Soldering defects on immersion tin and the impact of the tin-oxide layer

Outline

- INTRODUCTION
- FAILURE MODES OF SOLDERING IMMERSION TIN
- IMPACT TIN OXIDE LAYER
- POST TREATMENT-SOLUTION
- OXIDE LAYER & SOLDERING TEST
- SUMMARY & CONCLUSION

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Introduction

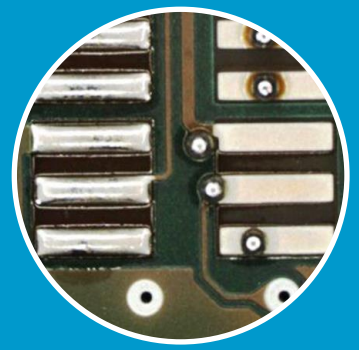
Immersion Sn

- Immersion tin is a final finish which is widely used in the printed circuit board (PCB) industry
- It provides a cost competitive surface protection with excellent corrosion resistance
- It is Pb-free final finishing, capable of multiple reflow soldering at lower metal thickness

Soldering Challenges

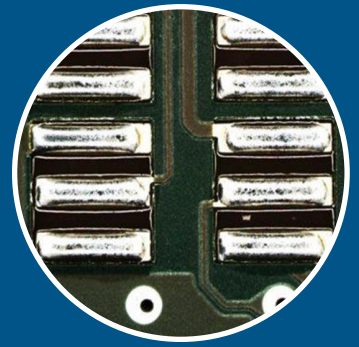
- Soldering problems can happen in the process
- On top of the tin layer an oxide layer is naturally formed
- The quality and thickness of the oxide layer can influence the solderabilty

Introduction



Non-wetting

Caused by a physical barrier between the surfaces to be joined



Dewetting

molten solder has coated and then receded, maybe caused by inadequate cleaning or inhomogeneous oxidation

Self Dewetting appears when oxide layer is damaged and cracks during 2nd reflow

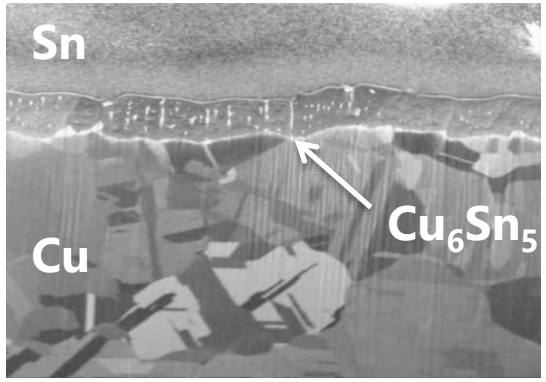
Root causes: 1) residues on Copper
2) contamination on Tin
3) evaporation of Volatiles from the solder mask

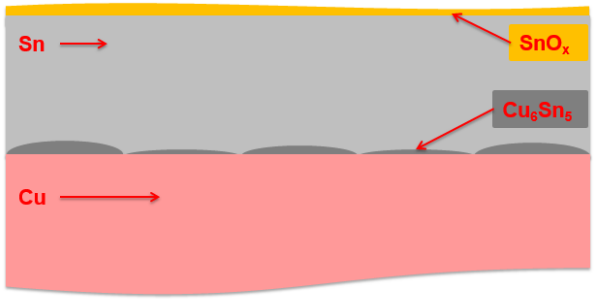
[4] R. Nichols, S. Heinemann, Soldering immersion tin, IPC APEX 2017

[5] R. Nichols, G. Ramos, L. Nothdurft, B. Schafsteller, Is it possible to use markers to select the right soldermask to optimize the yield of your selected finish?, SMTA impact 2015

Introduction

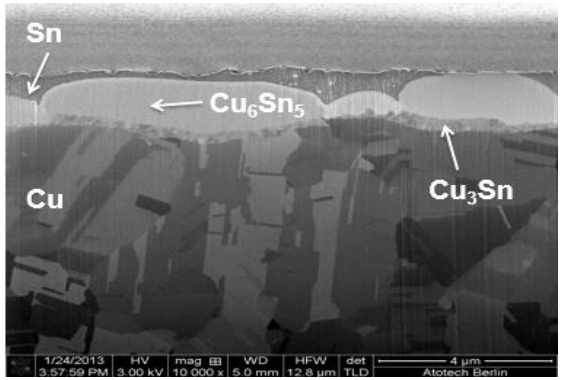
FIB of an as received

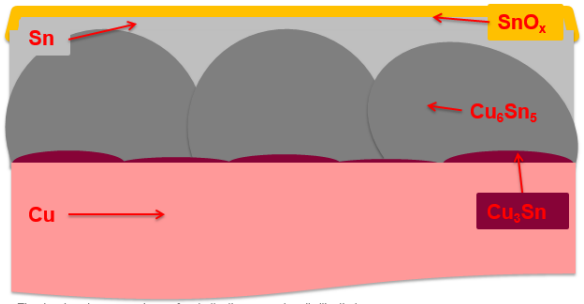




The drawing sizes were chosen for clarity, they are not really like that

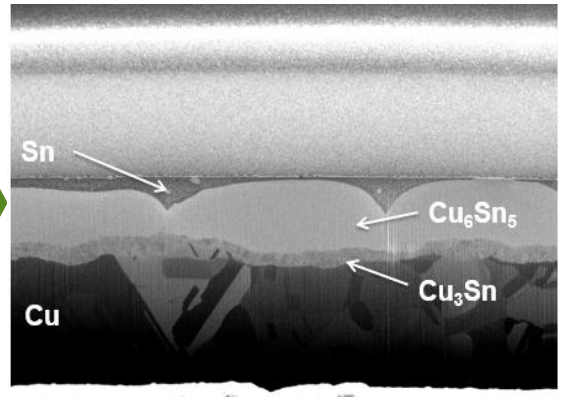
FIB after 1x reflow

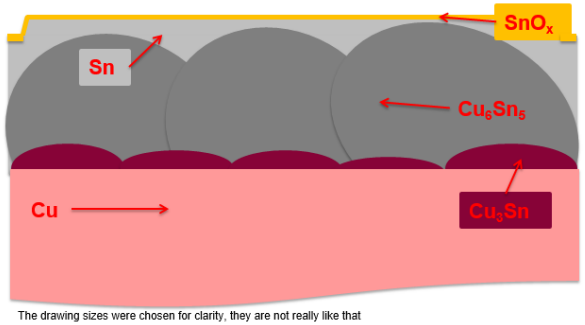




The drawing sizes were chosen for clarity, they are not really like that

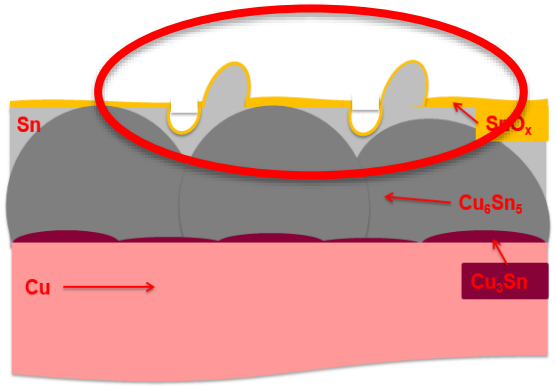
FIB after 2x reflow





The drawing sizes were chosen for clarity, they are not really like that

Potential defect:
Sn-Oxide layer breaks and liquid tin penetrates to the surface



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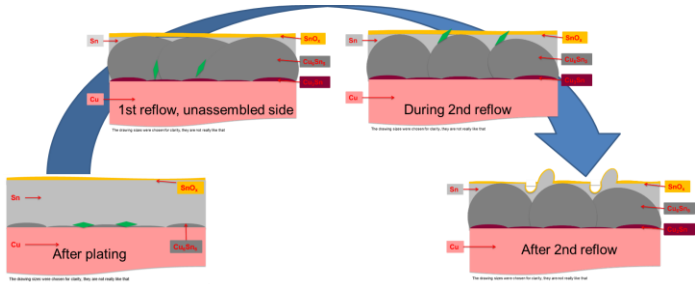
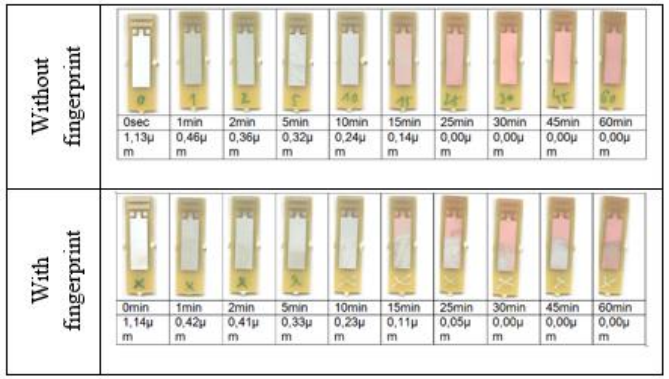
Failure modes soldering immersion tin

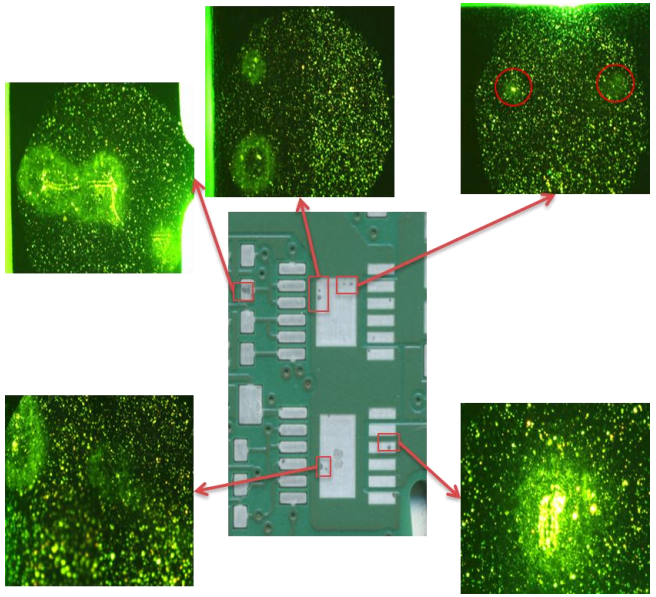
1) Residues on Copper





- Residues on Cu surface impact soldering performance

2) Contamination on Tin



- Molten areas show high fluorescence
- Clear correlation between shape of melting and fluorescence residues

3) Evaporation of Volatiles from the solder mask

UV-treatment	Reflow atmosphere	Appearance after 2nd reflow
No	Air	
No	Nitrogen	
Yes	Air	
Yes	Nitrogen	

- UV-treatment: reduces risk of evaporation/recondensation of SM products
- Air-atmosphere: creates thicker oxide layer

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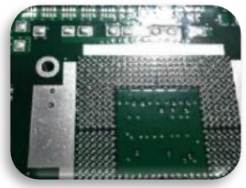
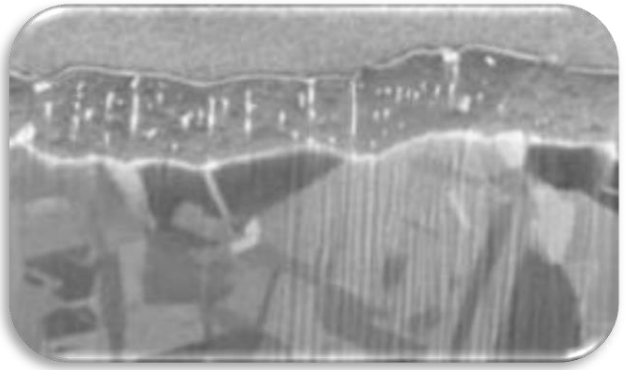
Tin Oxide Formation Impact

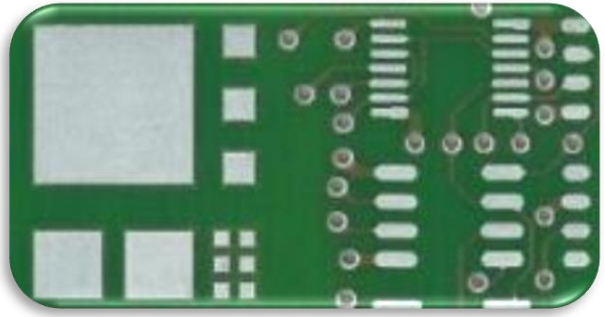
To prevent dark and shiny tin appearance after reflow oxide layer should be strong and even



Shiny Tin – 1xRF (LF, O_2<1000ppm)

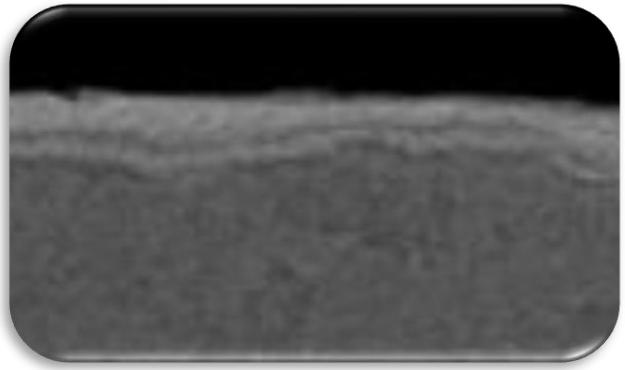


Cross section of normal tin surface as received
Surface roughness S_Q>250nm

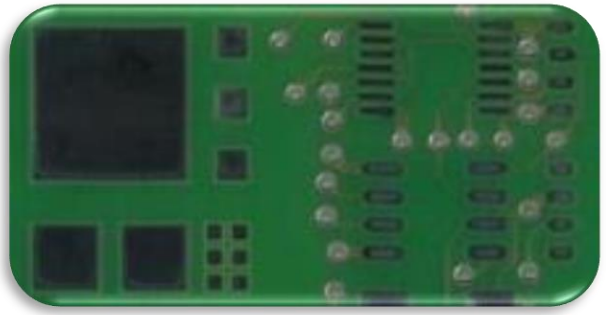


Not Shiny / Molten Tin

White and bright color of Tin
- light is recognized by detector



Cross section of shiny tin surface 1xRF (LF,O_2<1000ppm)
Very flat surface S_Q<100nm



100% Shiny / Molten Tin

Tin in scanned image appears dark
-light is not being recognized by detector

Tin Oxide Layer Impact

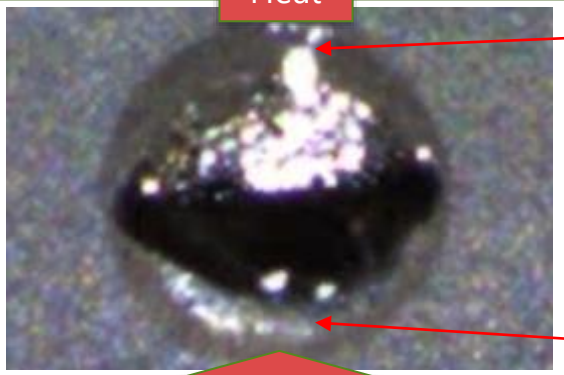
Solder dot before reflow

Sn-Oxide layer

Heat

Solder starts to melt, but flux didn't penetrate the Sn Oxide yet

Heat

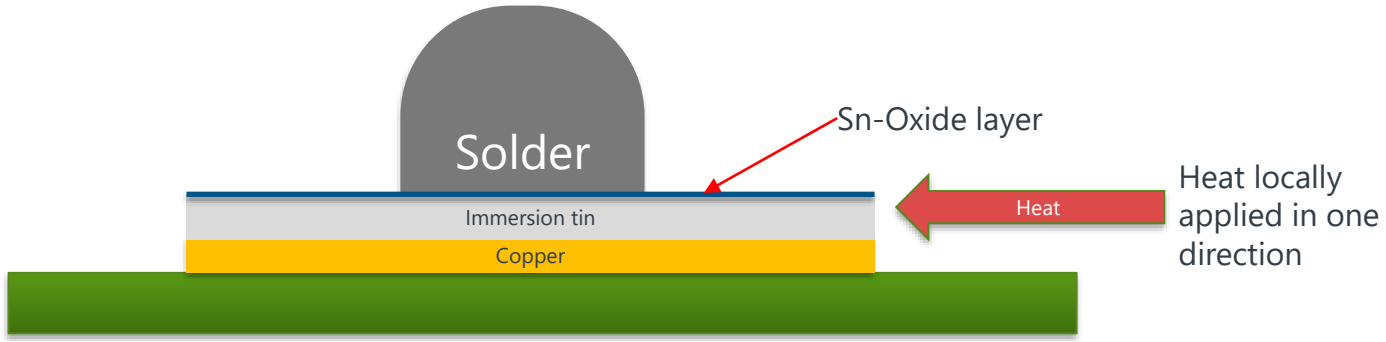


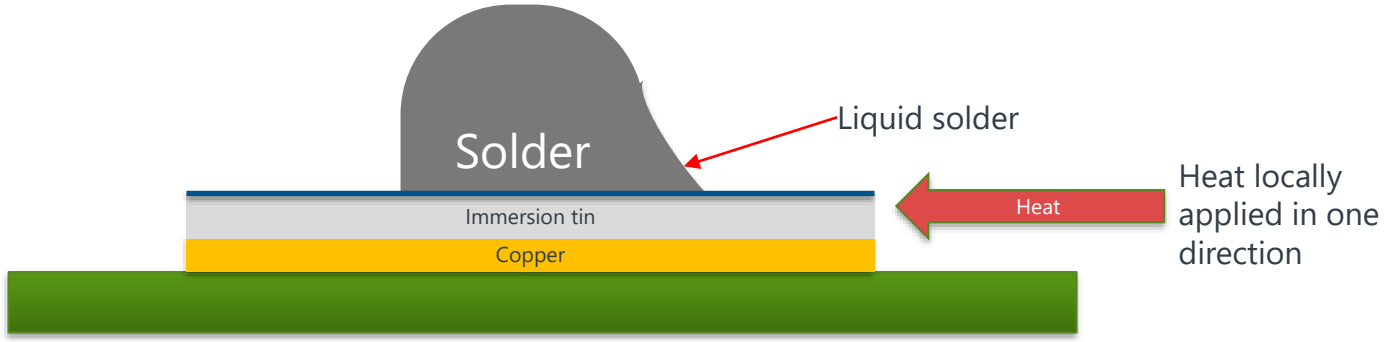
SnOxide Layer on top of liquid Sn

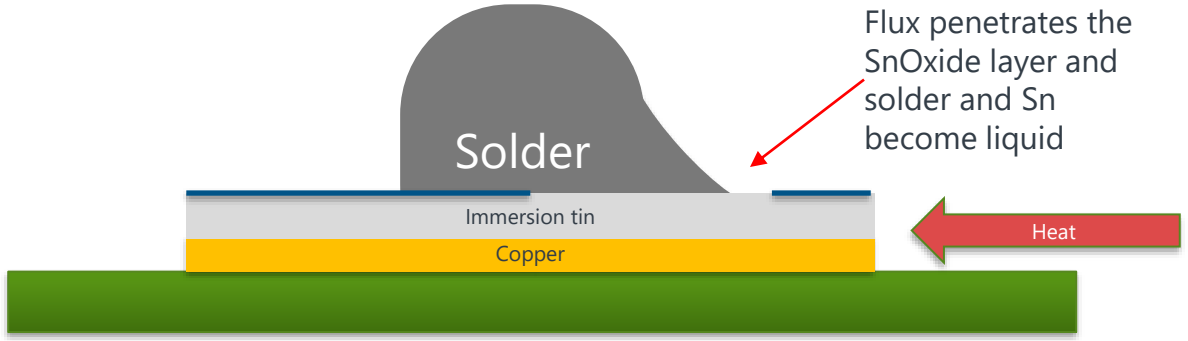
- Flux starts to penetrate the Sn Oxide and solder become more liquid

Shiny liquid tin w/o SnOxide-Layer

Heat





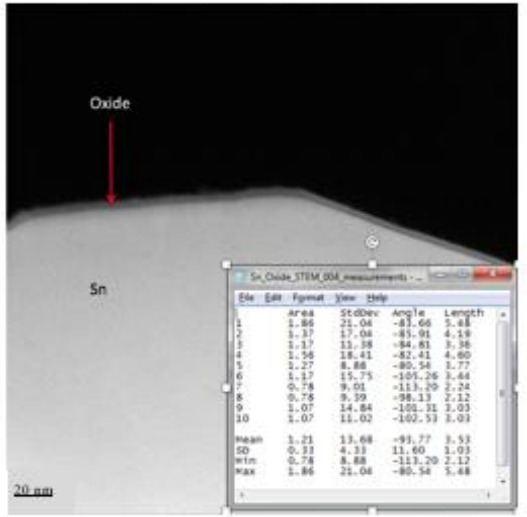


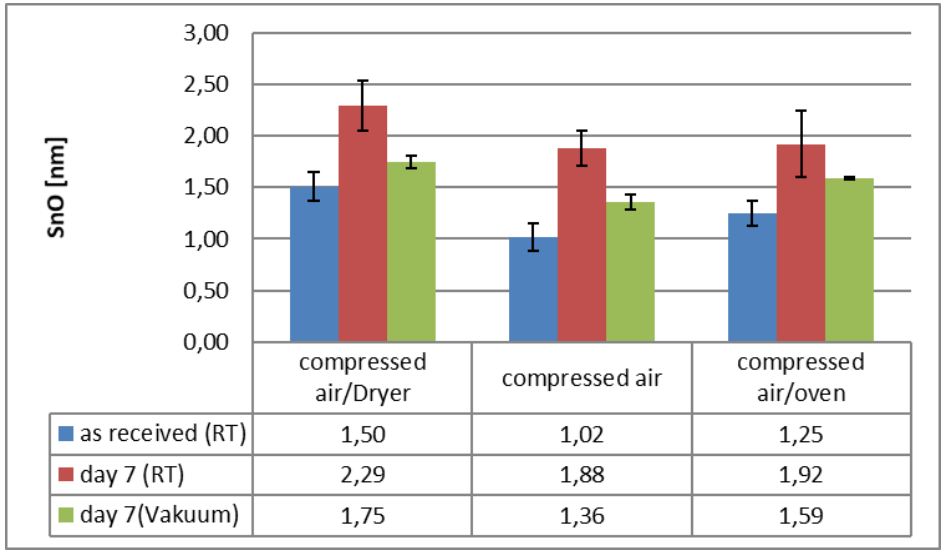
Oxide layer formation

- Impacting factors on oxide formation – measured by SERA and confirmed by TEM

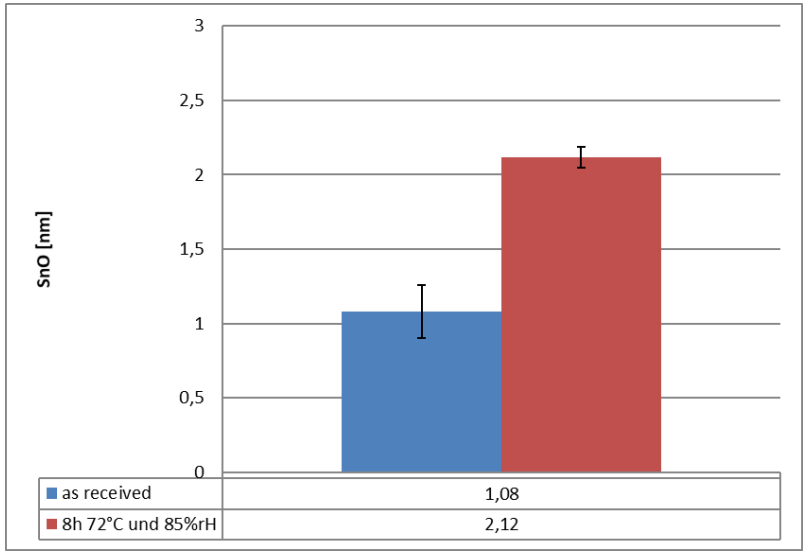
HAADF STEM (Sn Surface in region 2)

Average oxide thickness in this area is 3.5 nm.

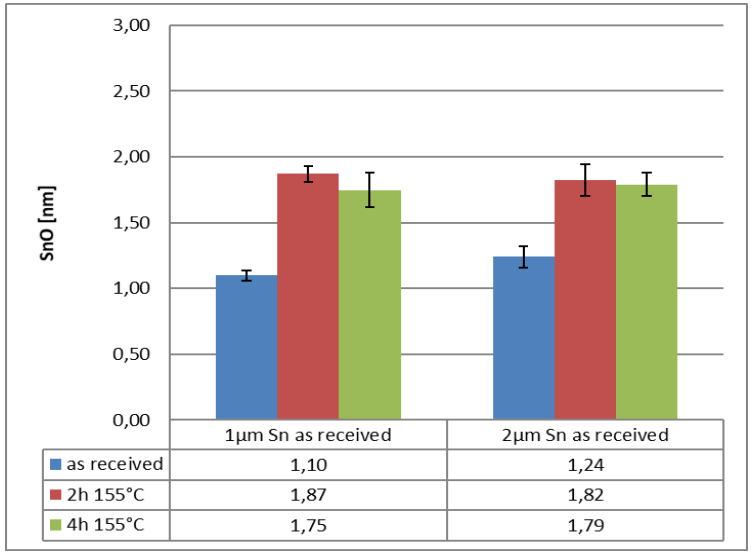




	compressed air/Dryer	compressed air	compressed air/oven
as received (RT)	1,50	1,02	1,25
day 7 (RT)	2,29	1,88	1,92
day 7(Vakuum)	1,75	1,36	1,59



as received	1,08
8h 72°C und 85%rH	2,12



	1µm Sn as received	2µm Sn as received
as received	1,10	1,24
2h 155°C	1,87	1,82
4h 155°C	1,75	1,79

- Vacuum packing inhibits oxide formation
- Low impact of drying temperature

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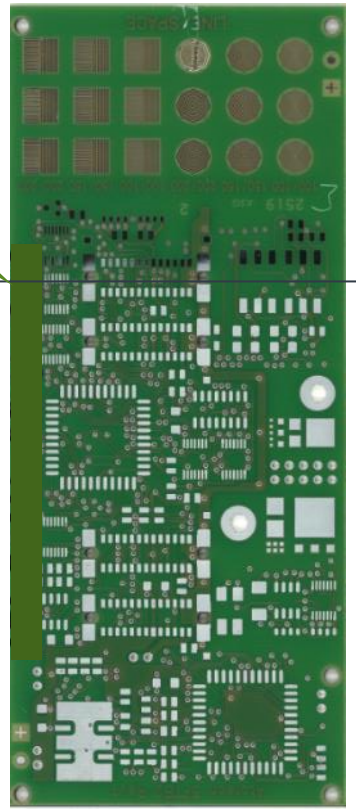
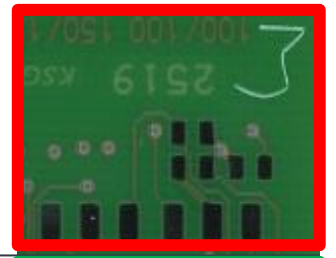
Oxide layer and shiny tin

- Increased oxide layer thickness leads prevents self de-wetting and discoloration

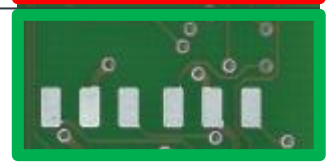
Solution level

1x reflow (LF, O_2<1000ppm)

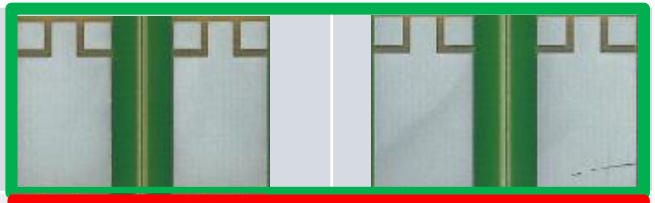




Dark, shiny tin
SnOxide < 1.0nm

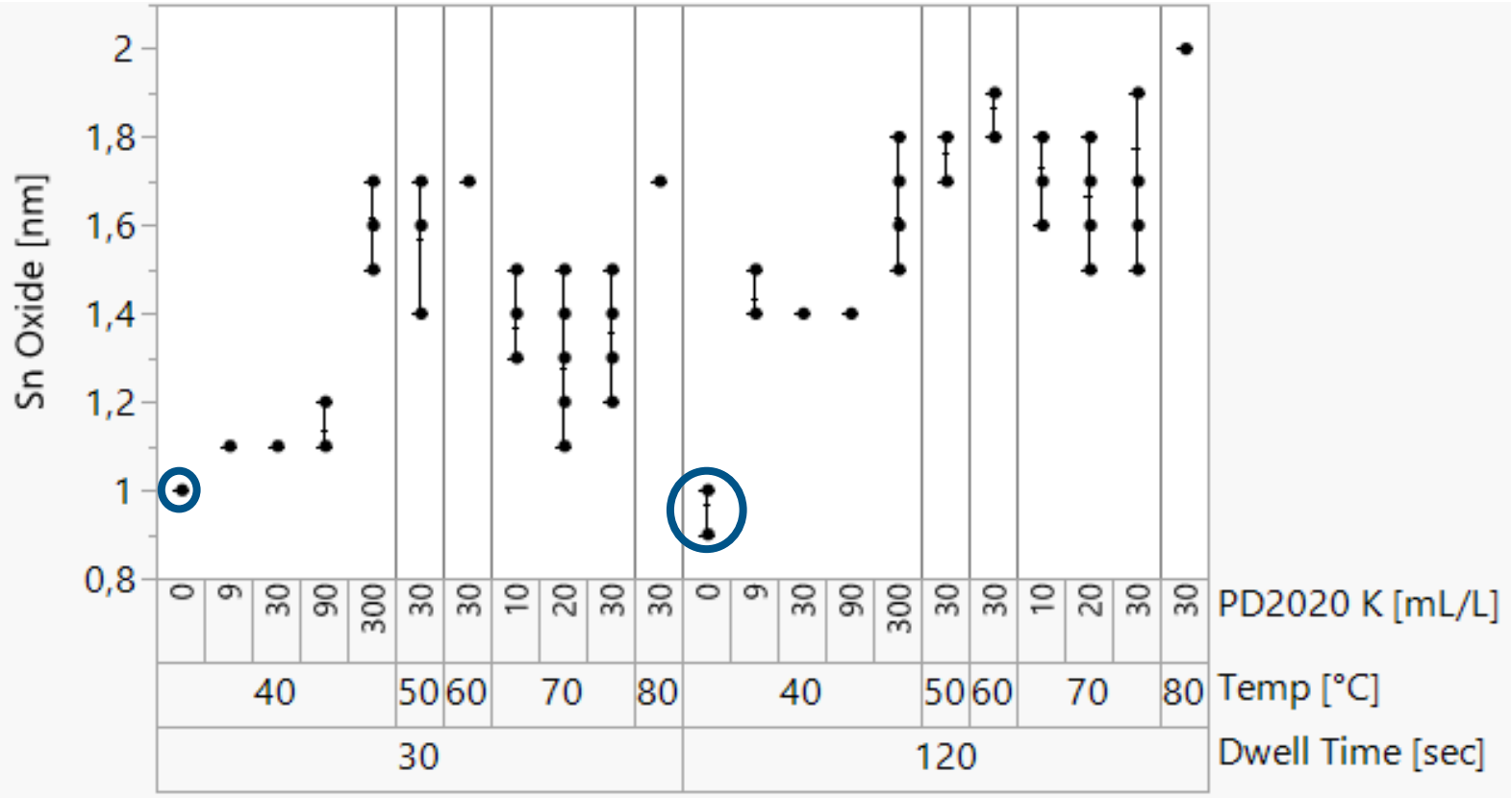


White and bright Tin
SnOxide > 2.0 nm

PostDip	Reflow Air	Reflow N2
Yes		
No		

Oxide layer formation

- Chemical treatment of Sn layer to increase oxide layer thickness



- Chemical post treatment with dedicated post-dip can significantly increase oxide layer thickness
- Increased temperature and dwell time further promotes oxide growths

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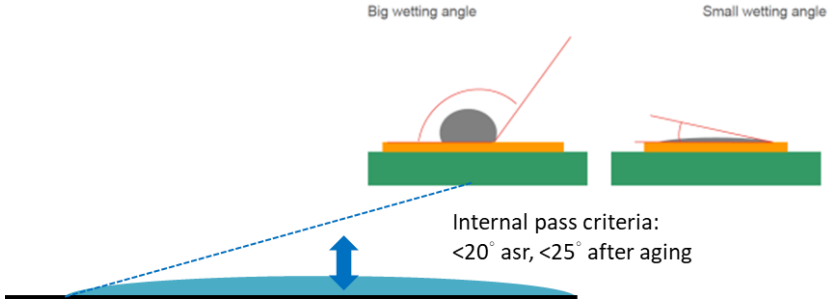
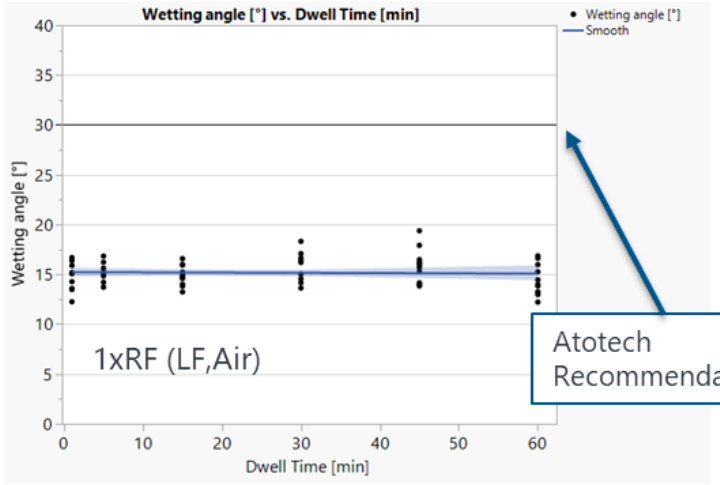
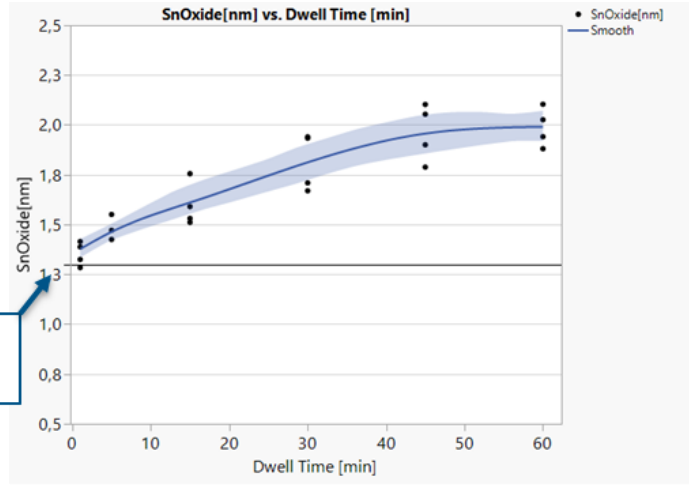
Oxide layer vs. solder wetting

- Impact Post-treatment on solder wetting

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







Atotech Recommendation

PD2020 with different dwell time 1-60min with temp.=65°C and PD2020 K = 10mL/L

Oxide formation has no negative impact on solder wetting performance

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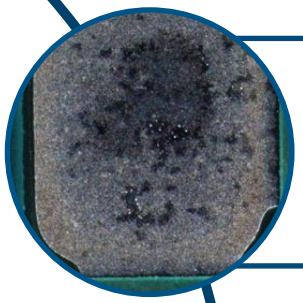
Summary and conclusion

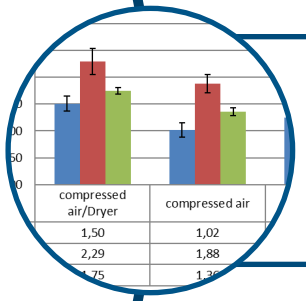
Potential root causes for weak Sn-Oxide layer formation:

- Solder mask
  - Volatiles from S/M can cause cracks in Sn-Oxide layer during reflow
- Short time between plating and packaging
  - Closed Sn-Oxide layer formed after 2-7 days
- Manual handling
  - Mechanical cracks
- MBB vacuum packaging
  - No/low Oxide formation in vacuum package
- Reflow soldering under N2-atmosphere
  - Slow oxide formation in N2-atmosphere

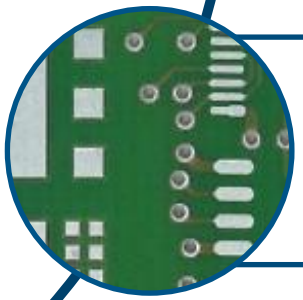
Summary and conclusion



Weak oxide layer and contaminations increase the risk for self de-wetting



Temperature/time have low impact, Vacuum packing inhibits oxide layer formation



Chemical post-treatment enhances oxide formation and prevents shiny tin, consequently, risk of self de-wetting

Summary and conclusion

Q & A

Thank you!

Britta Schafsteller,
Bernhard Schachtner,
Kenneth Lee,
Hubertus Mertens,
Gustavo Ramos