



ALD *Atomic Layer Deposition* **for space applications**

PCB-Assembly protection

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pic**sun**
AGILE ALD

ALD – Atomic Layer Deposition

- Is a batch coating process with surface chemistry
- Wide range of material, e.g. Al_2O_3 , TiO_2 , M-, M-C, M-N
- Typical; **100 nm** up to $\sim 0,5 \mu\text{m}$
- True 3D down to nanopores, no pinholes
- **Vacuum** deposition process
 - Substrates are degassed & heated (degas analyzed)
 - $\sim 40 \text{ C} - \mathbf{125\text{C}} - 400 \text{ C}$
- Mature IC manufacturing process
- Extremely repeatable in thickness & quality over time
- Chemically adhesion; will not peel off/flak
 - Dense,
 - Pinhole- and defect-free films
 - Digitally repeatable process

THE PRINCIPLE OF ALD



Introduction of molecules containing element B and reaction with element A on the surface.



Introduction of molecules containing element A.



Adsorption of the molecules on the surface.

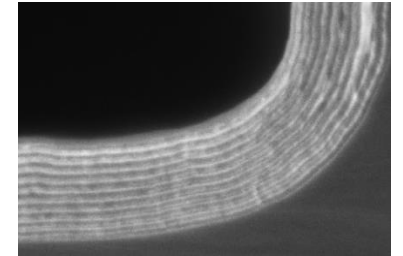


Completion of one monolayer of compound AB.

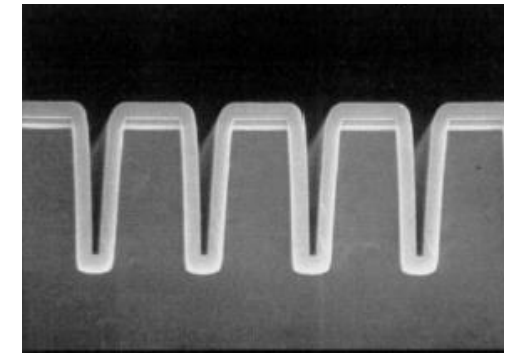
Repeat cycle till desired film thickness is reached.

Benefits of ALD for different areas on space application

THIN FILM GROWTH BY CONSECUTIVE ATOMIC LAYERS



- Tin whiskers mitigation; Main objective for ongoing ESA-funded activity
 - Reworkable: Components can be changed and the substrate re-coated
- Corrosion protection; ALD or PVD+ALD – most durable corrosion resistance; *670 h/salt spray*
- Excellent gas & moisture barrier; $4 \times 10^{-5} \text{ g/m}^2/\text{d}$, (PEN/PET $\sim 10^{-1} \text{ g/m}^2/\text{d}$);
 - Can be used for Sulfur & Creep Corrosion barrier, now used for coins; [Creep corrosion or similar test needs ?](#)
 - Prevent oxidation (of e.g. mirrors)
 - Degas plastic packages -> **ALD coat** -> **No moisture intake, nor release**
 - Tests to be carried out soon at ESTEC; [any proposal for components and requirement?](#)
 - Prevent gas leak from fuel/gas containers
- Optical filters, mirrors-layers, black-surfaces (~100 nm thickness)
- Possible mitigation of surface charging with (weakly) conductive transparent conformal coating



Widely applied for e.g. in IC industry, corrosion protection, moisture barriers...

How to do it

Roadmap

- Tin whiskers mitigation preliminary demonstrated and evaluated, now repeating experiment using a wider test matrix
 - Equipment available
- Plastic package encapsulation now demonstrating
- 3rd Phase; Validation
 - Validation planned, expected to start in ~1 year
 - Real (Flight representative) PCBs for validation – proposals for boards / components?
Interested partners?
 - Parallel use for down to earth applications (reliability), aka. industrial drivers
– We are searching partners!
- Demonstration / development now in process; next (e.g. EMS) collaborator, who can provide the coating service (*should be requested by 'OEM'*)

Tool examples

P300; 27 x 27 x 27 cm³

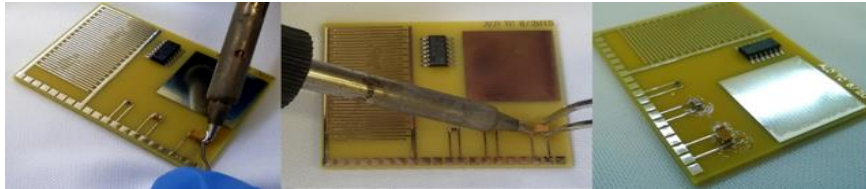


(other, **P1000**; diam 60cm, h70 cm)

PCBA protection by ALD

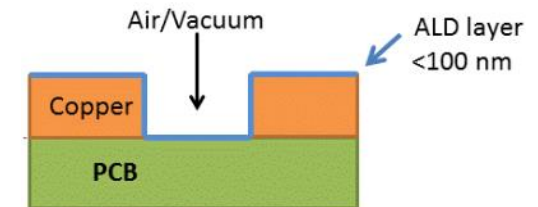
Conformal PCB assembly coating with a difference

- Blocks tin whiskers*
- Excellent moisture (& gas) barrier
- Corrosion barrier even against some liquids
- Can be reworked
- Can be patterned



– and in some cases not needed for patterning for contacts

- Can be combined with other methods
- Ensuring high surfaces insulation resistivity, no RF changes
 - Obtain higher environmental reliability with even while decreasing conductor spacing (decreased side)
 - With “~0 added weight”

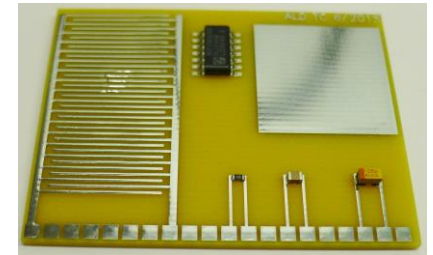


* Tin whiskers growth prevented in model substrates, see later

Atomic Layer Deposition for conformal coating of PCB assemblies and components

 [ended; Evaluation of Atomic Layer Deposition \(ALD\) Conformal Coating to Mitigate Tin Whiskering - 4000113005/14/NL/PA, 2015](#)

- Testing and validation planning of ALD for complete PCB(A) conformal protection
- 1st stage has demonstrated
 - **Mitigation** of tin whiskers
 - **Conformal** applicability ALD for PCBA, >80 V breakthrough voltage;
 - *even higher voltage with increased layer thickness; Reworkable*
 - Deposition and testing **processes** were evaluated; best in use, ALD tool available



 [ended; Atomic Layer Deposition for Tin Whiskers Mitigation and Cure on Space Electronics Manufacturing \(4000122745/18/NL/LvH/gp\), 2018](#)

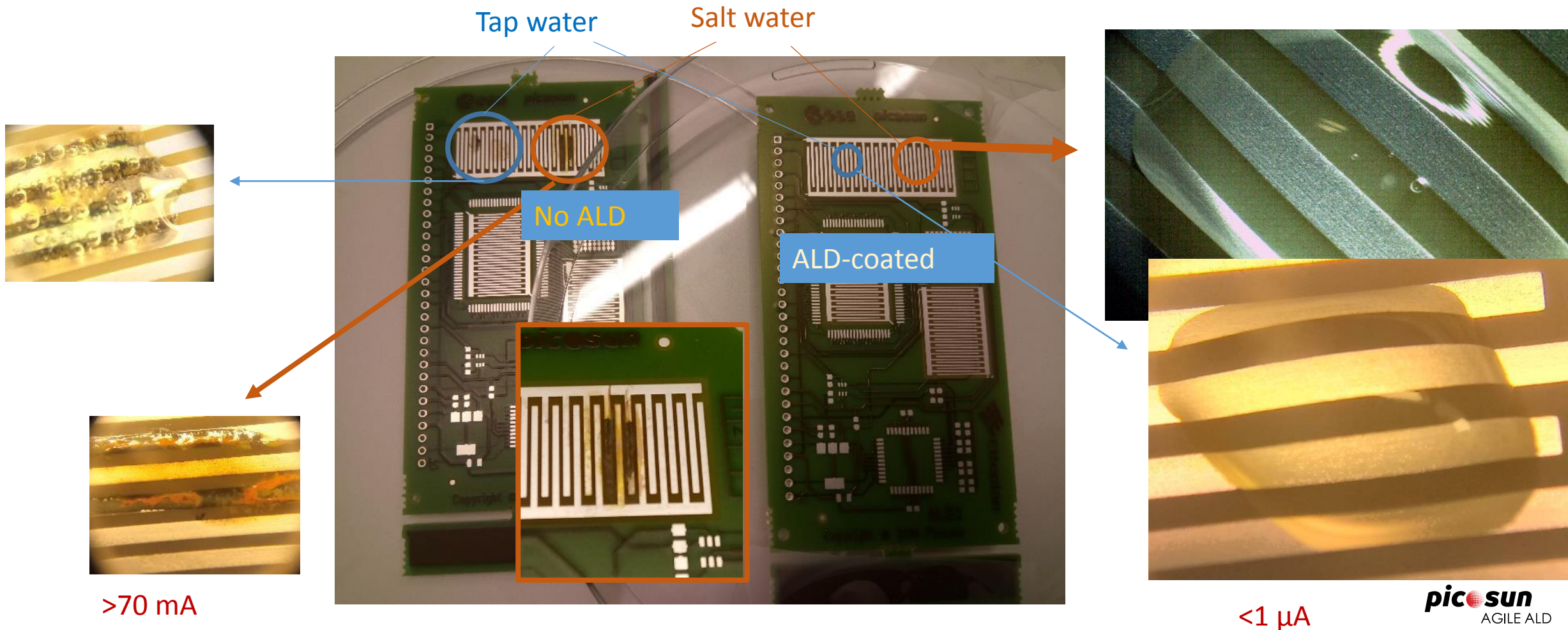
- 2nd stage started 1/2018
 - Verification of 1st stage experiment & Route planning to establish validation of ALD coating for suppliers
 - Testing of ALD-encapsulation of plastic packages for space use and increased lifetime in ambient
 - Test boards with relevant space grade AND off-the-shelf components (polymer packages)

What are your critical components to be validated? Your required test board?

Parallel B2B projects have stated for automotive, medial...

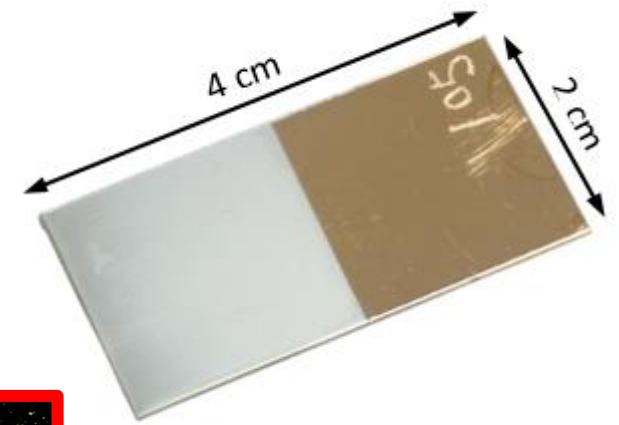
BIASED CORROSION

Drop of salt water on *Imm*-Ag coated electrodes, 3.3v bias



ACCELERATED SN-WHISKERS GROWTH PROCESS

ALD prevents the growth



After electroplating;
Only 'dirt particles from plating'

Whisker density
(cm⁻²)

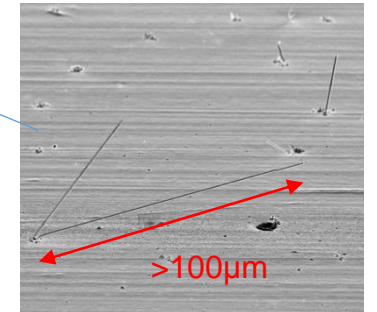
Day 0

~2,5mm

100-
1000

Day 25
No coating

~2,5mm

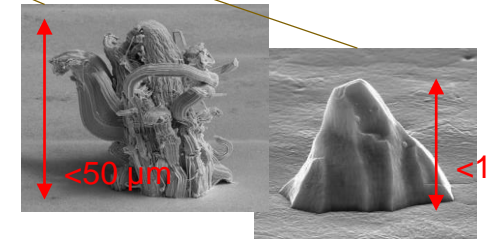


Tin whisker

0

Day 25
ALD-coating

~2,5mm



Eruption, Hillock/nodule formation

Quick questions?

More detailed discussion & material tomorrow
2nd Oct. (pref. before noon)

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Thank you!

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