Device Packaging 2020 - Fountain Hills, AZ USA - March 2-5, 2020
Visit www.imapsource.org for more IMAPS papers

ATOTECH

Autocatalytic Tin

how to overcome process limitations to introduce a new solution for thick tin plating

Dr. Britta Schafsteller/ Atotech / March 2020

Technology for tomorrow's solutions

Contents

Introduction

Autocatalytic Tin

Introduction - Motivation

Reduction

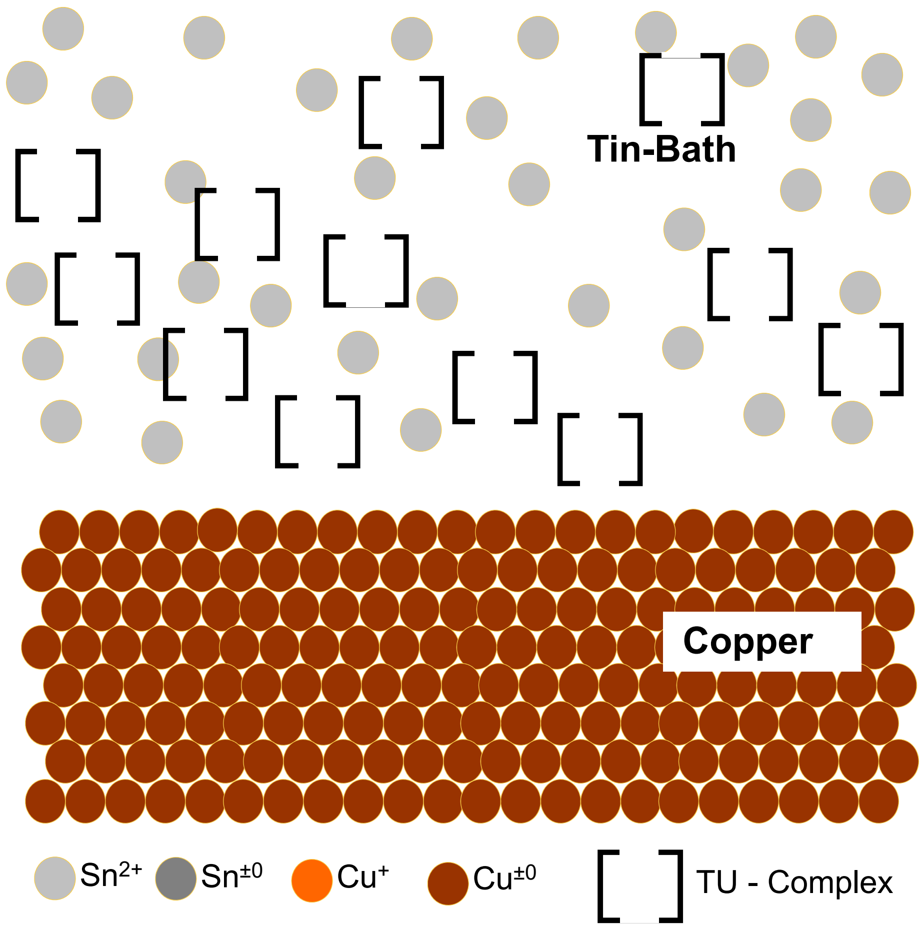
Immersion reaction: **$2\,Cu + Sn^{2+} \rightarrow 2\,Cu^{+} + Sn$**

Oxidation

$Cu^{+} + e^{-} \rightarrow Cu \quad E° = 0{,}521\ V$

$Sn^{2+} + 2\,e^{-} \rightarrow Sn \quad E° = -\,0{,}138\ V$

TU complex lowers the potential of Cu → Cu less noble than Sn



Autocatalytic Tin

Introduction - Motivation

Limitations of the immersion reaction process

- Cu diffusion in deposit is slow (limitating process step)
- Deposit thickness is limited
  - IMC is formed during assembly process and free tin is consumed
  - Solderability limited with increasing reflow cycles
- Copper track is dissolved during deposition – limitations for fine structures

→ Autocatalytic deposit offers potential solution due to

→ Low limitation in deposit thickness

→ No limitation to substrate metal

Electrochemical results

Autocatalytic Tin

Electrochemical Results - Method

- QCM: quartz crystal microbalance QCM200 system from Stanford Research Systems (USA) with a platinum coated 5 MHz quartz crystal and a potentiostat (PGSTAT30) from Metrohm (Germany).

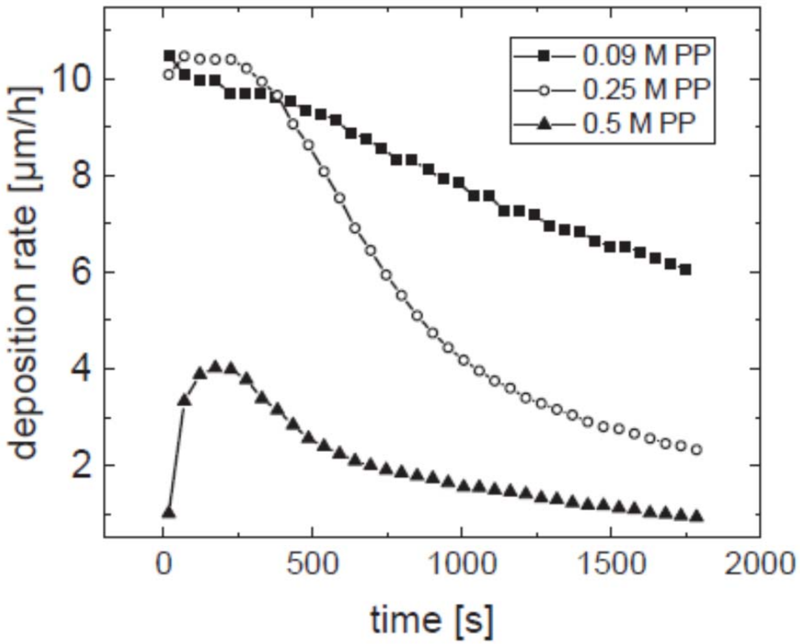
- The electrode was electroplated with a copper layer of 1µm. The electrode potentials were measured in reference to Ag/AgCl/KCl(sat).

Autocatalytic Tin

Introduction - Motivation

Typical property of an tin electrolyte containing Pyrophosphate (PP)

- Drop in deposition rate during first minutes of plating
- Effect is independent of reducing agent, appears also in electrodeposition
  - Electrochemical investigations showed impact of PP adsorption

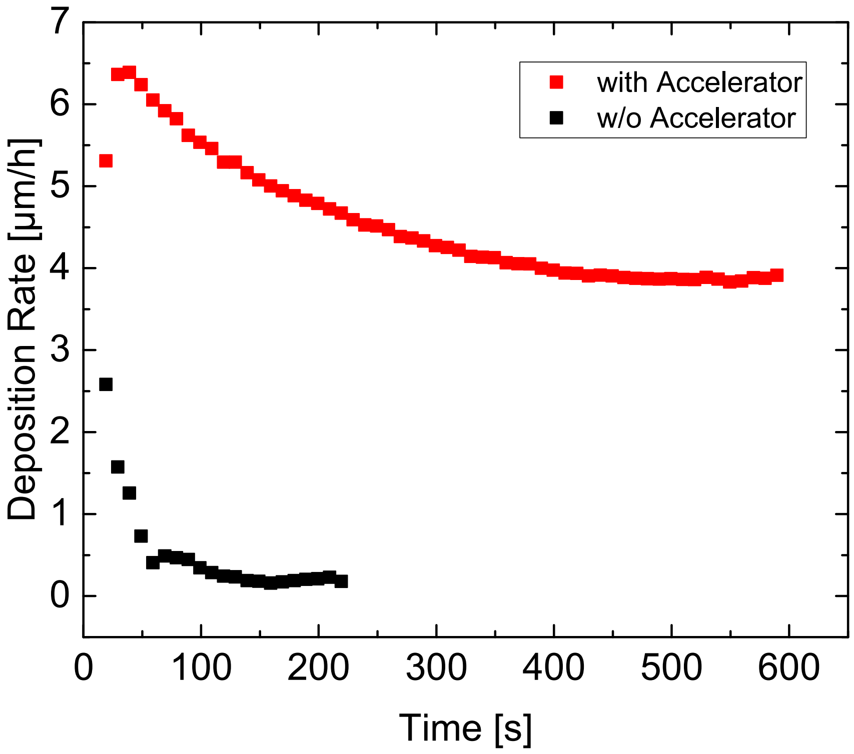


ATOTECH

Autocatalytic Tin

Introduction - Motivation

- Introduction of Accelerator Additive to inhibit PP adsorption
- Plating rate can be kept stable over longer plating times



Bath Properties

Autocatalytic Tin

Process Flow

Temp [°C]	Dwelling Time [min]	Process
45	5	Cleaner
RT	1	DI water Rinse
30 - 35	1	Micro Etch
RT	0.5	DI water Rinse
RT	1	Predip (optional for different metal substrates)
65 - 75	60	Autocatalytic Tin bath
50	1	DI water Rinse
RT	5	Blower/Dryer

Autocatalytic Tin

Reaction principle

Deposition is promoted by electrons from the reducing agent

No displacement reaction between tin and substrate! No Cu attack !

Principle:

$2\ Red^{x+}$	**$\rightarrow 2\ Red^{x+1+} + 2e^-$**	**Oxidation**
$Sn^{2+} + 2e^-$	**$\rightarrow Sn^0$**	**Reduktion**

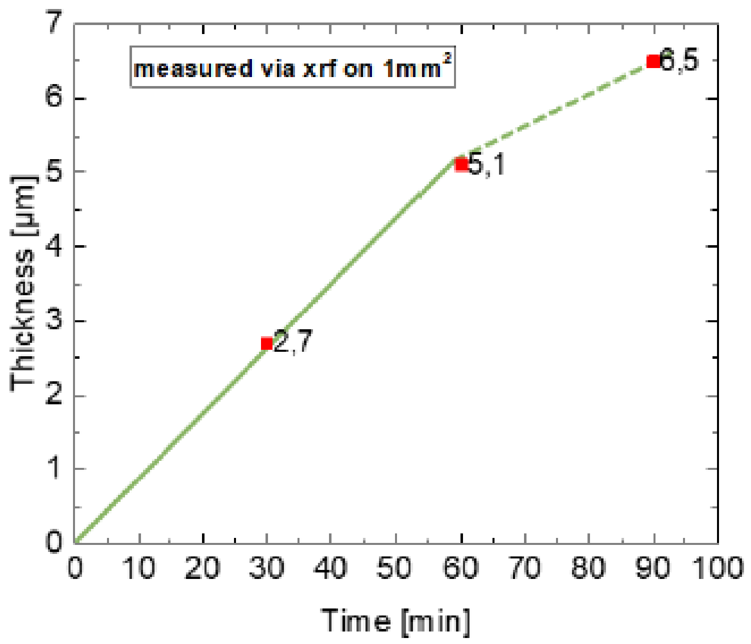
$$2\ Red^{x+} + Sn^{2+} \rightarrow Sn^0 + 2\ Red^{x+1+}$$

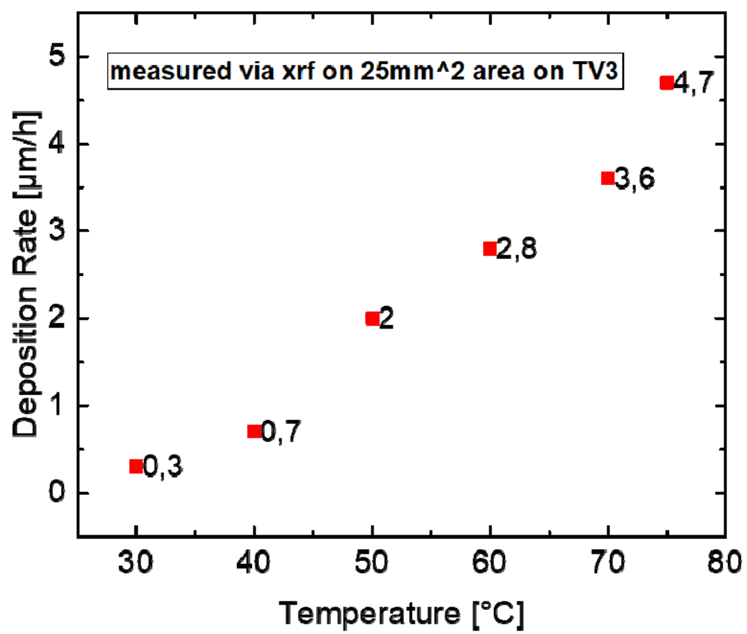
ATOTECH

Autocatalytic Tin

Details

- Plating rate is stable over time – can be adjusted by temperature



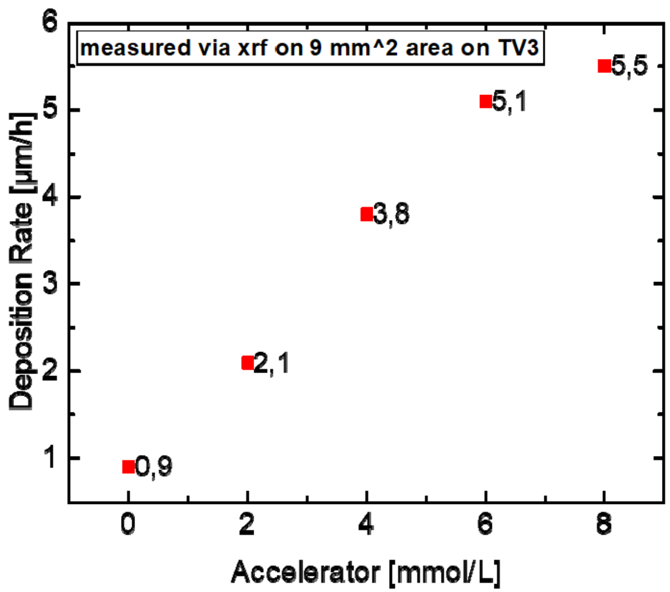


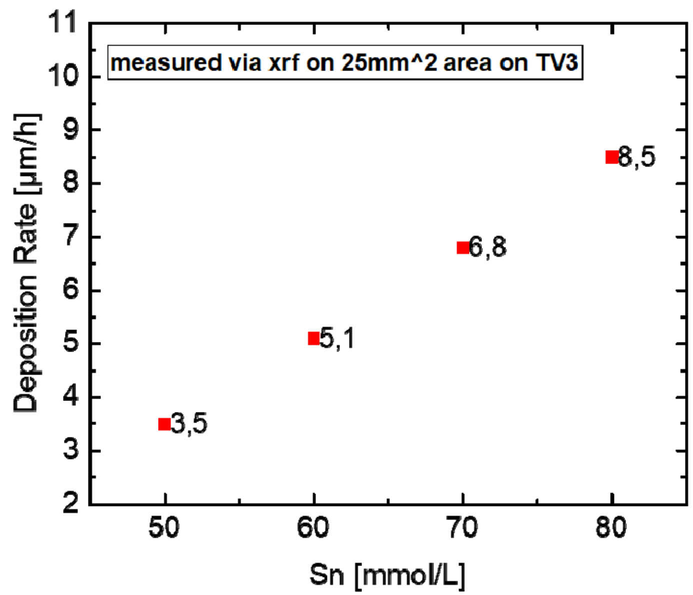
Deposition rate vs. Temperature

Autocatalytic Tin

Further Details

- Plating rate can also be adjusted by variation of Accelerator and Sn content





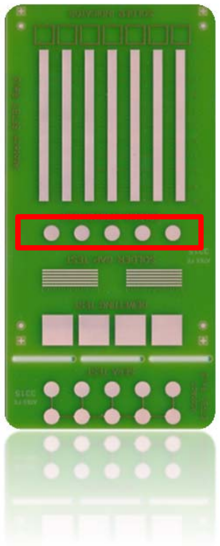
ATOTECH

Layer Performance

IMAPS

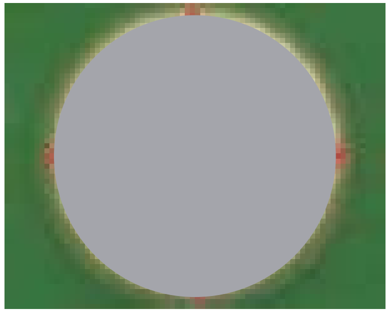
Autocatalytic Tin

Layer Performance – Solder Spread test



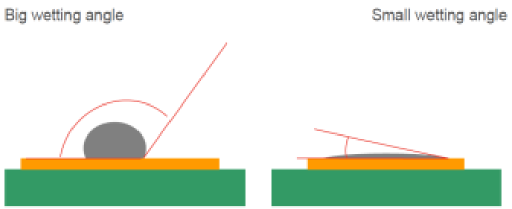
Method

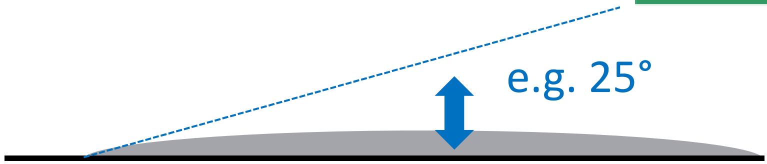
Print solder paste



Solder paste printer:	Ekra E2
Solder Paste:	Senju M31
Stencil diameter:	1000 µm
Number of Dots:	5
Reflow oven:	Rehm Compact Nitro B 2100 – 400
Reflow Profile:	Solder indicator, lead-free
Reflow Atmosphere:	Air
Measurement by:	Olympus SZX16 Optical Microscope

Evaluation





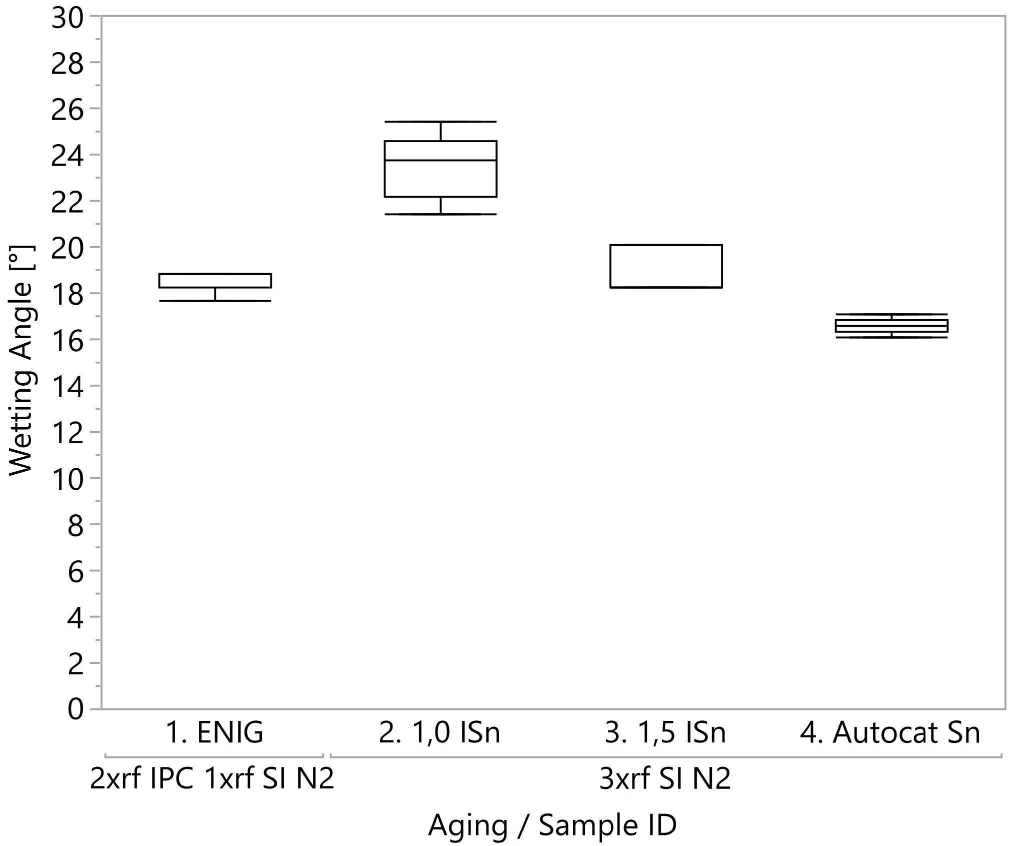
Solder spread test area

→ Unprinted:

→ Printed:

Autocatalytic Tin

Layer Performance – Solder Spread test



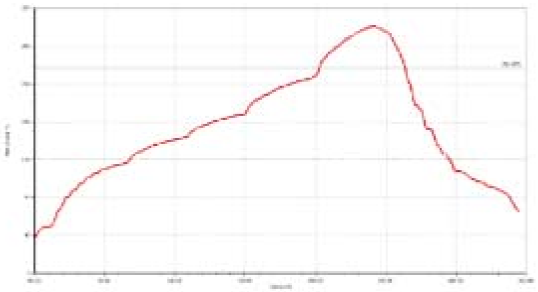
Sample ID	Surface Finish	Nickel [µm]	Gold [µm]	Tin [µm]
1	ENIG	5.5	0.05	
2	ISn			1
3	ISn			1.5
4	Autocat. Sn			1.8

Improved solder wetting with increased tin thickness

Device Packaging 2020 - Fountain Hills, AZ USA - March 2-5, 2020
Visit www.imapsource.org for more IMAPS papers

Autocatalytic Tin

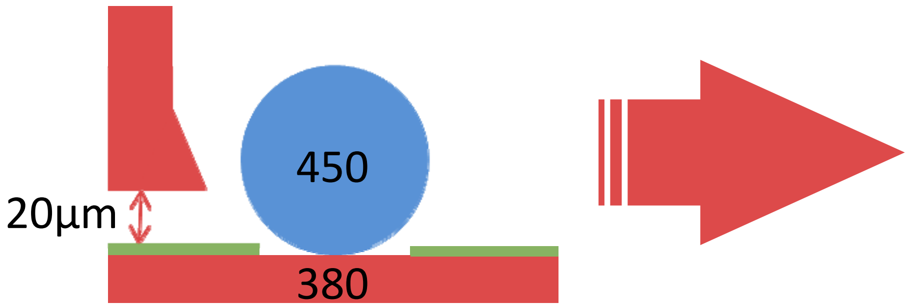
Layer Performance – Ball Shear/High Speed Shear testing



- LF Reflow profile, peak temperature 250°C
- 30 solder balls tested per condition

Sample ID	Surface Finish	Nickel [µm]	Gold [µm]	Tin [µm]
1	ENIG	5.5	0.05	
2	ISn			1
3	ISn			1.5
4	Autocat. Sn			1.8

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%



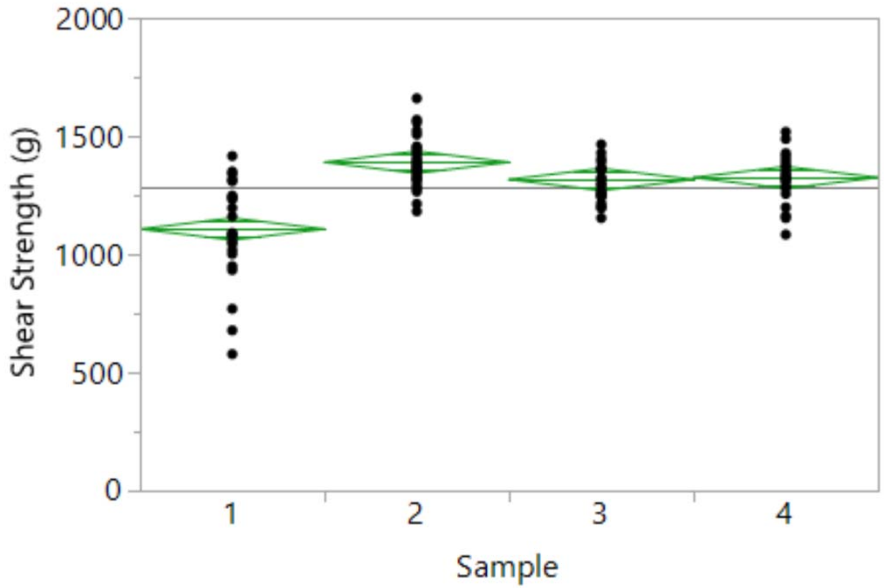
HSS test conditions
SAC 305:
0.9 m/s (Ø450µm)

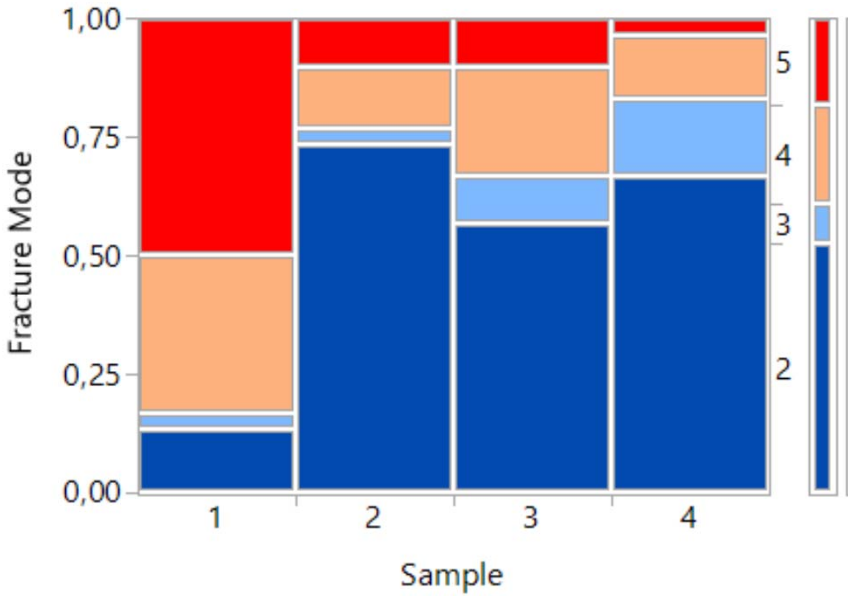
Autocatalytic Tin

Layer Performance – HSS test

Sample ID	Surface Finish	Nickel [µm]	Gold [µm]	Tin [µm]
1	ENIG	5.5	0.05	
2	ISn			1
3	ISn			1.5
4	Autocat. Sn			1.8

Shear strength and fracture mode after 5 x reflow





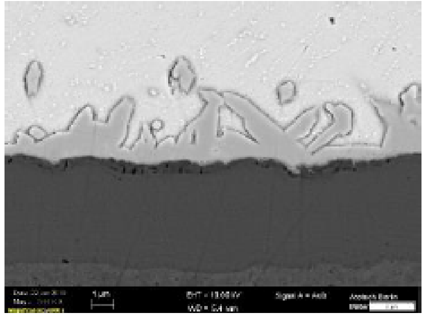
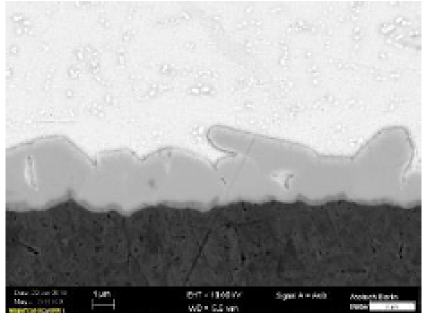
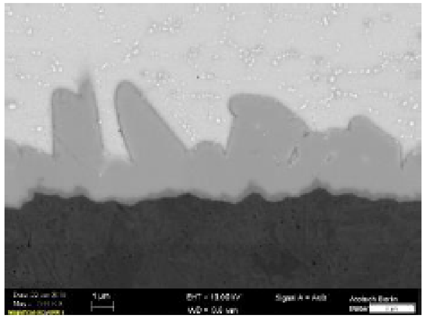
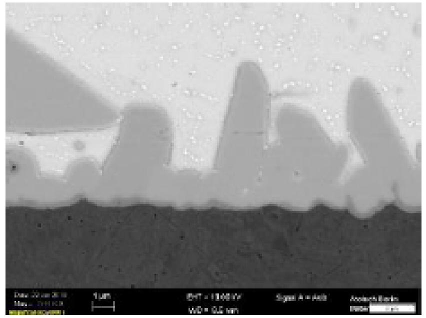
More brittle fracture with ENIG, no significant difference in Sn-coatings

Autocatalytic Tin

Layer Performance – IMC

IMC comparison

- Similar IMC formation for all three tin deposits
- More nodular IMC shape for ENIG deposit caused by $(Cu, Ni)_6Sn_5$ formation

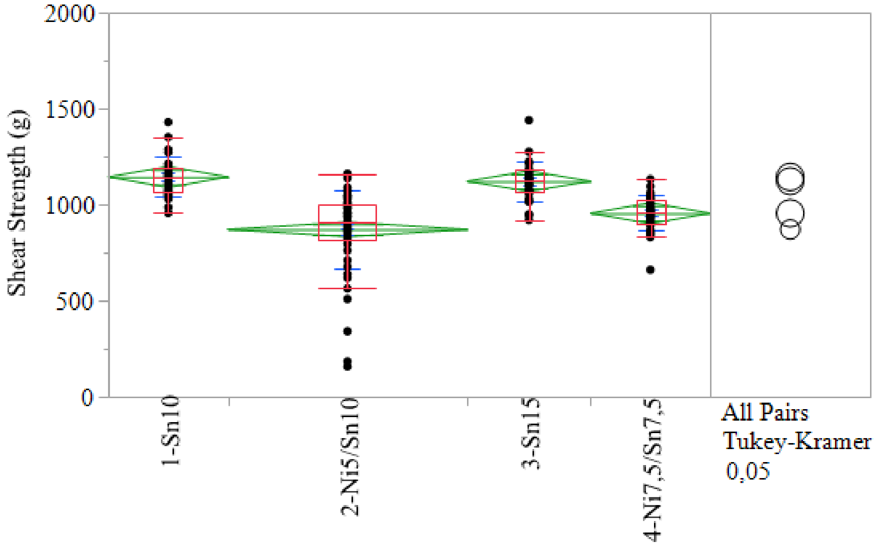
	
SAMPLE 1 - ENIG	SAMPLE 2 – IMMERSION TIN, 1µM
	
SAMPLE 3 – IMMERSION TIN, 1.5 µM	SAMPLE 4 –AUTOCATALYTIC TIN

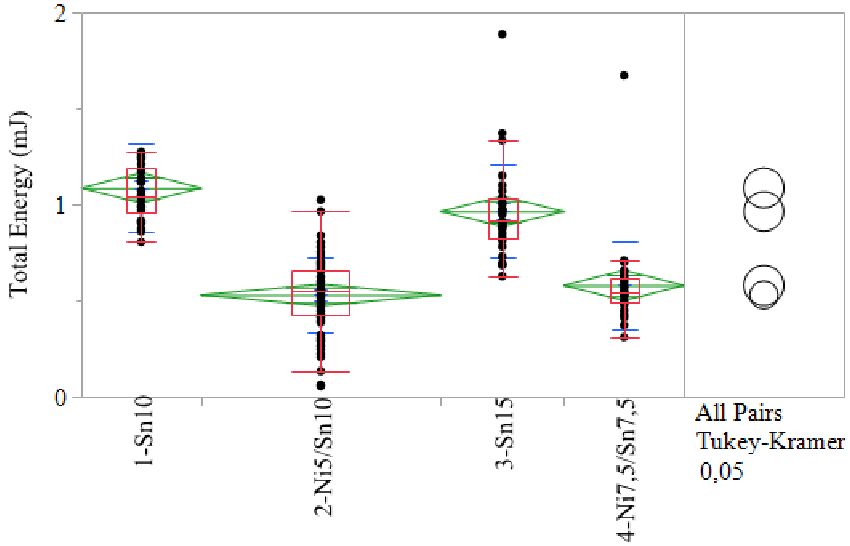
More brittle fracture with ENIG can be explained by different type of IMC

ATOTECH

Autocatalytic Tin

Layer Performance – HSS 1 x RF





Connecting Letters Report

Level			Mean
1-Sn10	A		1144,4330
3-Sn15	A		1122,3502
4-Ni7,5/Sn7,5		B	955,3669
2-Ni5/Sn10		B	870,8649

Levels not connected by same letter are significantly different.

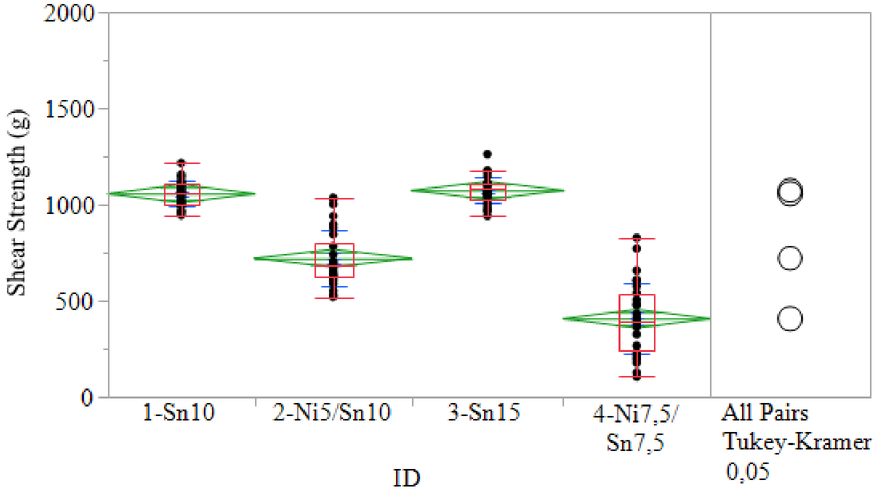
Connecting Letters Report

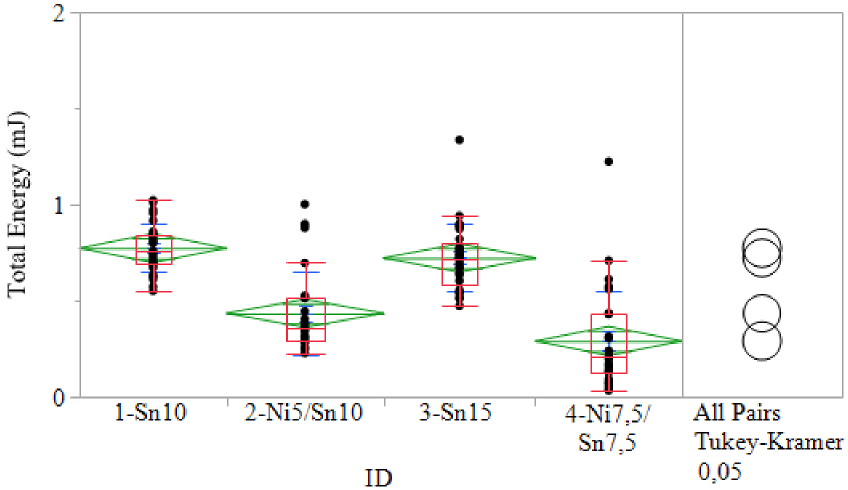
Level			Mean
1-Sn10	A		1,0869287
3-Sn15	A		0,9646395
4-Ni7,5/Sn7,5		B	0,5793681
2-Ni5/Sn10		B	0,5293620

Levels not connected by same letter are significantly different.

Autocatalytic Tin

Layer Performance - HSS 5 x RF





Connecting Letters Report

Level				Mean
3-Sn15	A			1073,9221
1-Sn10	A			1056,6928
2-Ni5/Sn10		B		720,7431
4-Ni7,5/Sn7,5			C	406,8136

Levels not connected by same letter are significantly different.

Connecting Letters Report

Level				Mean
1-Sn10	A			0,77361225
3-Sn15	A			0,72244195
2-Ni5/Sn10		B		0,43441664
4-Ni7,5/Sn7,5			C	0,29111594

Levels not connected by same letter are significantly different.

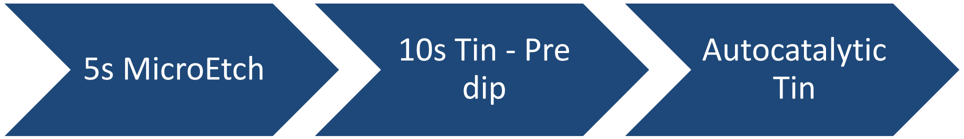
Roughness Study

Autocatalytic Tin

AFM Evaluation

6 Samples were prepared and investigated by AFM

Process Flow



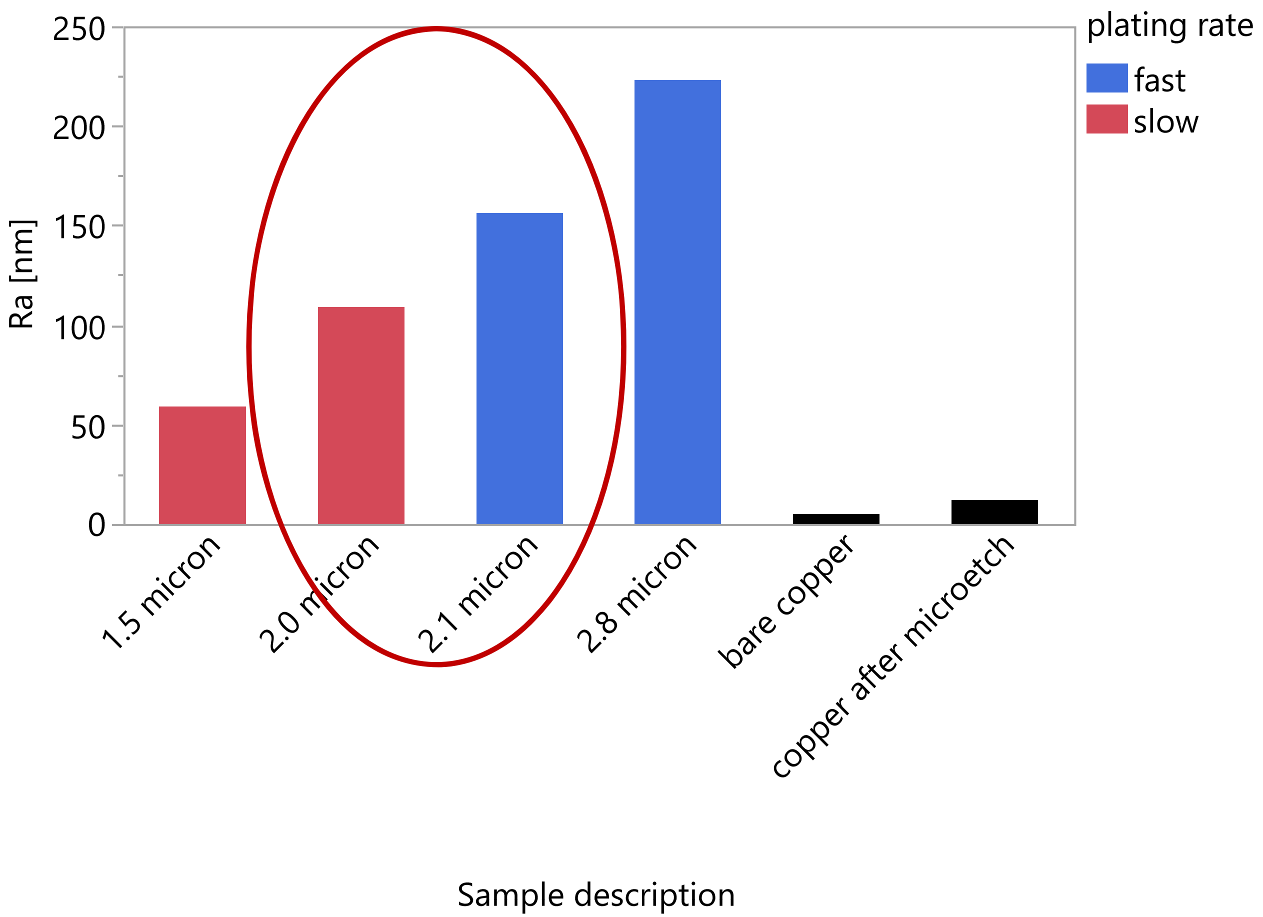
Sample No		R_A [nm]	Dwell time Autocat. Tin [min]
1	ITO/Cu3000A blank (Ref)	5	0
2	ITO/Cu3000A after Etch (Ref)	12	0
3	Sn 2.1 µm Bath 1	156	45
4	Sn 2.8 µm Bath 1	223	60
5	Sn 1.5 µm Bath 2	59	120
6	Sn 2.0 µm Bath 2	109	150

Bath 1 : high Sn^{2+}, fast deposition
2.8 µm/h

Bath 2 : low Sn^{2+}, slow deposition
0.8 µm/h

Autocatalytic Tin

Tin Thickness vs. Roughness



Roughness is adjustable by deposition rate

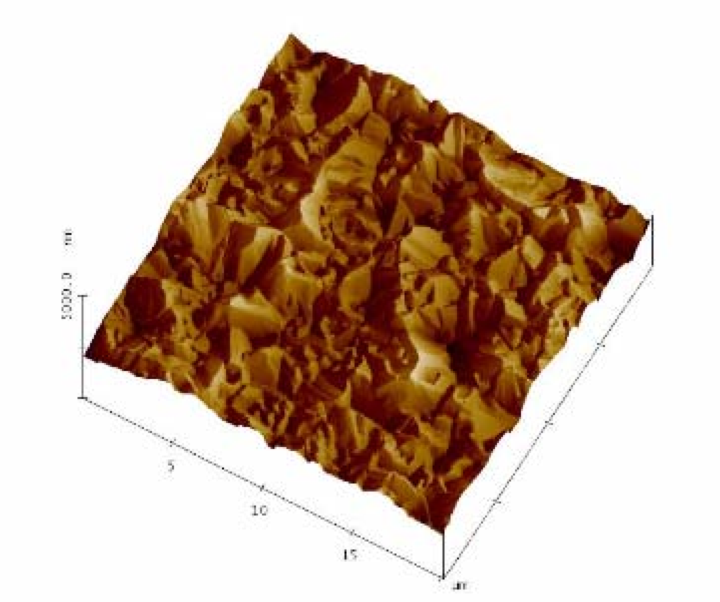
Autocatalytic Tin

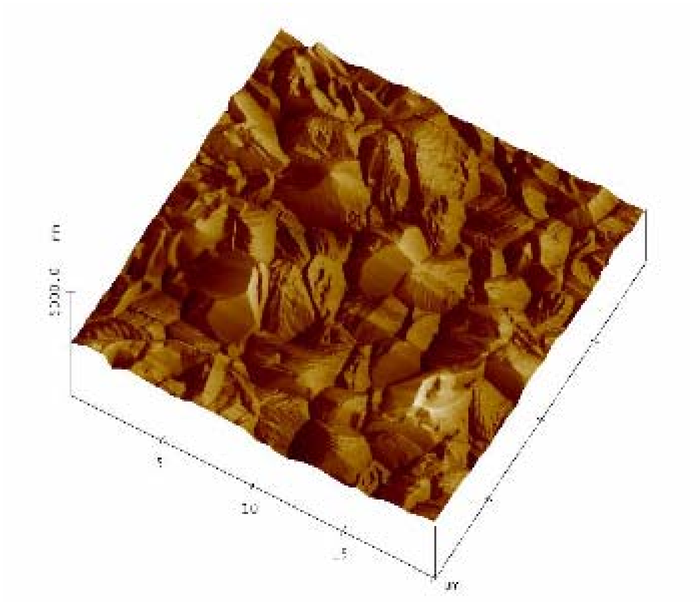
AFM surface topography

Bath 1 : high Sn^{2+}, fast deposition 2.8 µm/h

Bath 2 : low Sn^{2+}, slow deposition 0.8 µm/h

Requirement: 2µm Sn with R_a< 150 nm



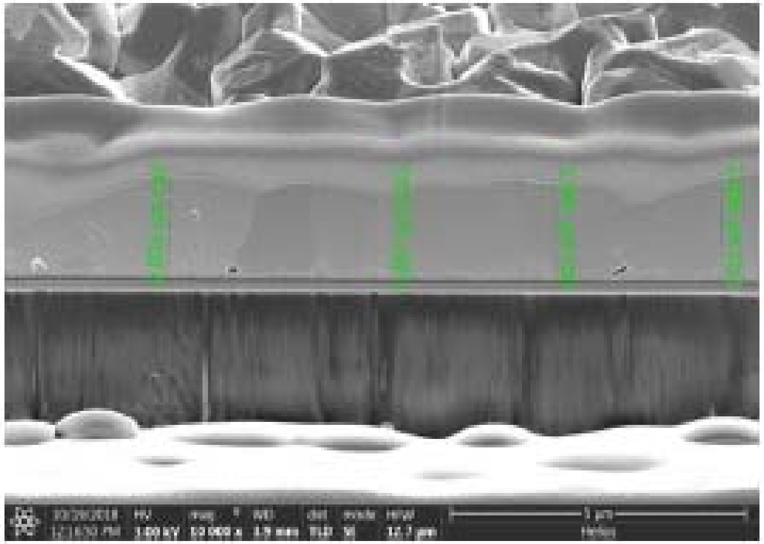


Summary and Outlook

Autocatalytic Tin

Summary and Outlook

- ✓ Continous Tin plating up to 5 µm/h
- ✓ Plating on Cu, Pd, Ag, Ni or Au is possible, no limitation to certain substrates
- ✓ Soldering performance proven to pass standard requirements
- ✓ Plating rate and roughness adjustable by bath parameters
- ✓ Potential new applications for E'less plating
  - ✓ QFN
  - ✓ Micro-LED applications
  - ✓ C4 Sn Bump
  - ✓ Al substrates



→ Further applications are being pursued

Thank you

for your attention!

Contact

Global head office

Atotech Deutschland GmbH
Erasmusstraße 20
10553 Berlin – Germany

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

Technology for tomorrow's solutions