NanoProof® Series
PCB Waterproof Technology
Edward Hughes
- CEO, Aculon Inc.

Mario Gattuso
- Senior Business Development Manager at Aculon,
AGENDA

- Overview
- Introduction of Henkel Strategic Partnership
- PCB Waterproofing Market Need
- Introducing NanoProof Series
- Application methods
- Competitive Comparison
- Independent NPL Testing
- Case Studies
- Q&A
Aculon is a leading provider of surface modification technologies

- **Surface Solution Experts** – develop & produce technologies to modify a broad variety of surfaces (metals, glass, polymers).

- **Treatments include** - create hydrophobic, oleophobic, hydrophilic, adhesion promoting treatments.

- **Treatments are very thin**, easy to apply and need minimal equipment.

- **3 Units** - Electronics, Oil & Gas, Specialty

- **Business Model**: develop & produce chemistry
Headquartered in San Diego, California, USA
New Strategic Partnership with Henkel
Henkel AG & Company, KGaA, is a German chemical and consumer goods company headquartered in Düsseldorf, Germany. It is a multinational company active both in the consumer and industrial sector.

- Headquarters: Düsseldorf, Germany
- Revenue: 22.6 billion EUR (2017)
- Number of employees: 53,000
- Electronics – Based in Irvine CA
- Innovative adhesives and sealants
Henkel / Aculon Partnership

• Henkel approached Aculon regarding our waterproofing technology as part of their overall waterproofing strategy.
• Aculon & Henkel Electronics have entered into a Strategic Partnership
• Focus – Large mobile device manufacturers
• Series 7 has been industrialized by Henkel, working on others

For target accounts i.e. Large mobile device manufacturers
• Aculon is the Technology Provider
• Henkel handles Commercial aspects, including:
  • Application testing & process support
  • Manufacturing, Supply, Invoicing, and Quality Assurance
  • Customer site technical support for both specification and product sites
The PCB waterproofing market is an emerging and exciting market as it is large (>$3BN).

Within 2 years waterproofing will a standard feature in many premium devices including smartphones, tablets and wearables.

Other devices that experience water damage will benefit from PCB waterproofing including desktops, laptops, IoT Devices.

In addition due to the process flexibility of applying Aculon’s solution based treatments we expect to see adoption in markets such as medical devices and for manufacturers who want to avoid the hassle of conformal coatings
What Problem Are We Solving?

By 2020 IDC projects that 1.7 billion smartphones will be shipped at a value of $398 billion.

But more than 900,000 smartphones per day are damaged by liquids globally!
Breakdown of Damage to Mobile Phones

- **Shattered Screens**: 49%
- **Broken Body**: 10%
- **Other**: 4%
- **Splashes & Spills**: 14%
- **Shallow Immersion**: 5%
- **Deep Immersion**: 12%
- **Unrecoverable water damage**: 6%

Source: IDC 2016
Water Damage = 35%

- Splashes & Spills: 38%
- Deep Immersion: 32%
- Shallow Immersion: 14%
- Unrecoverable water damage: 16%

Source: IDC 2016
Aculon, Where Waterproofing Meets – Brilliant!
In real life, consumers too often damage their devices

- Device dropped in pool or even toilet
- Unit exposed to outdoor environment – rain, humidity
- Household appliances exposed to water during operations
- Equipment (industrial and medical) exposed to wet working

WHY DO WE NEED WATERPROOFING?
The IPX standards provide a waterproofing scale, and possibly design changes.

<table>
<thead>
<tr>
<th>IPX Level</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>Protected against continual water submersion in underwater conditions.</td>
</tr>
<tr>
<td>7</td>
<td>Protected against water immersion for 30 minutes at a depth of up to 1 meter.</td>
</tr>
<tr>
<td>6</td>
<td>Protected against high pressure water stream from any angle.</td>
</tr>
<tr>
<td>5</td>
<td>Protected against low pressure water stream from any angle.</td>
</tr>
<tr>
<td>4</td>
<td>Protected against splashing water from any angle.</td>
</tr>
<tr>
<td>3</td>
<td>Protected against spraying water when tilted up to 60 degrees vertically.</td>
</tr>
<tr>
<td>2</td>
<td>Protected against spraying water when tilted up to 15 degrees vertically.</td>
</tr>
<tr>
<td>1</td>
<td>Protected against condensation or dripping water falling vertically.</td>
</tr>
<tr>
<td>0</td>
<td>No Protection</td>
</tr>
</tbody>
</table>
# RECOMMENDED IPX LEVEL FOR COMMON DEVICES

<table>
<thead>
<tr>
<th>LEVEL 1</th>
<th>LEVEL 2</th>
<th>LEVEL 3</th>
<th>LEVEL 4</th>
<th>LEVEL 5</th>
<th>LEVEL 6</th>
<th>LEVEL 7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dripping Water</td>
<td>Dripping water 15º</td>
<td>Spraying water</td>
<td>Splashing water</td>
<td>Waterjets</td>
<td>Power waterjets</td>
<td>Immersion Up to 1 m</td>
</tr>
<tr>
<td>Clothes-dryer</td>
<td>Clothes-washer</td>
<td>Telephone</td>
<td>Hearing Aids</td>
<td>Camera</td>
<td>Air-conditioner</td>
<td>Mobile Phones</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Clock</td>
<td>Doorbell</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Computer</td>
<td>Outdoor lighting</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Electric Drill</td>
<td>Junction Boxes</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Headphones</td>
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<td></td>
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<td></td>
<td></td>
<td>Laptop</td>
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<td></td>
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<td></td>
<td>Printer</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>Television</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>Automotive-electronics</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Bluetooth headsets</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Flashlight</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Aculon NanoProof® Series provides water protection from humidity to full water immersion

Winner Circuits Assembly
New Product Introduction Award
Aculon NanoProof® Series provides water protection from humidity to full water immersion

- Utilize proprietary technology
- Surpass competitive coatings in performance and ease of use
- Application equipment affordable and readily available
1. Reduce Product returns due to water damage
2. Improve yields as rework is possible after coating
3. No or minimal masking required
4. Coating is safe, non-toxic and can be used in factory environment
5. Affordable
<table>
<thead>
<tr>
<th>Technology</th>
<th>NanoProof 1.0</th>
<th>NanoProof 2.0</th>
<th>NanoProof 2.1</th>
<th>NanoProof 4.0</th>
<th>NanoProof 5.1</th>
<th>NanoProof 7.0</th>
<th>NanoProof 8.4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Description</td>
<td>Hydrophobic TMC based coating in hydrocarbon solvent</td>
<td>Hydrophobic polymer in hydrocarbon solvent</td>
<td>Hydrophobic polymer in methyl-cyclohexane</td>
<td>Hydrophobic siloxane based coating in hydrocarbon solvent</td>
<td>Hydro/Oleophobic fluoroacrylate based coating in fluorosolvent</td>
<td>Hydrophobic Polyolefin based in methyl-cyclohexane</td>
<td></td>
</tr>
<tr>
<td>Barrier Effectiveness</td>
<td>Good</td>
<td>Better</td>
<td>Extreme</td>
<td>Even Better</td>
<td>Best</td>
<td>Extreme</td>
<td>Extreme</td>
</tr>
<tr>
<td>Thickness</td>
<td>1µm</td>
<td>10µm</td>
<td>30-40µm</td>
<td>10µm</td>
<td>6µm</td>
<td>30-40µm</td>
<td>30-40µm</td>
</tr>
<tr>
<td>Includes UV Tracer</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Deformable?</td>
<td>Yes</td>
<td>Yes</td>
<td>During solvent evaporation</td>
<td>Yes</td>
<td>During solvent evaporation</td>
<td>During solvent evaporation</td>
<td>During solvent evaporation</td>
</tr>
<tr>
<td>Sprayable</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Dip/Dispense/Spray options</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Connectivity</td>
<td>Make electrical contact through barrier</td>
<td>Allows for push through connectivity</td>
<td>While drying only</td>
<td>Allows for push through connectivity</td>
<td>While drying only</td>
<td>While drying only</td>
<td>Allows for push through connectivity</td>
</tr>
<tr>
<td>Handling Post treatment</td>
<td>Ok</td>
<td>Carefully</td>
<td>Ok</td>
<td>Carefully</td>
<td>Ok</td>
<td>Ok</td>
<td>Ok</td>
</tr>
</tbody>
</table>
NanoProof material on the PCBA can be inspected by UV inspection system (UV fluorescent bulb).
Aculon NanoProof does not impact key components......

<table>
<thead>
<tr>
<th>Component</th>
<th>Fully Functional After NanoProofing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Antenna</td>
<td>Yes</td>
</tr>
<tr>
<td>Headphone* &amp; Microphone*</td>
<td>Yes</td>
</tr>
<tr>
<td>Push buttons</td>
<td>Yes</td>
</tr>
<tr>
<td>Camera</td>
<td>Yes</td>
</tr>
<tr>
<td>Speakers*</td>
<td>Yes</td>
</tr>
<tr>
<td>Sealed LCD Display</td>
<td>Yes</td>
</tr>
<tr>
<td>Unsealed LCD Display</td>
<td>NO – Don’t coat</td>
</tr>
</tbody>
</table>

* Excluding Nanoproof 5.1, 7.0, & 8.4
Types of Treatment: Aculon Treatments 2.1, 3.5, 4.0, 5.0, 7.0, 8.4

Voltages Tested: 3v, 6v, 12v, 18v

Time: 60 minutes i.e. 2X IPX-7

Conditions: Water and Salt Water

Board: IPC Multi-Purpose Test Board

Additional Testing for MIR, Salt Spray & Sweat Solutions

- Moisture & Insulation Resistance
  - IPC-CC-830B, AM1

- Salt Spray (Fog) Exposure
  - ASTM B117-11

- Sweat Solution
  - IBM-H6-0440-105
  - 24 hours at 10V to D and F combs
  - Resistance measured pre and post-test
NanoProof performs well even at 18 Volts!
New Technical Paper available soon! Release date September 15. All attendees to receive downloadable link after release.

Enabling IPX Level 7/8 PCB Waterproof Protection
• Board serves as a general proxy to compare insulation resistance of coatings.
• Does not represent real world results.
• In real life boards are populated with components (3D features)!
• Conformal coatings which pass IPC testing routinely fail when coated on populated boards.
• Need updated proxy for evaluating ability to protect real boards.
1. Coat LED strips

2. Dip in water while powered up

3. Evaluate components for failures

4. Determine if coating is capable of offering real world protection on 3D devices
Traditional Silicone: Fails

- Passes Traditional IPC Board Testing
- Fails Testing on LED Strip
- Very thick at 100uM
- Does not coat sharp angles
- Not real world IPX7
Traditional Acrylic: Fails

• Passes Traditional IPC Board Testing
• Fails Testing on LED Strip
• Does not coat sharp angles
• Not real world IPX7
NanoProof Extreme (2.1, 7,8.4): Pass

- Passes Traditional IPC Board Testing
- Passes Testing on LED Strip
- Successfully coats sharp angles
- After process optimization real world IPX7 performance possible
**Phase 1 Investigation**

- Conformal Coatings Are Well Characterized and Extensively Used
  - However have poor edge coverage and not moisture impermeable
- Hydrophobic coatings are generally thinner and can cover corners and fine features better
- Improvement in the hydrophobic nature of coatings leading to improved reliability in high humidity and condensation to get a balanced picture
- Using conformal coating as the bench mark and compare to:
  - Pure hydrophobic coatings
  - Hydrophobic coating on top of conformal coatings

**Phase 1 Conclusions**

- SIR in damp heat environment
  - No failures of Conformal & NanoProof coatings throughout testing
- No failures under condensation testing
  - UV-Cured shows very small drop in SIR when condensation present
  - Higher contact angle does not necessarily mean a better condensation test result
  - Can’t just put any two coatings
  - Improved performance with hydrophobic coating on top?

- Independent Verification that NanoProof Performs as well as Traditional Conformal Coatings on flat surfaces
- NPL in progress testing on 3D surfaces
The coating process depends on the application and including:

1. Spray
2. Dispense
3. Jet
4. Dip
Equipment required meets a variety of needs. From handheld to batch to inline to high volume automation.
Next Generation Waterproofing Technologies

1. Gasketing – (Henkel)
2. Vacuum Deposition – (P2i/ Semblant)
3. Next Generation Liquid – (Aculon, 3M)
## Next Generation Options: Gasketing

<table>
<thead>
<tr>
<th>Pros</th>
<th>Cons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Effective Initial Performance</td>
<td>Complicated</td>
</tr>
<tr>
<td>IPX 5+</td>
<td>Use valuable real estate</td>
</tr>
<tr>
<td></td>
<td>Requires silicone “port” plugs</td>
</tr>
<tr>
<td></td>
<td>Prone to catastrophic failure</td>
</tr>
<tr>
<td></td>
<td>Expensive - $5-$8 all in</td>
</tr>
</tbody>
</table>

*Not a long term solution*
<table>
<thead>
<tr>
<th>Pros</th>
<th>Cons</th>
</tr>
</thead>
<tbody>
<tr>
<td>IPX 2-5 Performance</td>
<td>Complicated</td>
</tr>
<tr>
<td></td>
<td>Masking / demasking</td>
</tr>
<tr>
<td></td>
<td>Expensive Capital equipment</td>
</tr>
<tr>
<td></td>
<td>Batch Process</td>
</tr>
</tbody>
</table>
### next generation options: nanoproof extreme

<table>
<thead>
<tr>
<th>Pros</th>
<th>Cons</th>
</tr>
</thead>
<tbody>
<tr>
<td>IPX3-7 Performance</td>
<td>Can contain solvent (VOC)</td>
</tr>
<tr>
<td>Easy to Apply</td>
<td>Process optimization intensive</td>
</tr>
<tr>
<td>Cover complex features</td>
<td></td>
</tr>
<tr>
<td>Cost effective &lt; $1</td>
<td></td>
</tr>
</tbody>
</table>
# Technology Comparison

<table>
<thead>
<tr>
<th></th>
<th>Gasketing</th>
<th>CVD / Parylene</th>
<th>NanoProof</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Performance</strong></td>
<td>IPX 5+</td>
<td>Often IPX 3</td>
<td>IPX 4-7+</td>
</tr>
<tr>
<td><strong>Application methods</strong></td>
<td>Adhesive &amp; Manual</td>
<td>Vacuum Deposition only</td>
<td>Multiple– Dip, spray wipe</td>
</tr>
<tr>
<td><strong>Long Lasting Hydrophobicity</strong></td>
<td>No</td>
<td>Depends</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>Enables Rework</strong></td>
<td>No</td>
<td>No</td>
<td>Yes – easily</td>
</tr>
<tr>
<td><strong>Capital Equipment</strong></td>
<td>No</td>
<td>Yes &amp; Expensive</td>
<td>Minimal</td>
</tr>
<tr>
<td><strong>Production</strong></td>
<td>Continuous</td>
<td>Batch</td>
<td>Continuous</td>
</tr>
<tr>
<td><strong>Cycle time</strong></td>
<td>OK: 60-90 minutes depending on cure style/time</td>
<td>Slow : 1hr-5 hrs. depending on part size and thickness</td>
<td>Fast: &lt;1 minute</td>
</tr>
<tr>
<td><strong>Ability to treat complex parts</strong></td>
<td>No</td>
<td>Maybe – depends on throwing capability</td>
<td>Yes – low surface energy solution</td>
</tr>
<tr>
<td><strong>Masking required</strong></td>
<td>No</td>
<td>Yes and must be “gas tight”</td>
<td>No</td>
</tr>
<tr>
<td><strong>Lowers Internal reject rate</strong></td>
<td>Sometimes – Difficult or not possible to rework</td>
<td>No – cannot rework</td>
<td>Yes – can rework</td>
</tr>
<tr>
<td><strong>Energy Usage in Production</strong></td>
<td>Low</td>
<td>No – cannot rework</td>
<td>Low</td>
</tr>
<tr>
<td><strong>Part Size</strong></td>
<td>No Limit</td>
<td>No limit</td>
<td></td>
</tr>
<tr>
<td><strong>Cost</strong></td>
<td>High per unit</td>
<td>No limit</td>
<td>Low</td>
</tr>
</tbody>
</table>
Case studies:

1. Bluetooth headsets
2. Wearable devices
3. Outdoor home electronics
4. Hearing aids
5. Mobile
BLUETOOTH HEADSETS

Requirement: Protection from sweat and splashing water, full immersion proofing not required. IPX3 required, IPX4 desired.

Collaboration: Aculon treated customer test parts in addition to evaluations at customer site to finalize process.

Time: 6 months

Material selected: NanoProof 4.0

Application: Excluding audio speaker, all electronics sprayed utilizing PVA FCS300 Valve

Performance: Passes customer IPX4 Qualification
WEARABLE DEVICES

Requirement: Protection from sweat and splashing water, full immersion proofing not required. Needs to protect from rain and shower exposure. IPX4 required, IPX5 desired

Collaboration: Aculon treated customer test parts via spray for initial testing. Customer testing identified high voltage components needing additional protection solved by application of spot treatment to reach spec.

Time: 6+ Months

Material selected: NanoProof 4.0 & NanoProof 8.4 combo

Application: All electronics sprayed with 4.0 utilizing PVA FCS300 Valve. Spot application of 8.4 on sensitive components.

Performance: Passes customer IPX5 Qualification
Requirement: Protection from splashing water from rain and irrigation equipment, full immersion proofing not required. IPX5 required, IPX6 desired

Collaboration: Aculon/Customer collaboration determined most robust option (5.1) needed to protect high voltage components.

Time: 9 months

Material selected: NanoProof 5.1

Application: Excluding audio speaker, and optical components all electronics sprayed utilizing PVA FCS300 Valve with NanoProof 5.1. Electrical connections made using diluent solvent.

Performance: Passes customer IPX5 Qualification Required
**Requirement:** Protection from sweat and splashing water, full immersion proofing not required. IPX3 required, IPX4 desired.

**Collaboration:** Customer obtained and tested samples successfully

**Material selected:** NanoProof 4.0

**Application:** Excluding audio speaker, all electronics sprayed utilizing PVA FCS300 Valve

**Performance:** Passes customer IPX4 Qualification
**Cell Phones**

**Requirement:** Protection from sweat, splashing water, high pressure water & full immersion proofing. IPX6 or IPX7

**Collaboration:** Direct collaboration with several cell phone manufacturer working toward IPX7 success.

**Time:** 12 months + estimated 3 months

**Material selected:** NanoProof 7.0,

**Application:** Nordson Intellijet
These include:

1. **Performance** - Ability to achieve IPX-7

2. **Continuous production**

3. **Fast cycle times** - No cure cycle, no masking

4. **Push through Connectivity™** - the ability to allow to you make connection post treatment application and eliminates need for labor intensive masking & de-masking.

5. **Ability to rework** – the treatment can be removed allowing the board to be reworked. PCB that have been treated with Conformal coatings or CVD processes are very difficult to rework and in most cases cannot be reworked and need to be scrapped.
Aculon will work with you to determine best application process...
Flexible approach designed to increase your probability of success...

- **Customer Trial (Good)**
  - Customer buys NanoProof to test on products
  - Customer run tests

- **Aculon Trial (Better)**
  - Customer sends aculon devices to treat.
  - Customer tests

- **Customer & Aculon Collaboration (Best)**
  - Set up Design of Experiments to determine best treatments for application
  - Review results and iterate
In summary

- Leading supplier of NanoScale Repellency Technology
- Qualified and in production on numerous applications
- Easy to apply & cost effective
- NanoProof® Series provides options based on performance requirements
- Proven to outperform competitive technology
- Aculon supply NanoProof series globally
PERFORMANCE. SURFACE. SOLUTIONS

For Questions Contact Mario Gattuso  gattuso@aculon.com

THANK YOU

www.aculon.com