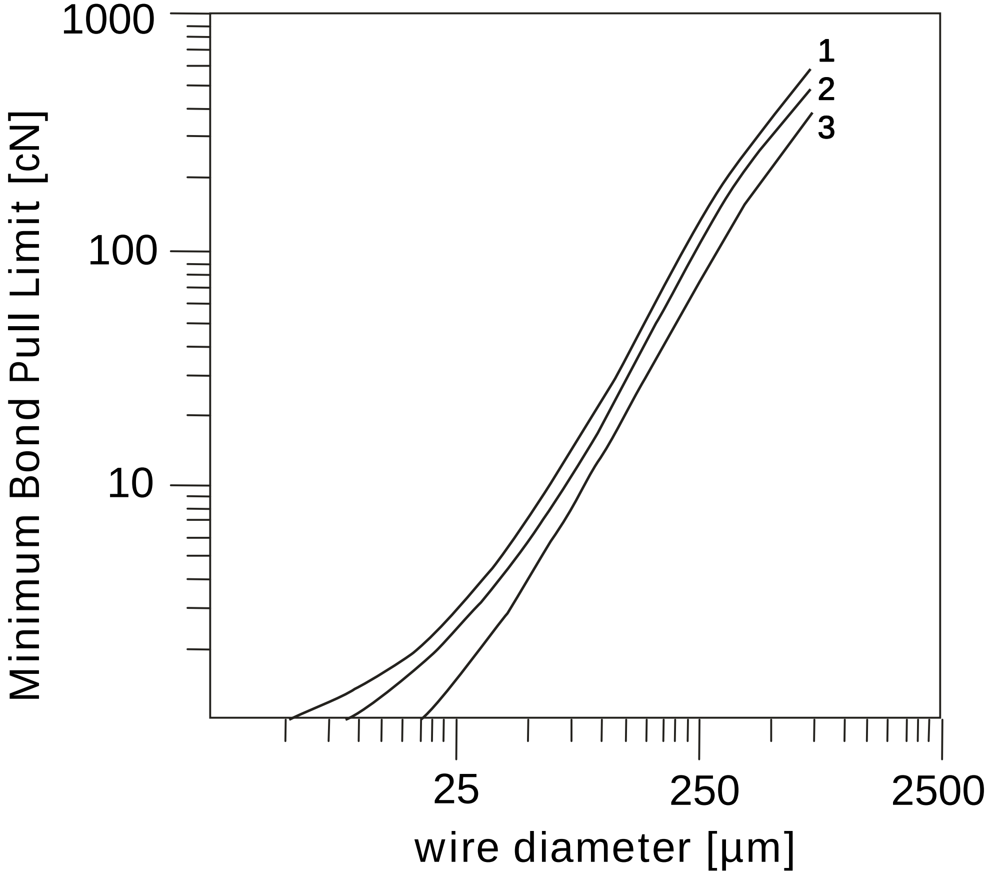


$$F = F_1 = F_2 \quad \text{if} \quad \beta_1 = \beta_2 = 30°$$

	Conditions	
Characteristics	**laboratory**	**fabrication**
pull force		
- average value (based on nondeformed wire)	>50 %	>50 %
- standard deviation (based on average value)	<15 %	<25 %
- proportion of values < (based on standards) cN	0 %	0 %
lift offs		
- pull lift off	0 %	<10 %
- bond lift off	0 %	0 %

Wire Bonding Quality Assurance and Testing Methods

Minimum pull forces for destructive pull test (MIL STD 883, Methode 2011):



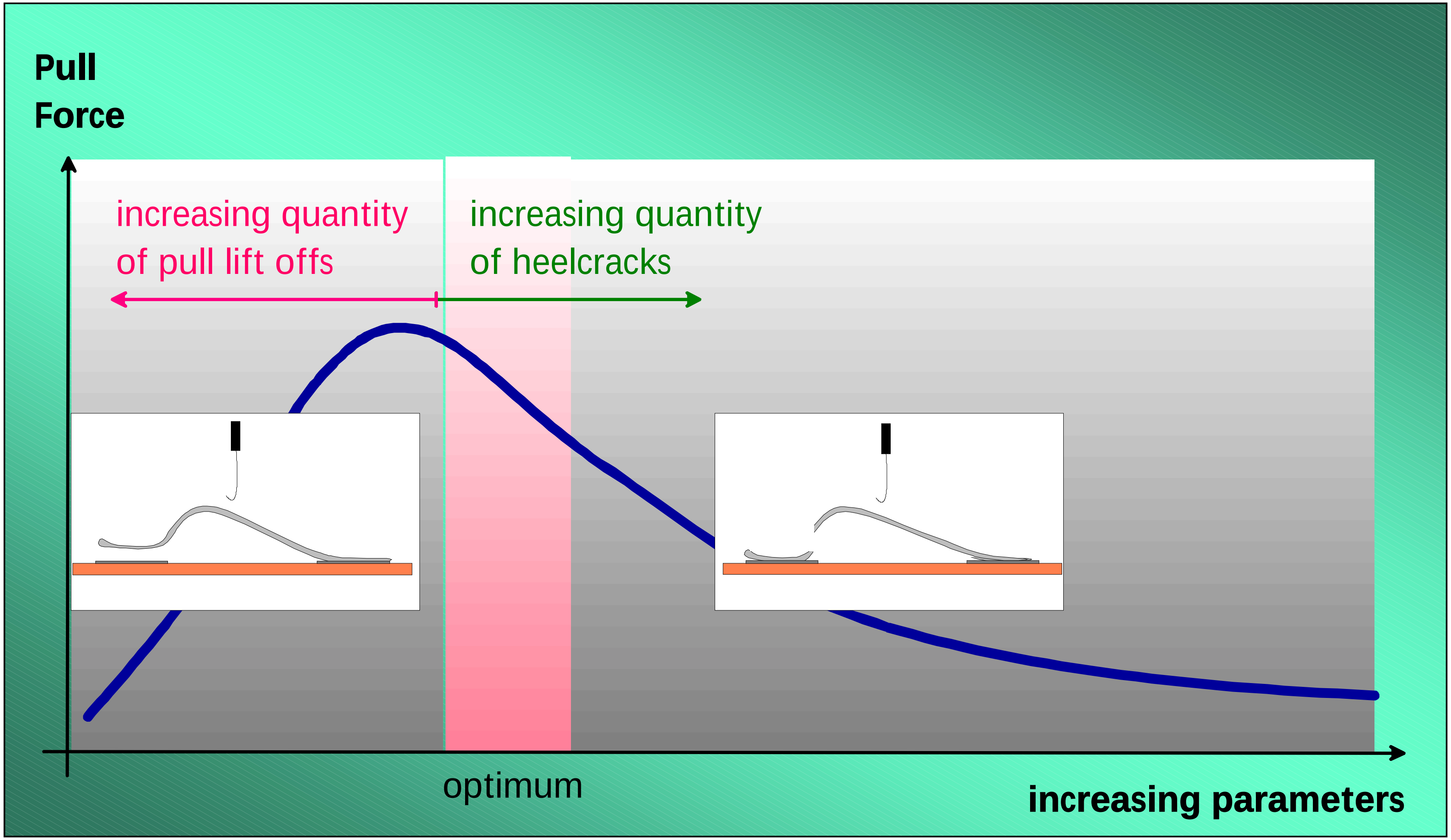
Wires:

1 Au (preseal)

2 Al (preseal)
Au (postseal)

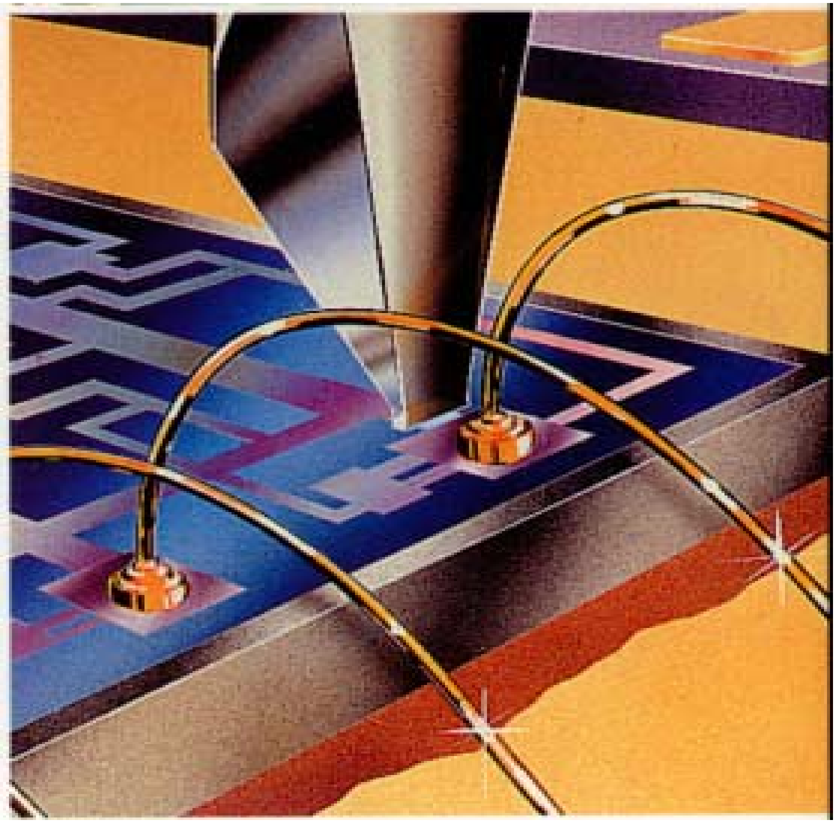
3 Al (postseal)

Wire Bonding Quality Assurance and Testing Methods

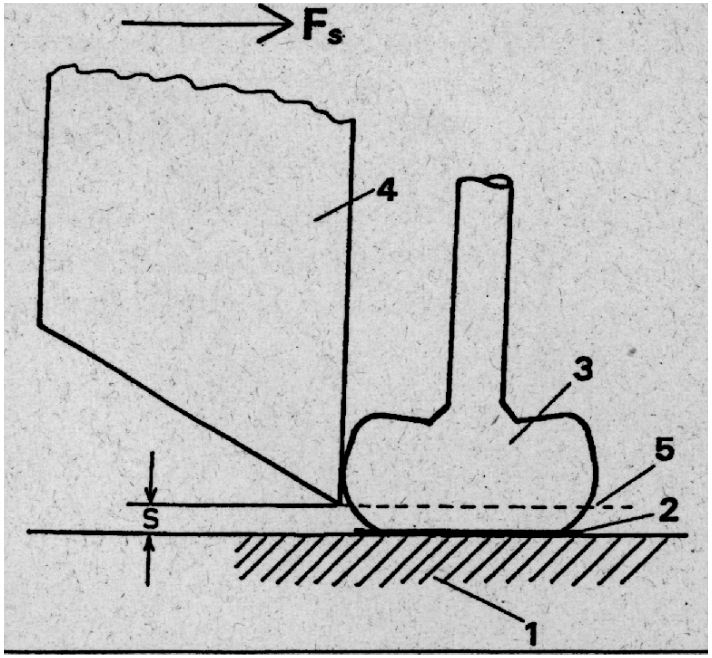


Wire Bonding Quality Assurance and Testing Methods

Principle of shear test



Source: Dage and „DVS-Merkblatt Drahtbonden“



1 Substrate/Pad	
2 Interface Ball/Substrate	
3 Au-Ball	
4 Shear Tool	S Shear Heigth
5 Shear Level	F_S Shear Force

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Wire Bonding Quality Assurance and Testing Methods

Standard report of pull test: Standard AlSi1 wire (30 µm)

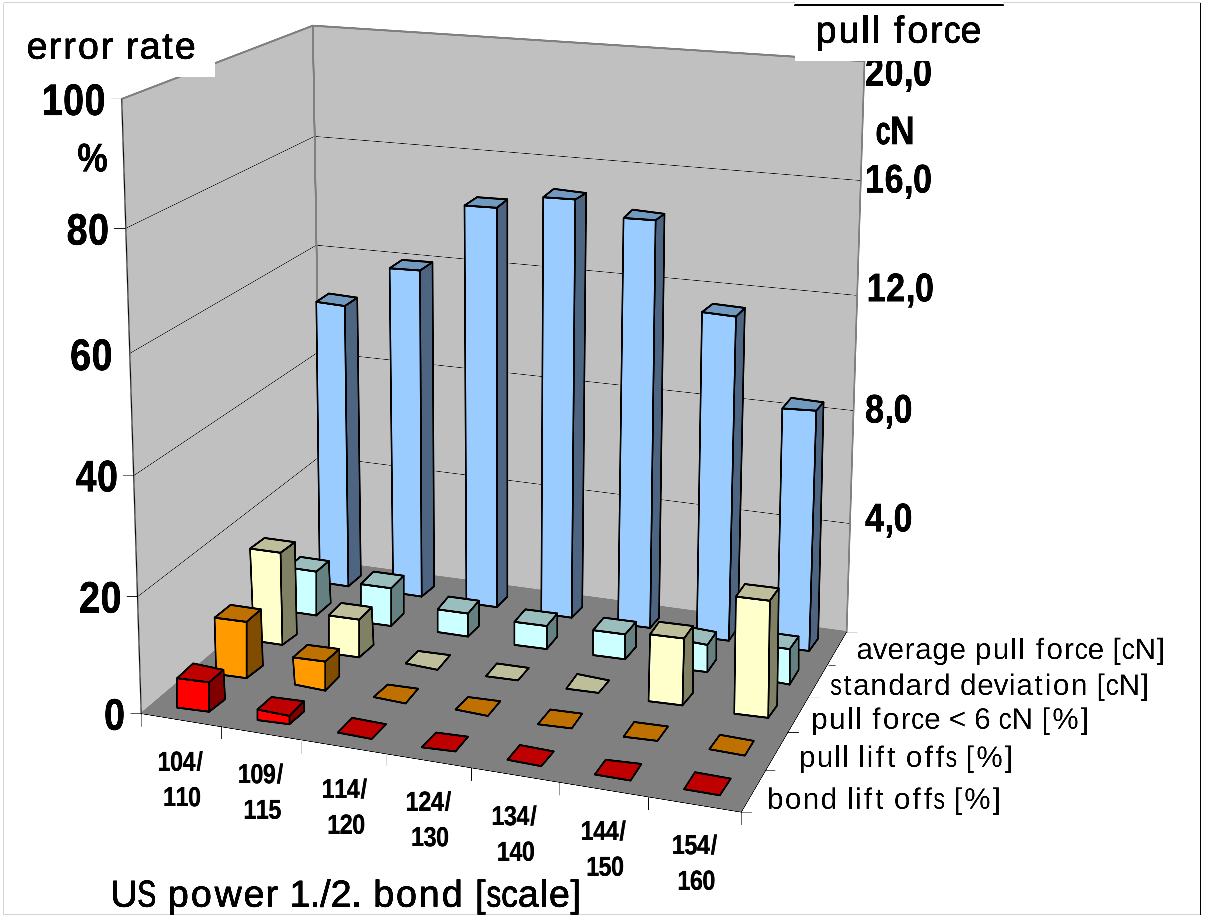
US power 1./2. bond [scale]	average value pull force [cN]	s [cN]	pull force < 6 cN [%]	pull lift offs[%]	bond lift offs [%]
104/110	10,5	1,6	16,7	10,0	5,0
109/115	12,0	1,4	6,7	5,0	1,7
114/120	14,5	0,9	0,0	0,0	0,0
124/130	15,0	0,8	0,0	0,0	0,0
134/140	14,5	0,9	0,0	0,0	0,0
144/150	11,5	1,0	11,5	0,0	0,0
154/160	8,5	1,2	20,0	0,0	0,0

number of tests: n = 30

US time: 30 ms

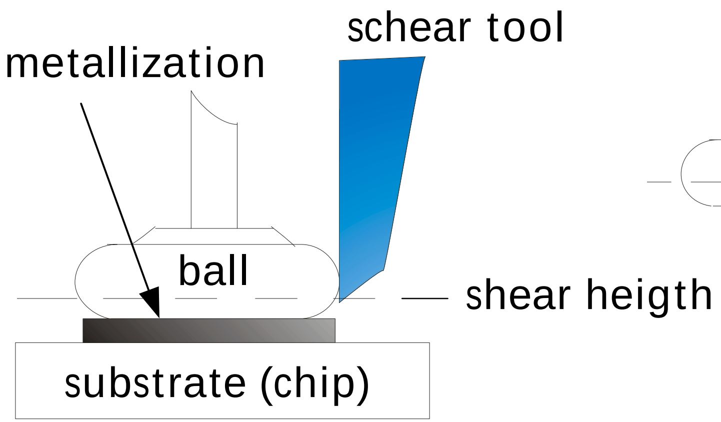
bond force: 32 cN

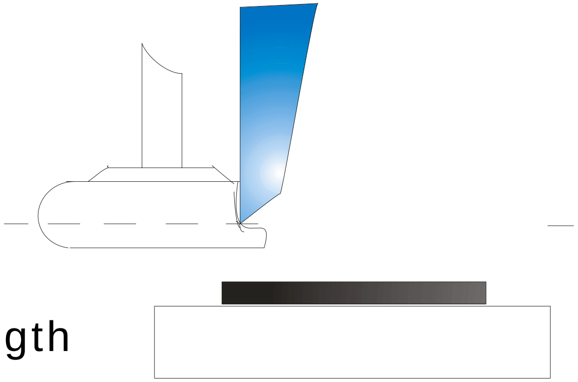
tensile wire strength: 19 cN



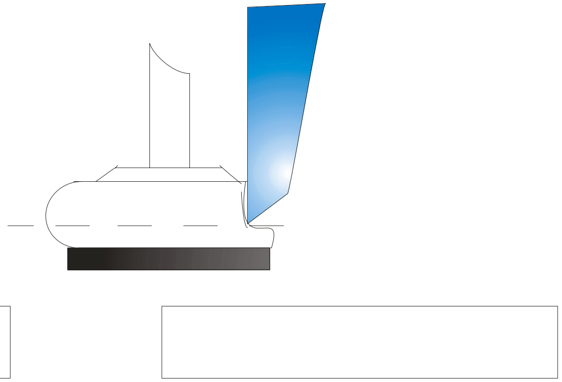
Wire Bonding Quality Assurance and Testing Methods

Failure modes while shear test

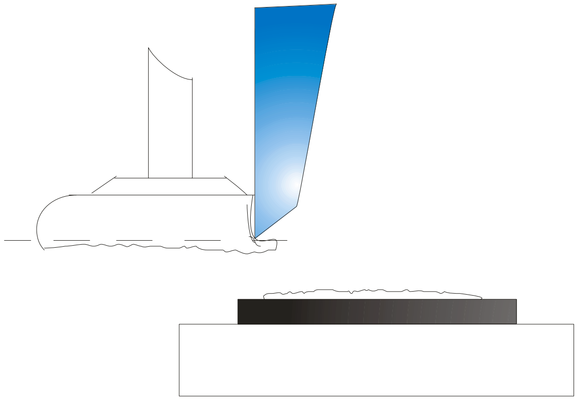




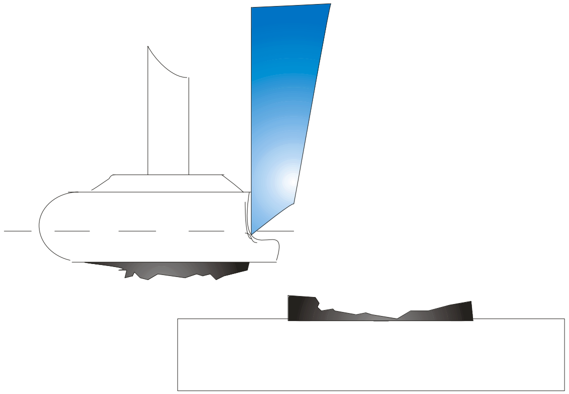
Ball lift off



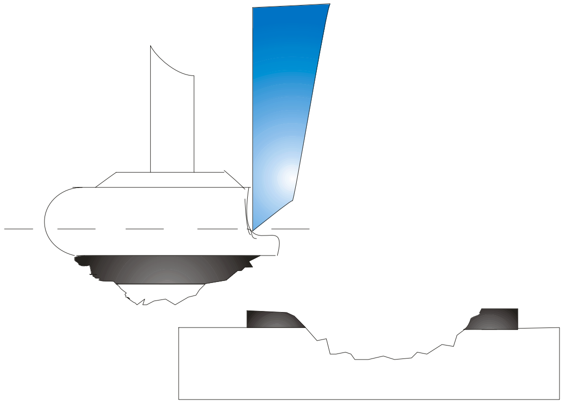
Metallization lift off



Ball shear



Metallization cracking



Chip cratering

Wire Bonding Quality Assurance and Testing Methods

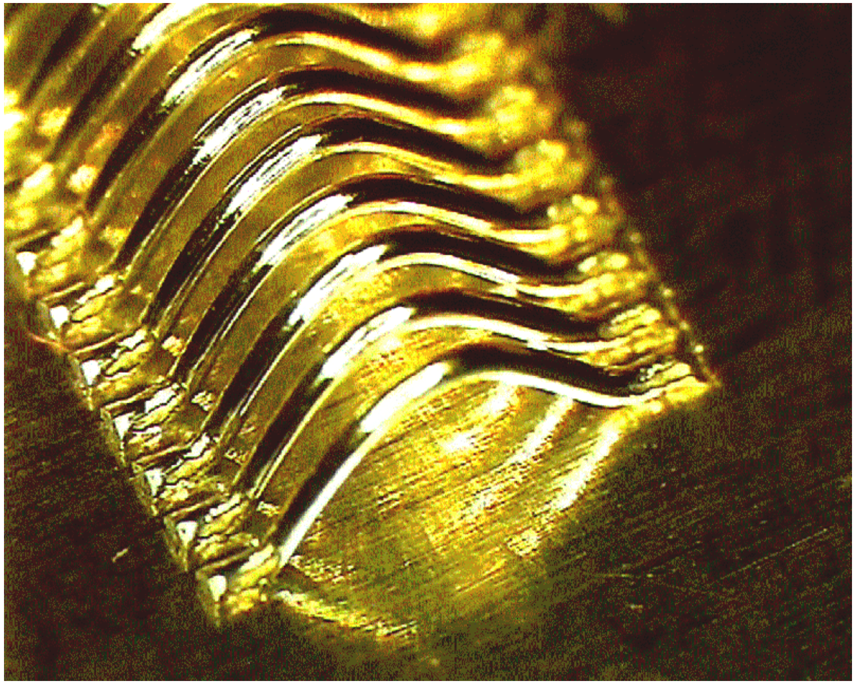
Quality criteria for ball shear testing (TS bonding)

Characteristics	Conditions laboratory	 fabrication
shear force		
- average value (based on minimum shear force value)	> 140 %	> 120 %
- standard deviation (based on average value)	< 15 %	< 20 %
- minimun shear force (based on ball diameter after bonding)	see beneath, no value < …	
lift offs		
- bond lift off	0 %	0 %
- shear lift off	0 %	0 %
- percentage off Au on pad	> 80 %	> 50 %
	no metallization lift off, no cratering	

Minimum shear value	ballbond diameter (µm)			
	50	75	100	125
shear force (cN)	15	30	45	75

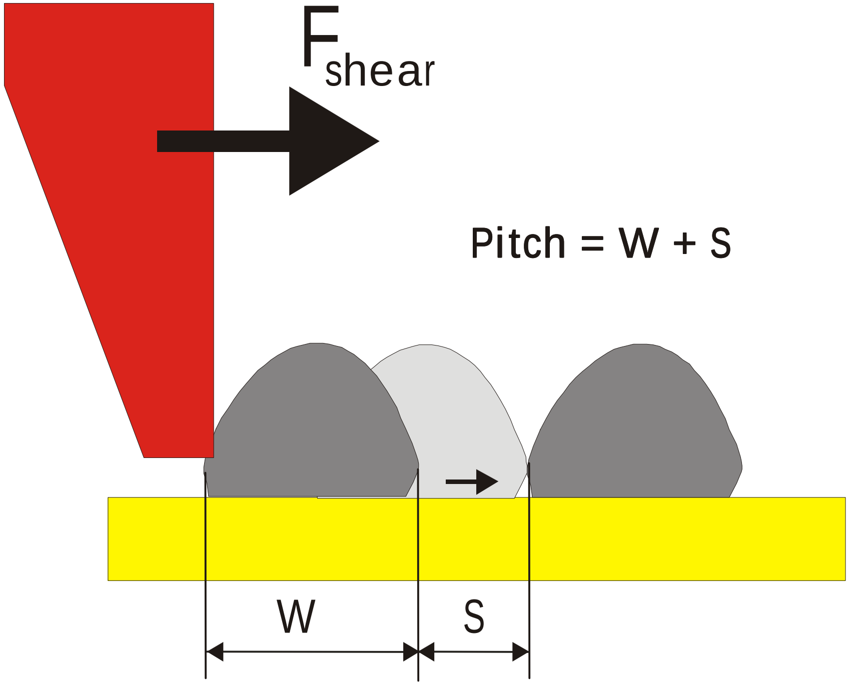
Wire Bonding Quality Assurance and Testing Methods

Heavy wire wedge shear testing



Heavy wire: 400 µm

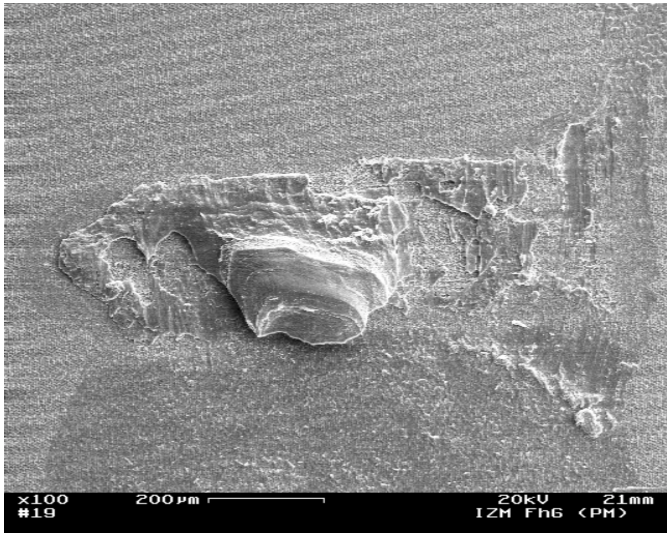
Pitch: 750 µm



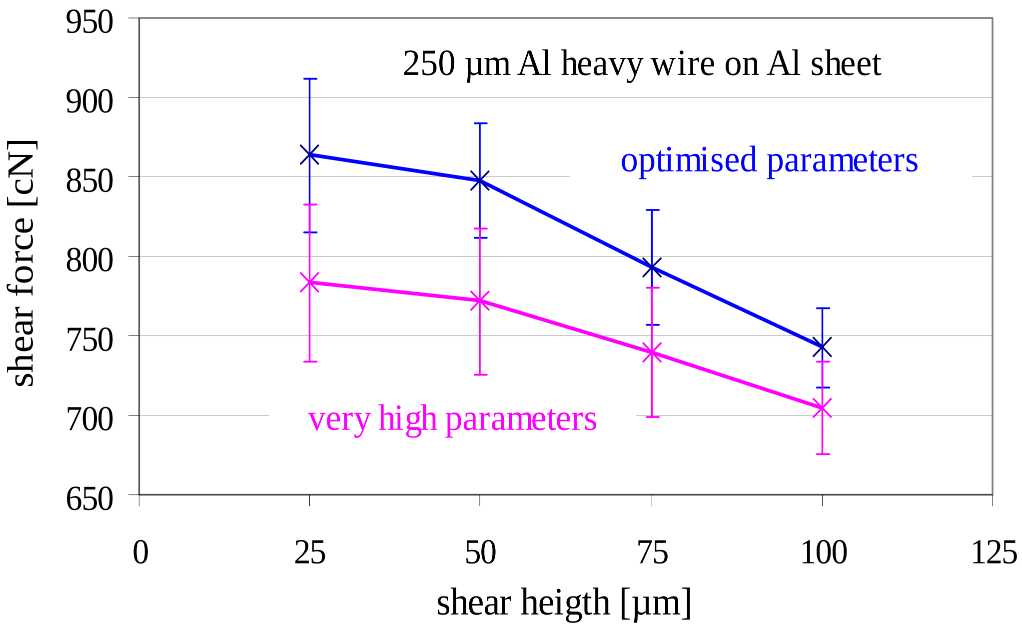
Principle of shear test

Wire Bonding Quality Assurance and Testing Methods

Problems while evaluation of heavy wire shear test results



Partial shear lift off



Questions: Where is the limit between shear lift off and shear through the bond? What shear heigth should be choosen while shear testing?

Source: IZM Berlin

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Wire Bonding Quality Assurance and Testing Methods

Load Cartridge Options:

1. Wire Pull		
Maximum Pull Force	Cartridge 1	100 g
	Cartridge 2	1 kg
	Cartridge 3	10 kg
2. Tweezer Pull/Peel		
Maximum Pull Force	Cartridge 1	100 g
	Cartridge 2	5 kg
3. Ball Shear		
Maximum Shear Force	Cartridge 1	250 g
4. Shear		
Maximum Shear Force	Cartridge 2	5 kg
	Cartridge 3	100 kg
Special Load Cartridges:		
High Force Tweezer Pull up to 10 kg		
Heated Bump Pull up to 10 kg		
Stud Pull		
Cold Bump Pull up to 5 kg		