PCB and Components Water Protection: Finally a coating that protects that is easy to apply and can be easily rework – Introducing Aculon NanoProof®

Miniaturization of electronic circuitry places tremendous pressure on manufacturers to develop new methods and technologies. Among the many challenges currently faced by PCB manufactures is incorporating water resistance. Traditionally, thick encapsulating coatings or mechanical gasketing have been used, however continued miniaturization has made these technologies difficult/costly to incorporate as many parts of the board must be masked to avoid insulating press-fit connectors or damaging sensitive components such as microphones. Aculon® NanoProof™ surface treatments offer protection from liquids without gasketing nor masking.

Water-resistance product offerings generally fall into three categories: no-mask solution based hydro/oleophobic coatings applied without the need to protect sensitive parts of the boards, conformal solution based hydro/oleophobics which repel fluids but require some level of masking or “keep-out” areas, and vacuum-deposited coatings (which also require masking) such as parylene-based treatments. Aculon® NanoProof™ surface treatments are no mask solution based hydro/oleophobic coatings eliminating the need for costly capital investment and avoiding the bottlenecking of vacuum based manufacturing or masking operations.

To demonstrate the effectiveness of Aculon® NanoProof™ surface treatments, we coated standard PCB test patterns (IPC-B-25A) with three different Aculon® surface treatments: Aculon® NanoProof™ 4.0, 3.5 and 5.0. IPC-B-25A boards meet the guidelines for testing conformal coatings (IPC-CC-830B) and solder masks (IPC-SM-804C). Aculon® NanoProof™ 4.0 and 3.5 are hydrophobic polymer-based coatings that repel water and provide inhibition of ion migration/electromigration. They are also designed to avoid the need to mask keep-out areas simplifying the manufacturing process. Aculon® NanoProof™ 5.0 is an oleophobic fluoropolymer coating that offers an increased level of protection by also repelling fluids with lower surface tensions.

Experiment Overview

The coatings were applied to printed circuit boards with electrical test patterns then the circuit boards were connected to an external power supply and maintained at a constant voltage while using a digital ammeter to measure current across the electrodes.

Using a modification of the IPX7[1, 2] testing standard (see IPX7 Test Method and Aculon® Modifications and Test Results), powered test boards were immersed in water or salt water for an extended time period at a variety of voltages. The circuit’s current was measured while immersed and charted to determine the effect of the water on the circuitry. Increases in the measured current are due to the development of a conductive path (essentially making an electrochemical circuit) through the water medium between the two electrodes. Successful inhibition of such conduction is achieved by coatings provide a barrier to ion migration. Additionally 3 strips of tin coated stainless steel were dip coated with each NanoProof™ coating and the conductivity measured over time to demonstrate NanoProof™ coatings do not prevent push through electrical connections.

Test Boards

In this evaluation, we chose IPC-Association Connecting Electronics Industries approved printed test boards IPC-B-25A[3] which are recommended in the guidelines for testing solder masks (IPC-SM-804C) and conformal coatings (IPC-CC-830B); the schematic for these boards is shown in Figure 1.

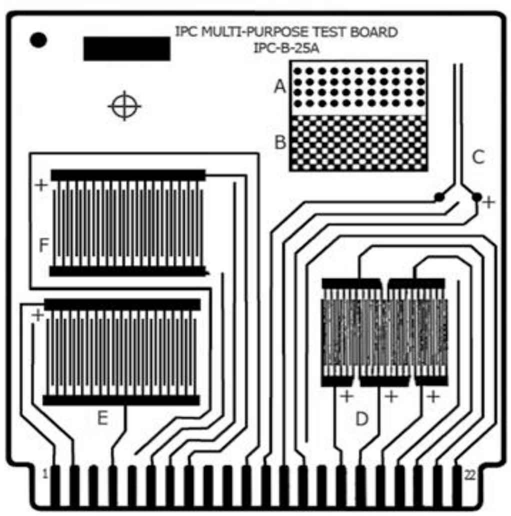


Figure 1. The IPC-B-25A printed test board

Board Preparation and Coating Application

Boards were cut vertically to isolate the E and F patterns, then to maintain testing uniformity, pattern F was used for immersion testing.

Prior to coating, the boards were cleaned with Ionox I3416 Cleaning Solvent, rinsed with IPA then blown dry with compressed air. This surface preparation was chosen to remove common contaminants such as flux residues, dust and other particulates which can result in coating deformities and provide conductive channels that would affect test results in an uncontrolled manner. Appropriate surface cleaning prior to coating is necessary.

Aculon® recommends dispensing, spray coating (in a controlled environment) or dip coating as application methods. For this study, dispensing and dip coating were used to demonstrate the flexibility of application options.

For dip coating, a polyethylene container was filled with the coating solution so the coating solution did not cover the board when the bottle was laid horizontally. The bottle was then shaken 5 times to coat the board, laid down horizontally and let rest 30 seconds. The boards were then removed horizontally and let dry at room temperature overnight. The coating drainage time and angle of the boards during removal controlled the thickness of the coating. The shorter the drainage time and more horizontal the board is removed, the thicker the coating. After drying the boards were potted with a silicone based sealing compound so that just the F pattern was left exposed. Prior to testing the boards were inserted into a standard card edge connector wired to the power supply and sensor. The board was then placed in a beaker of water and tested.

Dispense coating was done with a syringe after the boards had been coated with a silicone sealant leaving the F pattern isolated and uncoated. A volume of coating solution was dispensed to achieve the desired thickness and the coating allowed to dry at room temperature.

Spray coating can be done manually or by automated spray equipment.

IPX7 Test Method and Aculon® Modifications

The water immersion test was based on the IPX7 test standard that has been established by the International Electrotechnical Commission (IEC).[4, 5] The IP Code, sometimes referred to as the Ingress Protection Rating,[6, 7] is used to assess how well coatings are able to protect circuitry and devices from exposure to water or other contaminants.

We have chosen IPX-7 as the method for evaluation in this article as it is viewed as being a rather stringent test of the resistance of coated boards towards direct exposure to water. This test calls for an unpowered electronic device to be immersed in 1 meter of water for 30 minutes. After the 30 minutes, the device is removed and the power turned on. If it operates as it was designed, the device is considered to meet the IPX7 classification. In this test, finished devices (such as a mobile phone) are specified, however due to the vast difference in complexity in devices, we chose to expose test boards directly to water to eliminate the possibility of entrapped air pockets in finished devices affecting the results. While this increases the severity of the tests, it provides more reliability in testing.

Another modification to test at more rigorous levels than IPX7 was immersion in electrically conductive 5% aqueous sodium chloride. This modification approximates extremely aggressive 'real world' conditions like sweat immersion as sea water is on average 3.5% and sweat contains even less salinity. Sample boards were also tested at several voltages since power sources in electronic devices tend to vary substantially. A summary of the test methods is given in Table 1.

Test Method	Liquid Media	Time (Min)	Powered
IPX7	Water	30	No
A	Water	60	3, 6, 12 Volts
B	5% aq NaCl	60	3, 6, 12 Volts

Table 1: IPX7 and Aculon test conditions A and B

Using a BK Precision DC power supply model 1670A a constant voltage of 3, 6, and 12 volts was applied to the test pattern. The development of current flow across the open comb F test pattern from Figure 1 during the 60 minute immersion test was then measured with a Vernier Energy Sensor. After 60 minutes, the board was removed, rinsed with water and evaluated. The system for Test Methods A and B is

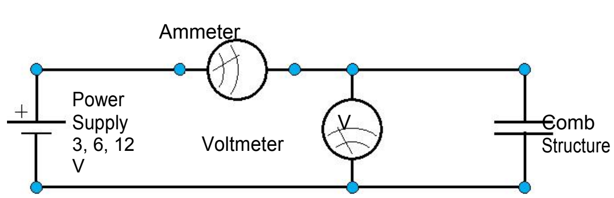


Figure 2. Circuit Diagram for Test Methods A and B

For conductivity measurements a HP 34420A Nano Volt/ Micro Ohm meter was used in 4 point probe mode with 2.54mm gold coated Harwin spring probes.

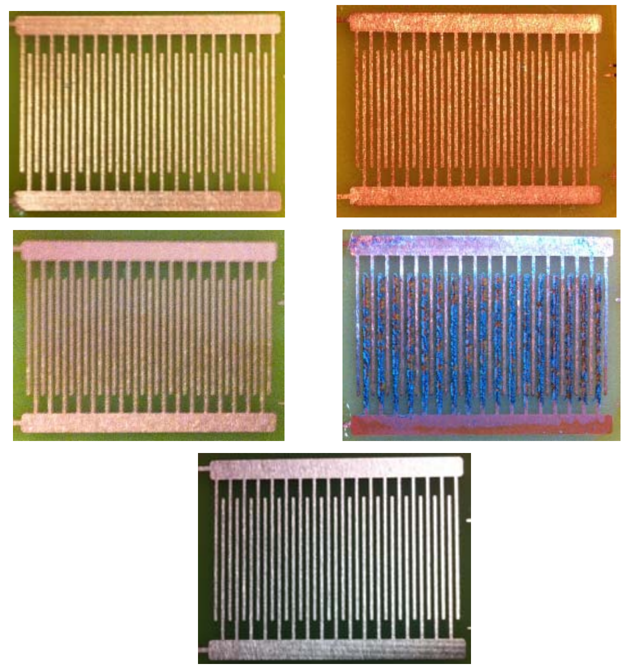


Figure 3. Test patterns coated with NanoProof™ 4.0, 3.5 and 5.0 after testing at 6V in water versus an uncoated pattern and an untested pattern.

Test Results

As previously explained, while the IPX7 standards call for the immersion of finished devices in water, our testing was performed on exposed boards to remove the effect of a specific devices' geometry on the utility of Aculon® NanoProof™ coatings for water-proofing electronics.

Additional modifications beyond enclosure removal were made to the IPX7 protocol to make testing more aggressive: 1) immersing in water or salt water, 2) delivering several different voltages to the circuitry during testing and 3) increasing the immersion interval time to 60 minutes. In every test condition, coated sample boards demonstrated a significant reduction in the amount of corrosion and degradation of the metal traces compared to uncoated samples boards. Figure 3 illustrates the extent to which Aculon NanoProof coatings were capable of protecting test circuits that were immersed in water with an applied voltage of 6V for 60 minutes. Note that after testing, the coated boards appear to be unchanged when compared to as-received test patterns.

For Test Method A, the F pattern of an IPC-B-25A printed test board was coated with NanoProof™ 4.0, 3.5, 5.0 coating and compared with the F pattern on uncoated boards. At all voltages NanoProof™ coatings showed minimal to no corrosion, dendritic growth, copper loss or line thinning (Figure 3). Uncoated boards showed significant corrosion, dendritic growth and line thinning (Figure 4(a)).

Test Method A

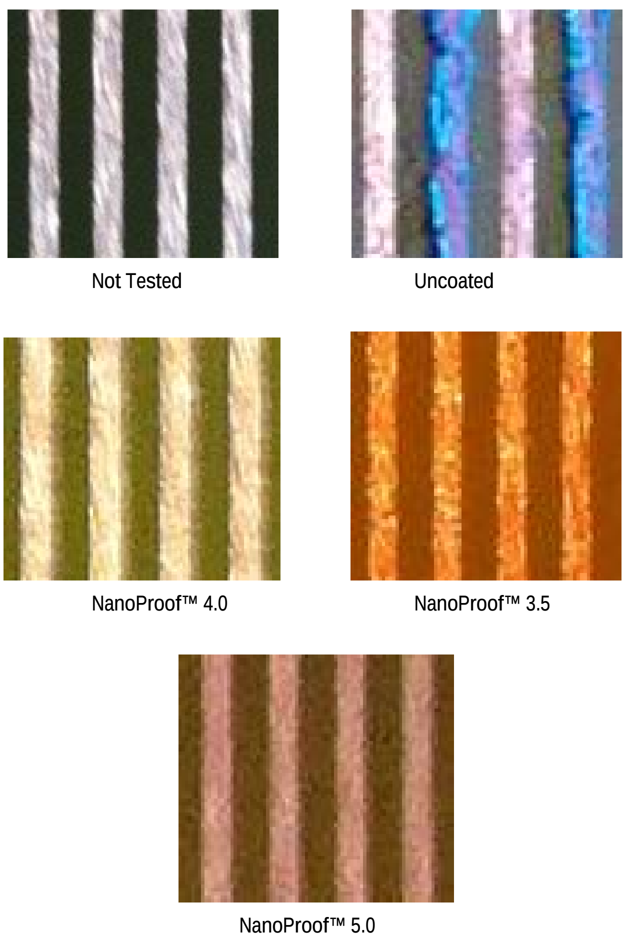


Figure 4(a): NanoProof™ 4.0, 3.5 and 5.0 - coated test patterns after versus uncoated samples in Test Method A. Dissolution of the uncoated boards is evident whereas coated patterns are largely unaffected.

For Test Method B, 5% aqueous NaCl (sodium chloride) was used as a more aggressive test condition. Even with an electrically - conductive fluid, NanoProof™ coatings protected the circuitry from damage, whereas instantaneous high current flow and dissolution of the copper traces was observed on uncoated test boards as illustrated in Figure 4(b). At extended time periods and increasing voltages, all of the copper traces were dissolved in the uncoated boards where the NanoProof™ coated boards remained intact. This illustrates how effectively these coatings protect electronic circuit.

Test Method B

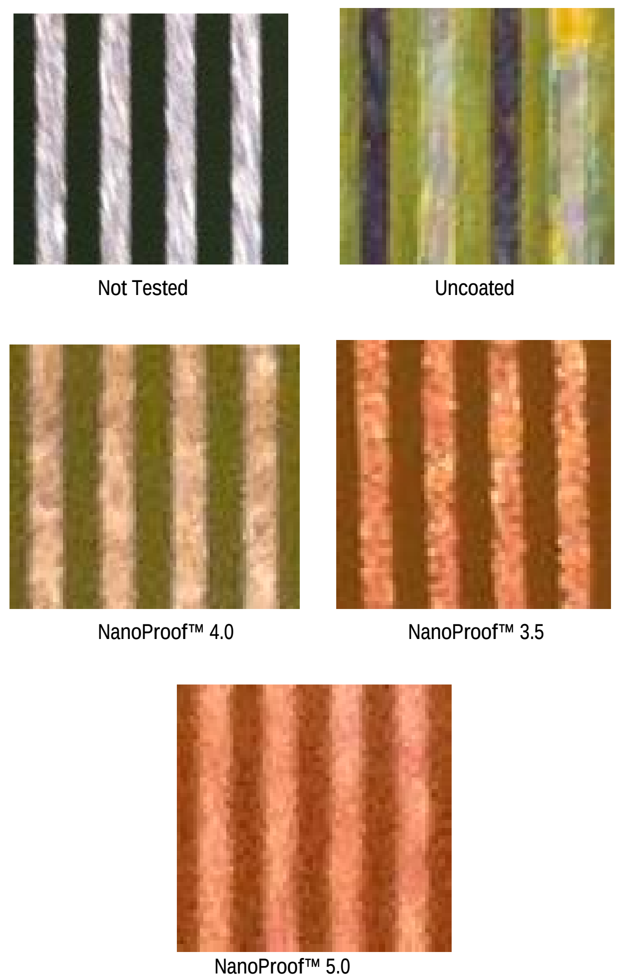
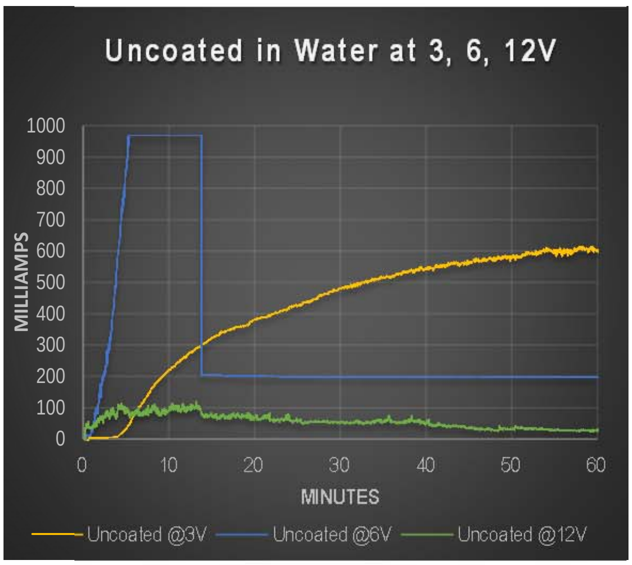
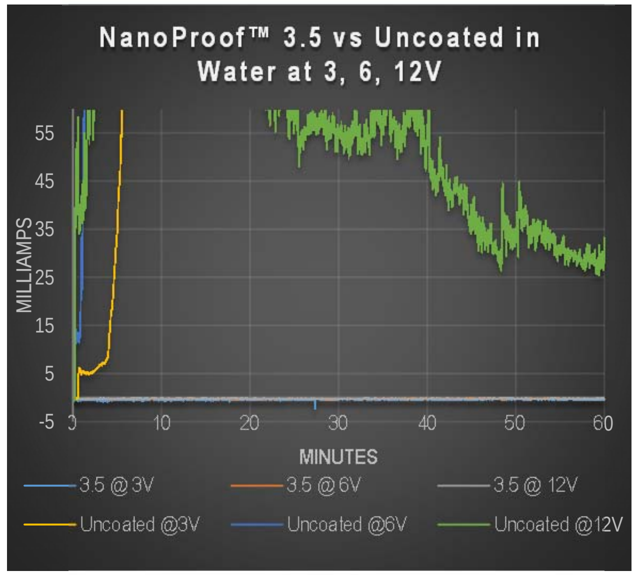


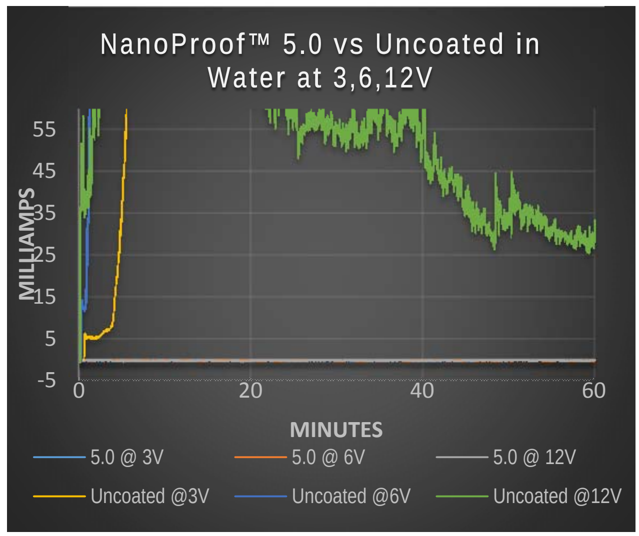
Figure 4(b): NanoProof™ 4.0, 3.5 and 5.0 - coated test patterns after versus uncoated samples in Test Method B. Dissolution of the uncoated boards is evident whereas coated patterns are largely unaffected.

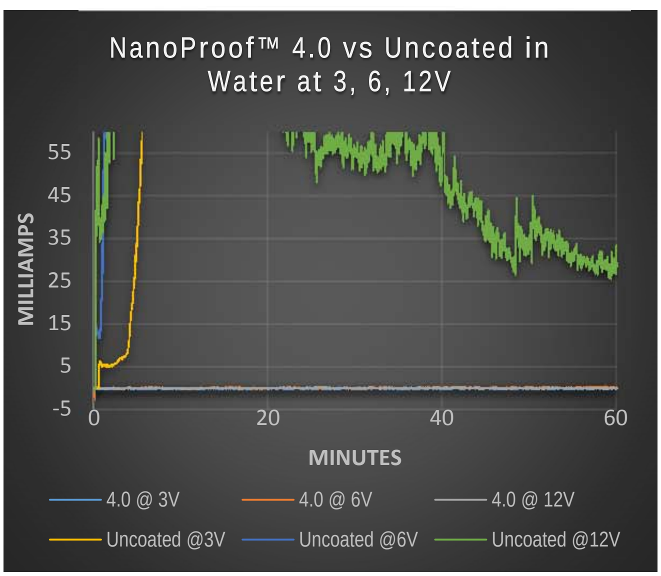
Current leakage of less than 10 milliamps was observed with NanoProof™ coated boards, whereas uncoated boards showed immediate and significant current leakage across the test circuit when using either Test Method A or B. The solution color visibly changed to from colorless to pale blue in the case of uncoated boards, indicating the formation of dissolved copper ions as the traces dissolved. This coloration was not formed with NanoProof™ coated test substrates. Uncoated test patterns typically failed quickly after testing began as the leakage current was greater than 1 Ampere, indicating a complete shorting out of the circuit through the surrounding fluid. Boards coated with NanoProof™ 4.0, 3.5 and 5.0 coatings did not fail in this manner as evidenced in Figure 5.

Test Method A

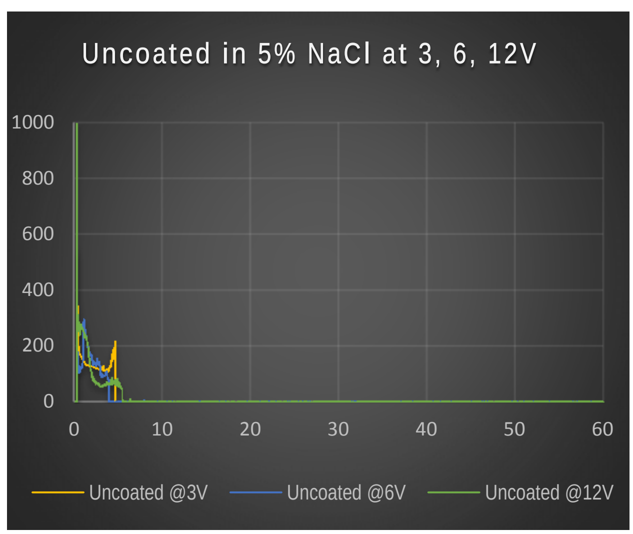


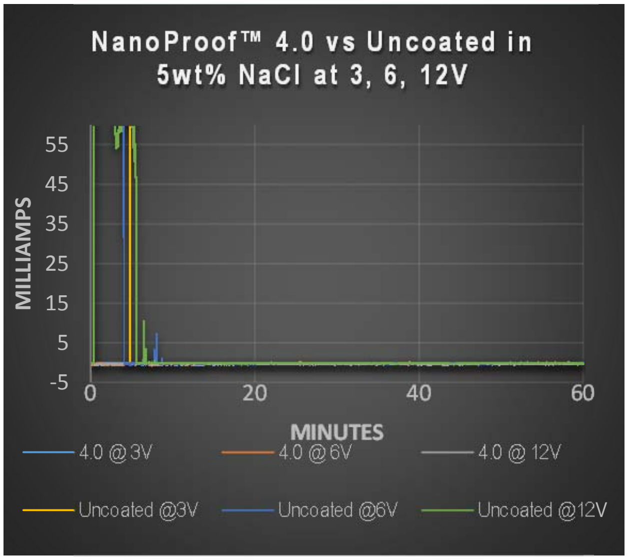


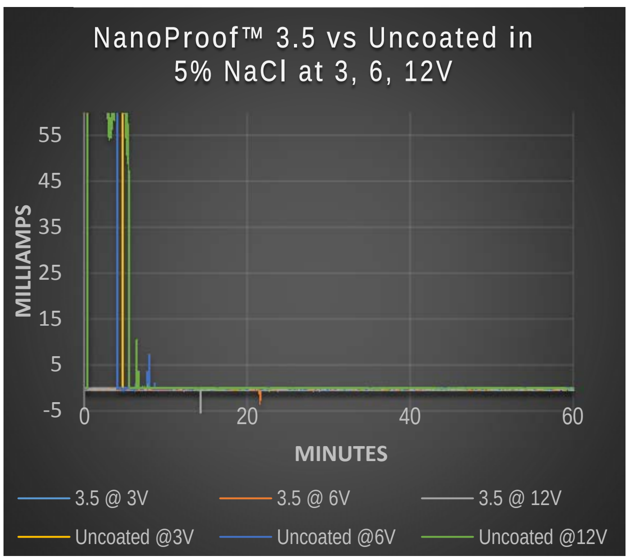


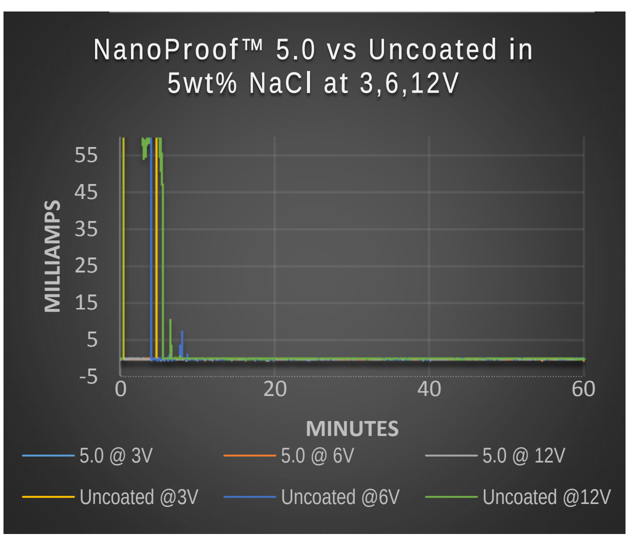


Test Method B









Uncoated test boards were visibly corroded and conducted significant energy when immersed with applied potential in both water and salt water. Test boards coated with NanoProof™ 4.0, 3.5 and 5.0 coating, however, showed negligible current flow and minimal to no copper loss even after 60 minutes immersion. This indicates that Aculon® NanoProof™ coatings inhibited ion migration (and therefore conductive path formation) even with high applied potentials and an electrically-conductive fluid.

NanoProof™	Test Method A (3V / 6V / 12V)	Test Method B (3V / 6V / 12V)
4.0	PASS / PASS / PASS	PASS / PASS / PASS
3.5	PASS / PASS / PASS	PASS / PASS / PASS
5.0	PASS / PASS / PASS	PASS / PASS / PASS

Figure 6. Summary of NanoProof™ Performance

Conductivity of the tin coated stainless steel samples was effectively unchanged over the measurement period, Figures 7(a) and 7(b).

NanoProof™ Coating	Average resistance uncoated	Average resistance 15 minutes
4.0	$4.30*10^{-4}\Omega$	$4.30*10^{-4}\Omega$
3.5	$4.32*10^{-4}\Omega$	$4.27*10^{-4}\Omega$
5.0	$4.27*10^{-4}\Omega$	$4.34*10^{-4}\Omega$

Figure 7(a). Average Surface Resistance for Uncoated Samples and Coated Samples (15 Minutes)

NanoProof™ Coating	Average resistance 30 minutes	Average resistance 60 minutes
4.0	$4.36*10^{-4}\Omega$	$4.33*10^{-4}\Omega$
3.5	$4.33*10^{-4}\Omega$	$4.27*10^{-4}\Omega$
5.0	$4.29*10^{-4}\Omega$	$4.34*10^{-4}\Omega$

Figure 7(b). Average Surface Resistance for Coated Samples (30 and 60 Minutes)

Summary and Conclusions

These results demonstrate how effectively Aculon® NanoProof™ Coatings create a robust barrier for electronic device components, protecting from water-induced damage during operation. Devices coated with Aculon® NanoProof™ can expect to achieve longer lifetimes under 'real-use' conditions in environmentally harsh conditions. We strongly recommend manufacturers use Aculon® NanoProof™ to protect sensitive, high-value electronic devices from environmental stresses.

References

[1]The IP Code is a test standard published by International Electrotechnical Commission (IEC) and describes the level of protection provided by an enclosure. For an explanation of the IP code see: http://www.ce-mag.com/archive/06/ARG/bisenius.htm

[2]IP Code Defined: http://www.osram.com/media/resource/hires/342330/technical-application-guide---ip-codes-in-accordance-with-iec-60529-gb.pdf

[3]IPC-Association Connecting Electronics Industries is an organization that sets standards used by the electronics manufacturing industry: https://www.ipc.org/default.aspx

[4]IEC 60529: Degrees of protection provided by enclosures (IP Code). International Electrotechnical Commission, Geneva: http://www.iec.ch/

[5]IP Ratings vs. NEMA Ratings: http://www.bisonprofab.com/ip-ratings-explained.htm

[6]Understanding the IP (Ingress Protection) Ratings: http://www.maximintegrated.com/app-notes/ index.mvp/id/4126

[7]Interpreting the acronym officially in the standard text: http://www.iso.org/iso/iso_catalogue/ catalogue_tc/catalogue_detail.htm?csnumber=39578

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