Solderable Surface Finishes: One of the key Factors impacting the overall Reliability of Electronic Products

The black pad failure mode: false negatives v false positives

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TNO Technical Sciences - Materials for Integrated Products


innovation for life

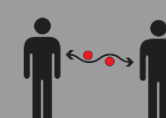
The mission of TNO

TNO connects people and knowledge to create innovations that boost the sustainable competitiveness of industry and well-being of society.

From idea to innovation:

Develop fundamental knowledge	Knowledge development	Knowledge application	Knowledge exploitation
With universities	With partners	With customers	Embedded in the market




Areas of Expertise

- Technical Sciences
- Behavioural and Societal Sciences
- Earth, Environmental and Life Sciences

TNO Technical Sciences in Eindhoven.

Themes:

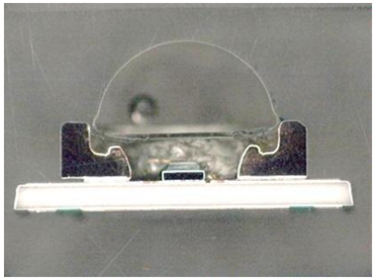
HEALTHY LIVING
INDUSTRIAL INNOVATION
DEFENCE, SECURITY AND SAFETY
ENERGY
MOBILITY
BUILT ENVIRONMENT
INFORMATION SOCIETY

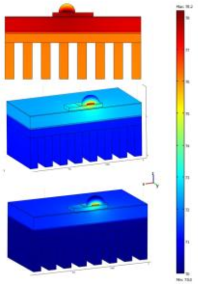
Consultancy
Contract research
Testing and certification
Licences
Performing statutory assignments

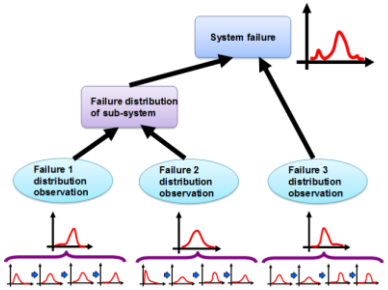
Materials for Integrated Products (MIP)

We know how to **assess, control and enhance the performance** of multi-material components in demanding environments

- by combining **expertise on materials and their processing**,
- with **physical experiments** and **computer-aided modelling and simulation**







From materials, interconnects and packaging to system reliability.

Some soldering Basics

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“Soldering is a simple Operation” [1]

“It consists of the relative positioning of the parts to be joined, of wetting the surfaces with molten solder and allowing the solder to cool down until it has solidified”

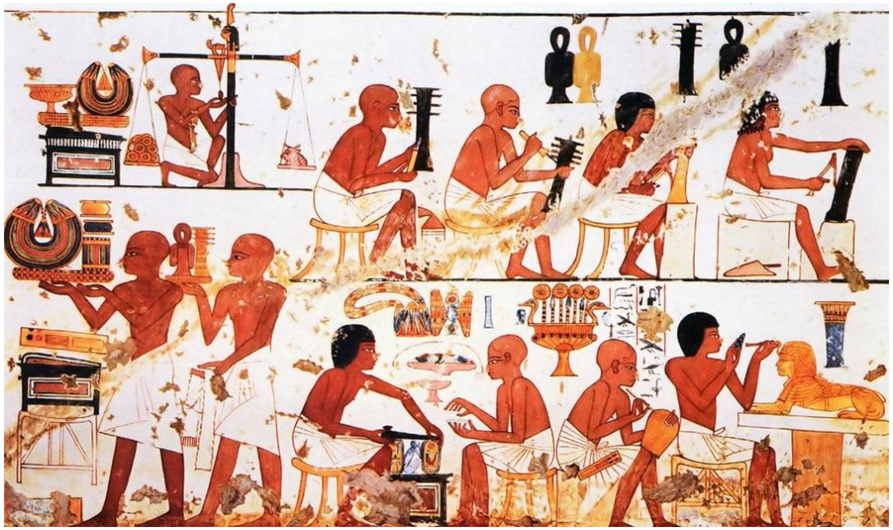
Note: solder has a lower melting point than the base materials. The base materials itself will not melt.

[1] Klein Wassink, R.J., “Soldering in Electronics (Second edition)”, ISBN 0 901150 24 X, Electrochemical Publications LTD, 1994.

History of Soldering: It started with Jewellery

- 6,000 years ago: Humans first worked metals
- 5.000 years ago: Egyptians were “soldering” gold jewellery
- 4.000 years ago: Soldering came of age with the discovery of tin
- 19th century: Industrial revolution greatly expanded the use of solders

For many years soldering was mainly used to make jewellery, cooking ware and tools (weapons)



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Alloys: Classifications and melting Temperatures

- Tin (Sn) based soldering alloys (eutectic compositions)

450 °C	↑	Brazing *"Hard solderen"*	
	↓	Soft soldering	
280 °C			AuSn20
260 °C		↑	**High temperature range**
227 °C			SnCu0.7
221 °C			SnAg3.5
217 °C			**SnAg3.8Cu0.7**
199 °C			SnZn9
183 °C			**SnPb37**
		↓	**Traditional low temperature range**
139 °C			SnBi58
117 °C			SnIn52

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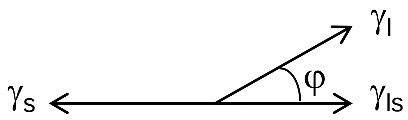
Wetting of Surfaces: an essential Parameter

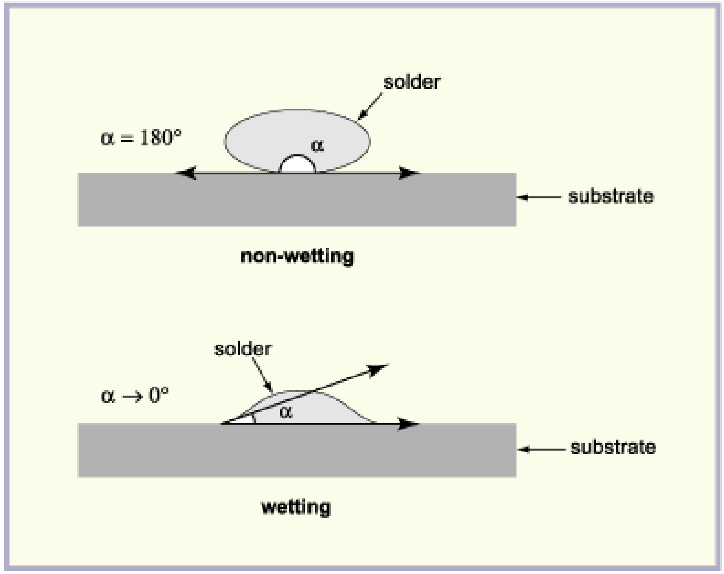
- Wetting: the mechanism by which molten solder adheres to the base metals which it joins

The extent to which liquid solder spread depends on surface tensions acting on the interface:

- γ_l, surface tension liquid
- γ_s, surface tension solid
- γ_{ls}, surface tension liquid-solid interface

Young's equation: $\gamma_{ls} + \gamma_l \cos \varphi = \gamma_s$



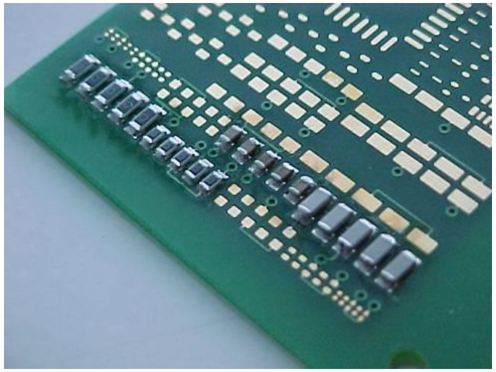


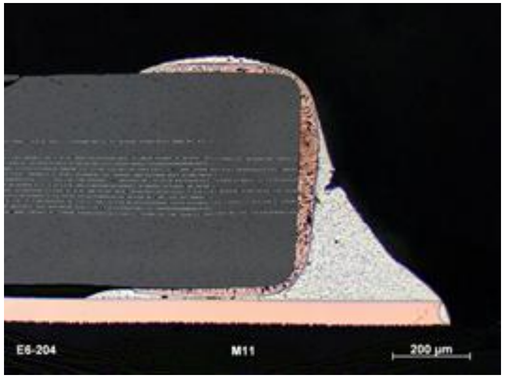
Low interfacial tensions due to solubility in solid state or forming of intermetallic compounds!

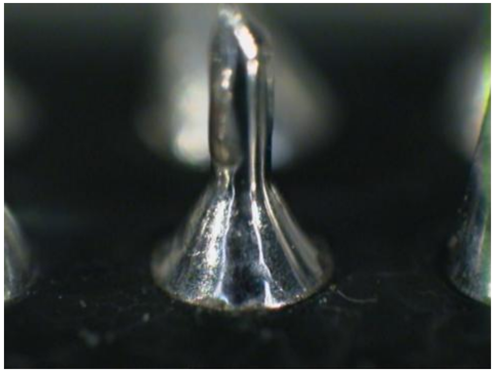
Note: wetting is only one important aspect of solderability!

The Basic Parts of and Electronics Solder Joint

- Electronic components with solderable surfaces
- Solder alloy: often used in combination with a flux
- Printed Circuit Board: Cu base material often provided with a solderable surface finish







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Solderable Surface Finishes

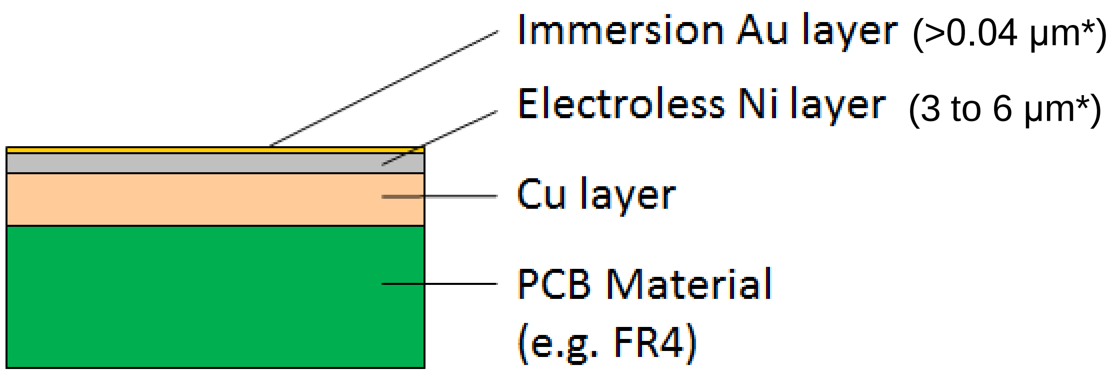

Examples Solderable Surface Finishes

- HASL (Hot Air Solder Level): *low-cost ↔ co-planarity*
- Immersion Ag: *planarity ↔ tarnishing (Ag_2S)*
- Immersion Sn: *planarity ↔ Sn whiskers*
- OSP (Organic Sold. Preservative): *low-cost ↔ shelf life*
- ENIG (Electroless Ni, Imm. Au): *solderability ↔ expensive, ...*

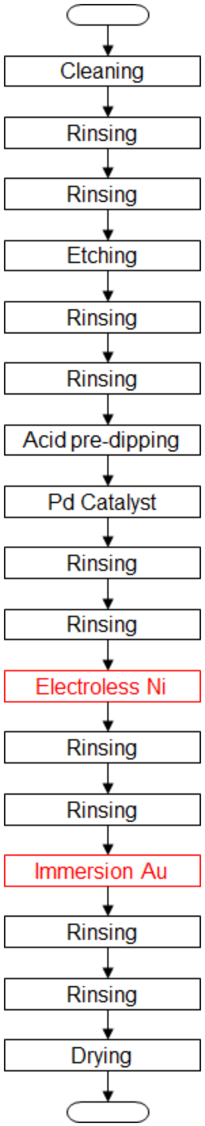
Selection based on: costs, volumes, alloy compatibility, fine-pitch capabilities, shelf life, operating conditions / reliability requirements, ...

Electroless Ni, Immersion Au (ENIG)

- The de facto standard choice of PCB solderable finish for high reliability, high value electronics is nickel-gold.



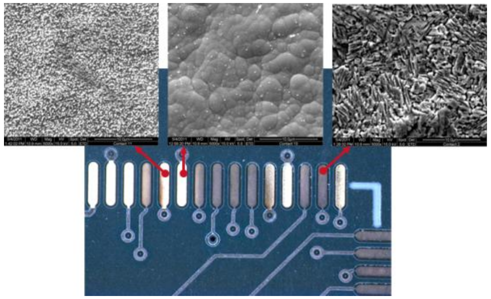
**IPC-4552*

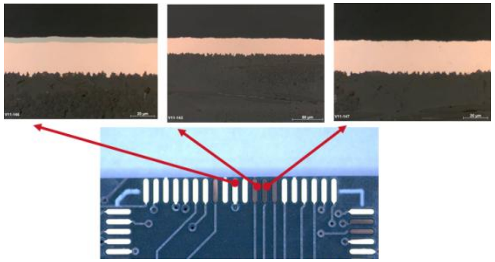


Potential ENIG Failure Modes

	Plating defect	Failure mode	Mechanism	Cause	S [severity]	O [occurrence]	D [detectability]	Ref.
1.0	Ni Oxidation	Discolouration, Ni noses	Oxidation	Pores in immersion Au layer				
		Poor solderability						
		Increased contact resistance						
2.1	Background plating	Plating on areas not intended to be plated	Metal available at non plating areas	Inproper rinsing				
2.2	Ni foot	Extraneous plating between pads	Metal available at non plating areas	Inproper rinsing				
3.0	Edge pull back	Less / no Ni plating at edge of pads	High concentrations stabilisers acts as catalytic poison	Concentration stabalisers / brightners too high in Ni bath				
				Whirls at pad edges / sharp geometries				
				Low loading				
4.0	Skipped plating	Discoloured pads (grey / black)	Immersion Au plating on Cu	Surface contamination on the copper or a static charge.				
5.0	Black pad	Discolouration	"Hyper" corrosion Ni-P layer	....				
		Inproper solder wetting		....				
		Non / de-wetting solder		....				
		Low solder joint integrity		....				

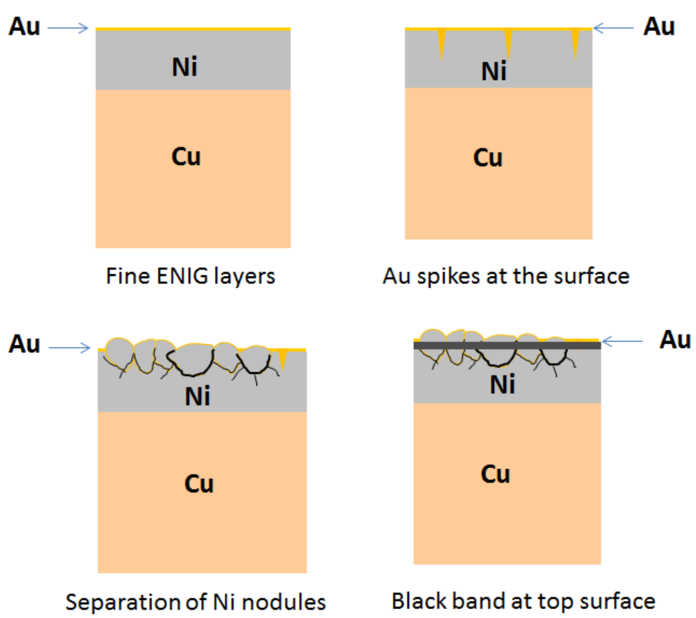
Skipped plating example:



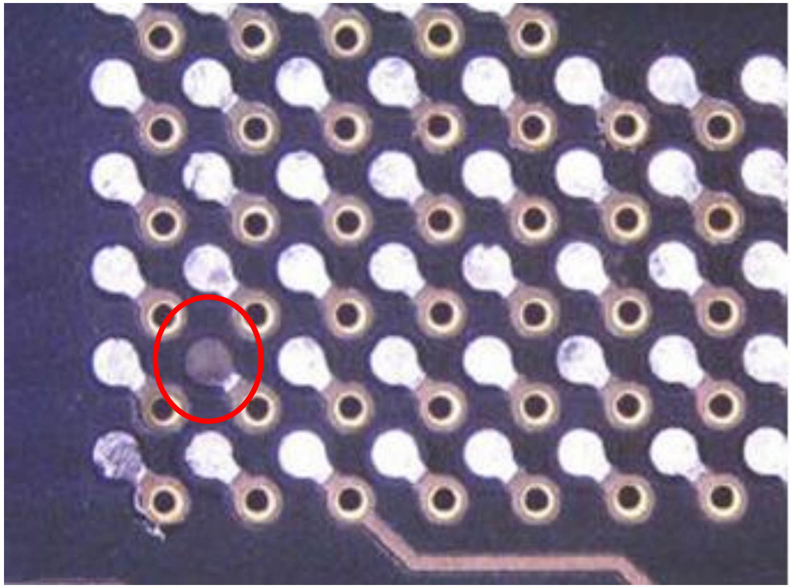


Black Pad: Hyper Corrosion Mechanism

- Local differences in plating rates immersion Au



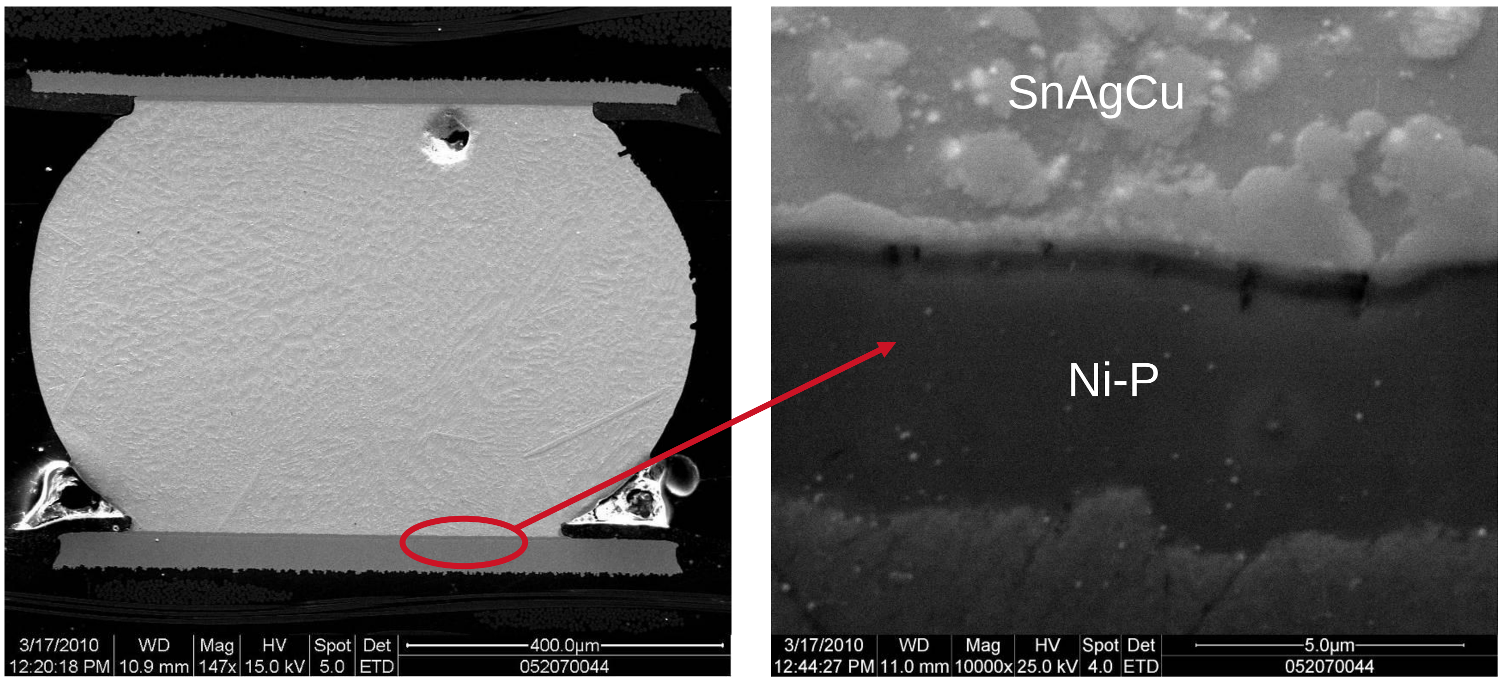
"Black pad stages"



ITRI, "ENIG Failure Mode Notes".

Solder Joint on ENIG Example: Ball Grid Array Ball

- Interface Ni-P and SnAgCu solder ball



Black Pad Situation nowadays

- Unjustified acceptances are still feared, while in practice most manufactures are dealing with high appraisal costs of unjustified rejects.

Decision table:

		DECISION	
		Reject H_0	Fail to Reject H_0
ACTUAL	H_0 True	**Type I Error** Producers Risk α-Risk False Positive	Correct Decision Confedence Interval: $1-\alpha$
	H_a True	Correct Decision Power: $1-\beta$	**Type II Error** Consumers Risk β-Risk False Negative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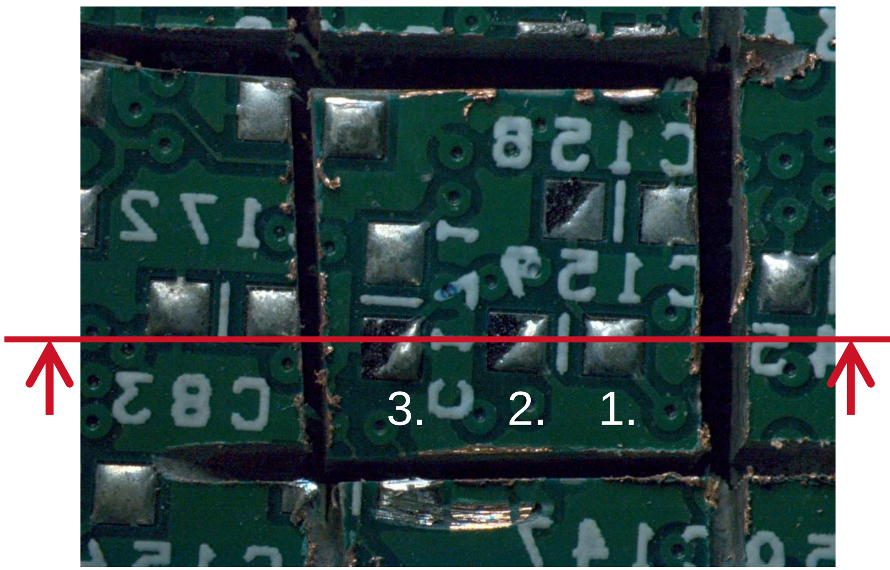
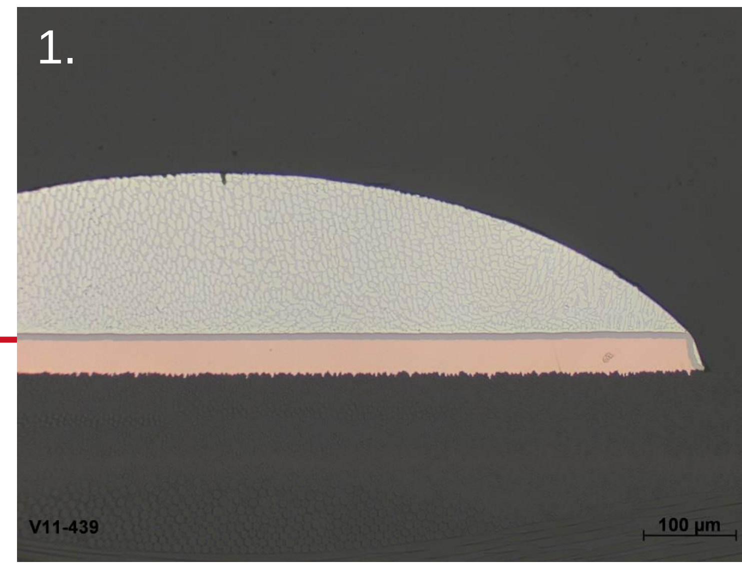
Failure Analysis Black Pad Suspect Boards

Board with non- / de-wetted areas (I)

- Black coloured non wetted areas



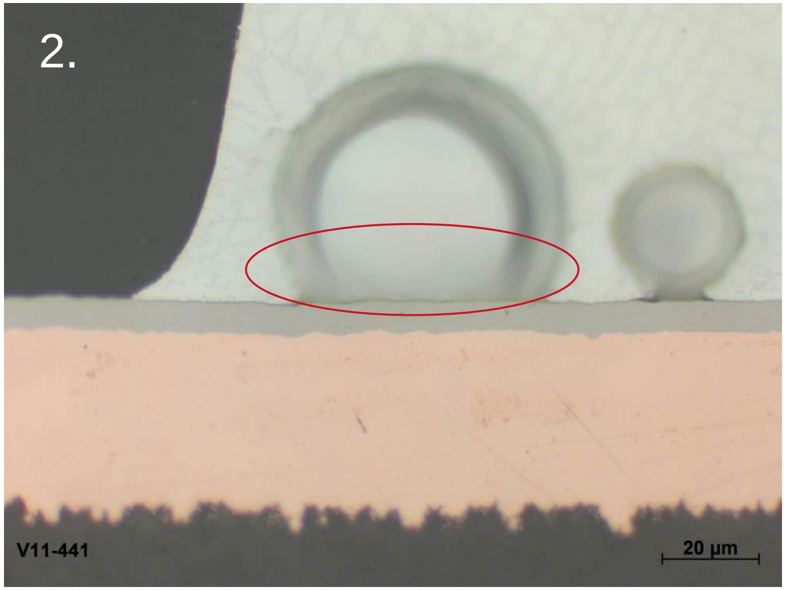
Cross-sectioned locations.



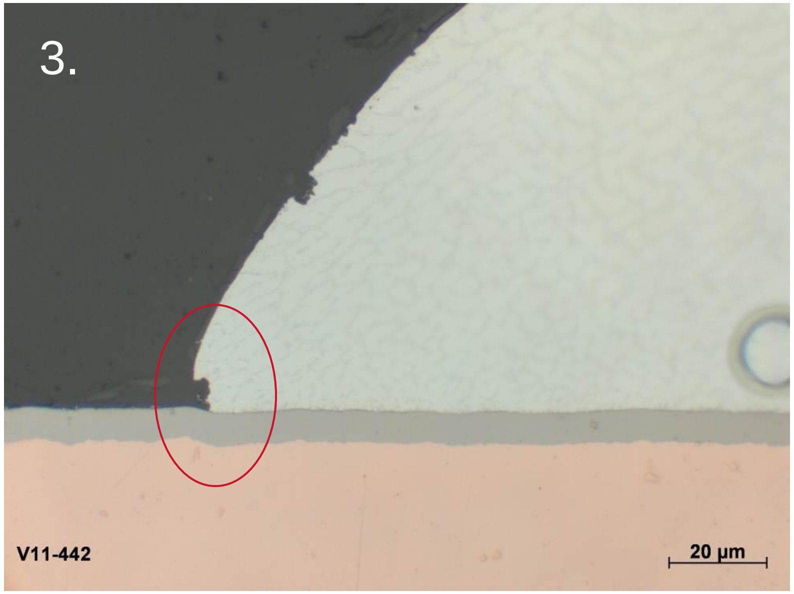
Proper solder wetting.

Board with non- / de-wetted areas (II)

- Black coloured non wetted areas



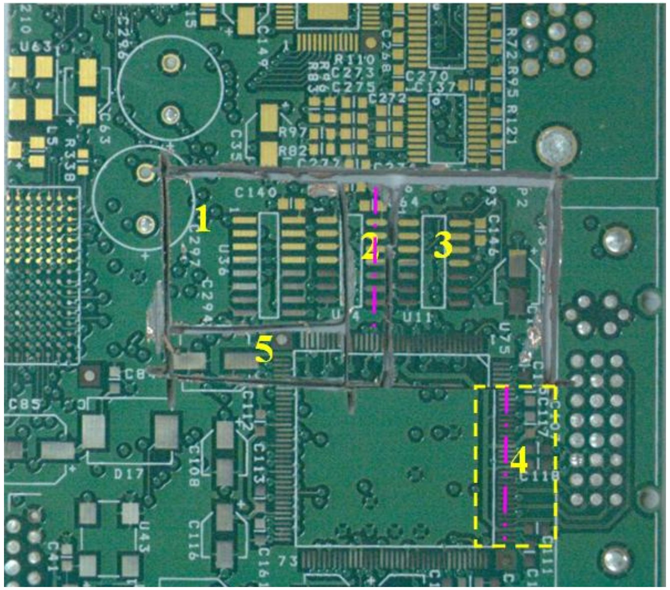
Voiding due to non-wetting.



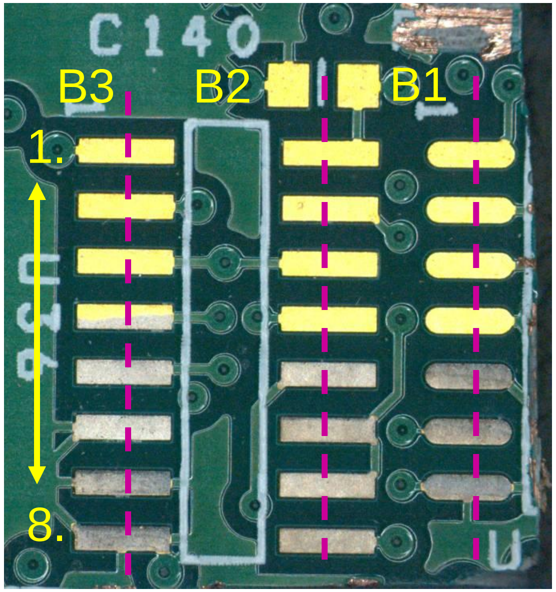
Ni and solder following Cu roughness.

Black Pad Suspect Board (I)

- ENIG board with stripped Au layer



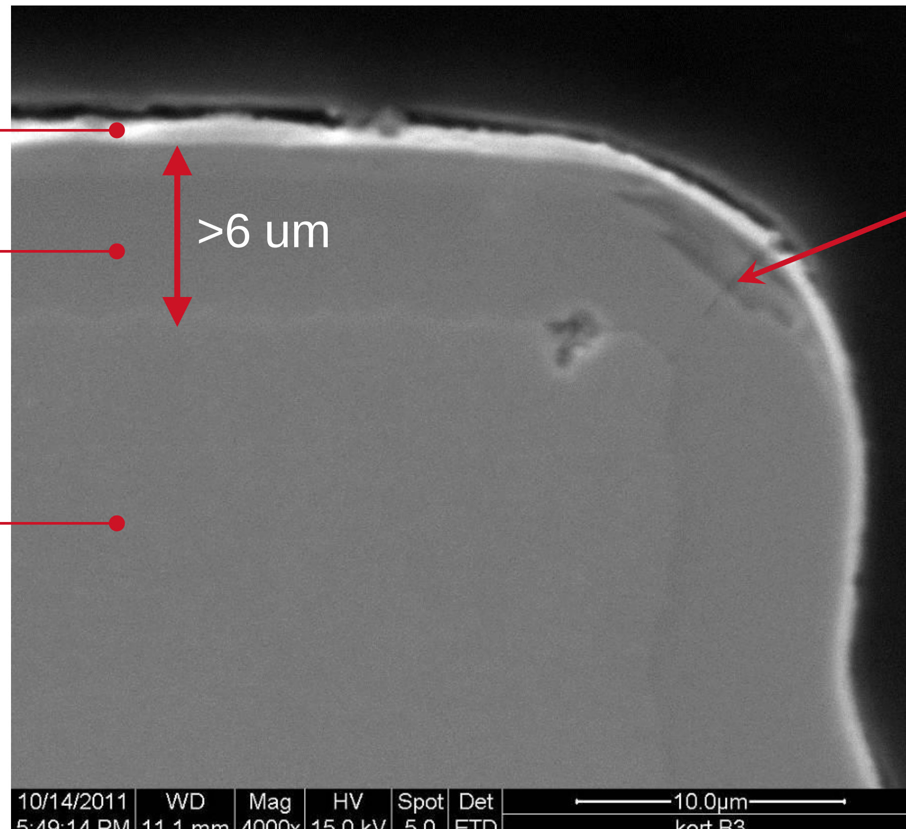
Analyses on topside



Location 3

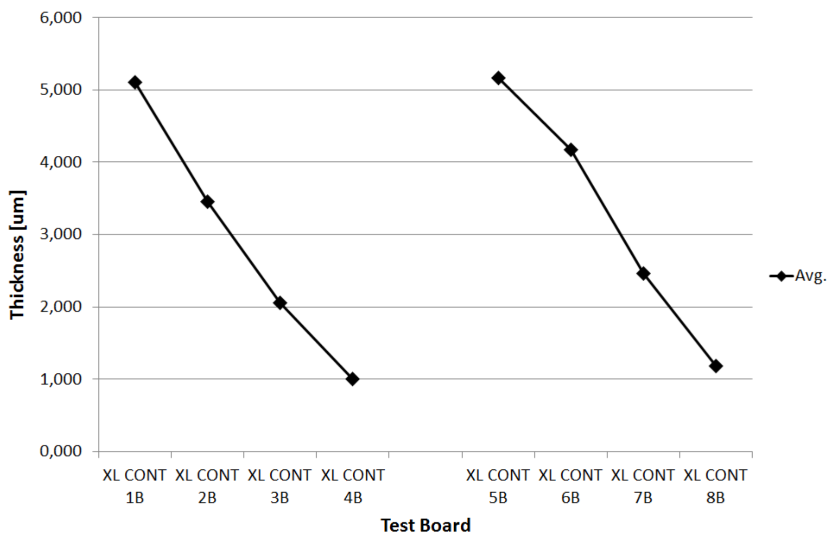
Black Pad Suspect Board (II)

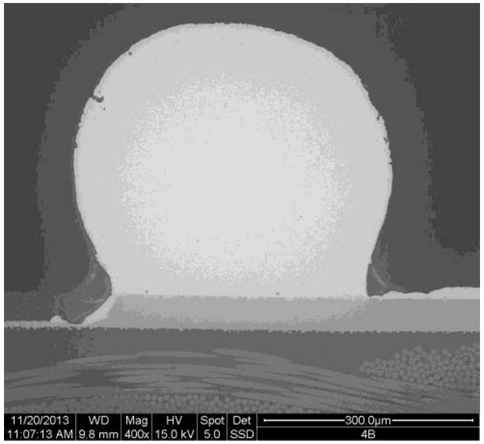
- Cross section of ENIG plated Cu conductor (B3, pad4)

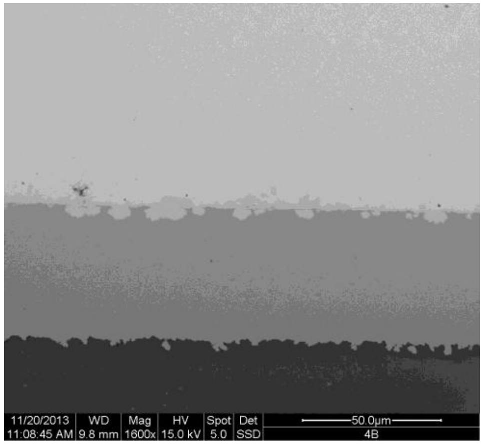


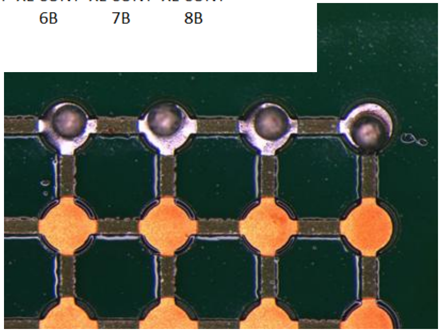
Attempts to Induce Black Pad

- Reducing Ni Thickness



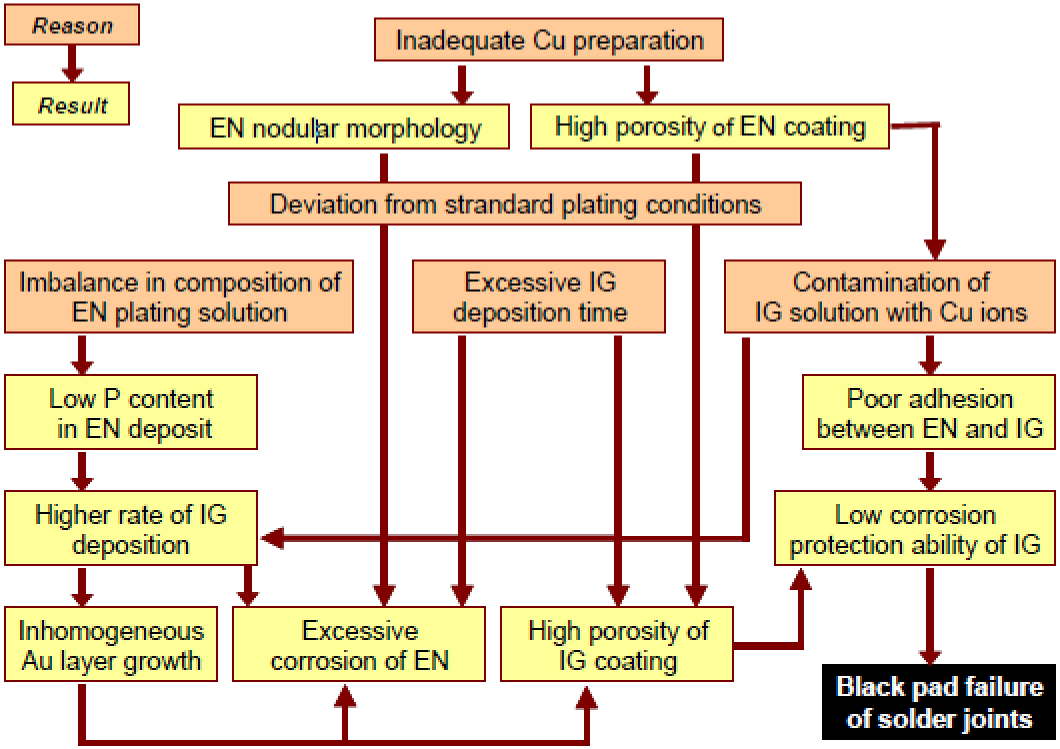






Summary on the Black Pad occurrence Reasons

- Overview based on failure mechanisms study* within ASPIS project



** Lithuanian Institute of Chemistry*

How to minimise the Black Pad Risk

- Control Cu roughness and surface condition
- Control electroless Ni layer morphology and thickness
- Control immersion Au layer thickness
- Control composition plating solutions
- ....
- ....

Tests running on alternative ENIG Finishes

- Aging test, IMC growth
  - Standard ITRI ENIG plating and XL plating boards
  - Samples @ t=0, 20, 100, 250 and 500 hrs.
- 85 °C / 85 %RH test
  - Standard ITRI ENIG plating and XL plating boards
  - Samples @ t=0, 250, 500, 750 and 1000 hrs.

Thank you for your attention!

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