

Known reliability with improved efficiency – the next generation Ni/Pd/Au finish



Dr. Britta Schafsteller/ Atotech / April 2021



Contents



1. Introduction
2. Process performance
3. Further opportunities
4. Summary and Outlook



Introduction

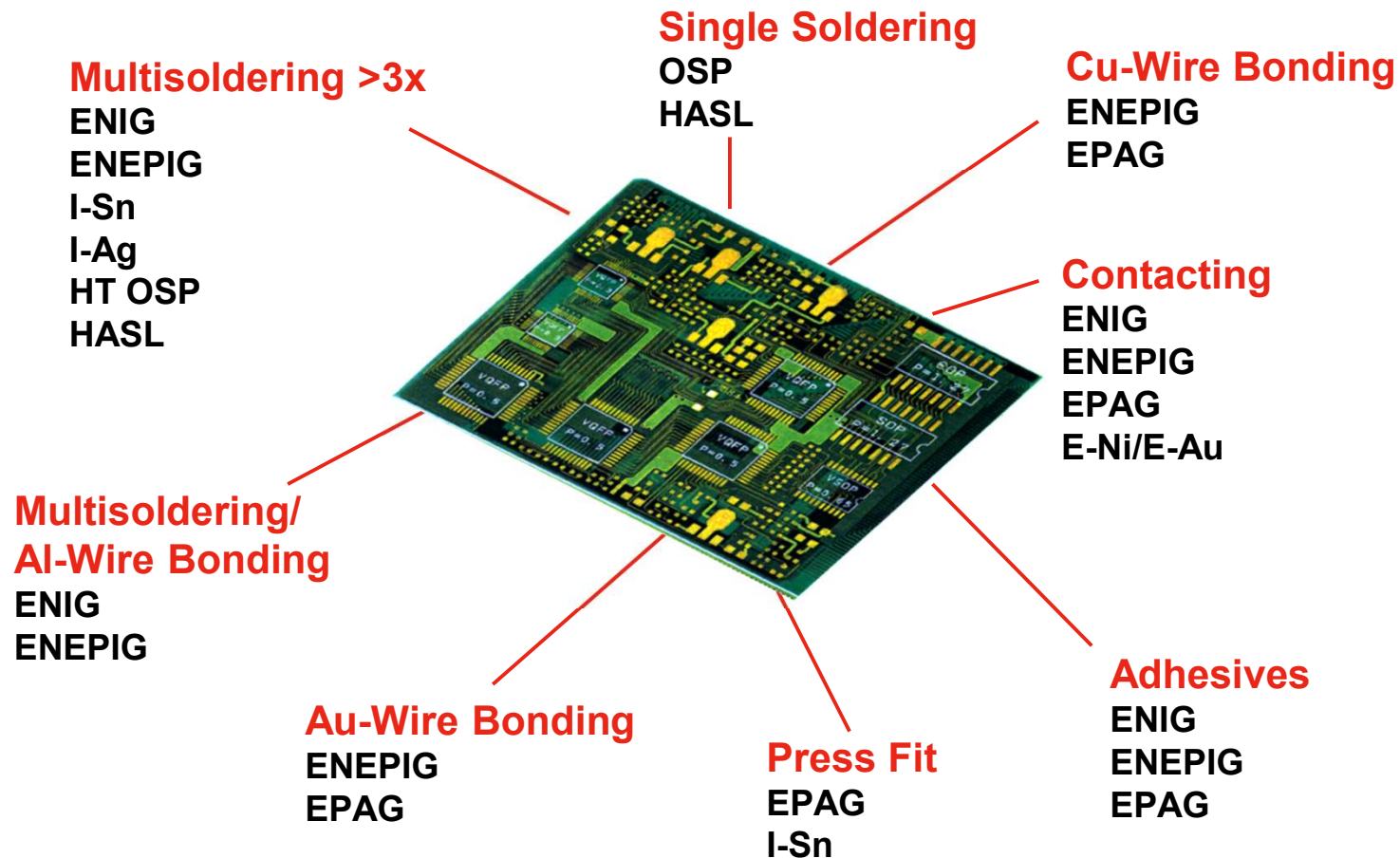




Introduction

Task of a Surface Finish

- Protect the copper surface from tarnishing and oxidation
- Maintain an active surface for various interconnect techniques



Introduction

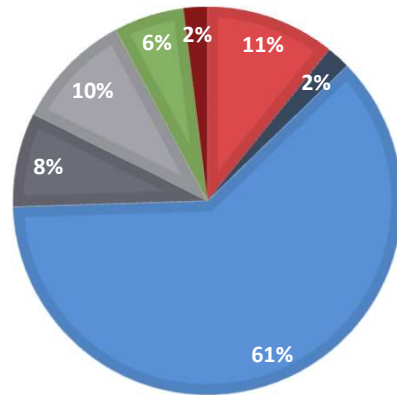
Background for development



- ENEPIG is a high end finish with increasing market acceptance

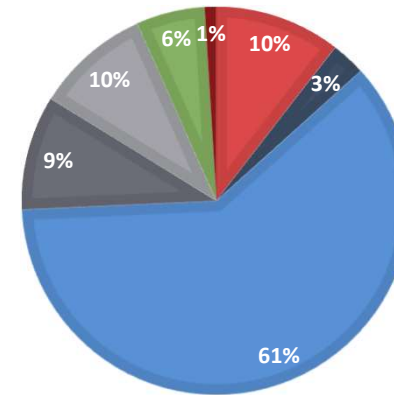
TOTAL AREA - 2016

■ ENIG ■ E'less Pd ■ OSP ■ HASL ■ ImSn ■ ImAg ■ others



TOTAL AREA - 2021

■ ENIG ■ E'less Pd ■ OSP ■ HASL ■ ImSn ■ ImAg ■ others

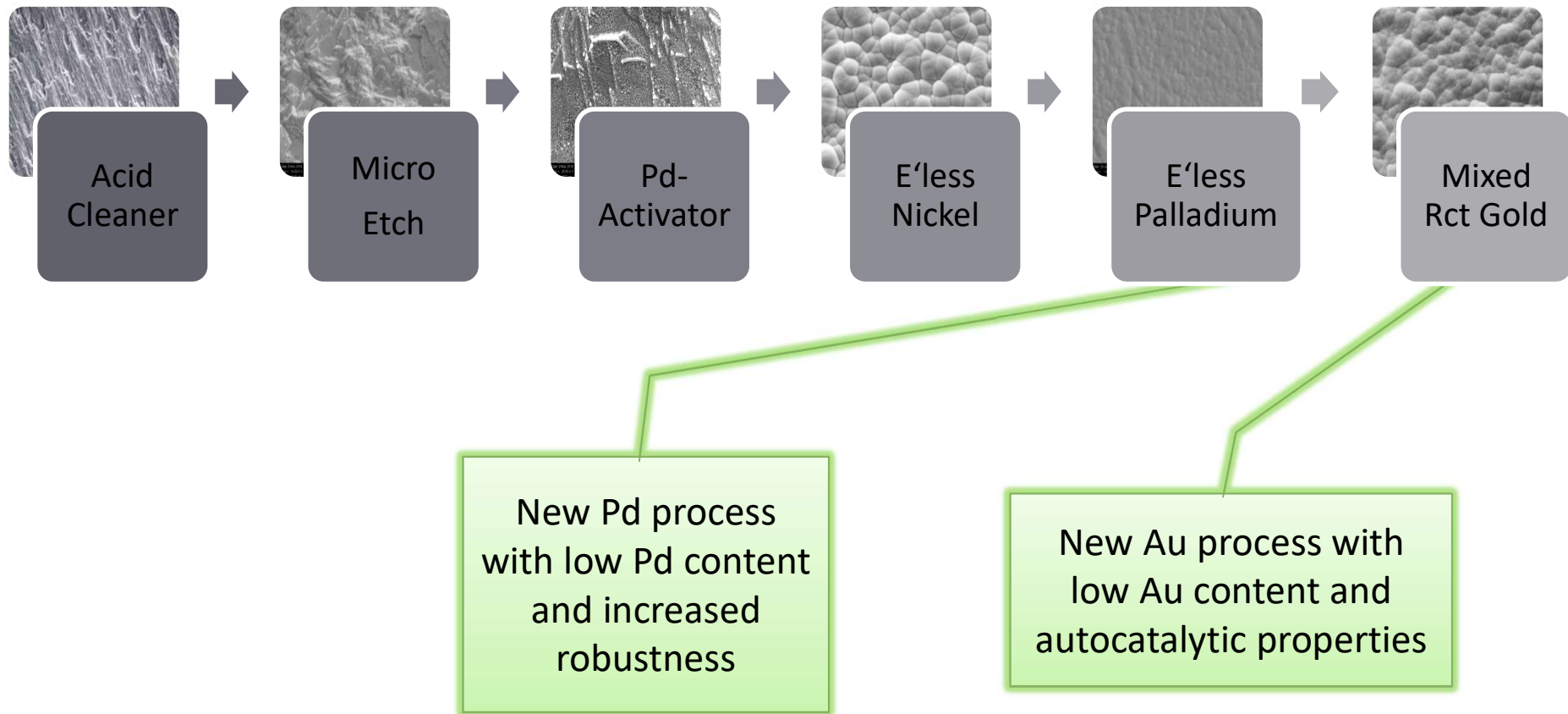


- But increasing Pd price pushes overall process cost



Introduction

NiPdAu process flow



Introduction

common process limitations



Ni/Au

- Cost of precious metals
- Brittleness of solderjoint
- ENIG-corrosion
- Not suitable for high frequency applications



Ni/Pd/Au

- Process operating window requires tight control
- Higher process costs compared to other final finishes due to use of precious metals
- Not suitable for high frequency applications



Pd/Au

- New application, not established – additional process line required
- Higher process costs compared to other final finishes due to use of precious metals

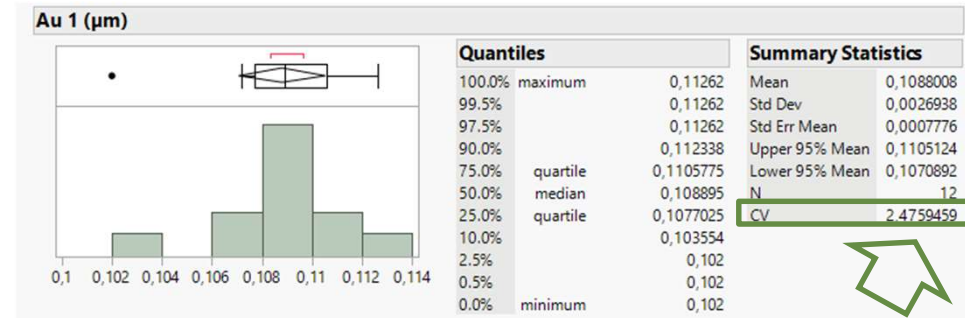
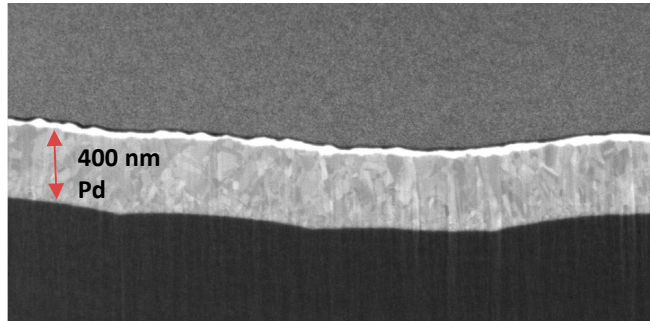


Solution

- lower precious metal content to reduce the drag out loss
- Improved thickness distribution
- Improved process robustness, extended bath life
- Universal solutions for multiple final finishes

Introduction

New process solutions



Features new Palladium

- Low Pd-content (0.5 g/l)
- High robustness against contamination, high Cu-tolerance
- Stable plating rate and performance over bath life
- Capable to plate high Pd-thickness (> 400nm)
- Capable to work for Ni/Pd/Au and Pd/Au



Features new Gold

- Low Au-content (0.5 g/l)
- High bath stability, no plate out
- ENIG corrosion level 0 and 1
- Excellent thickness distribution of < 5% COV
- Applicable for Ni/Au, Ni/Pd/Au, Pd/Au
 - No flash gold required



Process performance

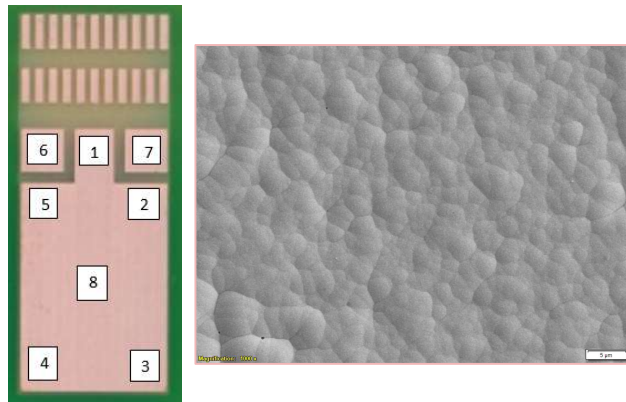




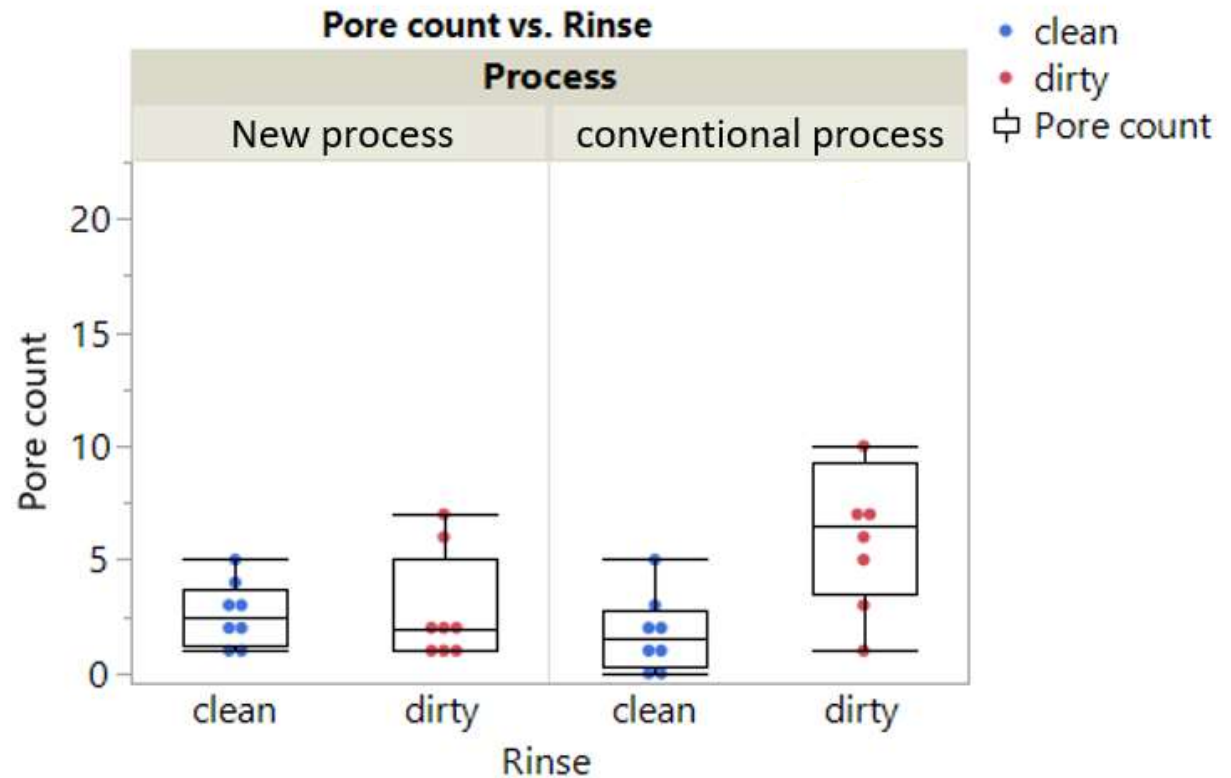
Process Performance

Process robustness of Pd-plating bath

- New process shows less sensitivity towards rinse contamination

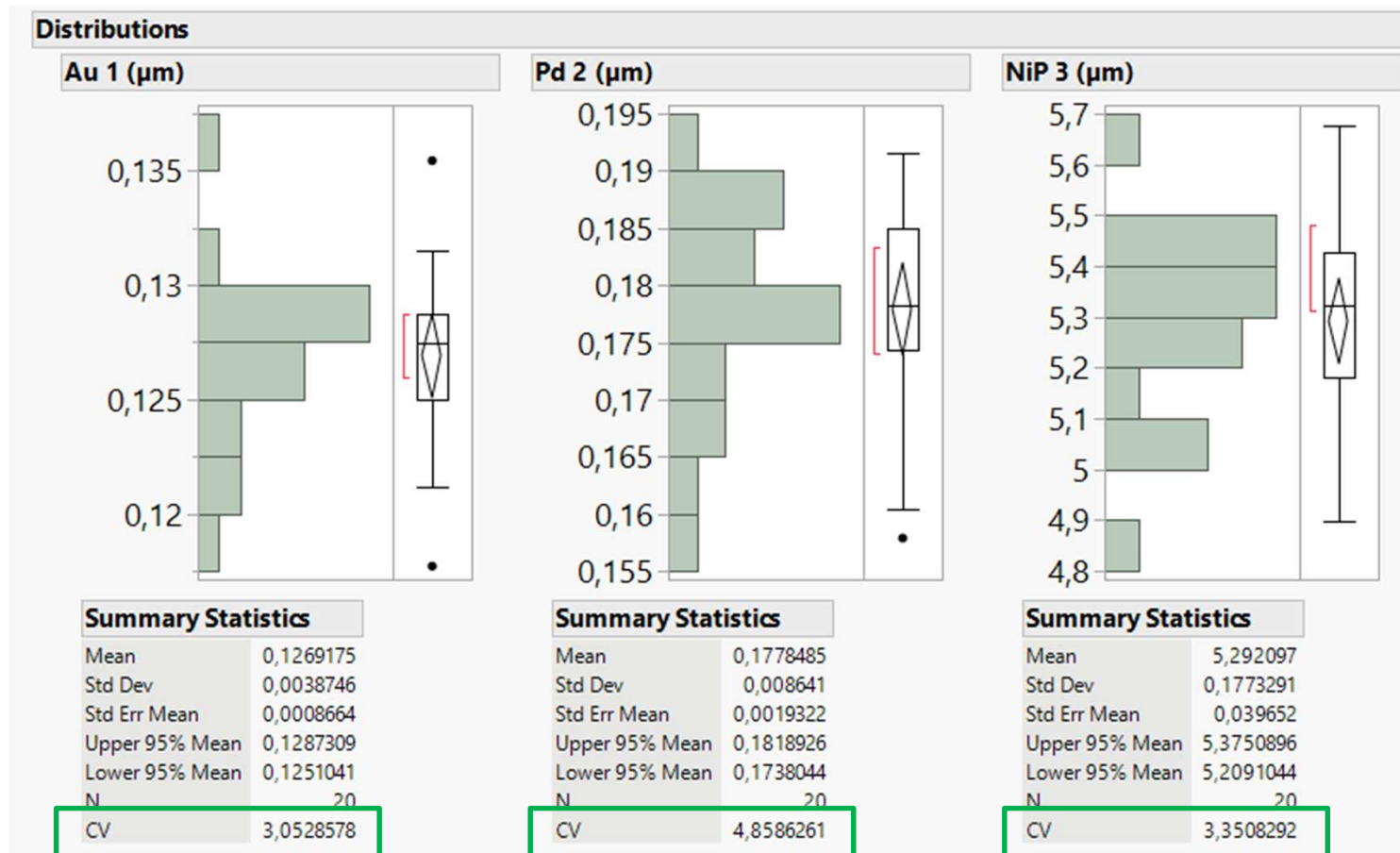
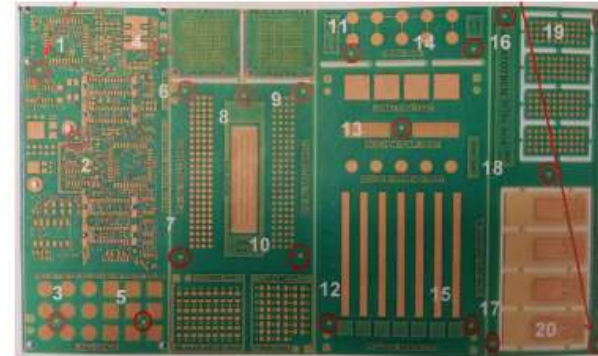


- Rinse after Nickel was contaminated to 500 μ S with Nickel bath solution
- Impact on Pd layer formation was checked by pore counting in SEM top view



Process Performance

Layer properties – Thickness distribution

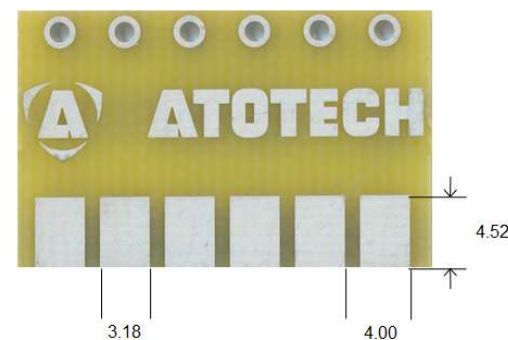
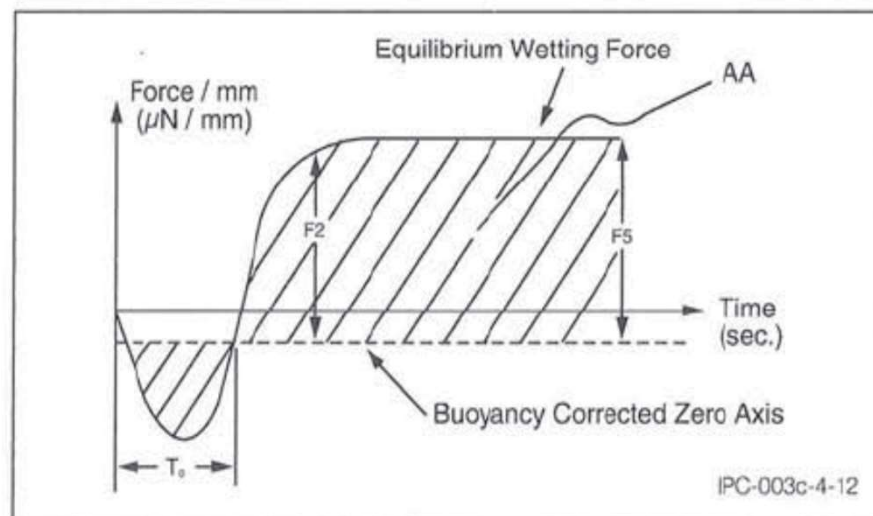




Process Performance

Wetting tests – Wetting balance

Wetting balance tester	Gen ³ Systems MUST System 3
Solder bath:	Sn96.5Ag3.0Cu0.5
Temperature:	255 °C
Flux:	Flux for lead-free soldering according to IPC J-STD-003C-WAM1&2
Immersion speed	5 mm/s
Immersion depth	0.5 mm
Immersion Angle	25°
Test time	10 s



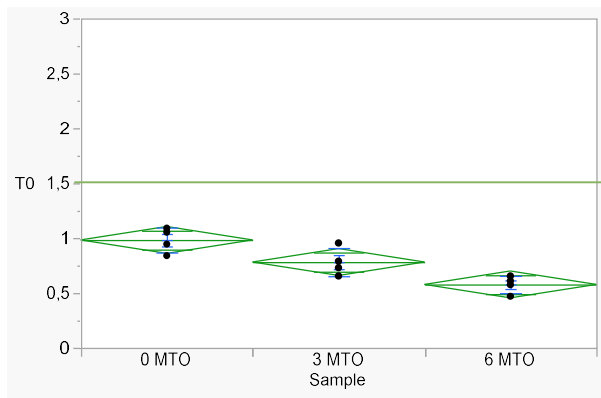
According to IPC J-STD-003

Process Performance

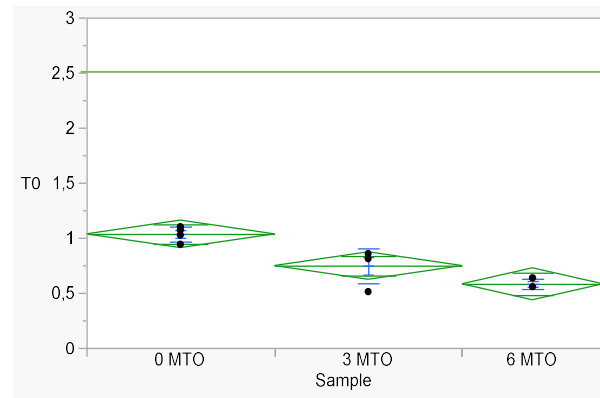
Wetting tests – Wetting balance



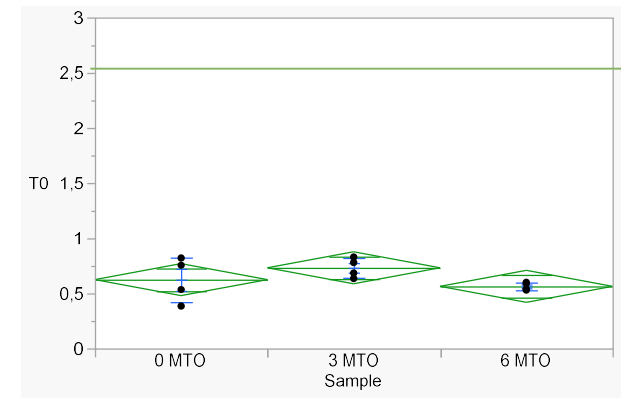
As received



2x IPC reflow



8h 72°C 85%RH



Criteria passed over full gold bath life



Process Performance

High Speed Shear Test - conditions

Ball type	Shenmao SM Ball PF684-S
Alloy	SAC 305
Ball diameter	450 μm
Flux type	Kester Tacky Flux TSF 6502
Reflow profile	TSF 6502 Leadfree Linear Profile
Reflow atmosphere	N ₂

Equipment	DAGE 4000 HS, Cartridge
Shear speed	0.8 m/s
Shear height	20 μm
Delay time	2-4 h
No. of balls	16 per condition

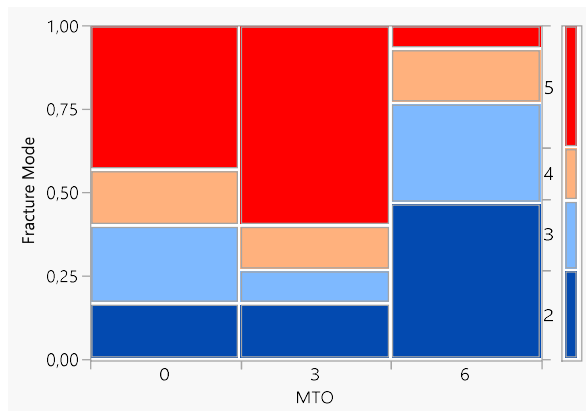
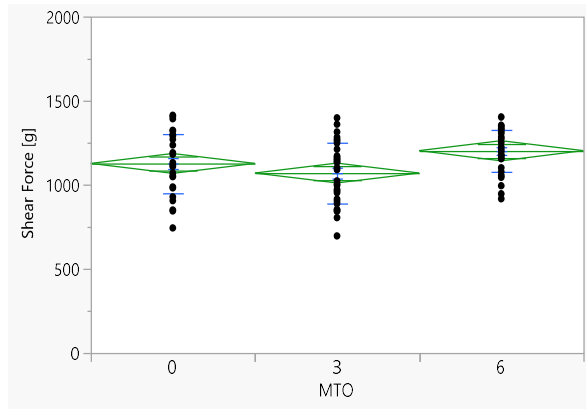
Mode 1	Pad pull-out
Mode 2	Intermetallic fracture < 5%
Mode 3	Intermetallic fracture < 25%
Mode 4	Intermetallic fracture < 95%
Mode 5	Intermetallic fracture > 95%

Process Performance

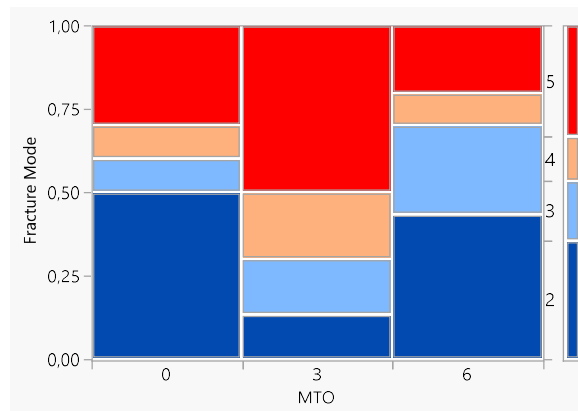
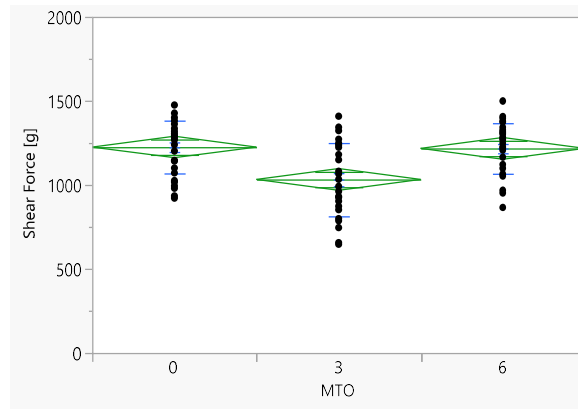
High Speed Shear Test - results



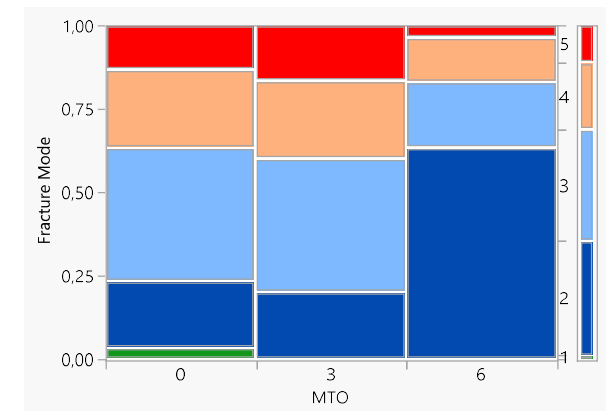
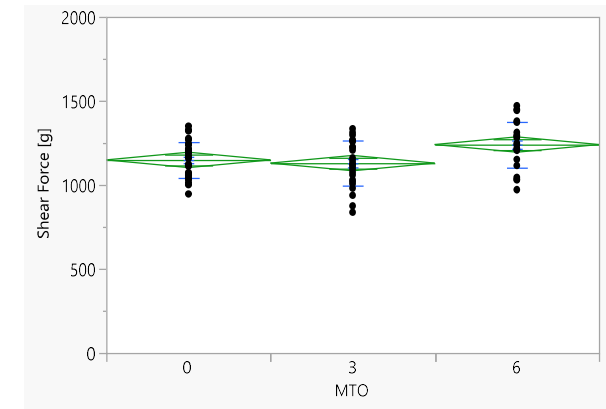
Asr/1x reflow



2x IPC reflow/1x reflow



8h 72°C 85%RH/1x reflow



Constant results even after thermal or humid aging

Process Performance

Ball shear test - conditions

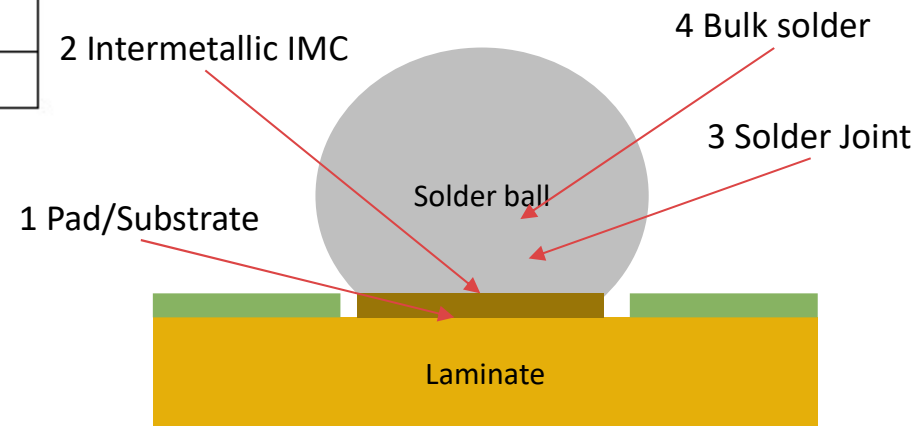


Ball type	Shenmao SM Ball PF684-S
Alloy	SAC 305
Ball diameter	450 μm
Flux type	Kester Tacky Flux TSF 6502
Reflow profile	TSF 6502 Leadfree Linear Profile
Reflow atmosphere	N ₂
PCB type	SFTB1 SMD BGA, SRO 380

Equipment	DAGE 4000, Cartridge BS5kg
Shear speed	210 $\mu\text{m/s}$
Shear height	50 μm
Delay time	2-4 h
No. of balls	30 per condition

Mode 1	Pad pull-out
Mode 2	Intermetallic fracture < 5%
Mode 3	Intermetallic fracture < 25%
Mode 4	Intermetallic fracture < 95%
Mode 5	Intermetallic fracture > 95%

According to JEDEC JESD22-B117A

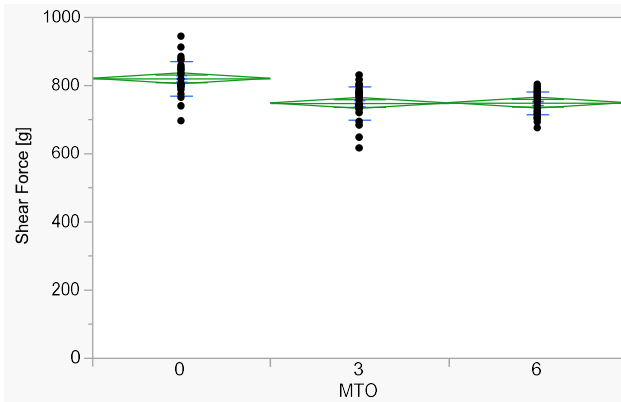


Process Performance

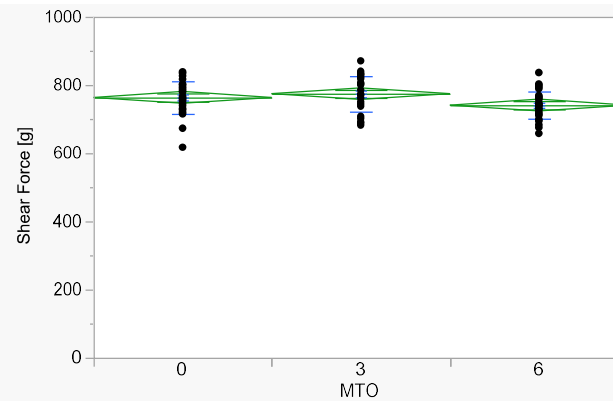
Ball shear test - results



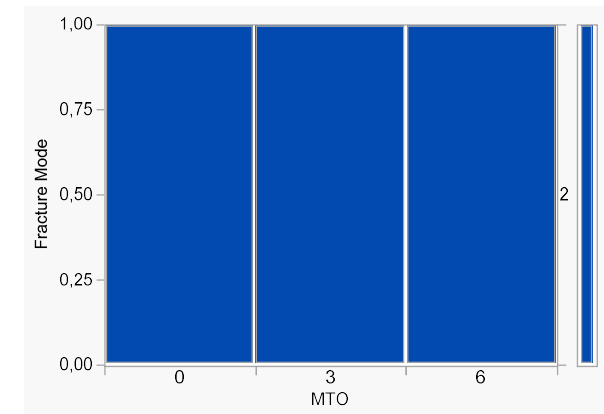
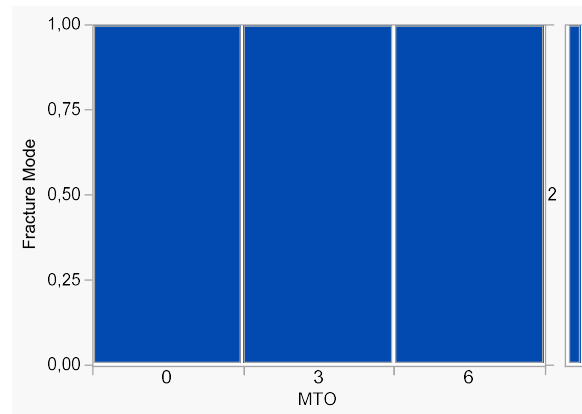
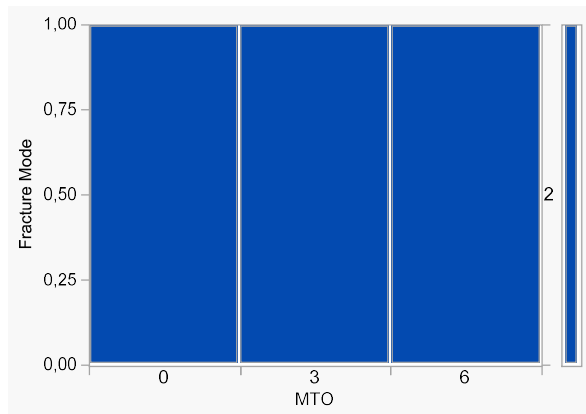
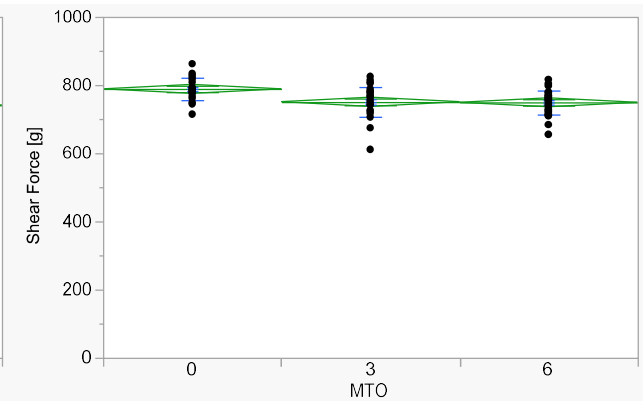
Asr/1x reflow



2x IPC reflow/1x reflow



8h 72°C 85%RH/1x reflow

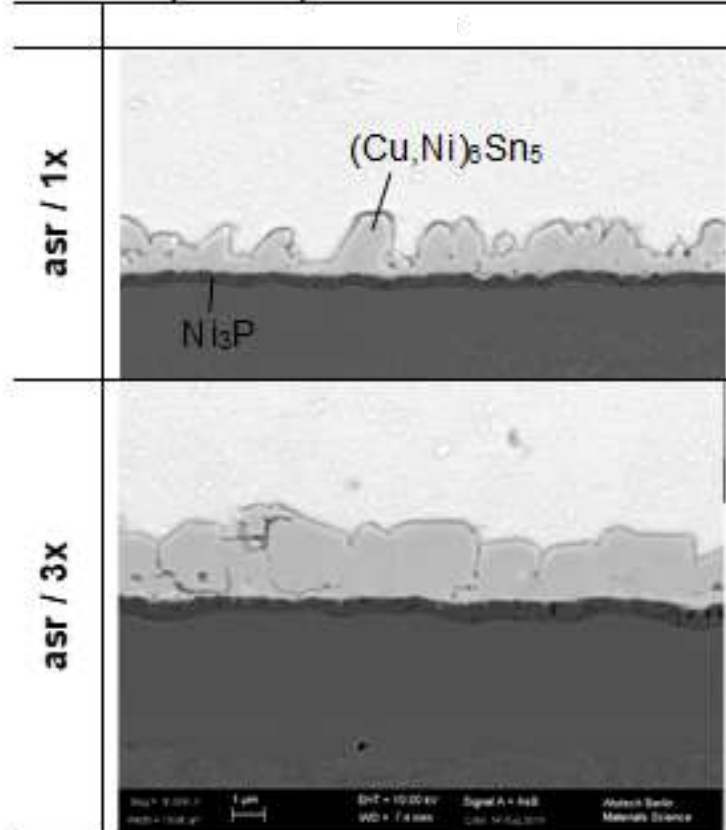


Constant performance over full gold bath life

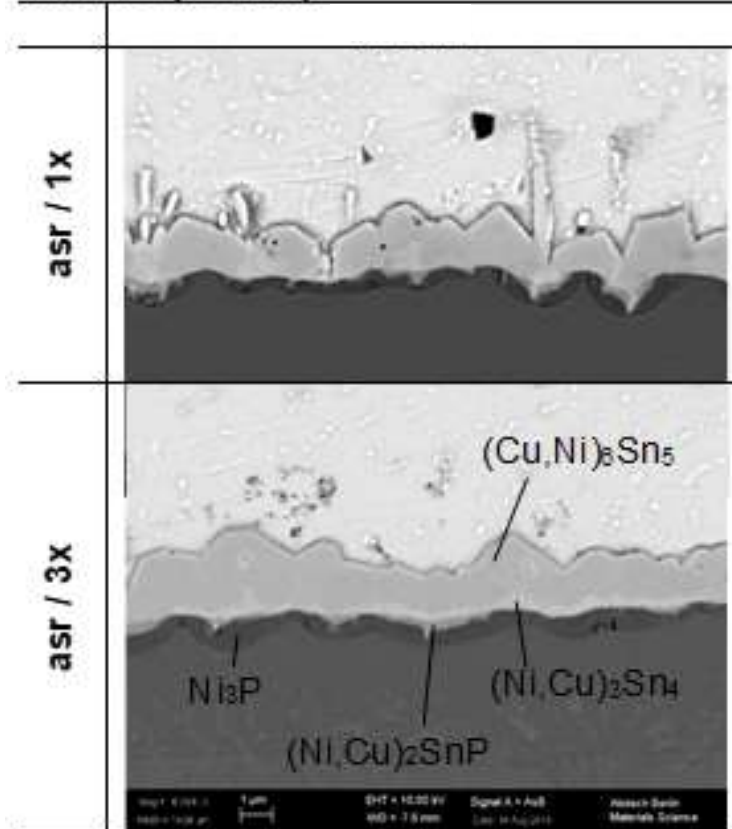
Process Performance

IMC Analysis

ENEPIG (150nm)



ENEPIG (400nm)



Continuous brick shaped IMC formation

Process Performance

Au-Bond test - conditions



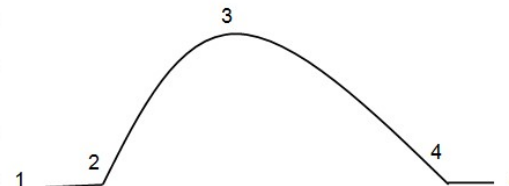
Ball-Bonder	Kulicke & Soffa Iconn High Performance Bonder
Bond wire	Tanaka GMH, $\varnothing = 23 \mu\text{m}$, break load = 9.9 g
Capillary	K&S 41488-3823-R35 (23 μm)
Pull tester	DAGE 4000; Cartridge WP100, Pull Speed = 500 $\mu\text{m/s}$
Temperature	150°C
No. of pulls	>30 per sample

Parameter	First Bond (Ball)	Second Bond (Wedge)
US-Power [mAmps]	120	130
US-Time [ms]	25	20
Bond Force [g]	35	60

**Pulltest Acceptance Criteria
According to DVS 2811
Recommendation:**

Fracture mode classification for Au wire bonding:

Mode 1	Wedge lift first bond
Mode 2	Neck break first bond
Mode 3	Wire loop break
Mode 4	Neck break second bond
Mode 5	Wedge lift second bond



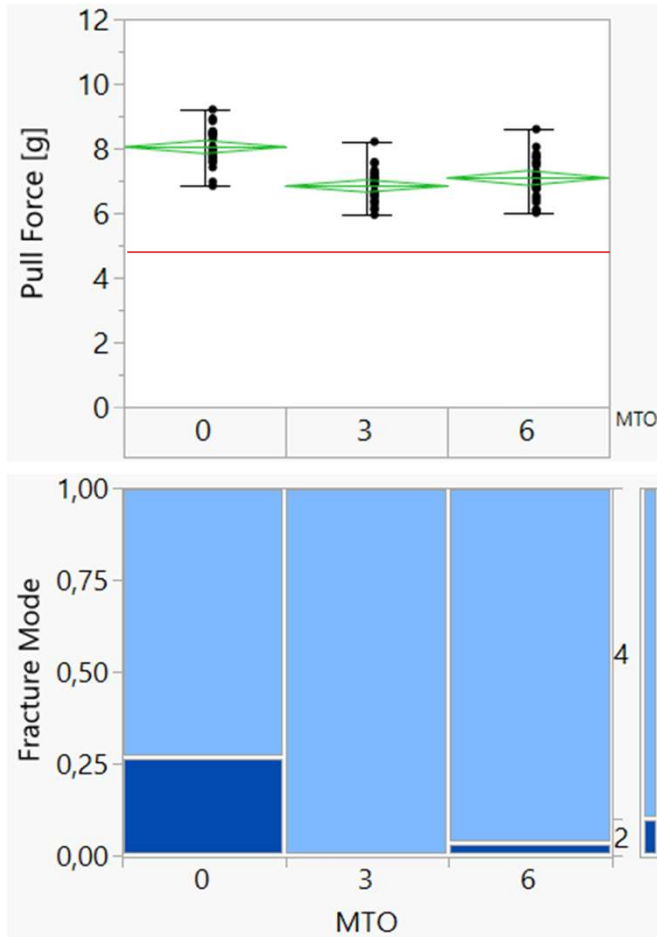
Mean value of force > 50 % of B.
load of wire (> 4.95 g)
Coefficient of variation CV (ratio of
std. dev. to mean value) < 0.15 (<
15 %)

Process Performance

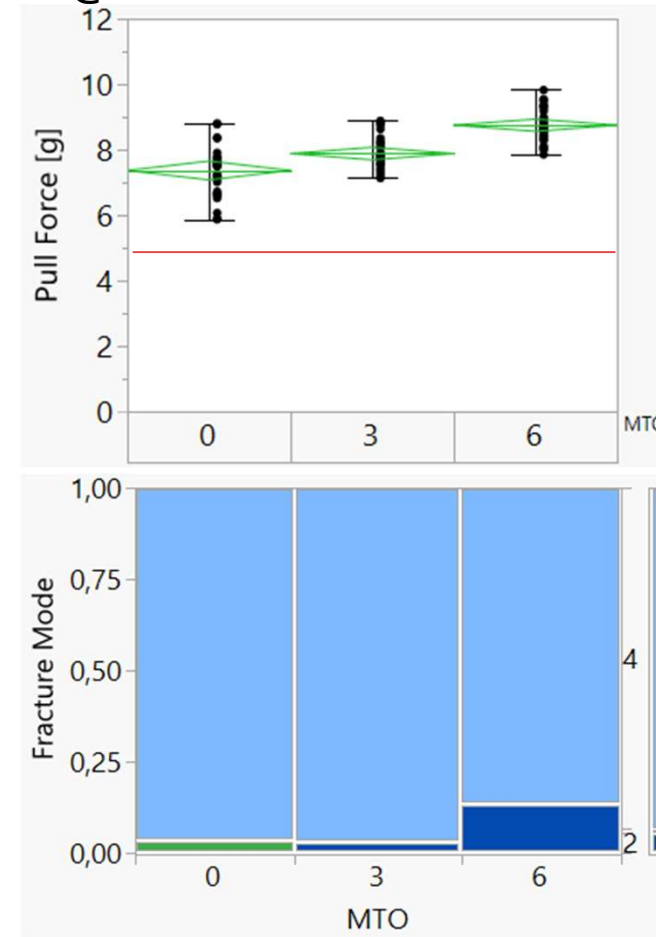
Au-wire bond test - results



As received



4h@150°C



Constant performance, no lift or peel offs observed

Process Performance

Al-Bond test - conditions



Pulltest Acceptance Criteria According to DVS 2811 Recommendation:

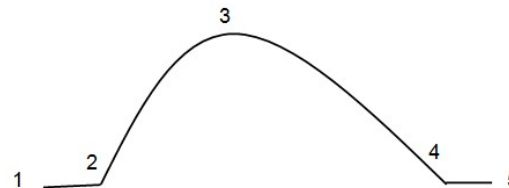
US-Bonder	F&S Bondtec 5630 Automatic Wedge/Wedge-Bonder
Bond wire	Heraeus AlSi 1%, $\varnothing = 25 \mu\text{m}$ break load ca. 15 g
Pull tester	DAGE 4000; Cartridge WP100, pull speed = $500 \mu\text{m/s}$
No. of pulls	30 per sample

Mean value of force > 50 % of B. load of wire (> 7.5 g)
Coefficient of variation CV (ratio of std. dev. to mean value) < 0.15 (< 15 %)

Parameter	First Bond	Second Bond
US-Power [a.u.]	100	95
US-Time [ms]	25	25
Bond Force [cN]	25	25

Fracture mode classification for Al wire bonding:

Mode 1	Wedge lift first bond
Mode 2	Neck break first bond
Mode 3	Wire loop break
Mode 4	Neck break second bond
Mode 5	Wedge lift second bond

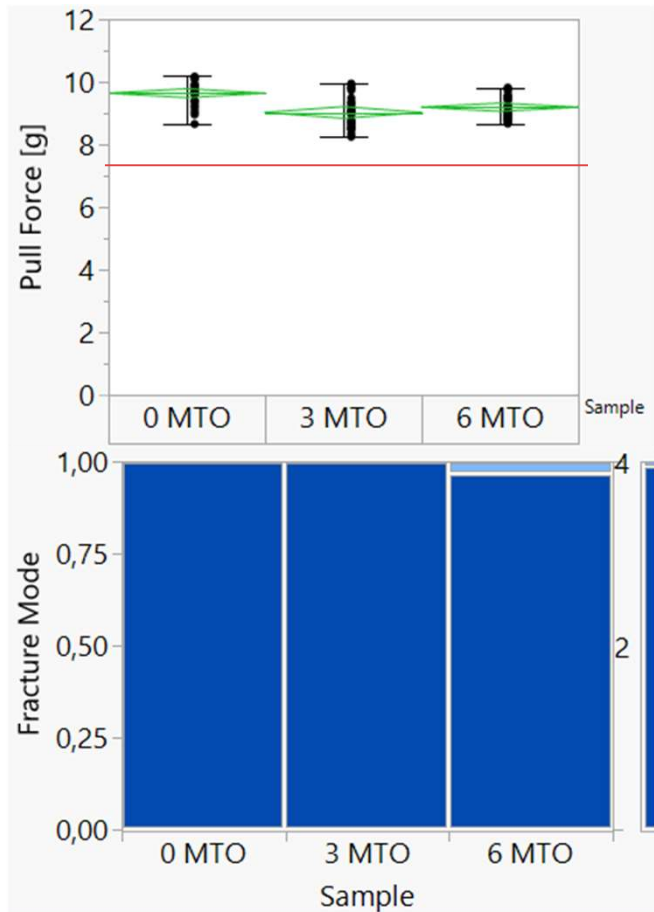




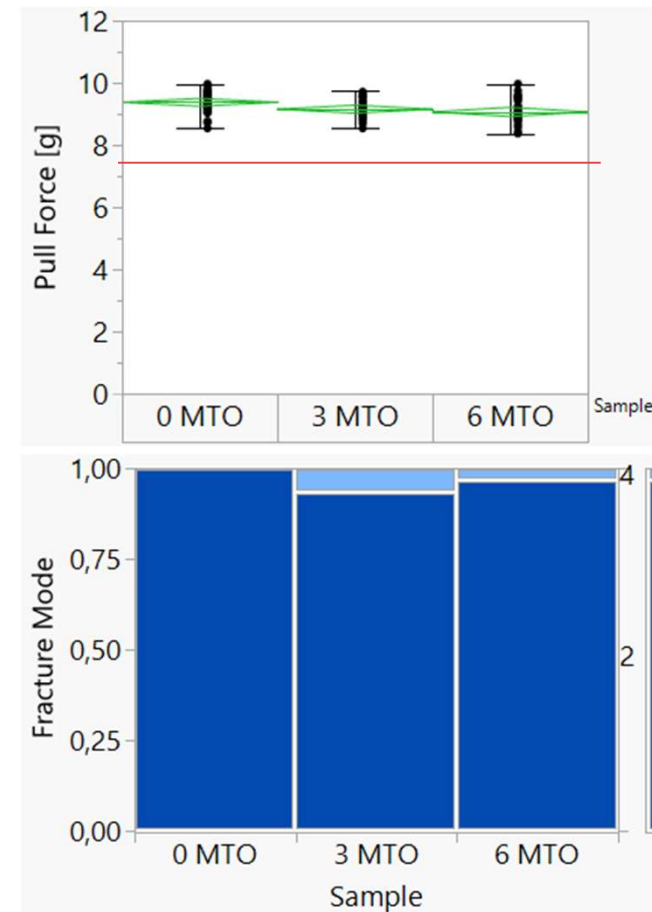
Process Performance

Al-wire bond test - results

As received



3h@120°C



Constant performance, no lift or peel offs observed



Further opportunities

ENIG

EPAG



New Gold for ENIG

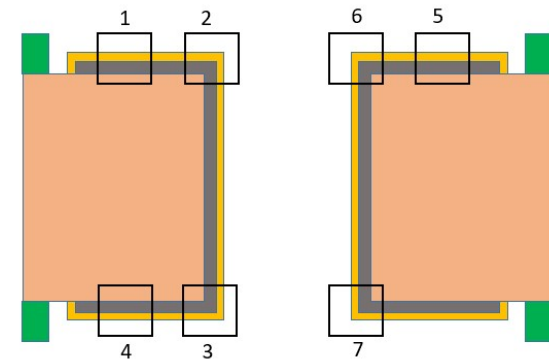
Ni/Au Corrosion – evaluation method



Sample ID	Pad/PTH ID	Number of identified corrosion events					Surface corrosion
		0 -20%	21 – 40%	41 – 100%	100%	>100 %	
1	1	3	5	1	0	0	0
1	2	2	3	4	0	0	0
...	...						

Rating table for corrosion evaluation

Evaluation of different areas on the PCB, several PTHs with 7 locations each in Cross section



New Gold for ENIG

Ni/Au Corrosion – evaluation method



1) Categorizing corrosion occurrence and depth

- **Level 0:** no corrosion events detected
- **Level 1:** less than 10 events with all events not deeper than 20% - or a single event with less than 40%
- **Level 3:** 10 or more events and more than 5 deeper than 40% - or surface corrosion with an extension of more than 30% of the image
- **Level 2:** every other observation

2) Rating how critical is corrosion related to full panel

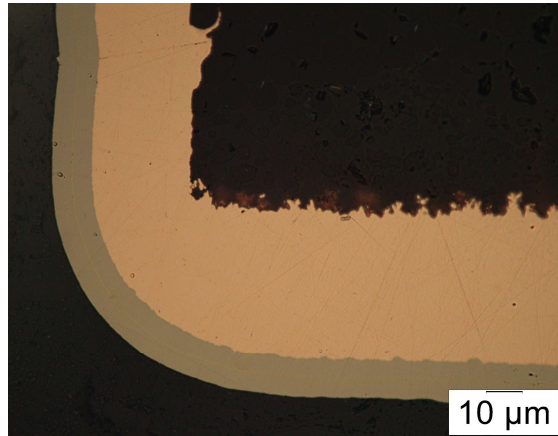
- **Corrosion rating 0:** no corrosion
- **Corrosion rating 1:** more than 60% of the investigated locations have a level 0 or 1
- **Corrosion rating 3:** more than 40% of the locations show a level 3
- **Corrosion rating 2:** all other observations

New Gold for ENIG

Corrosion performance – Au bath aging



- ENIG Corrosion performance by MTO



Rating
0
1
2
3

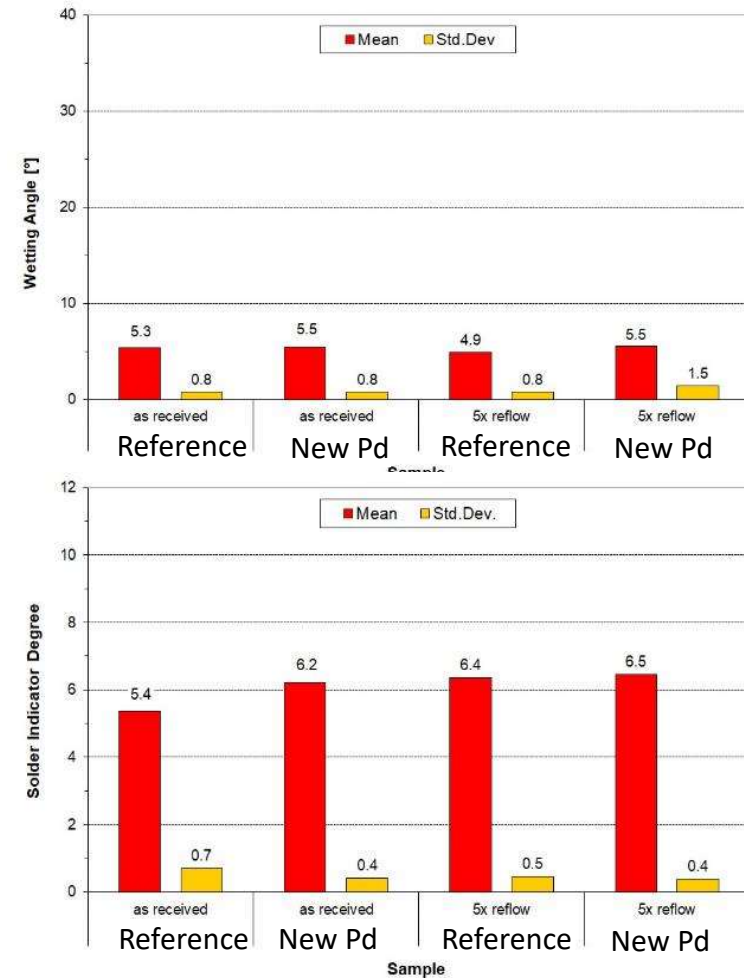
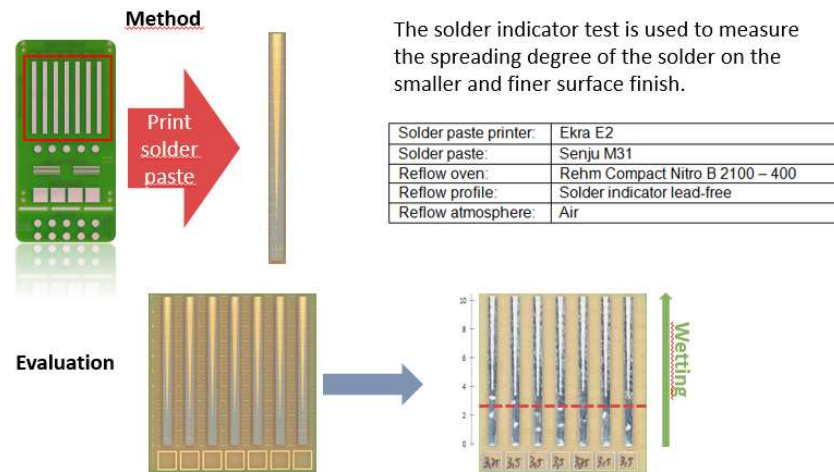
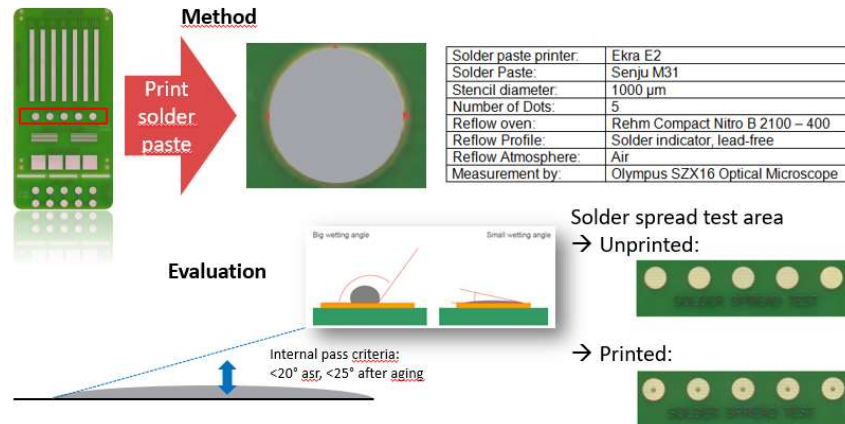
PTH		0 MTO										1 MTO										2 MTO										3 MTO									
		1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10
Location 1		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Location 2		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Location 3		0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Location 4		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Location 5		0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Location 6		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Location 7		0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Total Count	Total Count	Total Count	Total Count	Total Count	Total Count	Total Count	Total Count	Total Count	Total Count	Total Count	Total Count	Total Count	Total Count	Total Count	Total Count	Total Count	Total Count	Total Count	Total Count	Total Count	Total Count	Total Count	Total Count	Total Count	Total Count	Total Count	Total Count	Total Count	Total Count	Total Count	Total Count	Total Count	Total Count	Total Count	Total Count	Total Count	Total Count	Total Count	Total Count
Level 0		7	6	7	6	7	7	7	7	7	7	6	7	7	7	7	7	7	7	7	7	6	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	
Level 1		0	1	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Level 2		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Level 3		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Rating		0	1	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	

Excellent performance in terms of Ni corrosion



New Palladium for EPAG

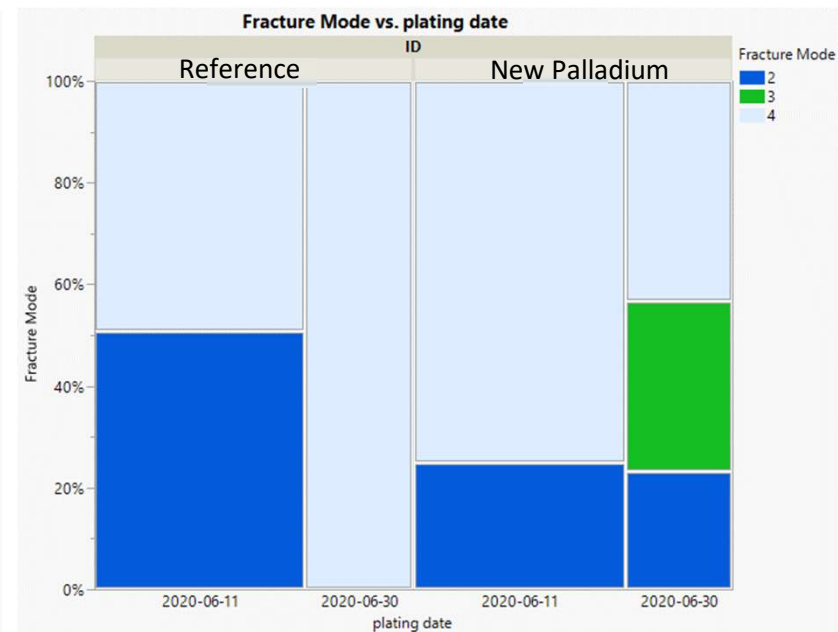
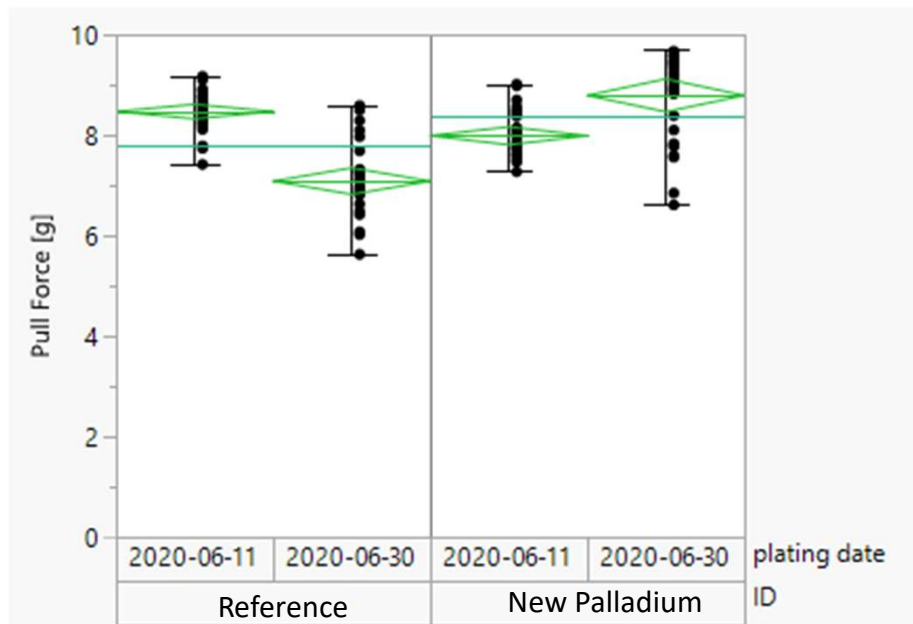
solder wetting



Excellent solder wetting, comparable to existing process

New Palladium for EPAG

Au wire bonding



Excellent wire bonding, no lift off or peel off



Summary



New Ni/Pd/Au

Summary

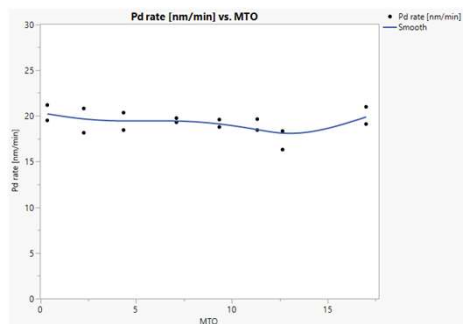


technical benefits

- New Palladium and Gold solutions for Ni/Pd/Au but also Ni/Au and Pd/Au
- Cost reduction by low Pd- and Au-content (0.5 g/l) and excellent thickness distribution with low CoV
- High robustness against contamination, e.g. high Cu-tolerance
- Stable plating rate and performance over long bath life
- Capable to plate high Pd- and high Au- thickness



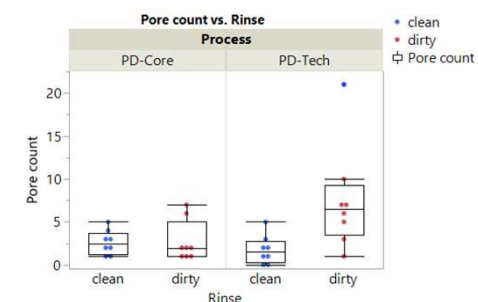
Stable plating rate



Low Precious metal content



High process robustness





Thank you

for your attention!

Global head office

Atotech Deutschland GmbH
Erasmusstraße 20
10553 Berlin – Germany

+ 49 (0) 30 349 85 0
info@atotech.com
www.atotech.com

