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Nanocoatings: The Solution to All of Our Environmental Protection Problems?

2015 NREL Photovoltaic Module Reliability Workshop

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Introduction

- Applying conformal coating or potting to provide environmental protection to electronics in outdoor applications is a very well-known and heavily used technique. This is especially true in solar and other green applications due to the severe environment (desert and tropical climates) and long-life expectations (25 years).
- A new class of nano-thin coatings that provide superhydrophobic capabilities have entered the marketplace with great fanfare. Superhydrophobicity is defined as having a wetting angle greater than 90 degrees and some materials have measured wetting angles exceeding 150 degrees.

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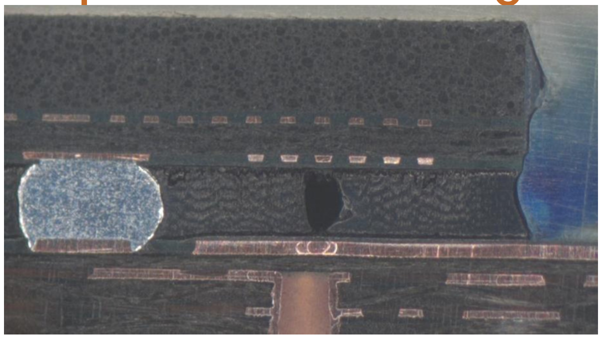
What's Wrong With Current Materials?

- Current conformal coatings all have their pros and cons
- Drives users to potting materials to compensate

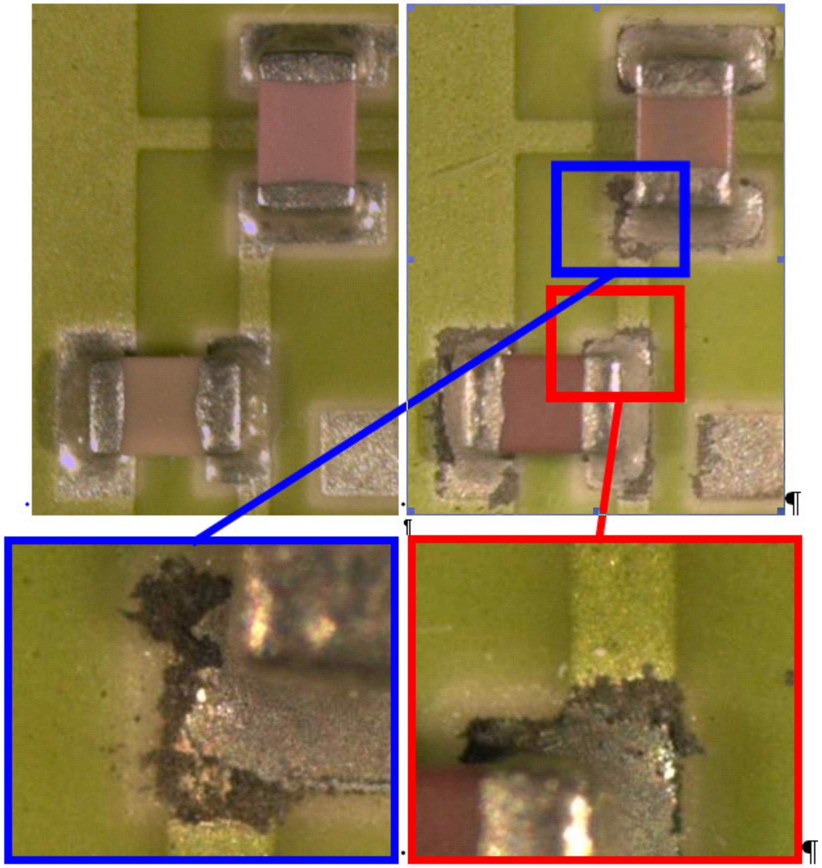
	Properties	Comments
Epoxy	Good adhesion Excellent chemical resistance Acceptable moisture barrier	Difficult to rework Needs compliant buffer Not widely used
Urethane	Good adhesion High chemical resistance Acceptable moisture barrier	Difficult to rework Widely used Low cost
Acrylic	Acceptable adhesion Poor chemical resistance High moisture resistance	Easy to rework Widely used Moderate cost
Silicone	Poor adhesion Low chemical resistance Excellent moisture resistance	Possibility of rework Moderate usage High cost
Paralyne	Excellent adhesion Excellent chemical resistance Excellent moisture resistance	Impossible to rework Rarely used Extremely high cost

Some Issues

- Coating getting under components – causing lifting



- Coatings are NOT hermetic – moisture will diffuse through



Sulfur penetration of Silicone – resulting in corrosion

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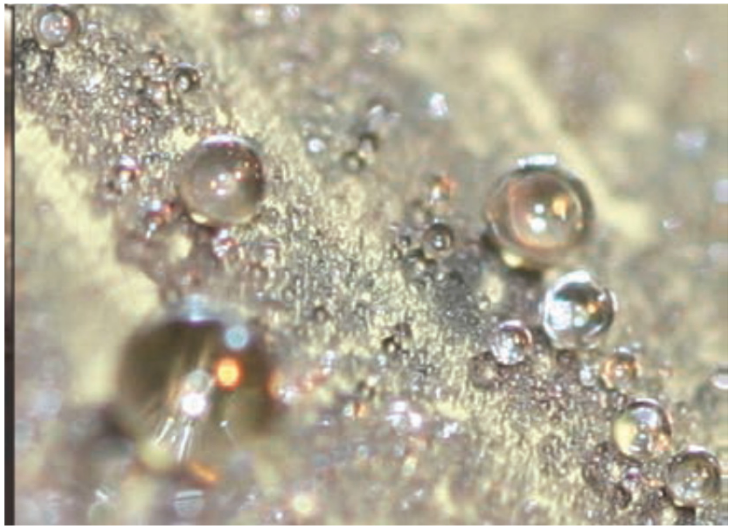
Super Hydrophobicity

- Definition: Wetting angle far greater than the 90 degrees typically defined as hydrophobic
  - Can create barriers far more resistant to humidity and condensation than standard conformal coatings



- How to get there?
  - Deposit materials with existing high surface tension (e.g., Teflon)
  - Replicate the surface of the Lotus Leaf

Nanodeposition of High Surface Tension Materials

- Several companies currently focused on the electronics market

P2i perform protect improve

GVD

Semblant

BARRIAN

ACT ACTivate nanotechnology

- The key technology for each company is the process, not necessarily the materials

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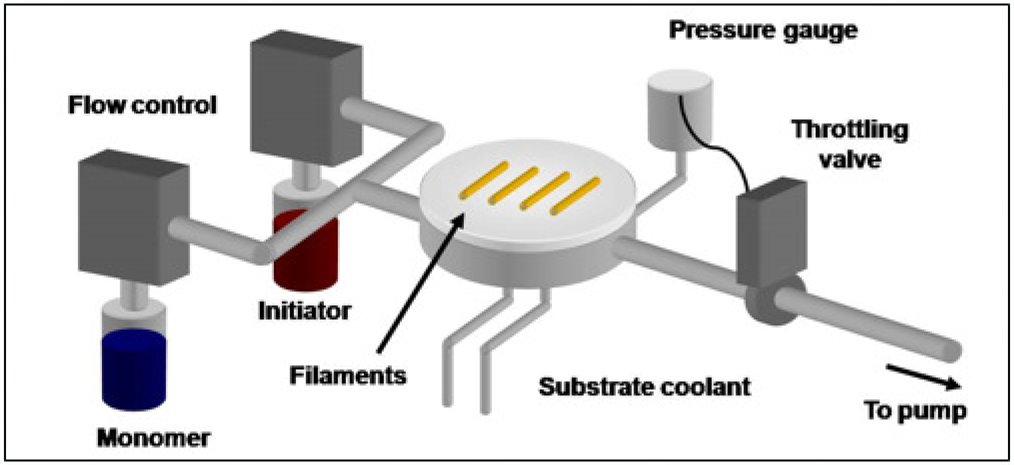
Nanocoating Companies

- GVD: Founded in 2001. Spinoff from MIT
  - Key technology is initiated chemical vapor deposition (iCVD) and PTFE and Silicone
- Porton Plasma Innovations (P2I): Founded in 2004. Spin off from UK MOD Laboratory and Durham University
  - Key technology is pulsed plasma and halogenated polymer coatings (specifically, fluorocarbon)
- Semblant: Founded in 2009. Spin off from Ipex Capital
  - Key technology is plasma deposition and halogenated hydrocarbon
- Barrian (Dry Surface) – Key technology is the integration of nanoparticles into existing conformal coating material to achieve superhydrophobicity
- ACT Nano Inc. -Key Technology is Advanced nanoGuard (ANG) that they say can be applied by dipping and is permanent because it is abrasion proof.

Process Technology

- Hydrophobicity tends to be driven by number and length of the fluorocarbon groups and the concentration of these groups on the surface
- The key points to each technology are:
  - Some are chemical vapor deposition (CVD) processes, with low vacuum requirements, Room Temperature Deposition Process
  - Variety of Potential Coating Materials (with primary focus on fluorocarbons)
  - Some incorporate nano-particles into a conventional conformal coating

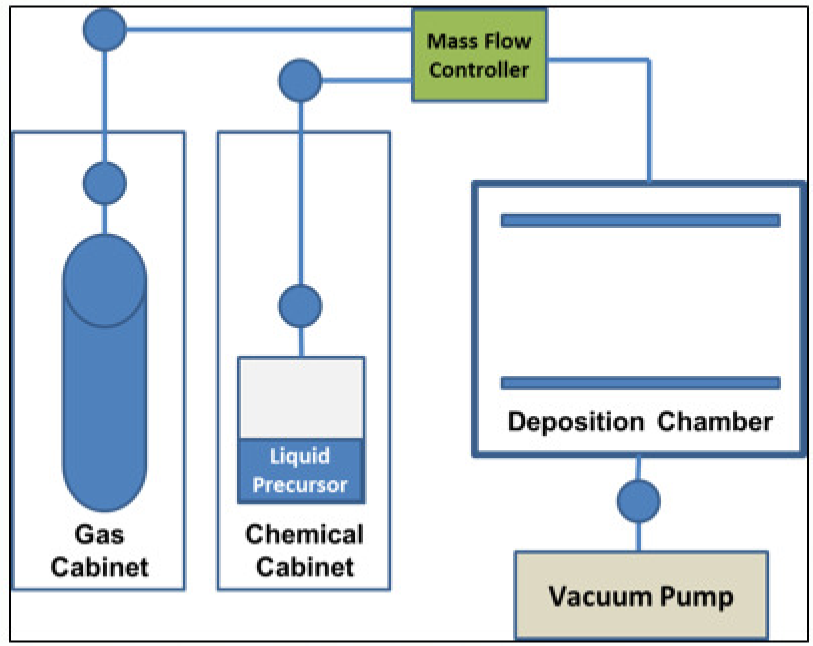
Semblant Process



http://web.mit.edu/gleason-lab/research.htm

- iCVD uses a chemical initiator to breakdown the monomer

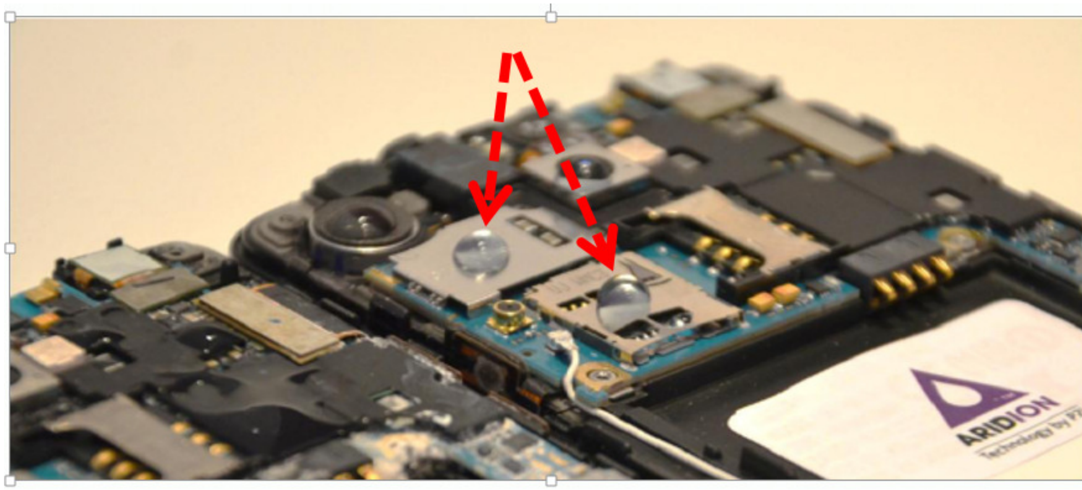
- Plasma-Enhanced CVD (PECVD) uses plasma to breakdown the monomer



Benefits (especially compared to Parylene)

- These are truly nanocoatings
  - Minimum Parylene thickness tends to be above one micron (necessary to be pinhole free)
  - These coatings can be pinhole free at 100 nm or lower

- Nanocoating allows for
  - Optical Transparency
  - RF Transparency
  - Reworkability
  - Elimination of masking



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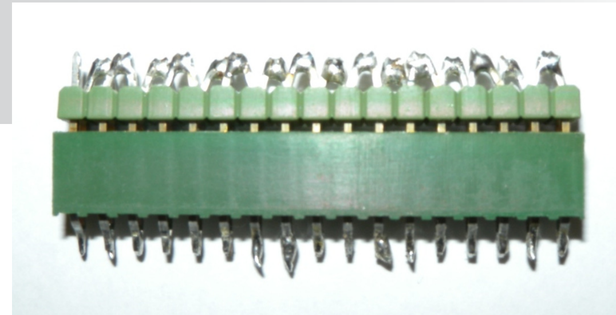
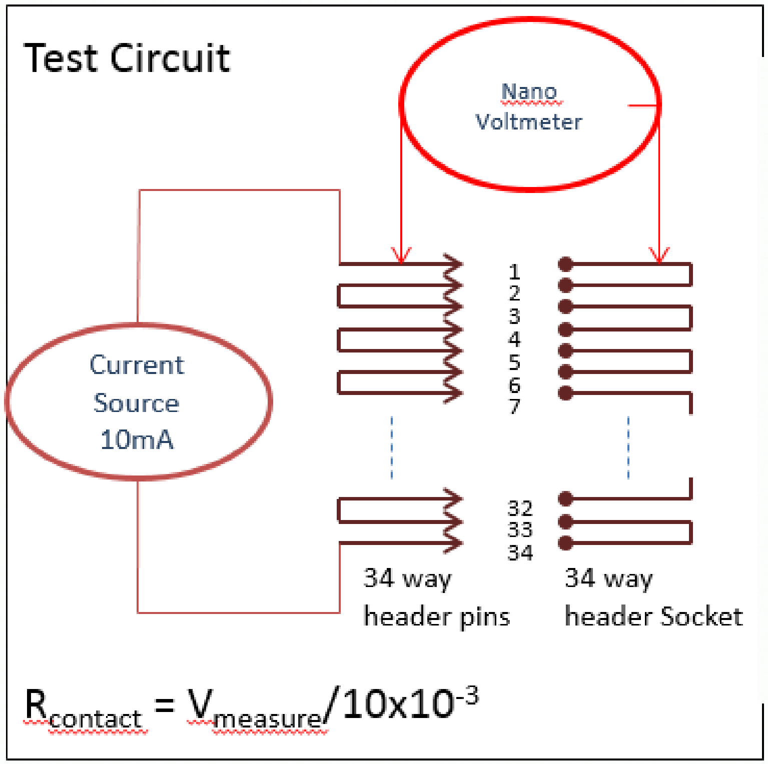
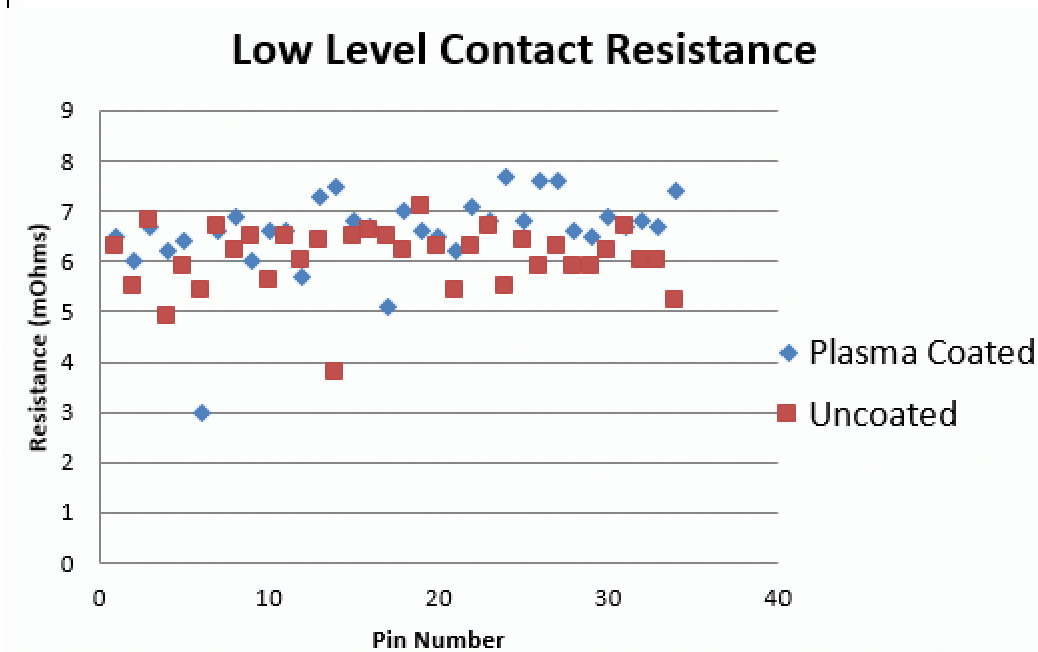
No Masking



LLCR Measurements
Current (A)
0.01
V comp (V)
0.1
Connector Male
34way Pin Header Au over nickel contact (TE Connectivity 1-215307-7)
Connector Female
34way Socket Header Au over nickel contact (TE Connectivity 1-826632-7)





Courtesy of Semblant

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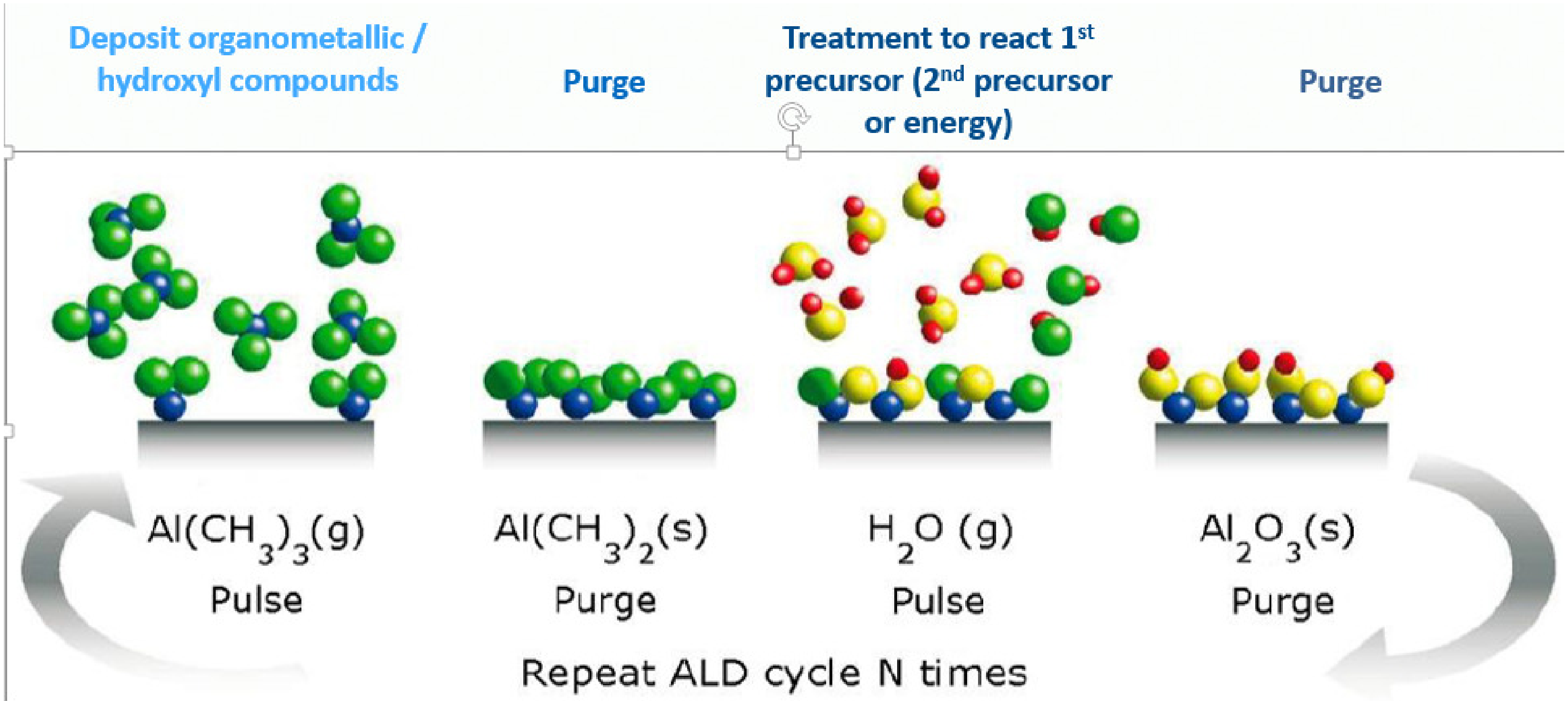
Risks

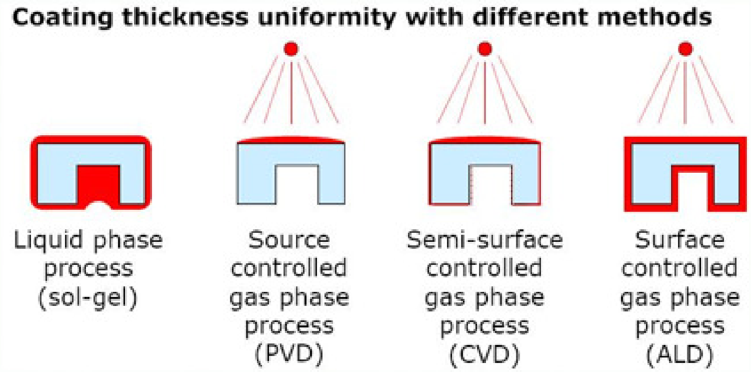
- Voltage Breakdown
  - Levels tend to be lower compared to existing coatings (acrylic, urethane, silicone)
  - Can be an issue in terms of MIL and IPC specifications
- Optically Transparent
  - Inspection is challenging
- Cost
  - Likely more expensive than common wet coatings
  - However, major cell phone manufacturer claims significant ROI based on drop in warranty costs
- Throughput
  - Batch process. Coating times tend to be 10 to 30 minutes, depending upon desired thickness
  - However, being used in high volume manufacturing

Atomic Layer Deposition (ALD)



- Developed in the 70s and 80s
- Sequential surface reactions
- Deposition rate of ~0.1 nm/cycle

ALD Continued



- Advantages
  - Deposition at low temps (80-150C)
  - Not line of sight (conformal)
  - Precise thickness control
  - Large area
  - Less stringent vacuum requirements (0.1 – 5 mbar)
  - Multilayer and gradient capability (it can be tailored)

- Northrop Grumman / Lockheed Martin estimated cost reductions of 50% vs. traditional hermetic approaches

Atomic Layer Deposition (ALD) Coatings for Radar Modules, DMSMS 2012

Risks

- The process can be very slow (100nm thickness can take over an hour)

- Not reworkable

- There have been challenges in regards to compatibility of ALD with existing electronic materials and manufacturing process
  - Clean surfaces with similar coefficient of thermal expansion (CTE) work best
  - De-adhesion and cracking sometimes observed when applied to metals, polymers, and surfaces with flux residue (requires some tailoring)

Barrian – Dry Surface

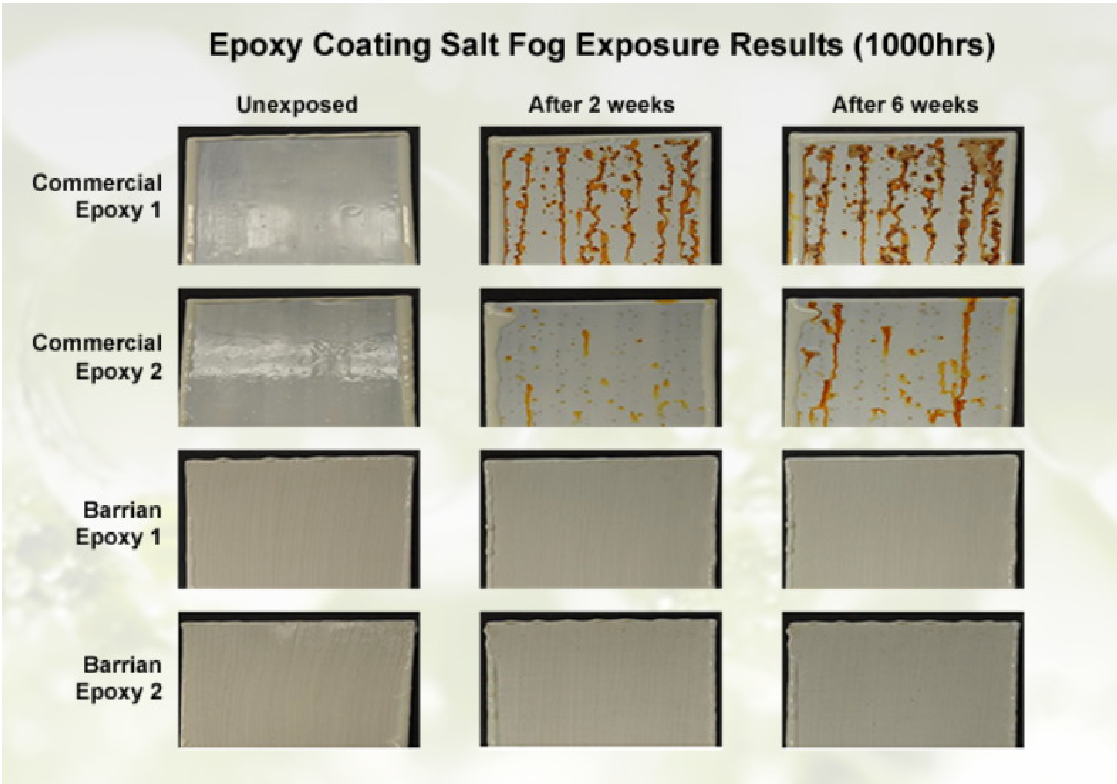
- Water droplets remain perched on the peaks in well-formed beads that can't adhere to the surface. Barrian duplicates this amazing waterproofing action by creating a microstructure of silica glass peaks. This precise surface geometry, combined with advanced low-surface-energy chemistry, results in optimal water beading that accelerates the flow of water over the surface, rendering the surface and the structure below it virtually unwettable

Photographs of water droplets on the surface of the 16F-7% after 54 sanding cycles (CA 153o±2).

The coating remains superhydrophobic as the coating is sanded away…all the way to the metal substrate!

Barrian

- Their process uses current conventional conformal coating materials like acrylic and integrates their proprietary nano particle formulation into the coating



Comparison of metal plates exposed for 1000 hours to a salt fog.

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ACT Nano

- ACT states that their material can take many forms and be applied more than once. Their focus seems to be on repelling water.

- No Masking of conductive Parts
- Can be integrated into Production lines

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THANKS

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