Engineered Reliability – Safeguarding Electrical Components and Devices with Nanocoating Technology

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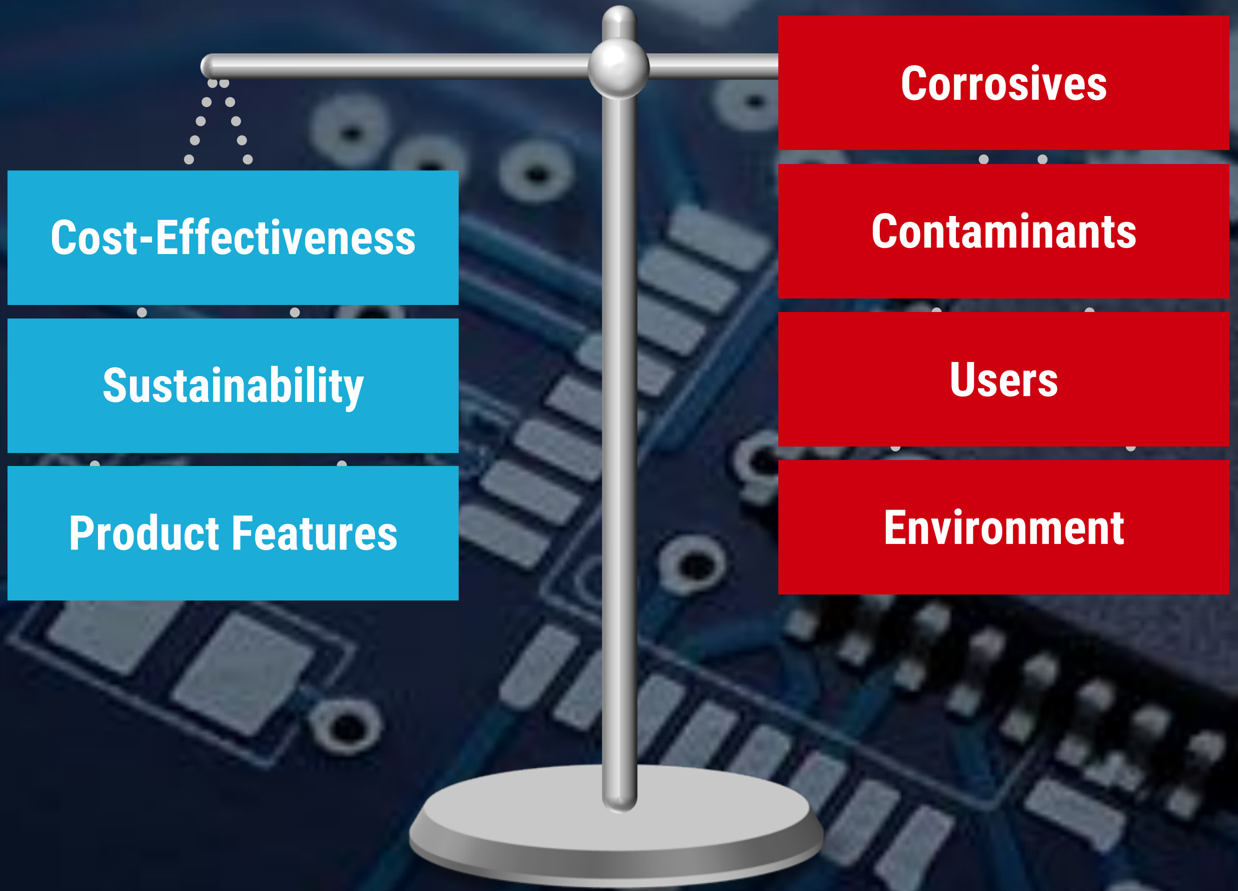
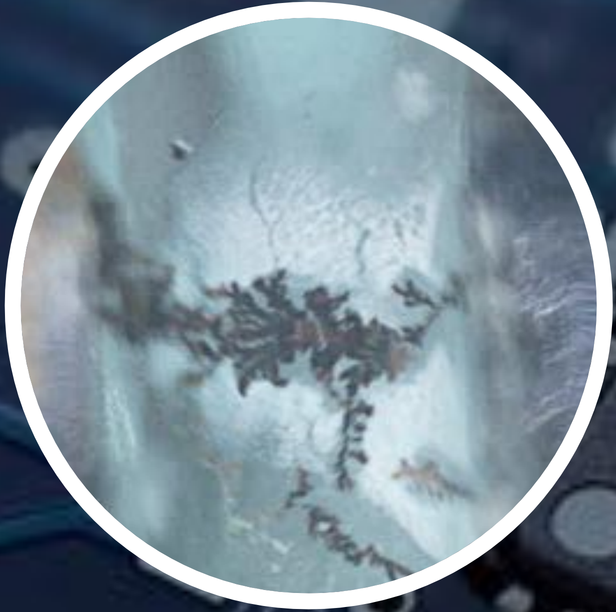
Director,
Nanocoating Applications

Balancing Your Designs



Failure To Plan

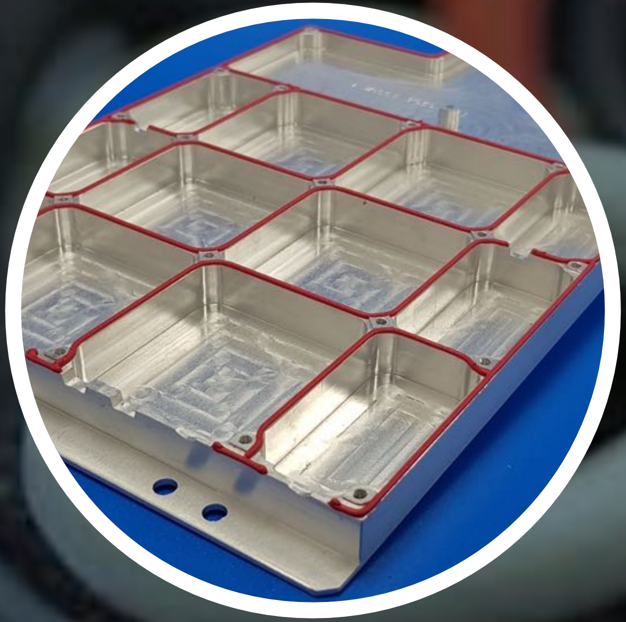
Creep Corrosion on Telecom PCBA



Dendrite Growth on Oil Rig Sensor

Condensation Corrosion on Cooled Components

Out With The Old



Mechanical Seals and Gaskets

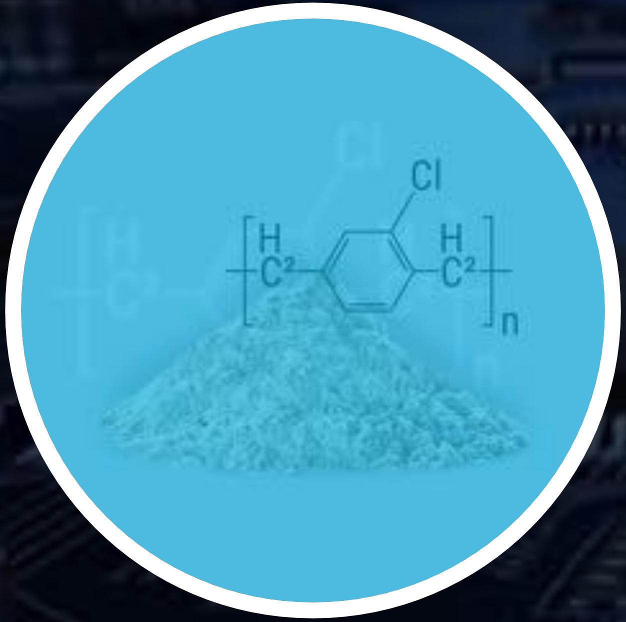
Traditional Conformal Coatings

Low-Tech Application Methods

Choosing the Right Coating

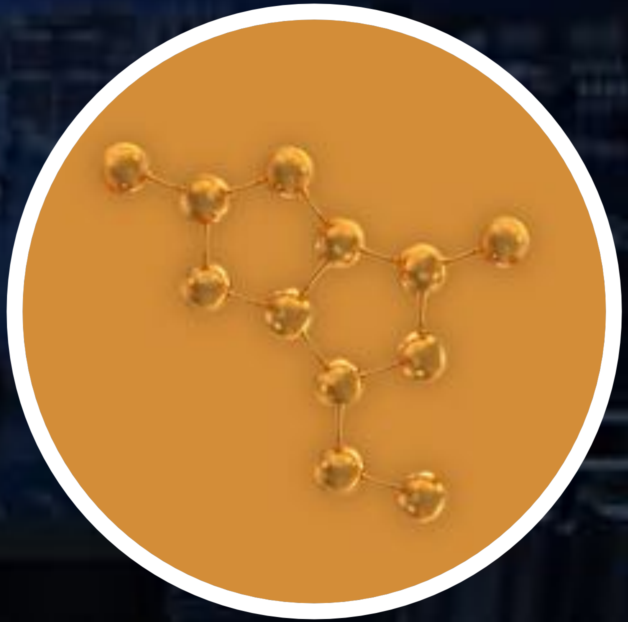
1. Breaking from traditional design
2. The shift towards next-generation protection
3. Critical coating properties
4. The physics and benefits of thin-films

Introducing Thin-film & Nano Coatings



Parylene Coatings

Plasma-Applied Nano Coatings

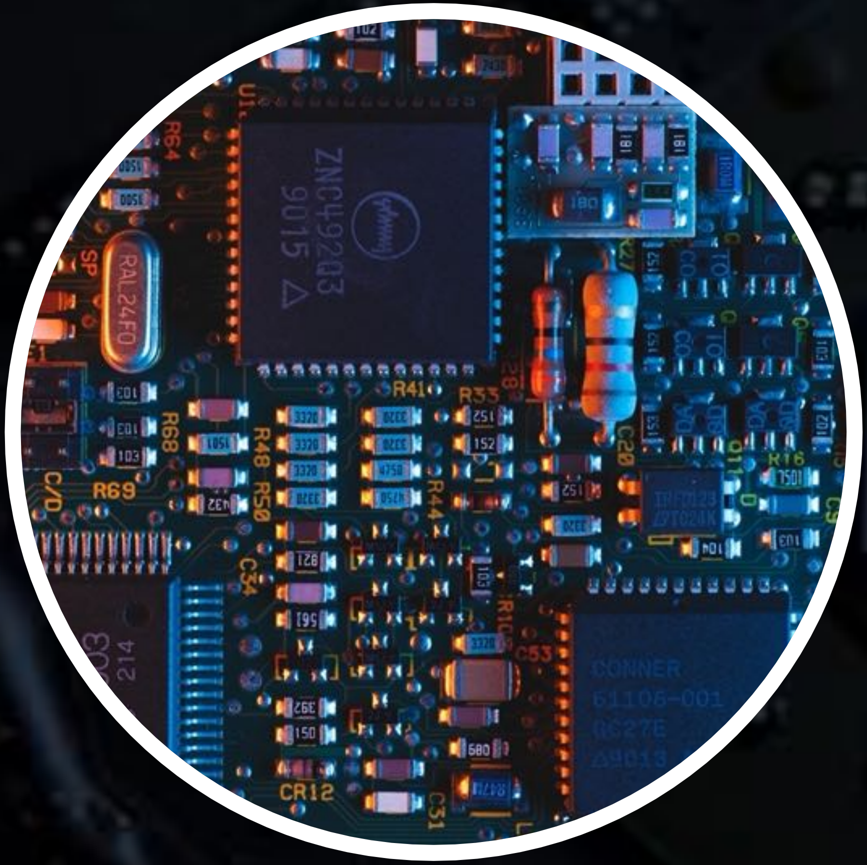


Atomic Layer Deposition Coatings

Coating Considerations

Protection Characteristic	Virgin PCBA	Mechanical Seals	Silicone Coatings	Parylene (CVD) Coating	Plasma (PECVD) Coating	Atomic Layer Coating (ALD)
Protection Barrier	None	Good (bad for impact)	Good (depends on application)	Excellent (adhesion critical)	Good (multi-layered)	Excellent (multi-layered)
Hydrophobic	No	No	Yes (>90°)	Partial (75-90°)	Yes (>90°)	Yes, multi-layered
Thickness	N/A	1-10 mm	0.1-10 mm	0.002-0.05 mm	< 0.005 mm	< 0.002 mm
Application Uniformity	N/A	N/A	Poor (pooling, wicking)	Excellent	Good	Excellent
Water Protection	Poor	Good: Ingress Poor: Egress	Good	Excellent	Good	Excellent
Sweat Submersion MTTF	Seconds	Varies	Weeks+ (for thick films)	Days to Weeks+	Minutes to Hours	Days to Weeks+
Durability	Low	Varies	Moderate	High	Low	Moderate
Masking Requirements	N/A	N/A	Costly selective application	High	Low	High

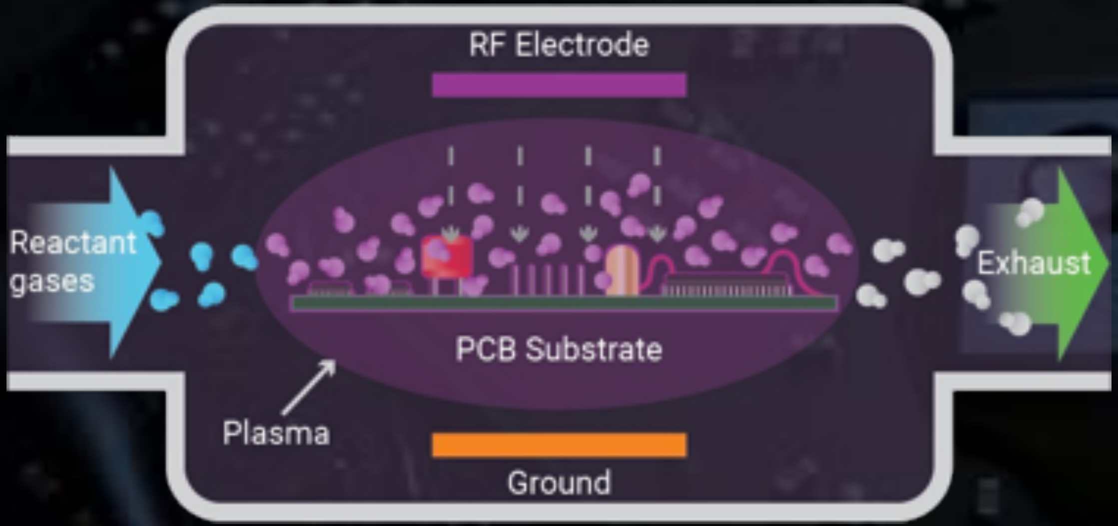
Benefits of Lower Thickness Coatings



- Improved thermal management
- Unimpeded wireless signals
- Less waste and weight
- Reduced masking/demasking
- Lower cost

PECVD Process Overview

Reaction Chamber



- Dry processing (efficient use of precursor materials)
- Deposition of wide material range
  - Hydrocarbons
  - Fluoropolymers
  - Silanes
  - Oxides
  - Metallics
  - Unreactive Precursors (N2, O2, C3H8)
- Further control over film properties through individual process parameters (i.e. Pressure or Power)

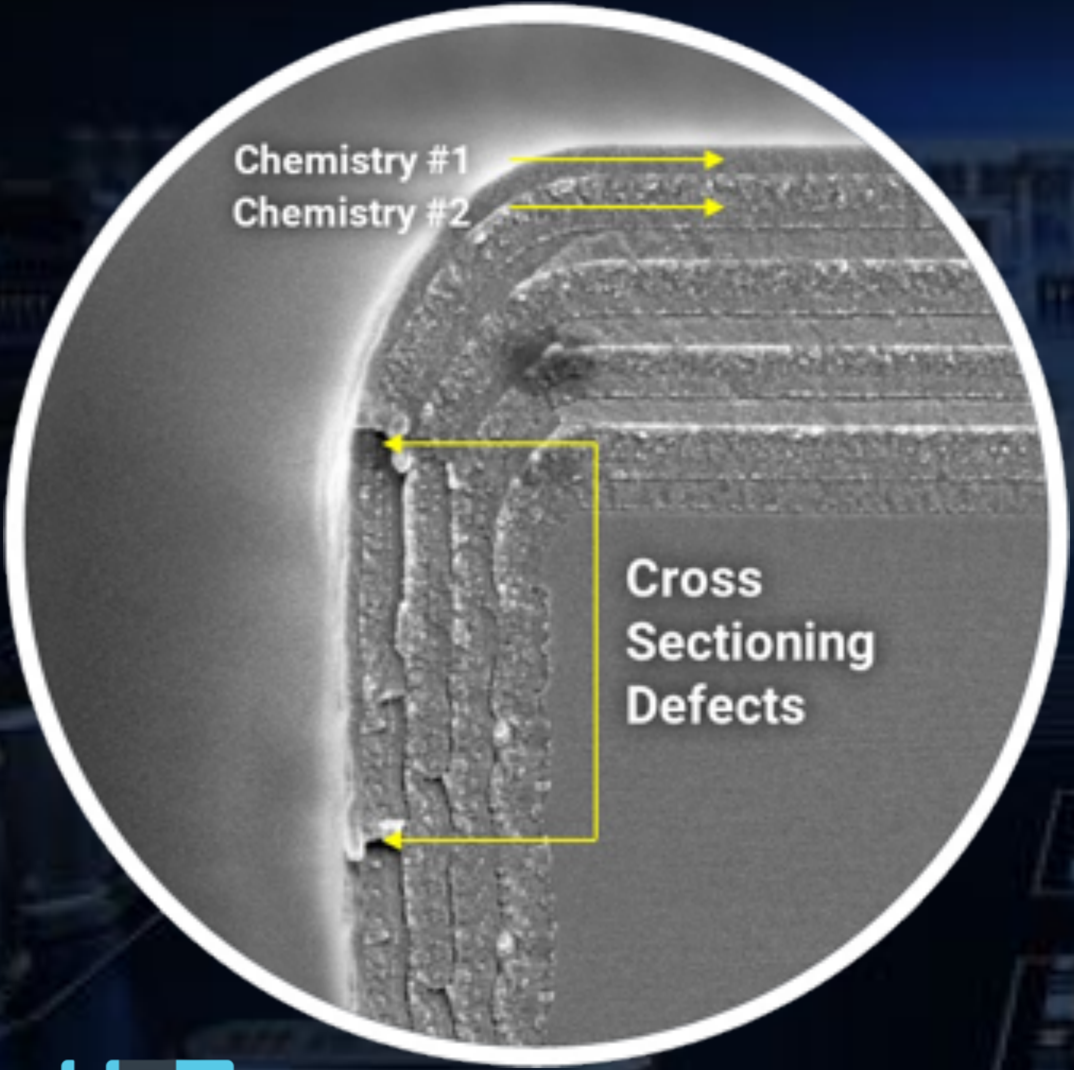
PECVD Process Benefits

- Thickness control from 0.02 to 5 µm
- One step, low temperature process
  - No post process curing required
  - Plasma clean and activation possible
    - Good adhesion to metallic and plastic surfaces
- Films are cross-linked, dense, pinhole free, conformal
  - Low solubility and good corrosion resistance
- Films can be layered using different chemistries

PECVD Equipment Benefits

- Larger chambers for high throughput and scalability
- Removable racks and trays for easy loading and project changeover
- Removeable deposition shields for easy cleaning
- Can use in-situ shadow masking to eliminate traditional masking/demasking processes
- Automated push button processing
- Automated data collection
- Remote monitoring

Multi-layer Plasma Chemistry

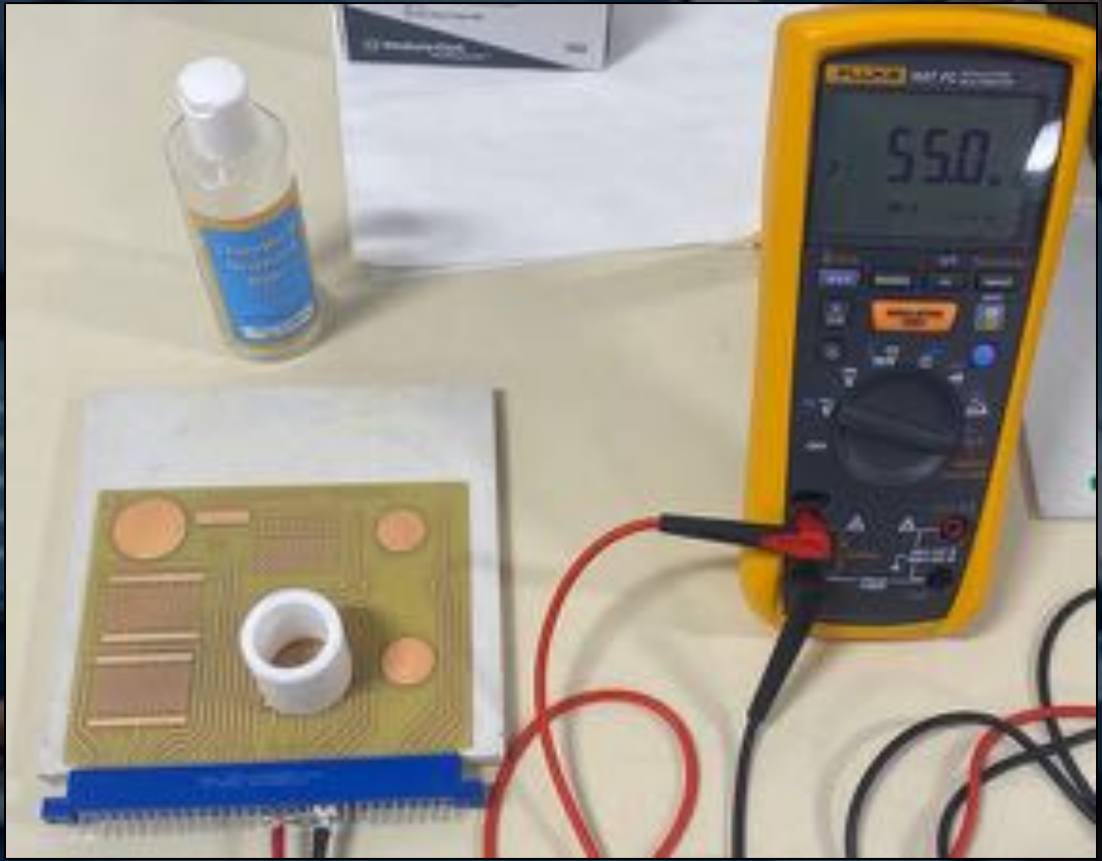


- **Defect density increased for thinner films**
- **Defect propagation mitigated by layers**
- **Conformality and masking/demasking trade-offs**

Performance Testing

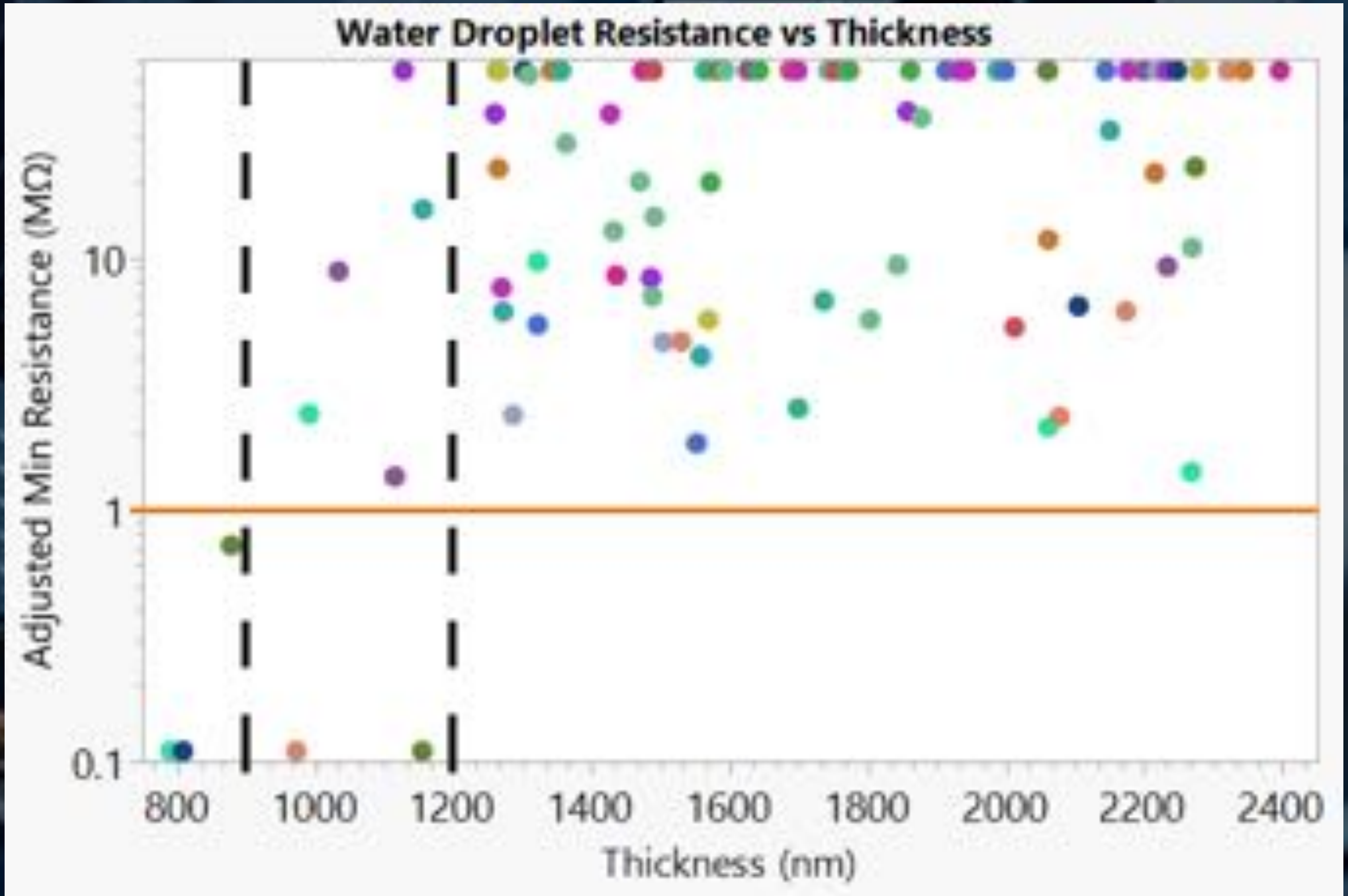
- Variety of tests performed to validate coating performance (mixture of standardized and custom-testing)
- Testing for PECVD coatings include:
  - Water Droplet Testing
  - IPX4 Testing
  - Dripping Sweat Testing
  - Temperature/Humidity Testing
  - Hydro/Lipophobicity Testing
  - Connect-Through Testing

Water Droplet Testing



- Water droplet on comb D pattern of multipurpose test board
  - Teflon tube to contain liquid
- 50 V bias applied
- Resistance measured after 60s
- >1 MΩ is pass criterion

Water Droplet Testing Results



- 94.4% of 90 boards passed
- 100% pass with coating > 1200nm thickness
- Failure rates increase for thinner coatings

Water Droplet Testing – Single Layer Films

- Homogeneous, single layered films tested from 2-12 µm thick
  - 2 µm failed water droplet test after 5s
  - 4-10 µm samples failed within 20s
  - 12 µm measured 2.5 MΩ after 60s
- Multilayered films reduced total thickness required to deliver similar performance in this test

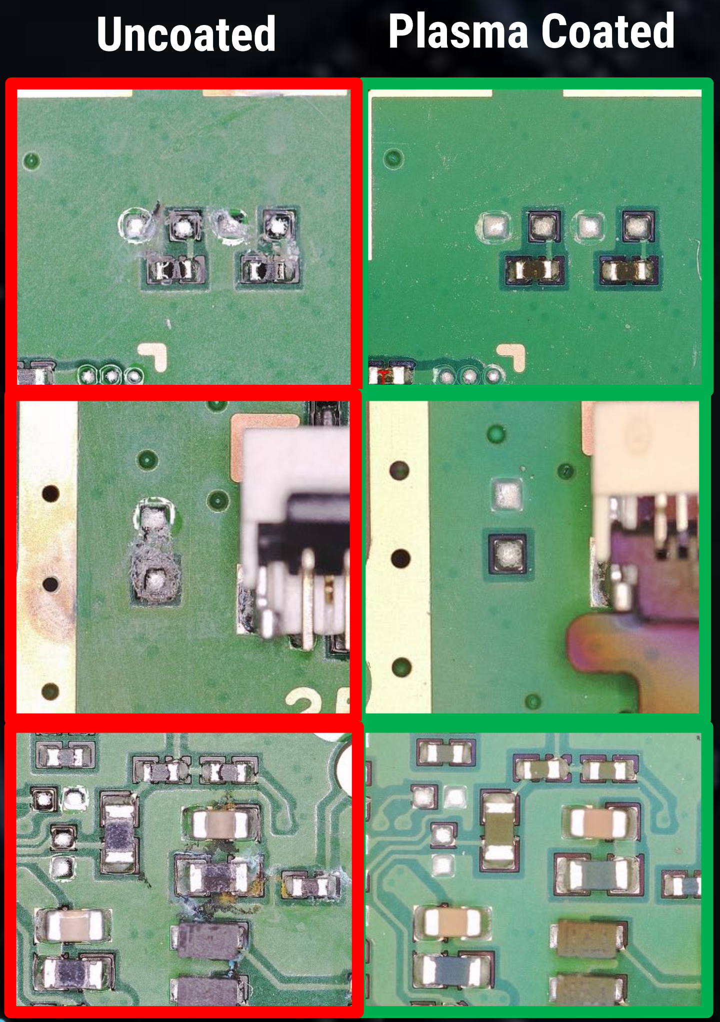
IPX4 Testing

Test Parameters for Tablets:

1. Play a movie and turn volume to 100%
2. Run water spray for 10 minutes
3. Remove tablet and dry off external water
4. Immediately perform post IPX4 functional checks
5. PASS if all functional checks pass after 48 hours


HZO
The following is a demonstration of HZO's internal IPX4 testing for Plasma-Applied Nano Coatings

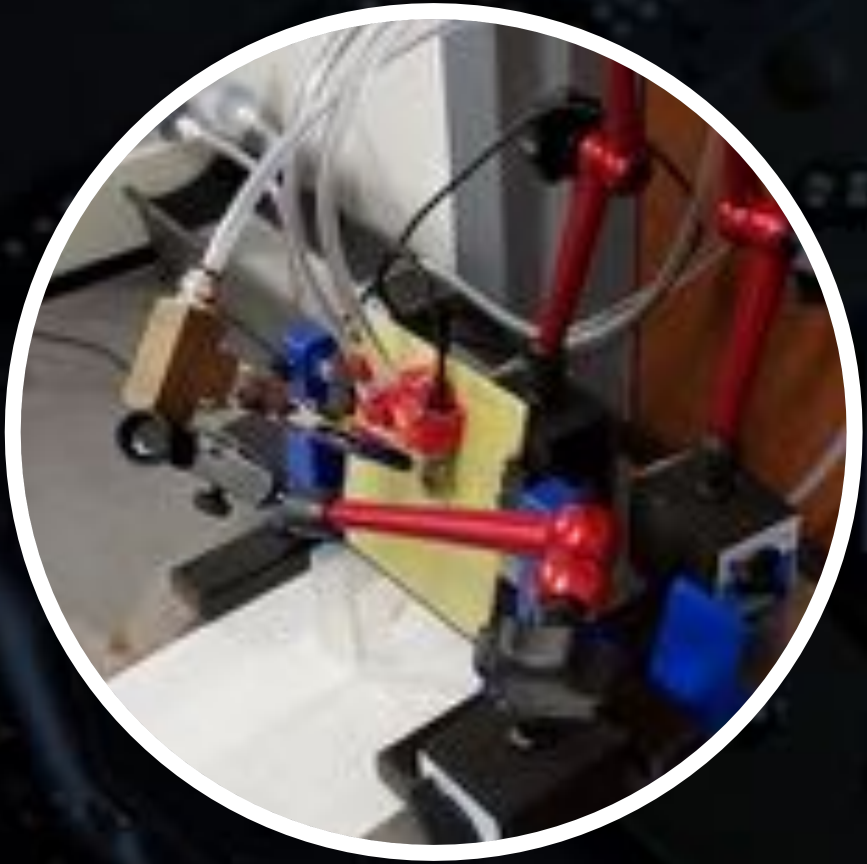
IPX4 Results



- Powered on for 48 hours
- Corrosion on uncoated tablets observed

Tablet	Post Coating	Post IPX4	Thickness (μm)	After 48 Hours
Uncoated	N/A	PASS / FAIL	N/A	FAIL
NC-10	PASS	PASS	1.6	PASS
NC-11	PASS	PASS	1.7	PASS
NC-12	PASS	PASS	1.8	PASS
NC-13	PASS	PASS	1.9	PASS
NC-14	PASS	PASS	2.0	PASS

Dripping Sweat Testing



Objective:

Simulate performance under repeated human sweat accelerated testing

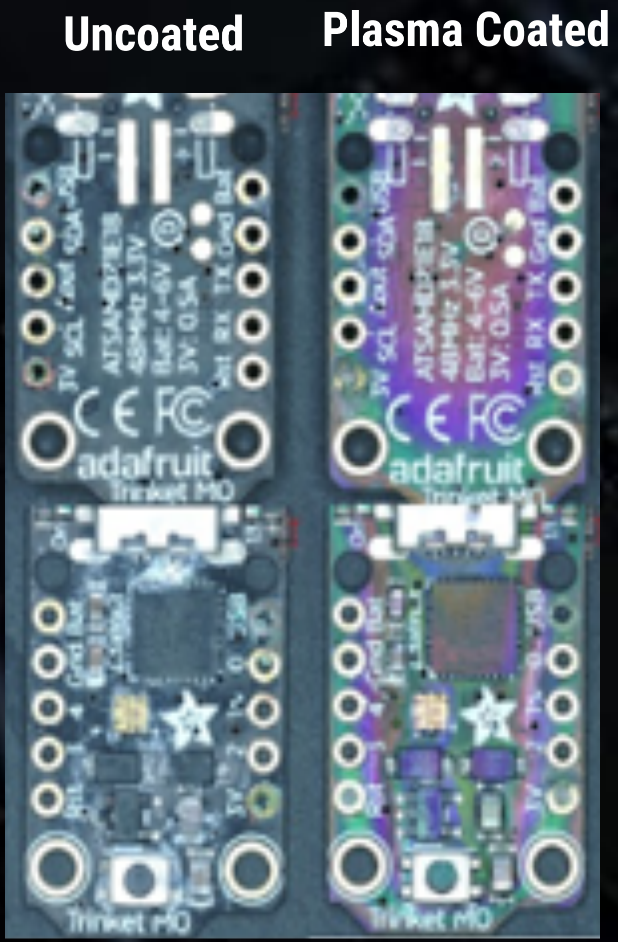
Testing Method:

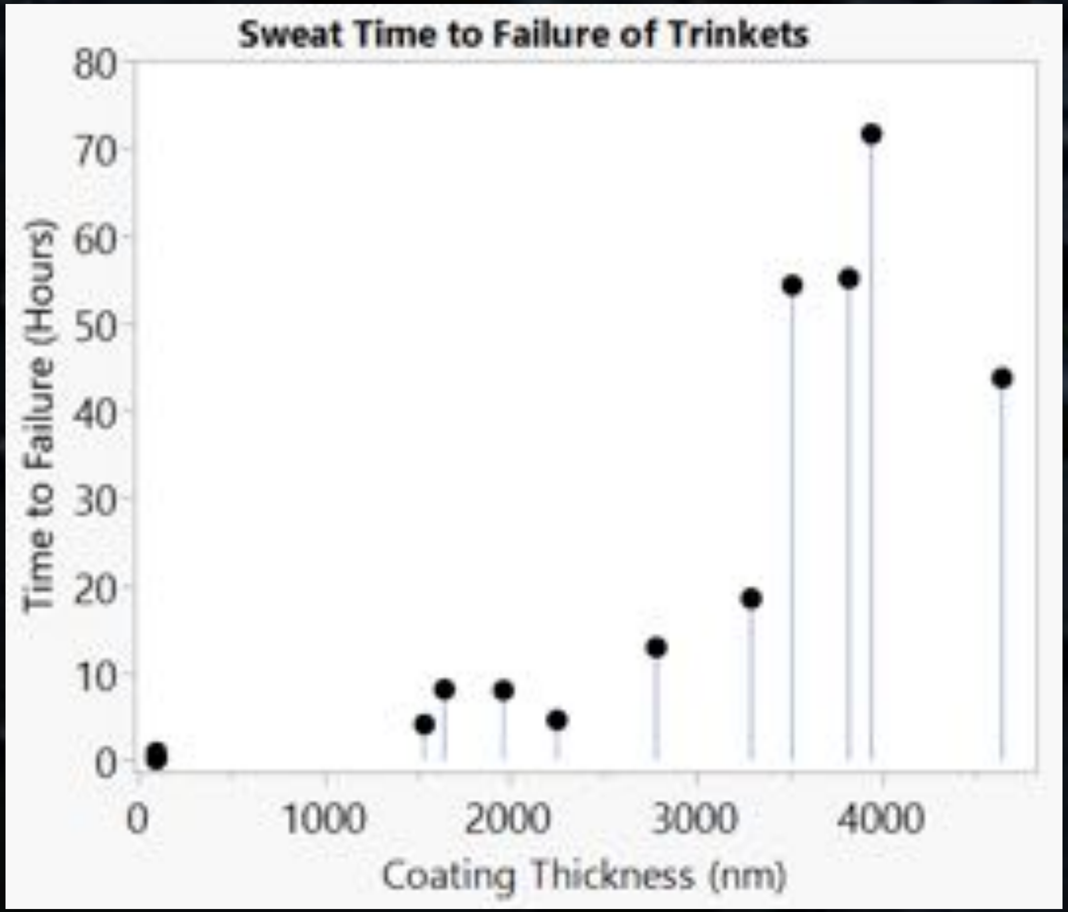
1. Power on (5 Volts) with constant USB communication
2. Drip with sweat solution for 1 hour at 1 drop/min
3. Power off, forced dry for 2 minutes, and left to dry further for the remainder of 1 hour
4. Repeat above cycle

Sweat Solution:

- Concentration of 0.17 M NaCl, 7 mM disodium hydrogen phosphate, 1.6 mM histidine, and 12.7 mM lactic acid

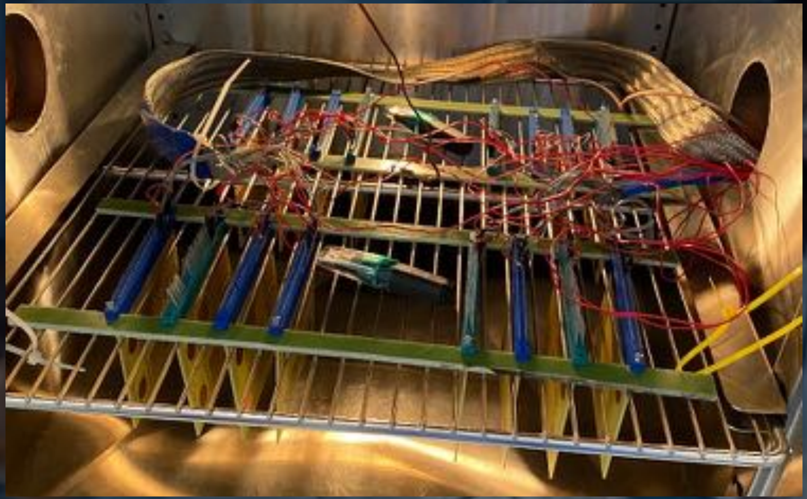
Dripping Sweat Results





- Time to failure (TTF) improved with increased thickness
- Salt builds up from the sweat and corrosion becomes observable

Heat Soak Testing



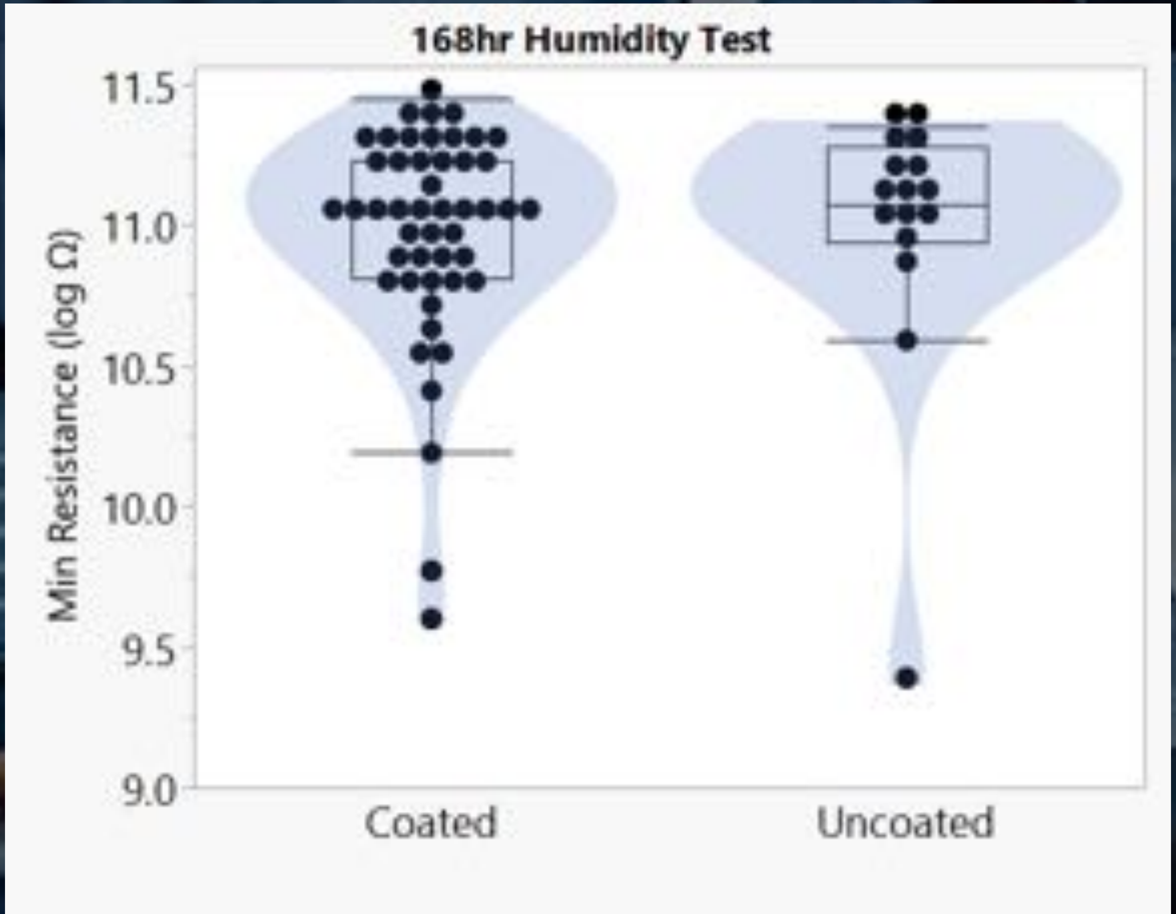
Objective:

To confirm that the coating does not lower electrical insulation during test

Pass Criterion:

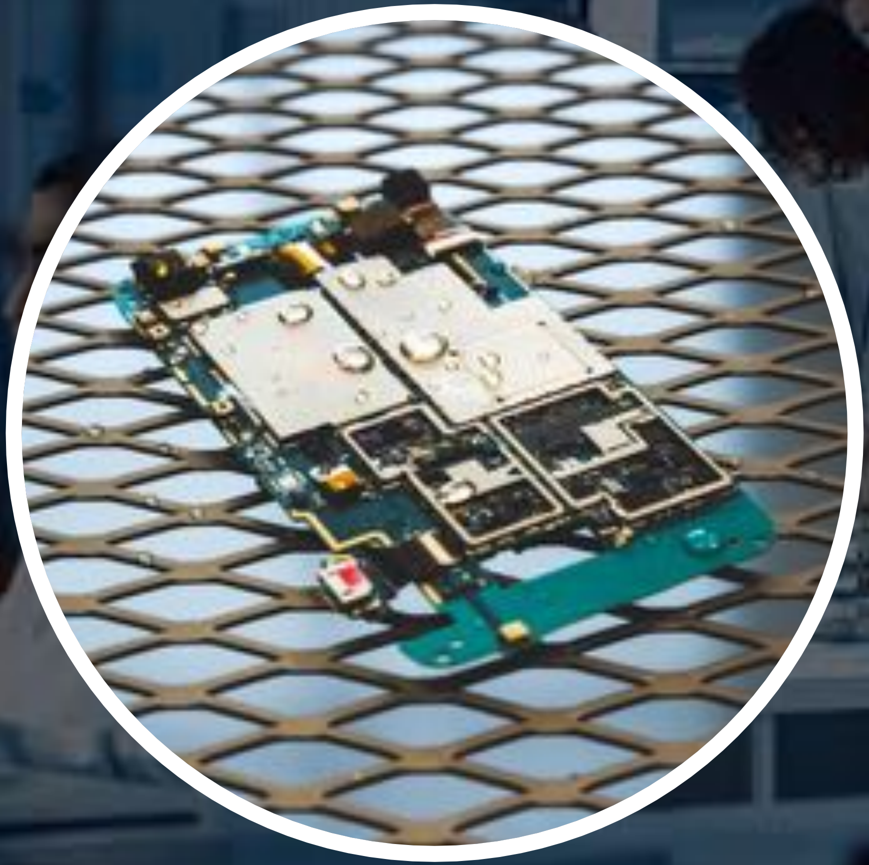
Resistance > 100 MΩ from 24 hours to the end of the 7-day test @ 40°C & 90% RH

Temperature / Humidity Results



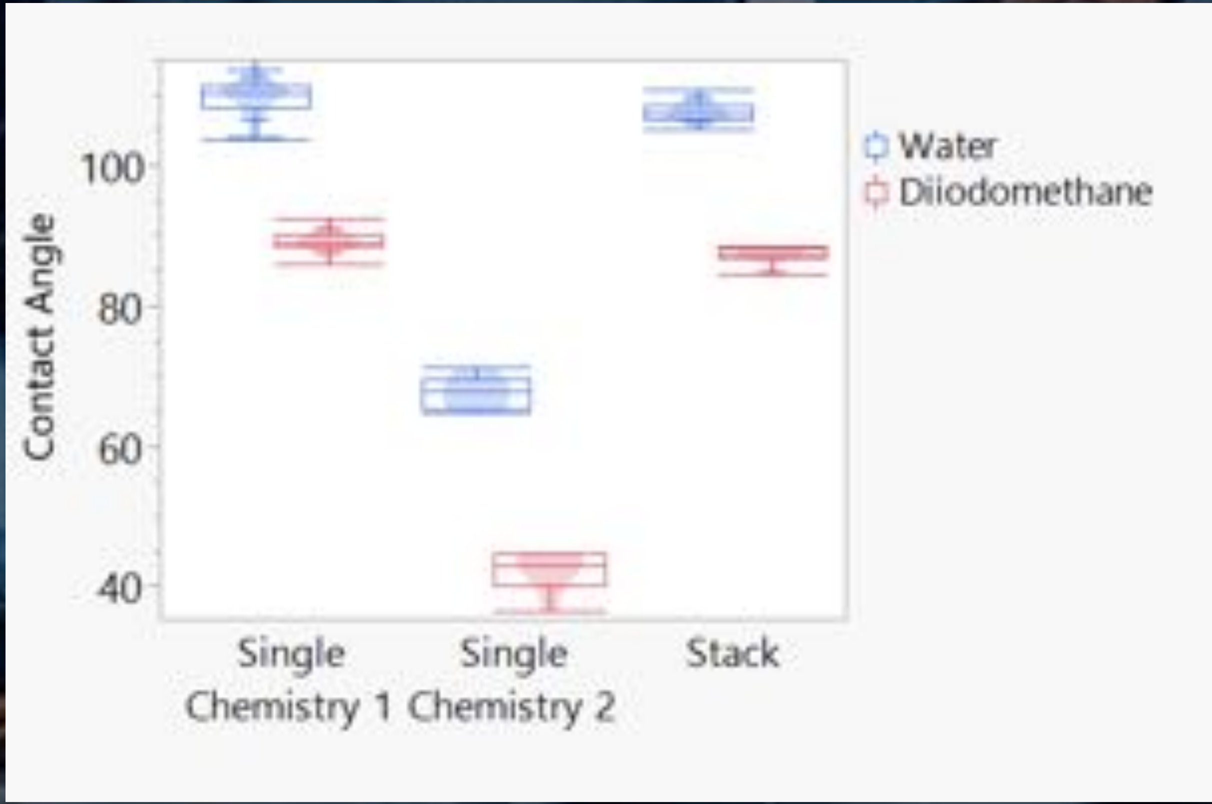
- All coated and uncoated boards passed
  - > 100 MΩ (8 log Ω) required
  - >1,000 MΩ (9 log Ω) observed
- Coating does not absorb enough moisture to cause conduction

Hydro/Lipophobicity Testing



- Hydrophobicity was measured using static water contact angle (WCA) measurements using Kruss DSA25E goniometer and deionized water
- Lipophobicity was measured using diiodomethane as the contact angle liquid instead of the deionized water
- Left and right measurements were recorded and averaged for each drop
- All contact angles were measured on films deposited on flat and smooth Si wafers

Hydro/Lipophobicity Results

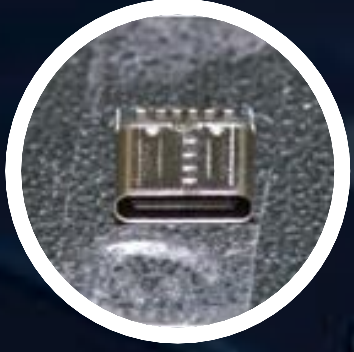


- The WCA of the Chemistry #1 single-layered films and the stacked films were measured in the same range
- Both films are hydrophobic (WCA > 90°), with contact angles ranging from 104° to 116°
- There is no significant difference between both the water and the diiodomethane contact angles of the single-layered coating and the stacked film.

Connect-Through Testing

USB 3.0 Type A

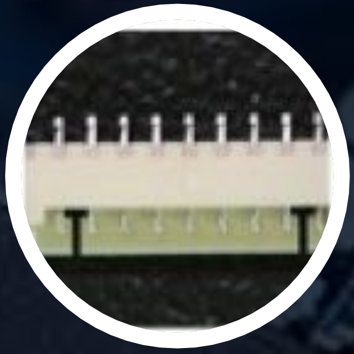
USB 2.0 Type C



USB 2.0 Micro B

8POS 2MM

SMD 9POS 1.25MM



B2B Molex 55650-0388

	USB 3.0 Type A	USB 2.0 Type C	USB 2.0 Micro B	8POS 2MM	SMD 9POS 1.25MM	B2B Molex 55650-0388
Thickness (µm)	0.8 - 4.7	1.1 - 4.7	1.1 - 4.7	1.6 - 2.0	1.6 - 2.0	1.3 - 1.5
Connection Resistance (Ω)	0.38	0.69	0.38	0.24	0.29	0.28
Uncoated Resistance (Ω)	0.25	0.70	0.35	0.2 - 0.3	0.2 - 0.3	0.2 - 0.3

Coating did not prevent electrical connections

HZO

Summary

- PECVD processes offer advantages over traditional conformal coating techniques
  - In-situ chemistry changes
  - Reduction or elimination of masking
  - Reduced footprint/costs
- Multilayered coatings reduce thickness required for effective barrier protection
  - Coatings can be used in many different applications or environments
    - Accidental spills or splash protection
    - Sweat
    - Humidity

HZO

Are You Ready To Design a Better Product?

Mission: HZO protects electronics from the most demanding environments with world-class nano-coatings to enable a better, more durable product.

2011

- HZO established - Utah
- Series A funding - inc. Li Ka-shing's Horizons Ventures, Ltd.
- 39 Workforce
- 1 Factory

2013

- Expand into China
- Clients include Nike, Dell, Motorola, and Rakuten
- 21 IP Assets
- 83 Workforce
- 2 Factories

2017

- HZO acquires ZPL Technologies
- 160 IP Assets
- 925 workforce

2018

- HZO acquires Semblant Ltd
- Pro750GEN4
- Spectrum of Protection launched
- 1826 Workforce
- 11 Factories

2019 / 2020

- Relocate to Raleigh, NC.
- Raised $70M for expansion
- Innovation – laser ablation & plasma ashing
- PRO800PL Introduction
- 370 IP Assets
- 4378 Workforce (2019)
- 14 Factories
- Expand to Vietnam

Future

- One stop shop – thin films
- Diversified business base
- Partnerships (CM, Formulary)
- Ongoing R&D Commitment
- Continuous "cost down" initiatives

Next Steps

Interested?
Visit us at Table #32