IPC-CC-830B Versus the 'Real World': Part 2

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Abstract
Conformal Coatings are often used to increase the reliability of electronic assemblies operating in harsh or corrosive environments where the product would otherwise fail prematurely. Conformal coatings are often qualified to international standards, intended to enable users to better differentiate between suitable conformal coating chemistries, but always on a flat test coupon, which is not representative of real world use conditions.

In order to better correlate international standards with real world-use conditions, three-dimensional Surface Insulation Resistance (SIR) test boards have been manufactured with dummy components representative of those commonly used on printed circuit assemblies.

A variety of commercially available, internationally qualified, conformal coatings have been applied to these coupons by a variety of common methodologies including dip, spray and selective-spray, at a variety of thicknesses. The applied conformal coatings were cured in accordance with the manufacturer's recommendations. The conformal coating thickness and coverage over critical areas was assessed by non-invasive optical methods.

The coated samples were then subjected to 1000 thermal shock cycles (-65°C to + 125°C) and salt-mist cycles to represent typical end use qualification testing. Voltage was applied to the SIR boards during the salt-spray test regime to better correlate to real use conditions. The corrosion evident on assemblies was visually assessed by optical microscopy under 4-40X magnification and compared with the measured SIR to assess corrosion resistance of the various process combinations.

Lead-free solder was used exclusively for this test, and water-washable, cleanable 'no-clean' and no-clean flux samples were included, to investigate the effect of cleaning on the overall reliability of the coated system.

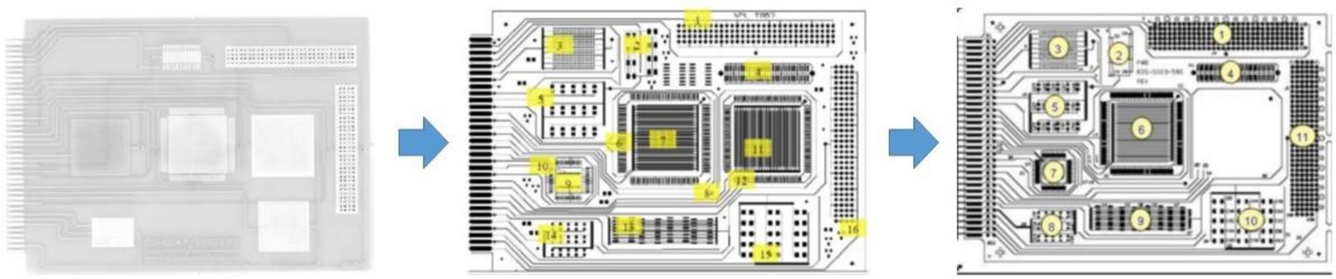
Conformal coating thickness and coverage were assessed for the various coating techniques. The results of the thermal shock and powered salt-spray test results are correlated back to the application method, coating thickness, flux, cleaning and coating chemistry to determine the best overall process and material combinations for high reliability applications.

Introduction
With the increased adoption of electronics in our everyday lives, and the increasingly demanding operating environments and reliability requirements, the use of conformal coating as a means of enhancing electronic reliability continues to grow in importance, particularly in safety critical applications[1].

Assembly process residues, or airborne contaminants in the operating environment can lead to the creation of metallic dendritic growth, leading to leakage currents which can degrade circuit performance or lead to premature circuit assembly failure[2,3]. Ionic species can react with the circuit board's metallic surface (under appropriate conditions, usually a monolayer of condensed humidity) to create these leakage currents. Should the contaminants be corrosive, under the end use environment, and the corrosion products be mobile (i.e. soluble in water) then they can migrate, between traces at different polarities, to further degrade performance, until at some point, the corrosion products form a dendrite-like growth of metallic compounds. This can cause an electrical short between the two traces. Often this will lead to catastrophic failure of the device in question[1,2,3]. This failure mechanism is known as electrochemical migration (ECM)[4]. In addition to the short-circuit failure mechanism, there is an open circuit failure mechanism that is caused by extensive localised corrosion to a conductive trace.[1,2,3],

Surface Insulation Resistance has been demonstrated to be a valuable tool for measuring the leakage current between conductive traces[1] and forms the basis for most standards relating to the minimum performance of conformal coatings. Materials characterisation, process or performance validation by SIR has a long history on flat 2D inter-digitated test coupons, and are the basis for many reliability evaluations and indeed, the basis of many of the international standards including MIL-I-46058C, IPC-CC-830 and IEC-61086.

The main issue with a flat 2D test coupon is that it does not really model the final product use. Kinner[5], Hunt et al.[6] and Pauls[7] all used variations on the same idea to test material combinations under conditions more similar to real end-use conditions, with various sites designed to trap residues or provide coating coverage challenges. These test boards are now called out in process evaluation methodologies such as IEC-61189-5 and IPC-5704. The design evolution is shown in Fig 1 below.



Kinner 2004 | Hunt et al. 2006 | Pauls et al. 2006

Fig 1. Evolution of B52 Test Coupon

Conformal coatings, are thin polymeric coatings that are applied to all, or particularly sensitive parts of an assembly, typically by brushing, dipping, spraying, selective spraying/dipping, and vapour/plasma deposition. Conformal coated assemblies are often able to survive environments that cause uncoated assemblies to fail[8,9]. However, most published work has shown a correlation between conformal coating coverage and the ability to protect circuit assemblies from these harsh environments [1,6,8,9]. Essentially the message is, if the coating is not present over metallic surfaces, then it will provide less than optimum protection. In fact, due to localised concentration effects, small voids in the coating coverage may actually increase the degree of corrosion[4,10].

Hillman et al[11], have undertaken a multi-year, state of the industry review, in which they have coated and cross-sectioned multiple IPC-B52 assemblies using a variety of common conformal coating materials (CC_830 'qualified') and normal application methods to evaluate the ability of the coating and process to coat the parts uniformly. The results published to date have shown a wide variation in nominal thicknesses, and uniformity with some coatings and application processes leading to much better sharp edge coverage than others. The wide variation in material thickness and lack of edge coverage would be expected to result in reduced protection in harsh environments.

So given that the material performance in the end-use environment is dependent upon a combination of the conformal coating material itself and the application process by which it is applied, it seems logical to extend this methodology to conformal coated assemblies. The IPC-B52 test coupon has been used for evaluating the electrochemical compatibility of typical process materials[7] as well as soldering[11], and cleanliness assessments/cleaning evaluations[7].

However, the components that cause problems for conformal coating are not necessarily the same as those that cause problems for cleaning. In addition, component types, arrays and placement become important factors to the success or otherwise of a conformal coating process. To this end, it was decided to design an original test coupon in the style of the B-52 coupon, but using a variety of components and arrays that might prove more challenging than the B-52 from a coating perspective. The coupons also contained bare 2D SIR patterns found within the international test standards. These assemblies would then be coated with a variety of materials claimed to meet the requirements of CC-830, by a variety of normal application methods, before being put through a sequential test program. The test program consisted of Thermal shock cycles designed to stress the coating, prior to a powered salt-mist test, followed by a long term steady state humidity test.

New Test Coupon Design

The test board was designed in two double-sided sections, conceived in a similar fashion to the B-52 board. One side was conceived to be an electrically active SIR coupon similar in design to the B-52 with the inclusion of regular 2D SIR comb patterns taken from the B25A pattern D, B24 and IEC-61086 coupons, whilst the other was intended for visual inspection, mechanical testing and material characterisation.

Normally, SIR dummy components are mounted on these types of test assemblies, but to simplify production as much as possible for an end user, the board was largely designed keeping the component terminations at the same bias, and making a measurement between the terminations as shown in figure 2.

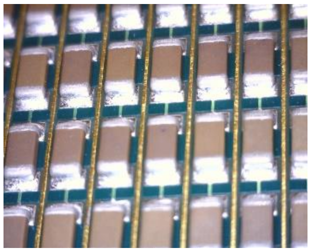


Fig 2 Components terminations at same bias

However, since the interest of this paper is largely related to the ability of the conformal coatings to prevent ECM, and knowing that ceramic components can be difficult to coat, some of the patterns were laid out with the terminations at a different bias as shown in figure 3.

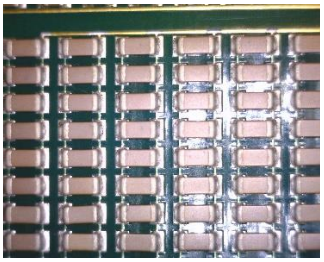


Fig 3. Component terminations at opposite polarity.

Due to the relatively fine pitch of the QFP selected, and given that the interest was primarily in evaluating the coating of the leads themselves, it proved necessary to use a dummy package and to use the pads themselves as the conductive traces, using alternating leads at the same potential as shown in fig 4.

Fig 4. QFP leads at alternating polarity.

The overall board design attempted to group fairly large arrays of discrete components, close to QFP and SOIC devices in arrangements typical of those seen on more problematic assemblies, as shown below in figure 5. Components were chosen to give higher standoff heights (more of a coating challenge), rather than finer pitch.

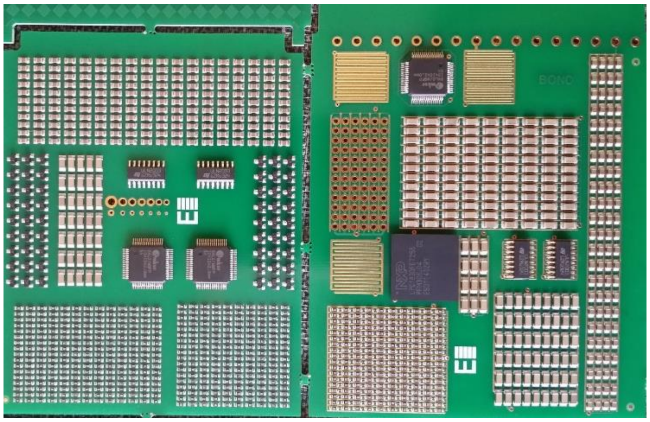


Fig 5. Top side view of new test coupon.

The bottom side of the mechanical / visual inspection / characterisation coupon is heavily borrowed from an EMS internal material characterisation board (Ref. Celestica), whilst the SIR board contains a 16 way connector tab, with a common bias distributed to the test patterns by a ‘zero-ohm’ bridge, to enable only specific patterns to be tested if required and to prevent excessive bias draw in case of a short developing as shown in figure 6.

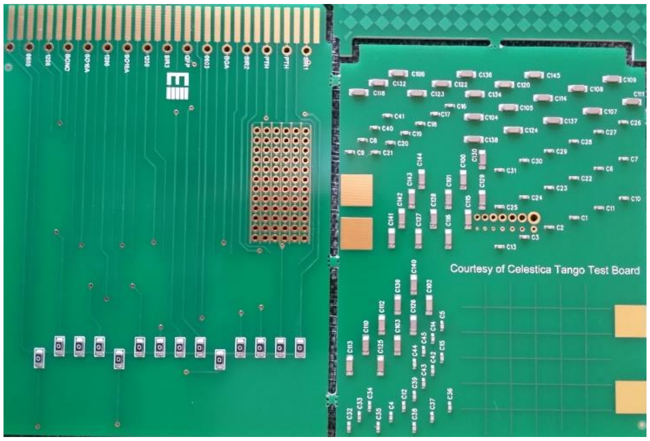


Fig 6. Bottom side view of new test coupon.

Unfortunately, the through hole vias on the SIR board intended for axial components to be soldered were not populated by the board assembler, but this may be rectified by the time this material is presented. Axial components are amongst the hardest to coat with conventional liquid conformal coatings and this data would have been very valuable. The SIR patterns are summarised in Table 1.

Table 1 – Summary of SIR patterns

SIR Pattern	Number devices in array	Line / mil	Spacing / mil
0805	92	8	8
1206	108	8	8
SO16A	1	8	4
1206 (Non-polarised)	12	8	8
SO16B	1	8	4
1206 (Polarised)	54	8	8
SIR 3	1	16	20
QFP	1	12	12
0603	180	8	8
BGA	1	8	8
SIR2	1	16	20
SIR1	1	16	8

Bare Boards
The bare boards were made from FR4 laminate with 1Oz Cu. They were supplied coated with a screen-printed glossy, liquid photoimageable solder mask and developed and cured in accordance with the manufacturer's instructions, including the required pre- and post-bake processes. The boards were then finished with an ENIG solderability finish. The board manufacturer was concerned that lead-free HASL couldn't be guaranteed to be bridge free, and they had no other finish available.

Soldering
The boards were assembled using both a water-washable lead-free paste (and cleaned with aqueous saponified cleaning), and a no-clean paste formulation that has previously been presented as being 'compatible' with conformal coating, using the manufacturer's normal process parameters. Both pastes were SAC305 alloys.

Conformal Coating
The conformal coatings selected were applied by a contract conformal coating service, using a variety of application methods, including brushing, dipping, manual spray, and selective coating (atomised spray and non-atomised film coating), using the contractor's normal application and inspection processes. All coated boards were cured in accordance with the manufacturer's recommendations as per the product datasheet, and left for at least 10 days at ambient laboratory conditions prior to testing.

The following materials were selected for the first phase of the study, and are shown in Table 2 along with the nominal thickness of the applied conformal coating was measured on the Copper test pads using an Eddy Current meter.

Table 2 – Conformal Coatings Selected for the Study

Designation	**AR1**	**AR2**	**UR1**	**UR2**	**UR3**	**UR4**	**UV1**	**UV2**	**SR1**	**SR2**
QUAL	MIL	CC	MIL	CC	CC	CC	MIL	CC	MIL	CC
Type	SB	SB	SB	SB	100%	100%	100%	100%	100%	100%
Cure	T	T	T	T	T	T	UV	UV	RTV	RTV
Temp / °C	85	85	76	70	70	70	NA	NA	RT	RT
Time / Mins	10	10	1800	60	10	10	NA	NA	1440	1440
Application Method	**Thickness / µm**									
Selective Vendor 1	30	25	52	45	100	100	75	54	125	115
Selective Vendor 2	75	55	75	70	250	250	130	120	143	128
Hand Spray	25	25	31	29	N/A	N/A	85	40	N/A	N/A
DIP	35	30	42	39	N/A	N/A	N/A	N/A	N/A	N/A

Soldering Interconnections
Since the thermal shock test regime was to be evaluated solely by visual inspection, the interconnects were not soldered until after the conformal coating process and thermal shock cycles had been completed. 1 mm, Teflon insulated, solid copper wire was hand soldered to the required test points, using a no-clean lead-free cored solder wire as shown in figure 7. A shield was used to prevent flux-reside spitting onto the test-board. The residues were left un-cleaned to minimize the potential for damage to the applied coating. To prevent the interconnect solder joints from being the cause of salt-spray failures, the solder joints and zero-Ohm resistors were completely encapsulated with a soft and flexible, hydrophobic polyurethane potting material, known to have good salt-spray resistance. The potting material was cured in accordance with the manufacturer's recommendations.

Fig 7. Soldering and Potting of interconnects

Test Regime

Many automotive company specifications for the evaluation of conformal coating, require a sequential series of tests to be performed on the test board, whereas most international and industry standards require a new-coupon be used for each specified test. This has 2 main drawbacks:

1. The use of a new coupon does not fully assess the long-term performance impact of consecutive test regimes.
2. Given the wide range of allowable thicknesses, it would be possible to tailor the applied thickness to suit the required test. It is entirely possible then, that there is no single thickness at which a material would be capable of passing all of the required tests.

It was decided therefore, to follow the consecutive test-method regime favoured by the automotive industry.

The test sequence performed is shown below in figure 8.

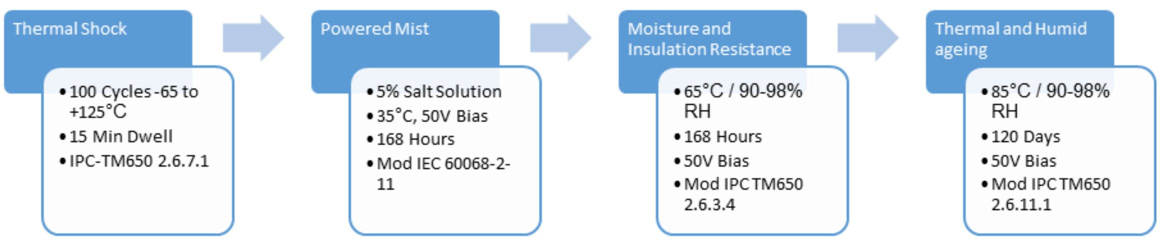


Fig 8. Sequential Test Regime

Experimental

Thermal Shock Testing

Thermal shock testing is intended to fatigue the coating prior to evaluating long-term performance of the conformal coating in surviving rapid transitions in temperature. The IPC TM650 2.6.7.1 test-method was used for the purpose of this evaluation, although it was extended to 1000 cycles, typical of automotive applications, and was performed in a newly delivered, factory calibrated production chamber (shown in figure 9). Assemblies were subjected to 1000 cycles from -65°C (-85°F) to 125°C (257°F), with 15 minute dwells at temperature extremes in accordance with IPC TM650 2.6.7.1. Boards were removed after 100 cycles and then at 250, 500, 750 and 1000 cycles and visually inspected for cracks, delamination and other deleterious conditions at 10X magnification.

The intention of this test regime, is that should the coating be unable to resist the required thermal shock cycles without cracking, it would then be more susceptible to corrosion failures during the powered salt-mist testing, with the consecutive powered humid and high temperature/humid conditions further driving corrosion in susceptible coupons.

Fig 9. Production thermal shock chamber

Salt-Mist Testing
Performed in accordance to IEC 60068-2-11, using 5% $NaCl_{(aq)}$ solution, in a calibrated production chamber (fig 10). Coupons were mounted in the chamber in vertical orientation to provide some draining, as typically seen in mounted assemblies. In a departure from the IEC test, bias was applied continuously during the test period, which was extended from 96 hours to 120 hours. The SIR of the test patterns were measured pre-, during (twice daily), and 48 hours post-test.


Fig 10. Humidity / Salt-mist chamber

Moisture and Insulation Resistance (MIR)
After the completion of the salt-spray test protocol, the test samples were removed from the production chamber, and the chamber was set to complete 5 automated clean and purge cycles to remove potential NaCl contamination. The boards were then placed back into the chamber, the drip guard attachment was fitted and the boards SIR were measured at ambient laboratory conditions (25°C, 45% RH). The chamber temperature was then raised to 65°C/50% RH and held for a period of 4 hours to let the chamber and boards equilibrate, prior to raising the humidity to 90-98%. 50V Bias was applied continuously to the boards, and SIR measurements were made twice daily during the 168 hour duration of the test. At the completion of the test, the humidity was reduced to 50% and then the chamber temperature was slowly reduced to ambient conditions to minimise chance of condensation. The boards were left a further 2 days at ambient conditions, prior to the final SIR measurement.

Thermal and Humid Ageing
Once the MIR testing was completed, the boards were loaded into a production Temperature/humidity chamber. The chamber was set to 25°C, 50%RH and stabilised for 4 hours prior to making the initial SIR measurement. The chamber was then ramped up to 85°C, and 85%RH. 50V bias was continually applied, the first MIR measurement was made after 1 day stabilisation, and measurements were made approximately every 2 weeks throughout the 120 day test. At the completion of the ageing period, the conditions were returned to 25°C/50%RH for 2 days before the final SIR measurement was made.

Results

Conformal Coating Application

All of the boards were inspected at 4-10X magnification, under black light (where applicable) prior to test commencement. In general, and as anticipated, more defects were discovered in the selectively coated assemblies, with sharp edge and component lead coverage and capillary flow effects, significantly worse than the other application techniques, especially for one of the UV curable coatings, UV1 as shown in fig 11.

Fig 11. Examples of Selectively applied UV1 conformal coating, showing poor edge and lead coverage.

One of the acrylic materials, AR2, was applied selectively, by what was described as a 'dry spray process' and was seen to give excellent uniformity and coverage of sharp edges and component leads as shown in Fig 12.

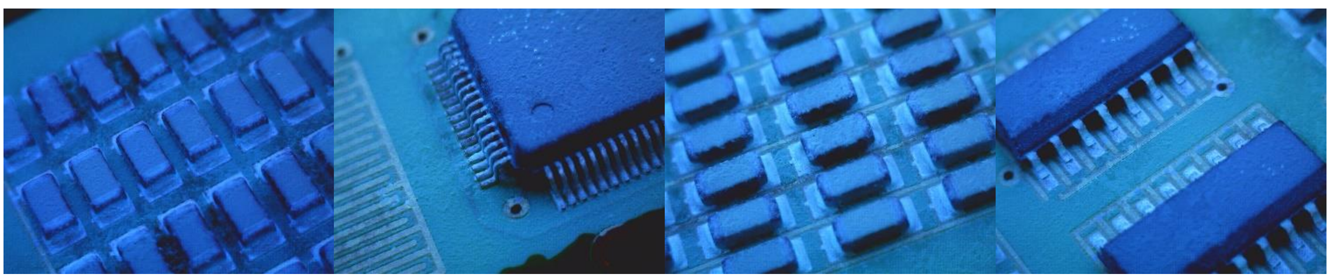


Fig 12. Examples of improved uniformity, sharp edge and lead coverage of AR2 applied by selective "Dry-Spray" process

Thermal Shock

At the time of writing, 750 thermal shock cycles had been completed. The maintenance team ignored the 'leave experiment running' sign and the first test regime was stopped after 19 cycles. The boards were removed from the chamber and inspected at 10X magnification for signs of cracking or any other stress induced defect. Polyurethane coating UR1 showed significant degrees of cracking and delamination after 19 cycles as shown in fig 13.

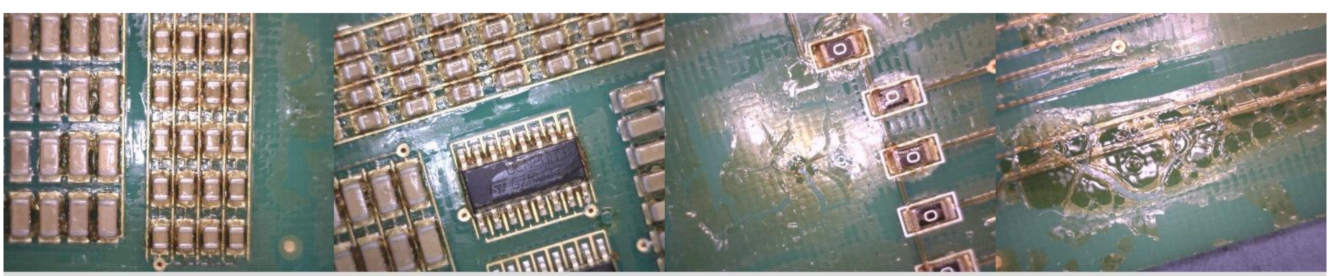


Fig 13. Examples of UR1 cracking and delaminating after 19 thermal shock cycles

UV curable conformal coating, UV1 showed signs of delamination from moulded component bodies as shown in fig 14.

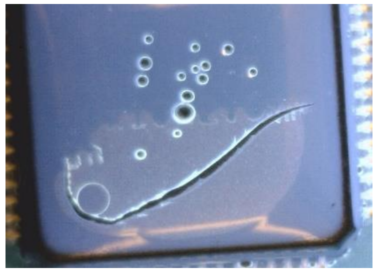


Fig 14. Cracking and delamination of UV1 on component body after 19 Thermal shock cycles.

At the completion of 100 Cycles, UR1 had continued to crack and delaminate, and UV1 showed clear signs of cracking, especially around solder joints. UV1, which was certified to withstand 100 cycles of the same thermal shock conditions on flat FR4 had failed somewhere between 20 and 100 cycles on a more representative test vehicle as shown in Fig 15.

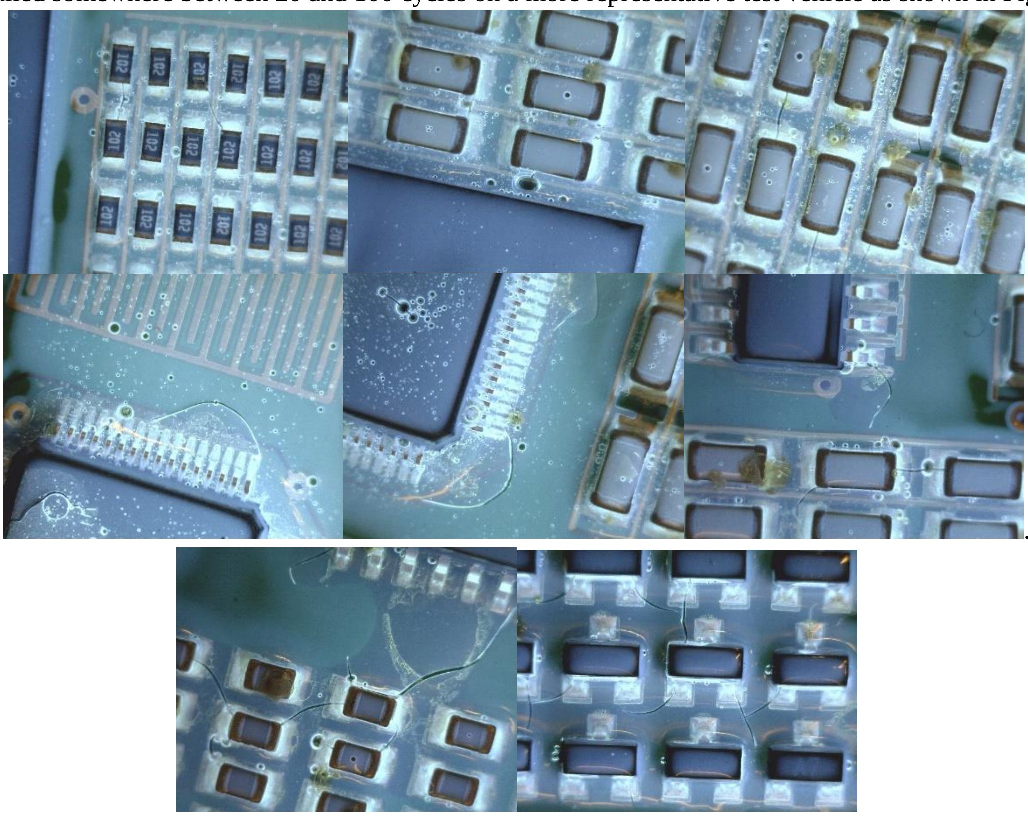


Fig 15. Extensive cracking of UV1 at 100 thermal shock cycles

By the completion of 750 thermal shock cycles, there were some small cracks evident on UR4 cleaned samples. One board had been supplied with extensive bubbles present, and it appeared that the cracks were initiating between bubbles, as shown below in figure 16. It was also noted that the coating had significantly darkened during the thermal shock cycles, and the UV tracer no longer functioned. The lack of UV tracer with increased thermal ageing was noted across all of the urethanes tested in this work. The other test vehicles, without the extensive cracking, showed the same darkening, but no crack formation.

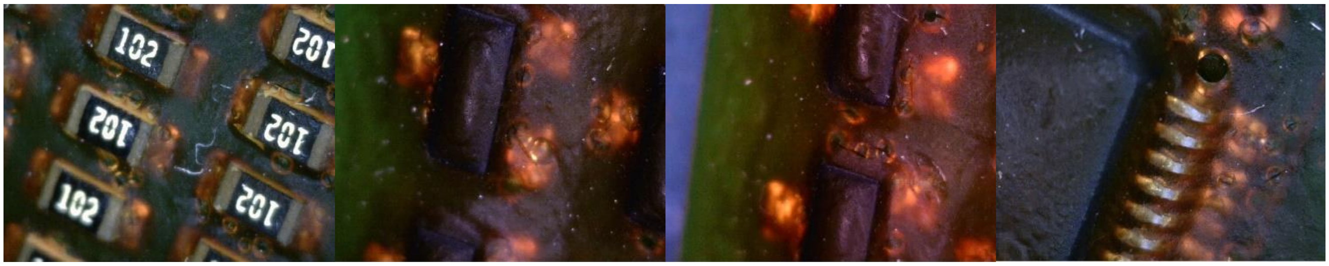


Fig 16 – Darkening and crack propagation through adjacent bubbles in UR4 at 750 thermal shock cycles.

To summarise the data from the thermal shock testing, coating/process combinations yielding cracking, delamination and other failure mechanisms within 100 cycles are highlighted in red in Table 3. Those combinations producing failures after 100 thermal shock cycles are highlighted in Orange. Those combinations that still showed an acceptable result after 750 cycles are shown in green.

Table 3 – Summary of Thermal Shock Cycles

Designation	AR1	AR2	UR1	UR2	UR3	UR4	UV1	UV2	SR1	SR2
Selective Vendor 1	30	25	52	45	100	100	75	54	125	115
Selective Vendor 2	75	55	75	70	250	250	130	120	143	128
Hand Spray	25	25	31	29	N/A	N/A	85	40	N/A	N/A
DIP	35	30	42	39	N/A	N/A	N/A	N/A	N/A	N/A

Salt-Mist Testing.
At the time of writing, the salt-mist testing had been performed on UR1 coated test-vehicles only, since it had failed to withstand 19 thermal shock cycles. The test vehicle selectively coated by vendor 2 was selected, since it had the best overall coverage for UR1 coated assemblies, but also the most extensive cracking and delamination. The results are shown in Fig 17.

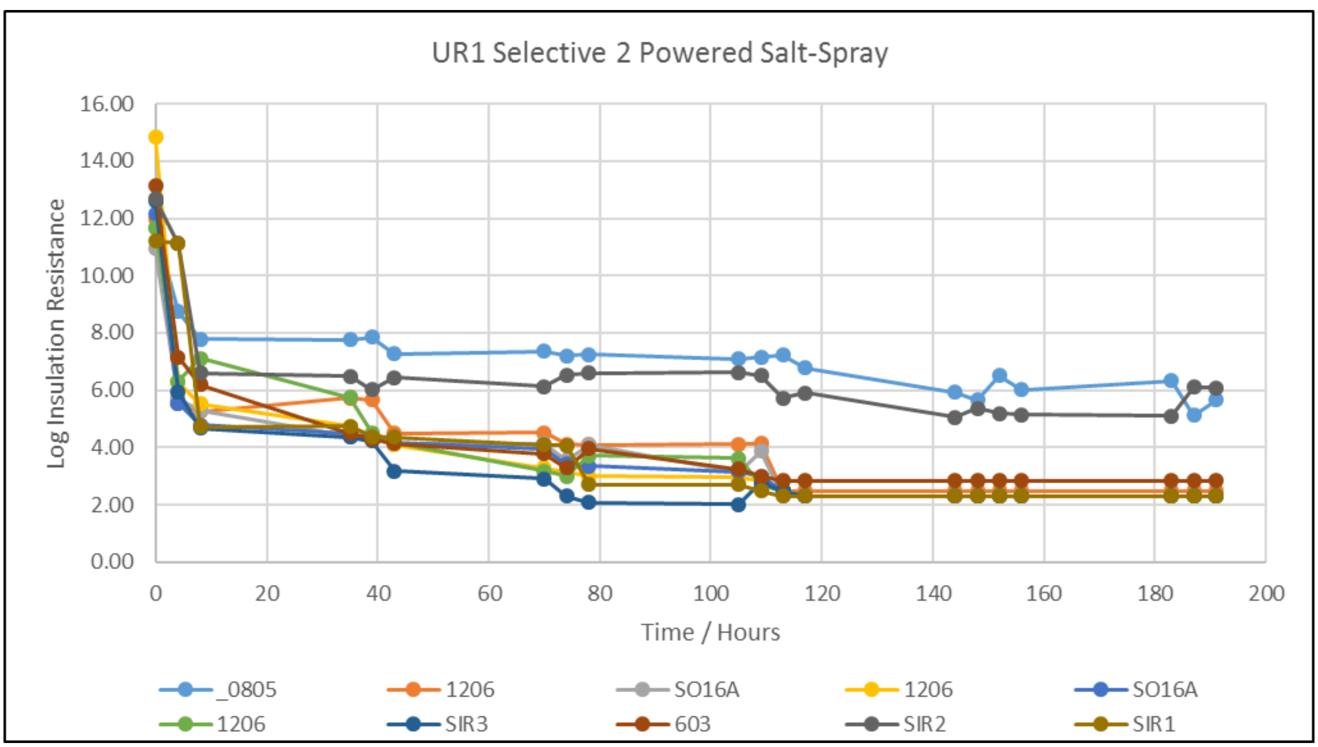


Fig 17. Powered salt-mist data for UR1 selectively coated by vendor 2.

The data started at normal, acceptable levels, but dropped very quickly to an unacceptably low level on all of the test patterns tested, intuitively suggesting that the cracked coating gave little or no protection to the test vehicles during the salt-mist testing. At the completion of the salt-mist testing, the boards were visually inspected at 10X magnification to enable better correlation with the SIR data. Example photos are shown in Fig 18, but in general, all show significant areas of corrosion product formation. It is worth noting the ENIG finish would be expected to be more corrosion resistant than Copper, Tin or Silver finished.

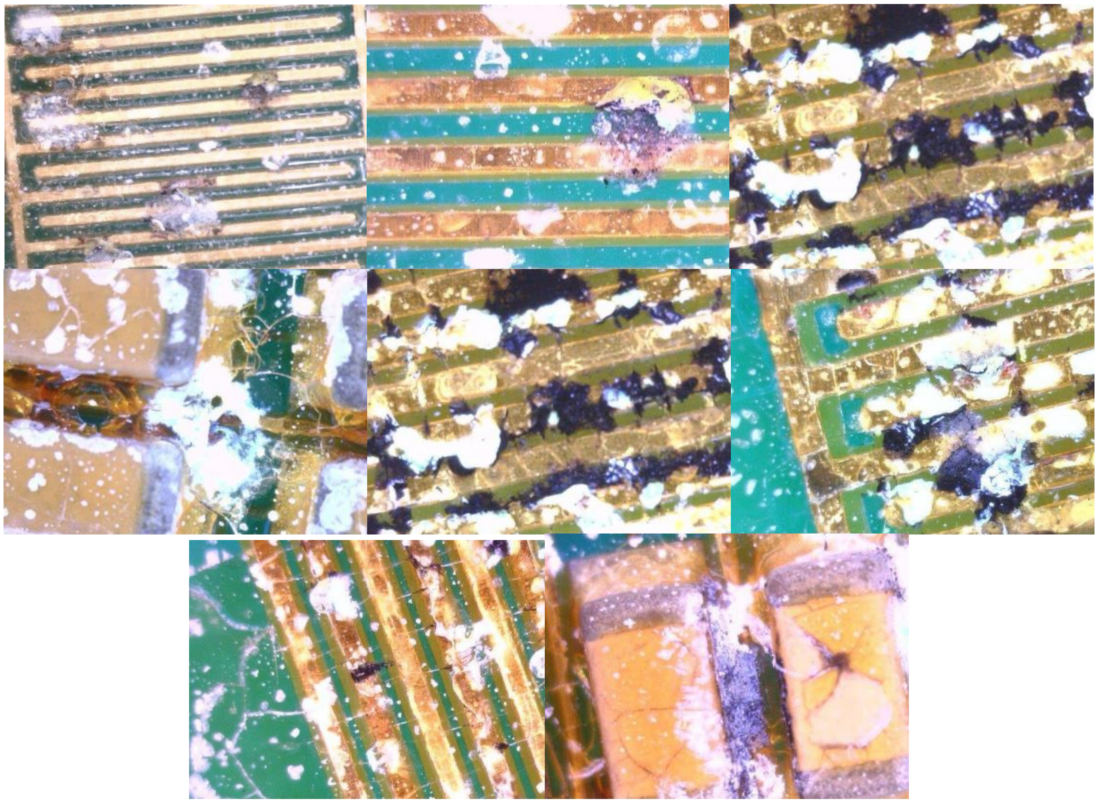


Fig 18. Examples of corrosion seen on UR1 test vehicles after powered salt-mist testing.

At the time of submission, the moisture and insulation resistance testing had not been started but results would be presented at the conference.

Conclusion

IPC-CC-830 is intended to discriminate high performance materials from materials that provide lower performance. However, all qualification data is produced on flat 2D, FR4 test coupons finished with bare Copper.

This work shows clearly that the flat-test board used for IPC-CC-830 qualification does not adequately stress conformal coatings during thermal shock testing, and that materials meeting the requirements of IPC-CC-830 cannot necessarily be assumed to meet customer expectations in real-life testing on populated assemblies, even when water-washable chemistry is used to eliminate the variable associated with no-clean residues.

Once the conformal coating is cracked, it will provide greatly reduced protection to the assembly against its operating environment. This has been highlighted through the use of a powered salt-spray test, on an admittedly small and incomplete sample set at this time. The ENIG finish is likely to be more corrosion resistant than other finishes, so it is expected that an alternative finish would yield even more corrosion products.

This work has been a first attempt to combine ‘process-qualification’ like test methodology with material performance evaluations of conformal coatings and has shown that the methodologies can be used together, but that there are possible refinements to be made on a continuous basis, both to the test vehicle and the evaluation criteria.

When the test matrix has been completed, it should be possible to make correlations between application method, coating thickness and performance under more real world conditions.

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Contents

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Introduction to International Standards

- 1972 MIL-I-46058 rev C published
- 1998 - MIL-I-46058C Inactive for new designs
- IPC-CC-830 intended to be equivalent industry standard
- IPC-CC-830-B current going into Rev C
- IEC-61086 is international standard

Comparison of standards

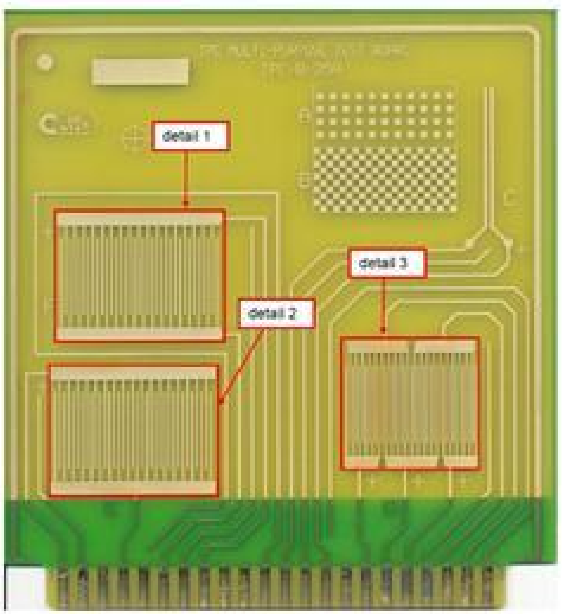
	MIL-I-46058C	IPC-CC-830	IEC-61086
Fungus Resistance	ASTM-G21	2.6.1.1	IEC-60068-2-10
Shelf-life	Aged material	IR/DWV	Visc/UV
Insulation resistance	Mil-STD-202		IEC-61086-3-1
Dielectric Withstanding Voltage	MIL-STD-202	2.5.7.1	IEC-61086-3-1
Q Resonance	ASTM D 150		N/A
Thermal Shock	MIL-STD-202	2.6.7.1	IEC-60068-2-14
Moisture Resistance	MIL-STD-202	2.6.3.4	IEC-60068-2-78
Flexibility	FED-STD-141	2.4.5.1	ISO 1519
Hydrolytic Stability	120 days 85C / 91-99% RH	2.6.11.1	N/A
Flame Resistance	FED-STD-141 (2021)	UL94 HB	IEC-60707
Salt Spray			IEC-60068-2-11

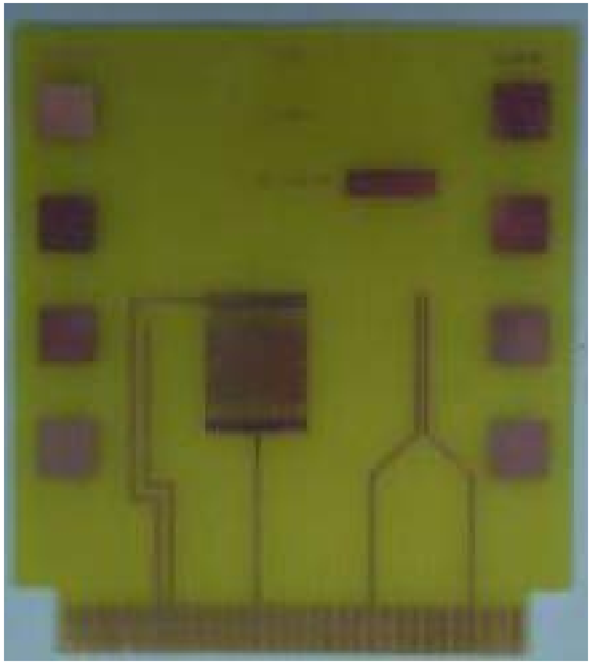
Comparison of standards

	MIL-I-46058C	IPC-CC-830	IEC-61086
Insulation resistance	RT	RT	RT
DWV	1500 V AC (60Hz)	1500 V AC (60Hz)	1500 V AC (60Hz)
Thermal Shock	-65 – 125C, 50 cycles	-65 +125C, 100 cycles	-65 +125C, 100 cycles
Moisture Resistance	7 days 65C / 95% RH	10 days 65C / 95% RH	10 days 65C / 95% RH
Flexibility	3mm mandrel	3mm mandrel	3mm mandrel
Hydrolytic Stability	120 days 85°C/ 91-99% RH	Same	1000 Hrs @ 125C
Flame Resistance	FED-STD-141 (2021)	UL94 HB	UL94 V
Salt Spray			35C / 5% NaCl

Similarity between standards

- All tests performed on 'flat' coupons
- Bare FR4 substrate





The Issues

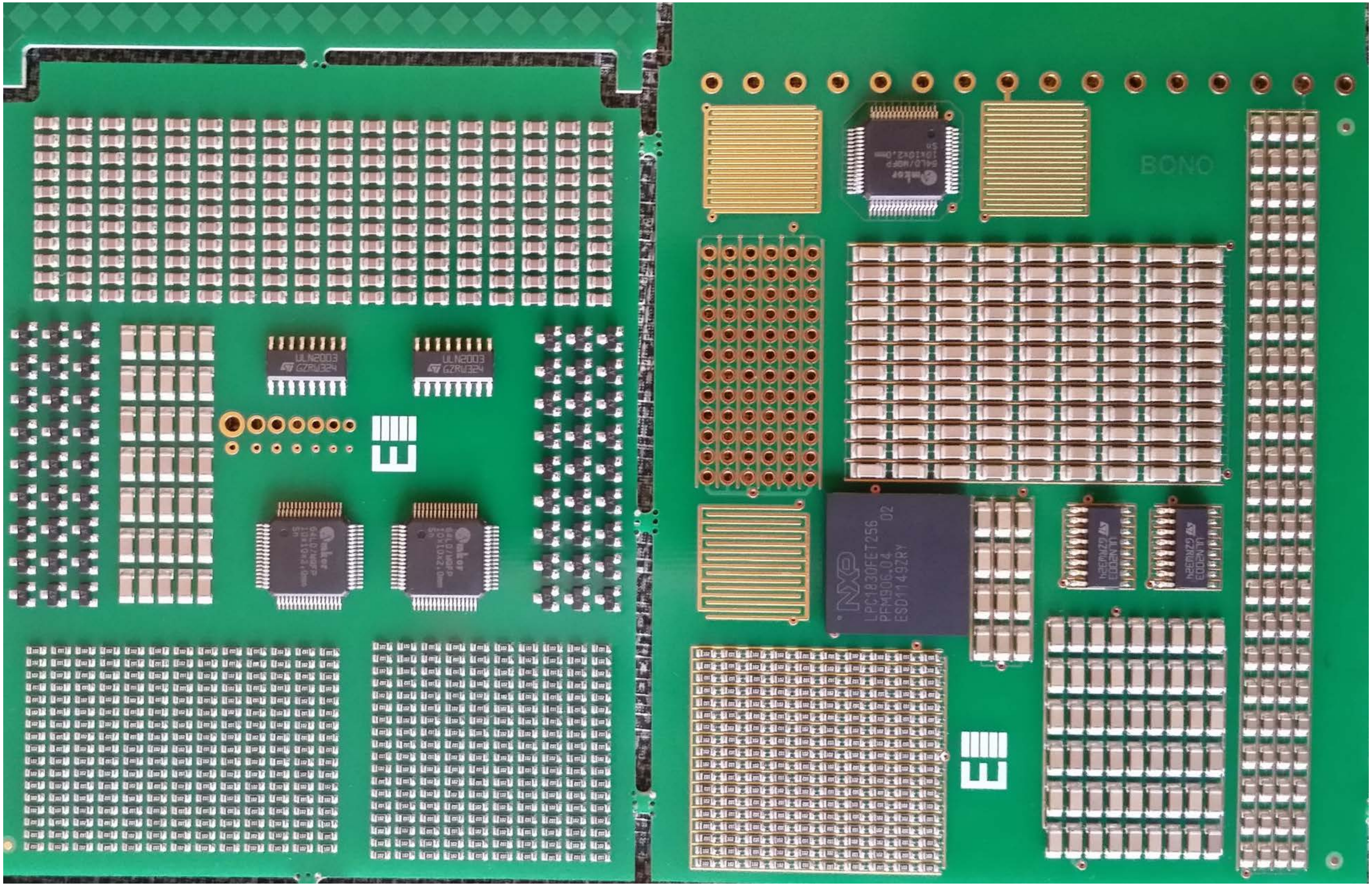
- Tests and methods, pass/fail criteria etc. C. 50 years old.
- Still trying to align CC-830B to MIL-I-46058C
- How meaningful is CC-830 as a predictor of material performance?
  - Tests performed in isolation (can tailor thickness to test)
  - Flat, cleaned substrates

New approach

- Use populated dummy assembly (3D) instead of flat (2D) coupon
  - Standalone SIR patterns
  - Integrated component array SIR patterns
- Solder mask not FR4
- ENIG finish
- Lead Free Solder (Water-Washable and NC)

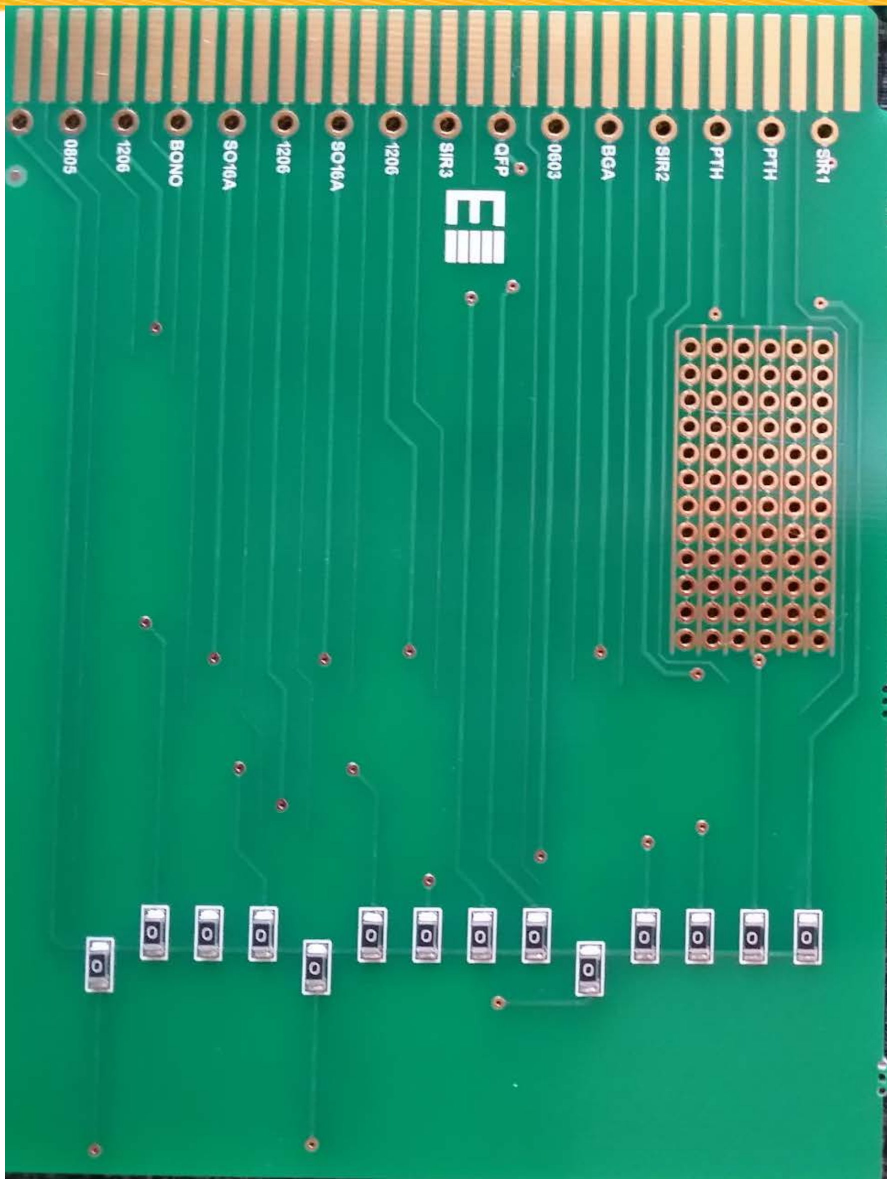
New approach

- Attempt to test and benchmark performance under more realistic conditions
- Coated boards subjected to sequential test regime

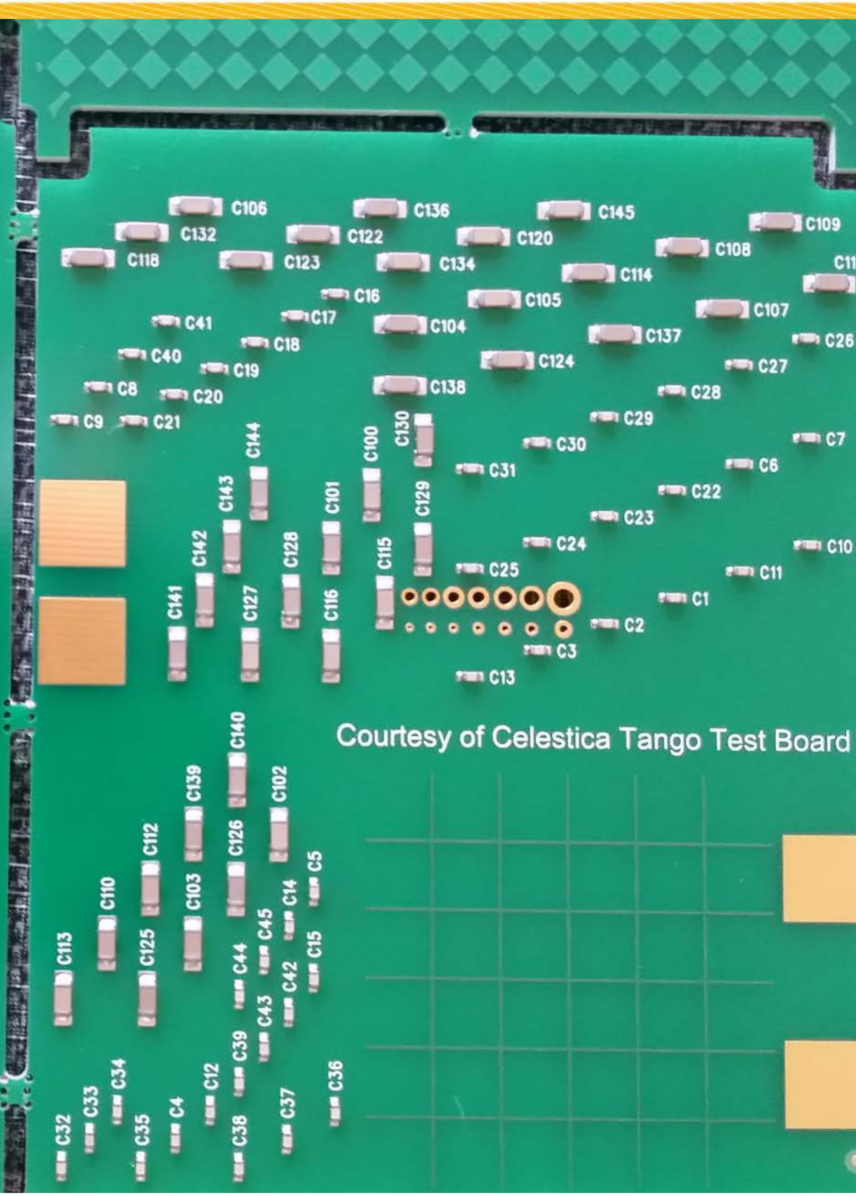


Visual Inspection

SIR Test board

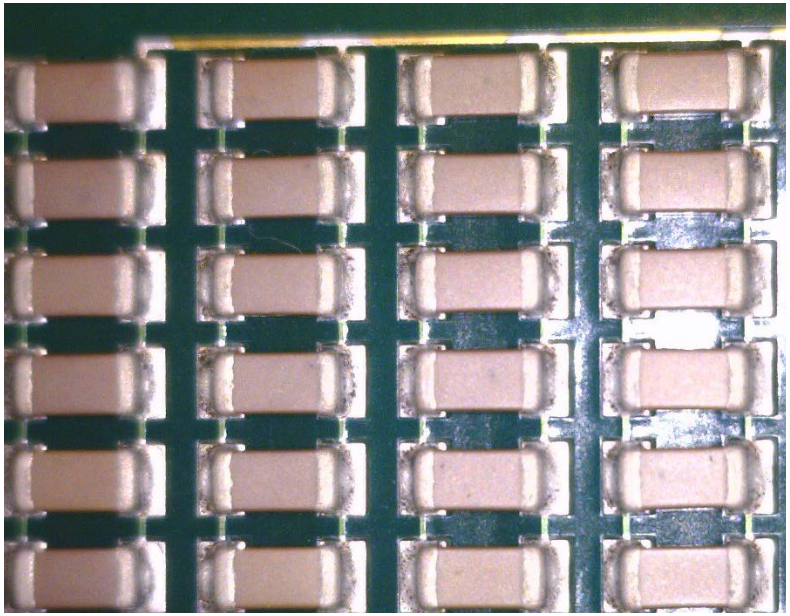


SIR Test board

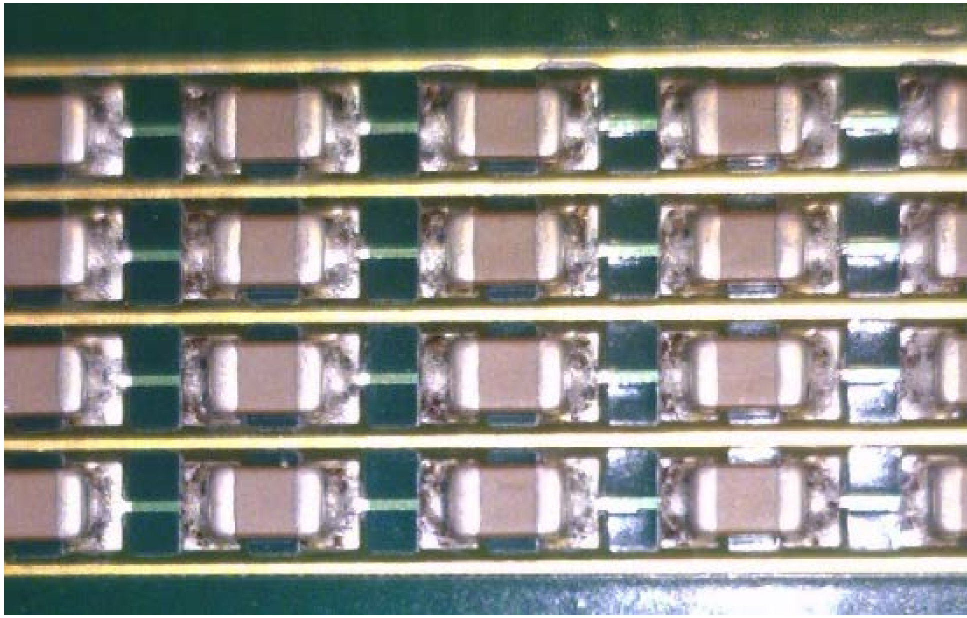


Visual Inspection

Component SIR patterns

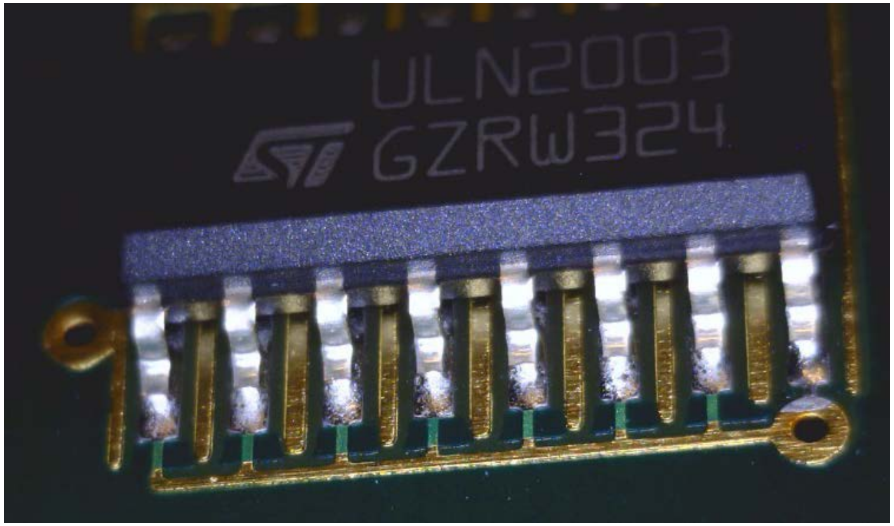


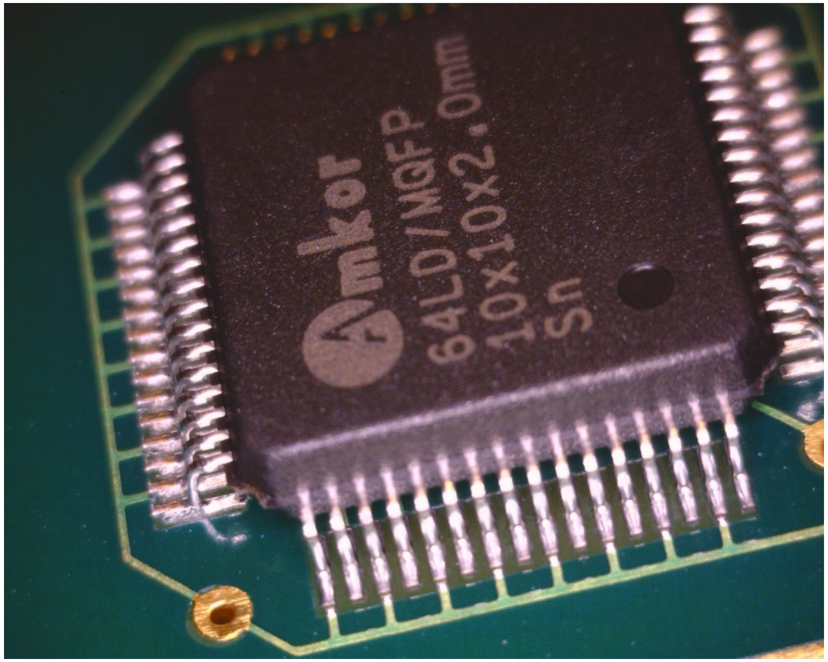
Terminations polarised



Terminations at same bias

Component SIR patterns





Leads at same bias

Leads at different bias – SIR dummy

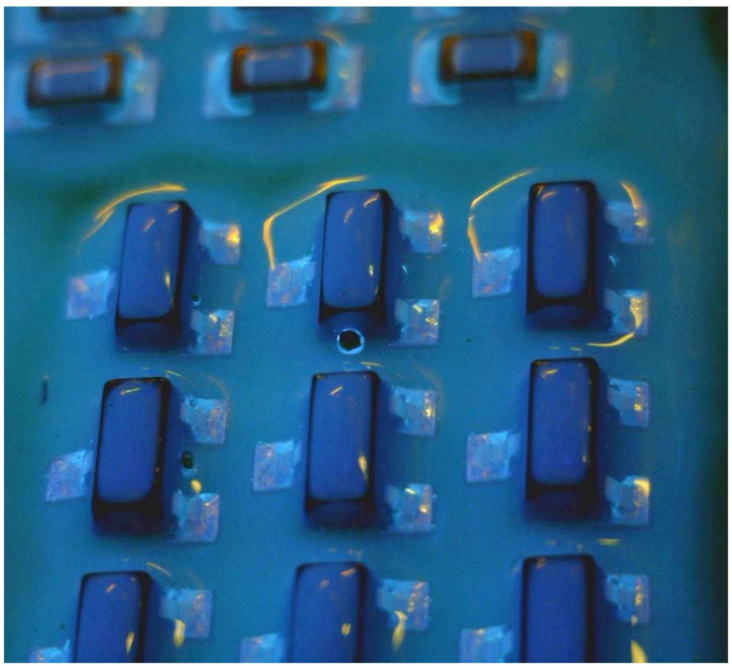
Conformal Coating Materials

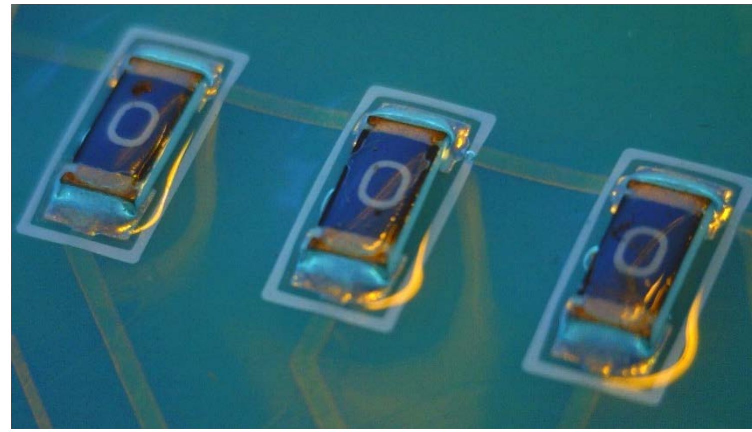
- Industry leading Materials (all liquid)
- All MIL-I-46058C, IPC-CC-830 or IEC-61086 ‘qualified’ (some all 3)
- Acrylic, Urethane, Silicone
- Solvent-based, 100% solids (Inc. UV curable/RTV, RTV and Thermal)

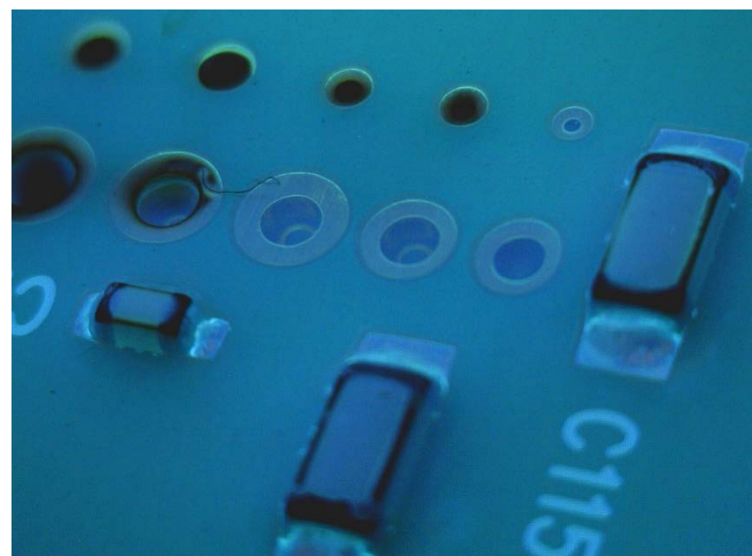
Application process

- Selective Coating, Hand-Sprayed and Dipped
- All materials applied by independent contract coating facilities (UK based)
  - Using 'normal-standard' application processes at 'normal nominal' thickness
  - Coated until component leads covered adequately
- Cured per manufacturers instructions
  - + 10 days at RT prior to tests

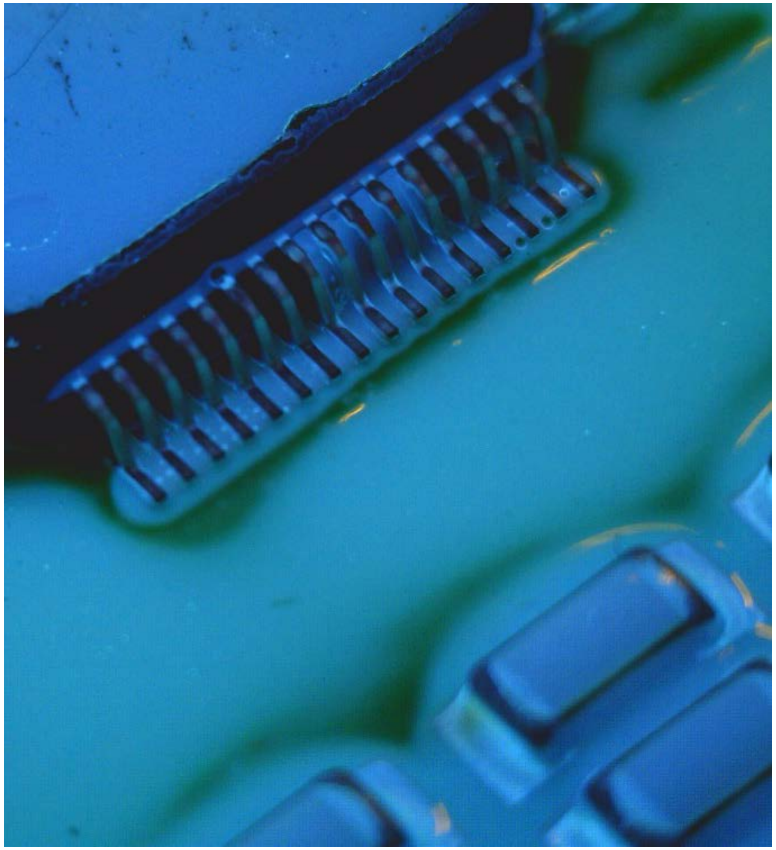
Examples of selectively coated assemblies

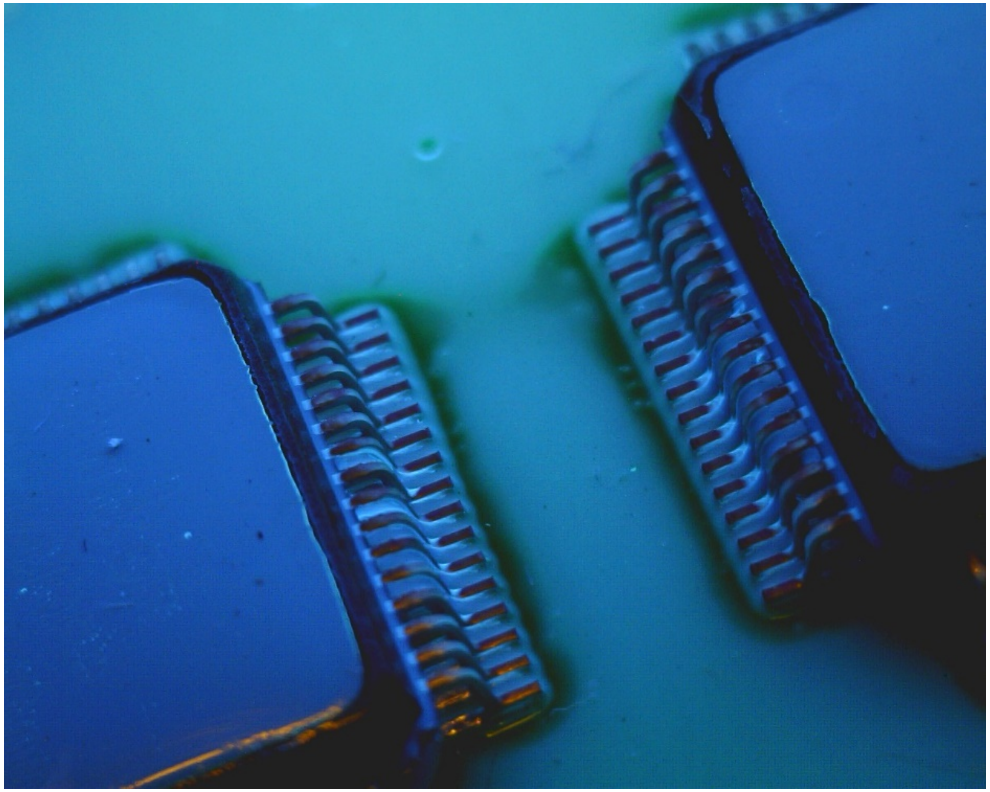




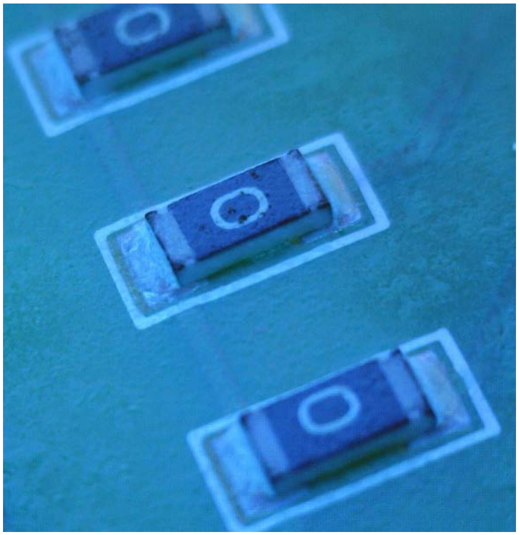


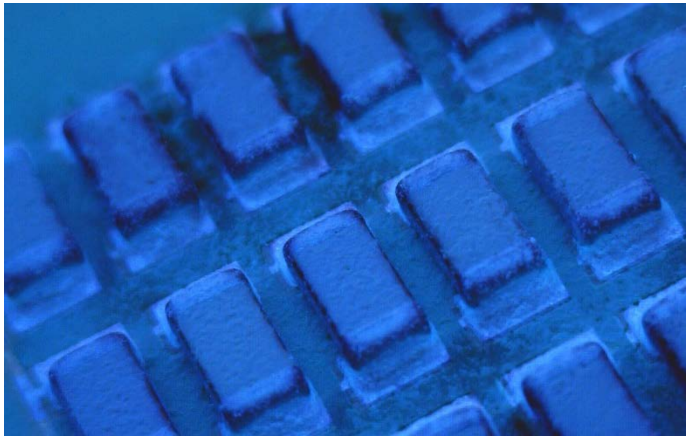
QFP leads

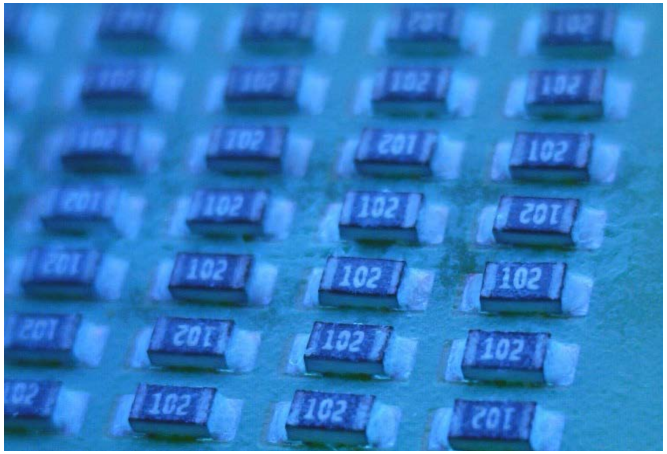


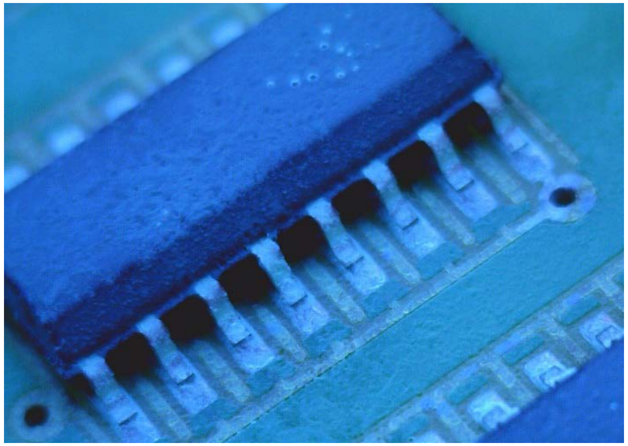


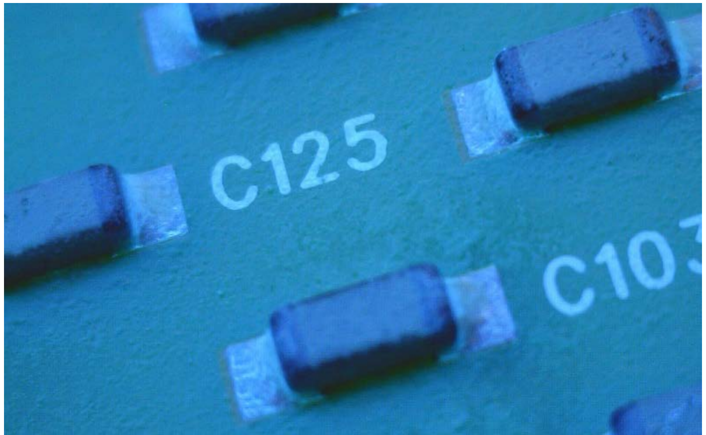
‘Dry Spray’



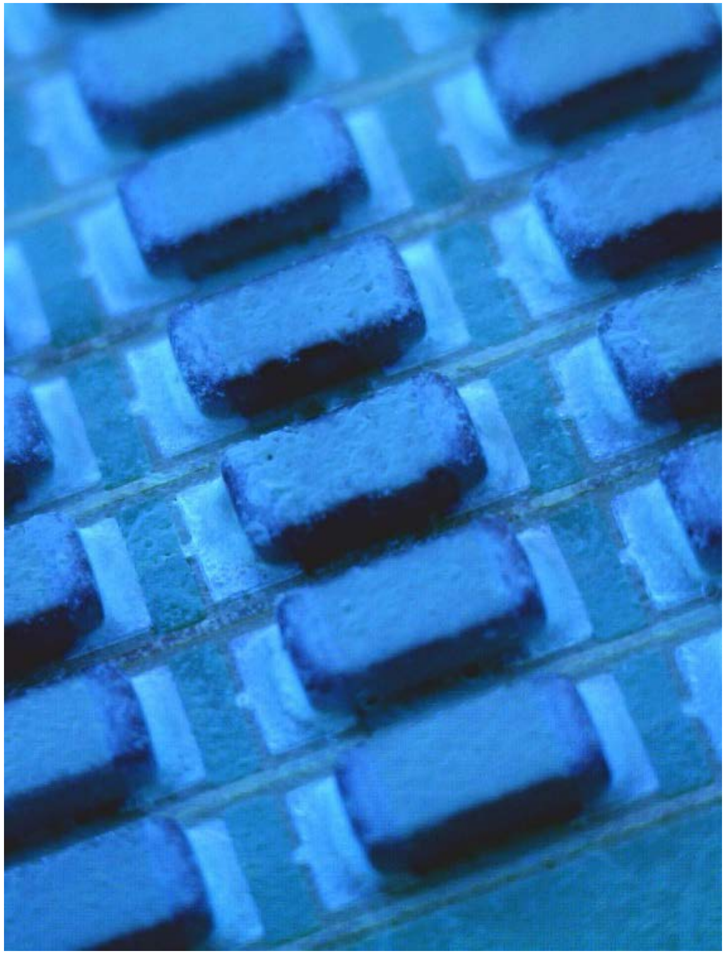


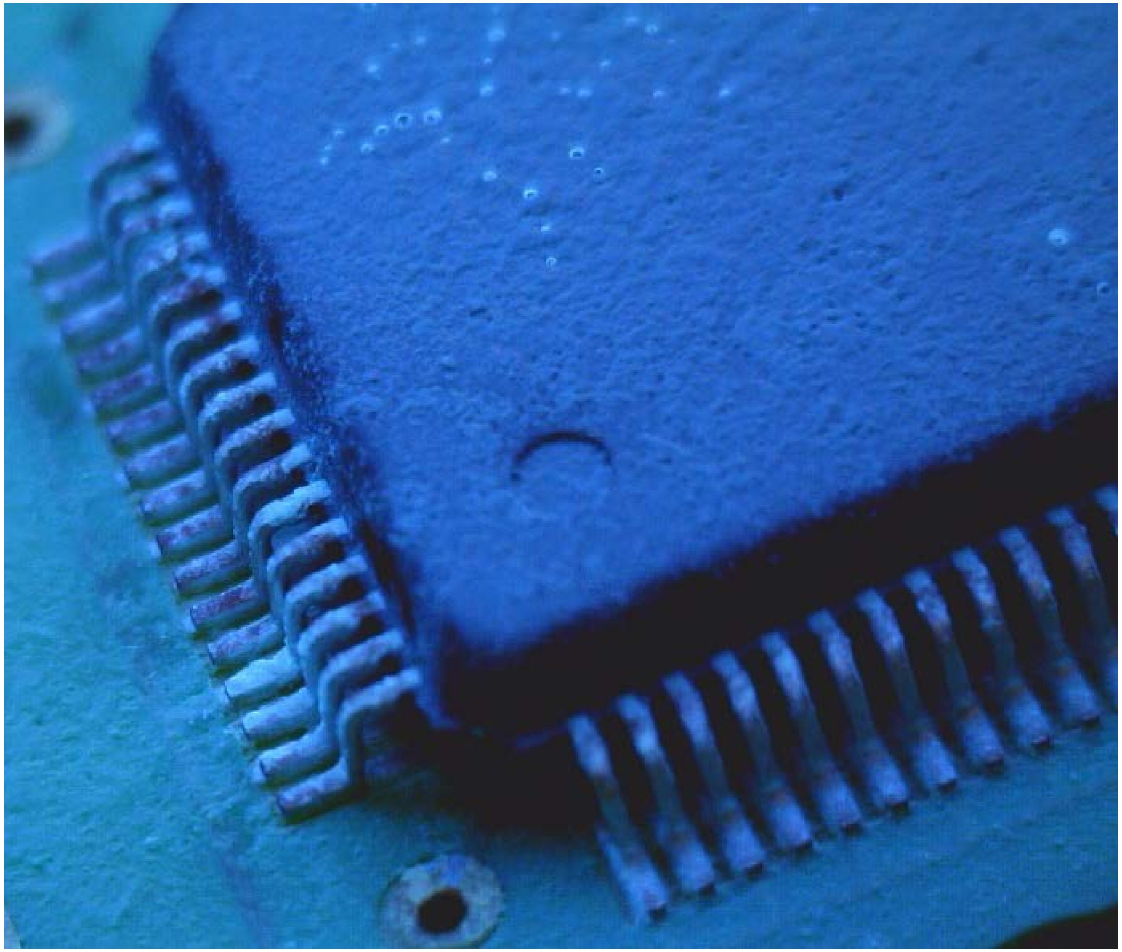






Examples of ‘Dry Spray’





Test Matrix

	AR2	UR1	UR2	UR3	UR4	UV1	UV2
QUALIFICATION	CC	MIL	CC	CC	CC	MIL	CC
Type	SB	SB	SB	100%	100%	100%	100%
Cure Type	T	T	T	T	T	UV	UV
Time at Temp / mins	10	1800	60	10	10	NA	NA
Temp / °C	85	76	70	70	70	NA	NA
Selective Atomised / mil	1	1.3	1.9	4	4	4	2
Selective non-atomised / mil	2.1	3	2.8	10.1	10.2	5.1	4.8
Hand Spray / mil	1.0	1.1	1.1				

Test Regime

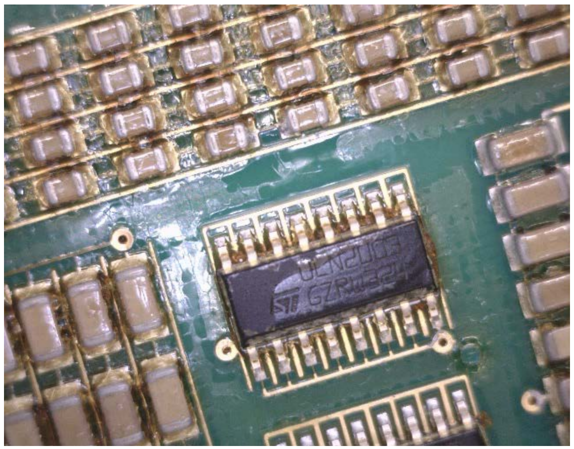
T Shock
- 100 Cycles -65C to + 125C, Air-to-Air, 15 min dwell

Salt-Mist
- 96 Hours, 5% NaCl, 50V Continuous bias

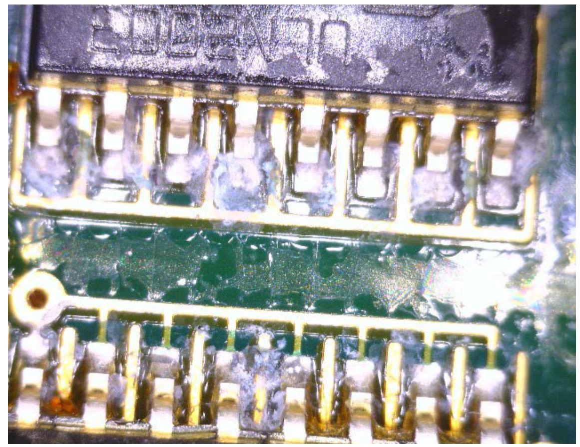
MIR
- 10 Days 65C, 85-95% RH, 50V continuous bias

Ageing
- 120 Days 85C/85-95% RH, 50V continuous bias

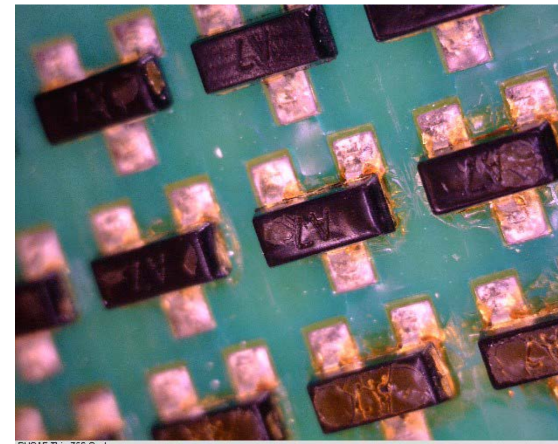
UR1 Thermal Shock Failures



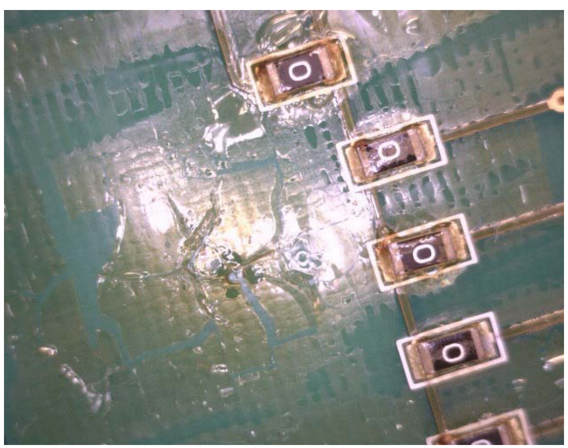
<19 Cycles

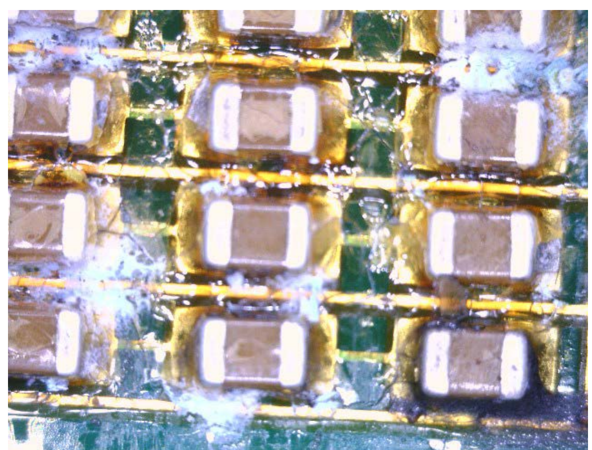


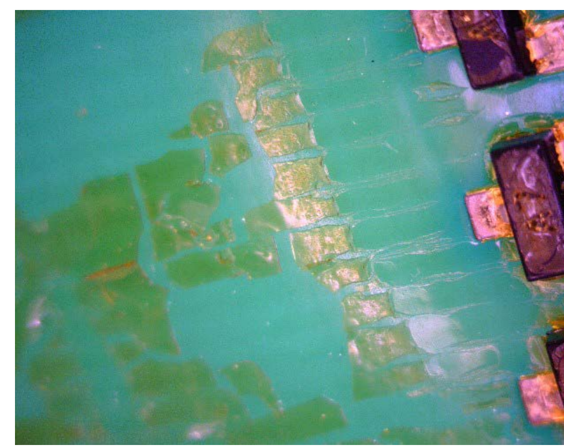
250 Cycles



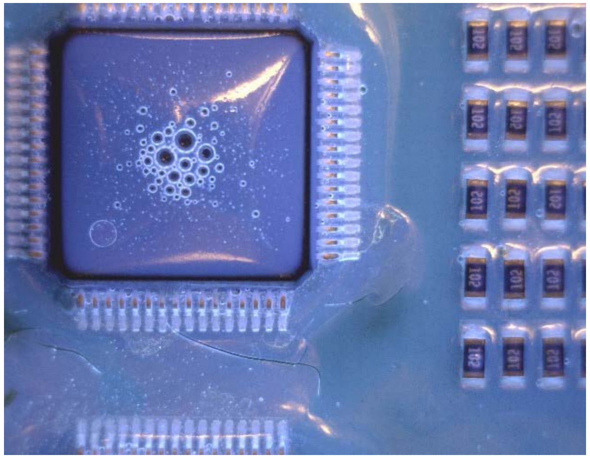
750 Cycles

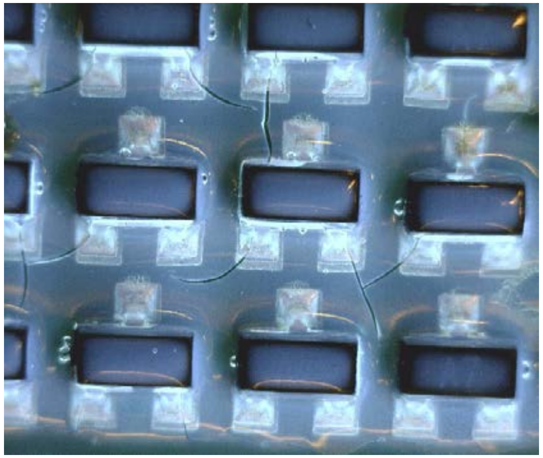


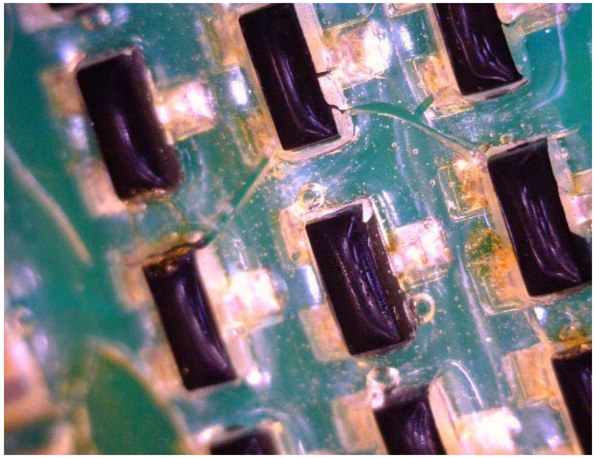




UV1 T Shock Cycles



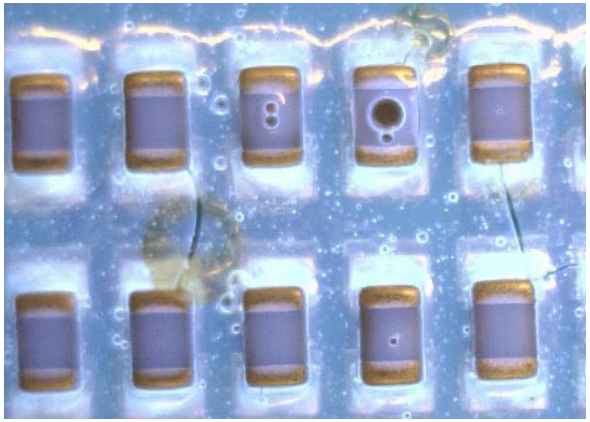


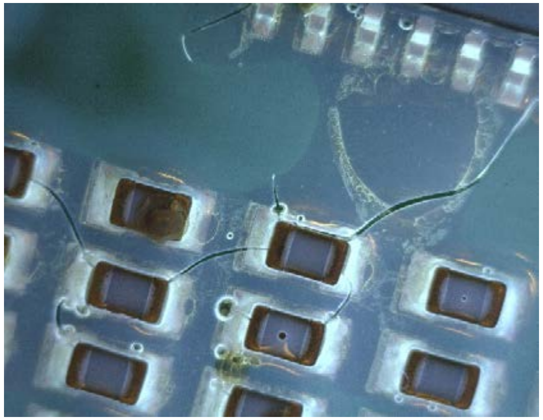


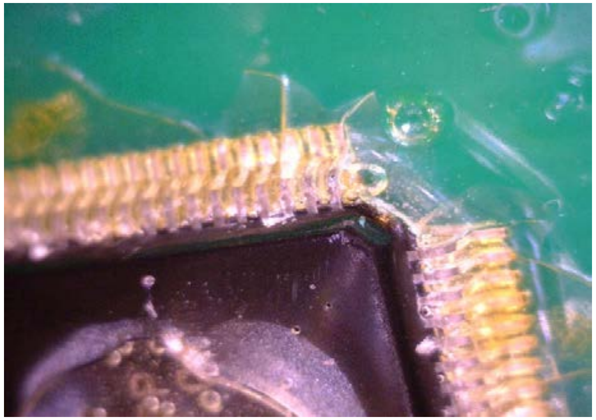
<100 Cycles

250 Cycles

750 Cycles

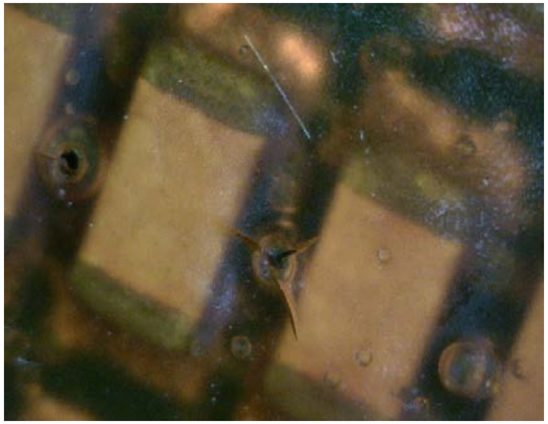
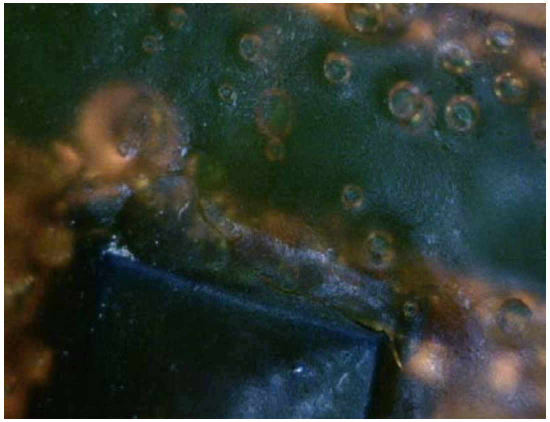
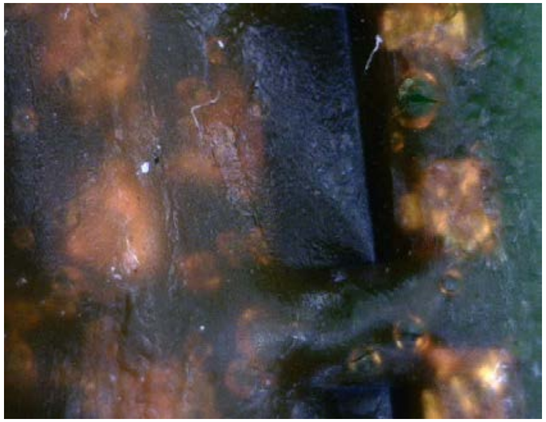
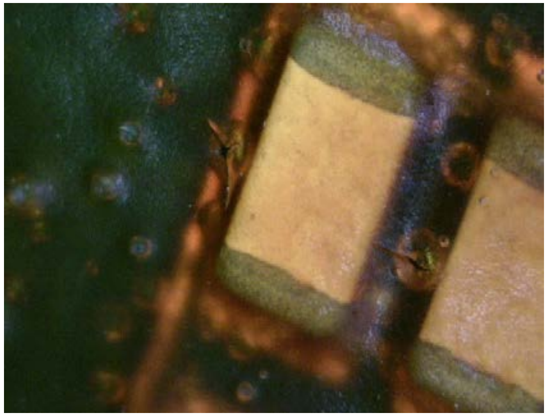




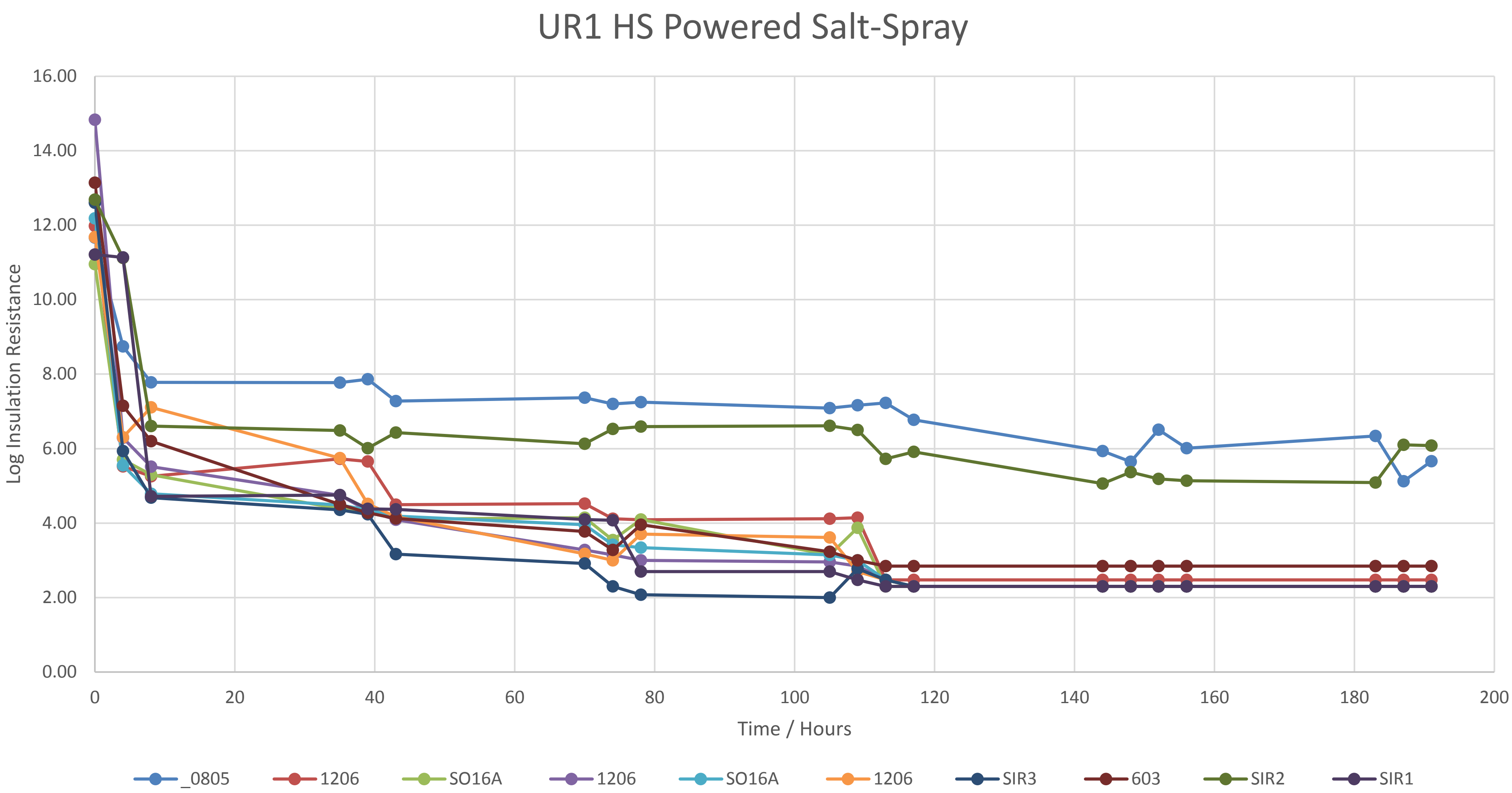


UR4 750 T Shock Cycles



Salt-Mist SIR Data



Conclusions

- 2/7 MIL/IPC-Approved products failed to withstand 100 thermal shock cycles
  - Cleaned assemblies
  - UR1 failed in less than 19 cycles
- UR1 showed rapid drop in IR during powered salt-mist testing
  - Evidence of significant ECM

Conclusions

- New test protocol established
  - Need more data
  - Refine test methods
- 3mm Mandrel Bend Test Relevance?

Further Work

- Develop Test Coupon further
  - Include bare laminate sections
  - Remove solder mask between traces
  - Match Squares of B25A, B24 and IEC SIR combs
  - Use less passive solder finish
- Continue to develop test matrix
- Include ‘nano-coatings’

Questions?