

**A METHOD TO QUANTIFY
THE SURFACE INSULATION
RESISTANCE PERFORMANCE
OF CONFORMAL COATINGS
EXPOSED TO DIFFERENT
TEMPERATURE/HUMIDITY
CONDITIONS**

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Approved on behalf of Managing Director, NPL, by Dr C Lea,
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SUMMARY

Typically conformal coatings based on different chemistries and formulated by different manufacturers are selected for a particular application on the basis of a single value for surface insulation resistance measured at a particular temperature and humidity. This information is limited in that the performance of the coating under a wider range of environmental conditions as might be encountered during the products lifetime cannot be assessed. This procedure describes a method for determining two indices that can be used to quantify the performance of conformal coatings over a range of temperatures under damp conditions.

1 INTRODUCTION

For electronics used in safety critical applications the reliability of circuitry exposed to a variety of different environmental conditions is of paramount importance. This can be significantly improved by coating circuit assemblies with a thin layer of plastic i.e. a conformal coating. The function of this physical barrier is to shield boards from dust, process solvents e.g. acetone, moisture, fuels, hydraulic fluids and abrasion from handling^{1,2}. Whilst this technology has been used in manufacture for some thirty years the problem of how to assess the performance of different coatings using a short-term *accelerated* test method remains. In this measurement note we describe a procedure that provides a rapid, cost effective method for characterising the performance of conformal coatings exposed to different temperature/humidity conditions.

1.1 THE MECHANISMS RESPONSIBLE FOR FAILURE OF CIRCUIT BOARD ASSEMBLIES

Before describing the test method it is worthwhile to recall the mechanisms responsible for circuit assemblies failing when exposed to harsh or humid environments. Circuit failure can occur as a result of electrochemical migration, corrosion and or cracking of solder joints.

Electrochemical migration occurs when ions flow through an electrolyte from one conductor to another that is at a different electrical potential. This ion flow represents a current leakage between the two conductors that can be measured as a fall in the surface insulation resistance (SIR). The flow of positively charged metallic ions between two conductors can lead to dendrites being formed on the cathode and subsequent short circuiting³. Typically the electrolytic medium through which the ions travel is water. The amount of water on the surface of a board immediately after manufacture is normally very little if the board has been suitably cleaned and dried. However this can change significantly with time especially if the board is exposed to damp atmospheres during service. The presence of organic residues such as the surfactants found in fluxes and other cleaning agents can facilitate the growth of dendrites due to their hygroscopic nature or their ability to form soluble complexes with metal ions.

Electrochemical migration results in corrosion of the circuitry although this process can also occur in the absence of an applied voltage. Corrosion of circuitry can lead to loss of conductor and current leakage due to bridging between adjacent conductors by corrosion products. Cracking of solder joints can also occur as a result of thermal cycling due to differences in the thermal expansion coefficients of the board component material, conductor and solder. There is some evidence to suggest that this susceptibility to cracking can be marginally reduced by conformal coatings⁴. However the efficacy of the coating in this role depends on its chemistry and how well it coats the soldered junction.

2 TEST METHOD

2.1 BOARD DESIGNS AND MATERIALS

Tests designed to probe the moisture resistance and thermal behaviour of conformal coatings have to account for potential variations arising from:

- the bonding between each coating and different substrates e.g. FR-4 laminate, ceramic and flexible boards.
- interactions between the coating and the board finish e.g. hot air level soldering (HASL), resist.
- the degree of cure of the coating.
- differences in the coating thickness.
- differences in the composition of ‘generically equivalent’ coatings supplied by different manufacturers e.g. water or solvent based acrylics.
- pre- and post-treatment of the boards i.e. cleaning procedures, storage and handling.
- different test conditions.

Given this complexity we have chosen to measure the surface insulation resistance of a simple board design comprising of three double comb patterns. The influence that these different conditions have on the SIR values can then be studied by depositing the comb patterns on to different types of board and finishes. This simplistic arrangement avoids the additional problems that arise during conformal coating of boards that have dummy components mounted on them i.e. ensuring that soldered joints are effectively shrouded.

2.1.1 Selection of board materials and test patterns

The test coupons are square boards of length 100 mm manufactured from the substrate e.g FR-4. Figure 1 shows the design of the test pattern. The track width of three double

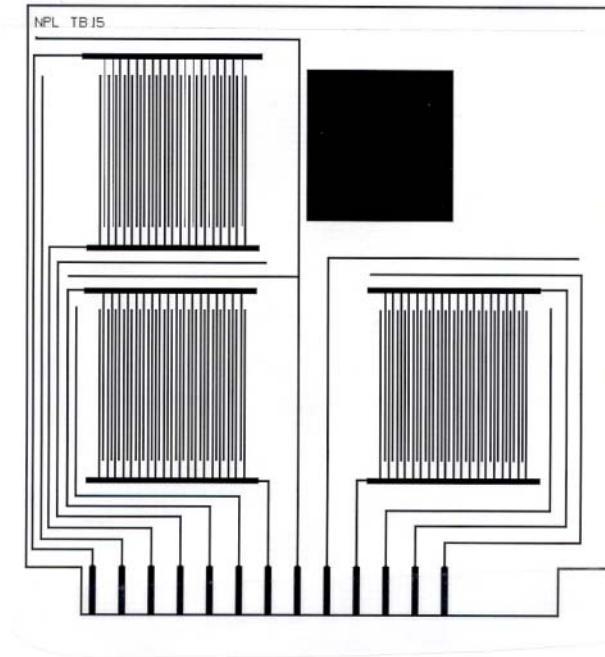


Figure 1: The test pattern used to generate SIR data.

combs of dimensions 25 mm x 25 mm is 0.35 mm. The pitch and gap are 0.3 and 0.15 mm respectively. The SIR is measured via a 32 way edge connector. The 25 mm square metallised pad on the board can be used to compare the adhesion of different coatings to this area and the bare board by cross-hatch or similar measurement techniques.

2.1.2 Selection of coatings, finishes and resist

Conformal coatings can be applied to the test board by the manufacturers preferred method, e.g. spraying, dipping or vacuum deposition either on one or both sides. Repeated application of the coating material can be used to explore the effect that thickness has on SIR. There is some evidence to suggest that single applications of coating can produce microscopic pin-holes that moisture can penetrate. However the susceptibility of different materials to this phenomenon is likely to be related to the solvent content of the coating solution and the thermal profile used to remove the solvent.

2.1.3 Pre-coating treatment

It is particularly important to ensure that the wiring assembly, particularly around the solder tabs is clean. In a comparison of ultrasonic and solvent extraction cleaning of the wiring assembly the latter proved to be more successful at removing stray ionic contamination. Hence prior to coating the boards should be cleaned with an isopropyl alcohol/water mixture. After cleaning the boards should only be handled by their edges by operators wearing latex gloves to avoid contamination prior to coating.

2.1.4 Curing procedure

Cure the coatings following the manufacturers recommended procedures. After coating and curing package the boards into moisture-proof bags containing desiccant material. Sheets of lint and acid free tissue inserted between the boards can be used to prevent them from coming into contact with each other.

2.2 SURFACE INSULATION RESISTANCE MEASUREMENTS

2.2.1 Test conditions

Exposing the test boards to alternating wet and dry environments over a range of different temperatures enables the performance of conformal coatings to be assessed and compared. This procedure has the potential to provide valuable information concerning the expected in-service performance of coatings applied to circuit assemblies.

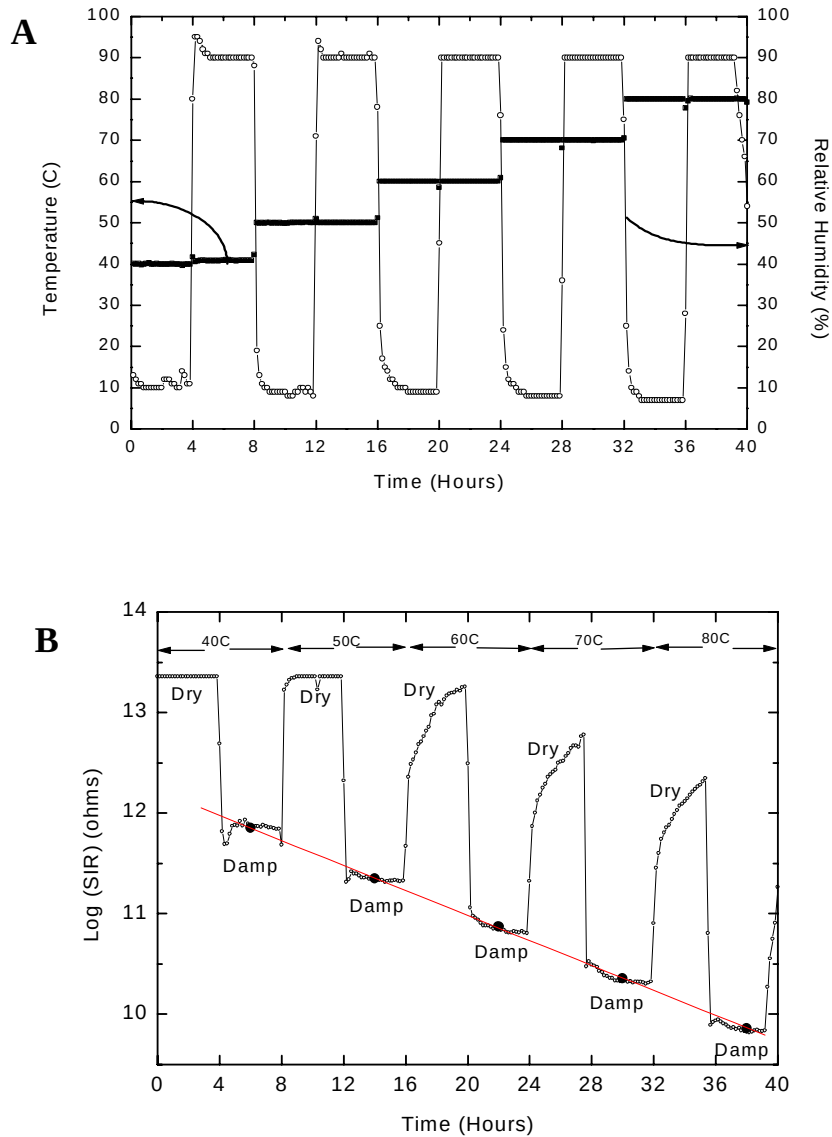


Figure 2: The SIR behaviour of a conformally coated test board shown in B corresponds to the test temperature/humidity profile shown in A.

A typical measured profile for humidity and temperature during a test is shown in Figure 2A. From this figure it is evident that the humidity is cycled over a two hour period from 10% RH to 90% RH. This humidity cycle is superimposed on to a stepped temperature profile where each step is maintained for a period of four hours. The temperature and humidity conditions within the environmental chamber should be monitored by wet and dry platinum resistance thermometers.

During the test period a +50 V biased voltage is continuously applied across the double comb patterns. A $10^6 \Omega$ limiting resistor should be included in each measurement channel.

2.2.2 Data collection.

The apparatus used to measure SIR should have a current sensitivity of approximately 1×10^{-11} A. A sampling interval of 5 to 10 minutes enables changes in SIR to be closely monitored under different environmental conditions during the 48 hour period of the test.

3 DATA ANALYSIS

3.1 Visual Appearance

After exposure to the temperature – humidity profile the boards should be visually examined for evidence of corrosion or dendrite growth. In some circumstances a low powered optical microscope is helpful for this inspection. Record any instances of corrosion and or dendrite growth.

3.2 Derivation of SIR measures

The signal to noise ratio of the SIR data can be improved by averaging the SIR values measured for the three double combs contained on each board. This is most easily achieved by using an analysis or spreadsheet package.

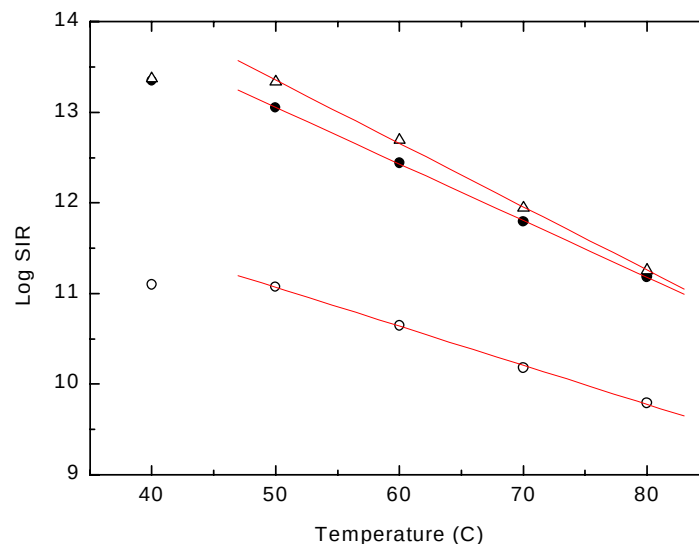


Figure 3: Linear least squares fits to a plot of the average values of log SIR measured during each damp cycle as a function of temperature for different conformal coating formulations

A plot of log SIR versus time is shown in Figure 2B. The peaks and troughs seen in the plot correspond to the damp and dry phases of the humidity cycle. The SIR temperature

indices are derived from measurements made during exposure of the board to damp conditions at temperatures in excess of 40°C. Typically log SIR of the boards measured at 40 °C is beyond the measurement capability of most test equipment, and for this reason these data are not used to derive the indices. The average value for each SIR measurement made under damp conditions is then plotted versus time. Typical plots are shown in Figures 2B and 3. Linear least squares fits to these data are used to generate a predicted value for log SIR at 50°C and a slope that describes the temperature dependence of log SIR. The departure of the data at 40°C from the linearity shown in figure 3 is commonly seen and a reason for placing more emphasis on SIR measurements made at 50°C above. The reason for this departure from linearity is unclear although it appears to be unrelated to any limitations of the SIR measurement apparatus to detect low current strengths.

4 USING THE INDICES

Currently decisions regarding the suitability of a particular manufacturers coating for a given application are based on a single SIR value. However a single measurement of SIR measured at a fixed humidity and temperature gives little information about the performance of the coating under a range of different combinations of environmental conditions. The SIR temperature indices are able to offer a profile of the coatings SIR behaviour as a function of temperature and humidity. This information can be used to compare different chemical compositions of the coatings and different manufacturer's formulations as shown in Figure 4.

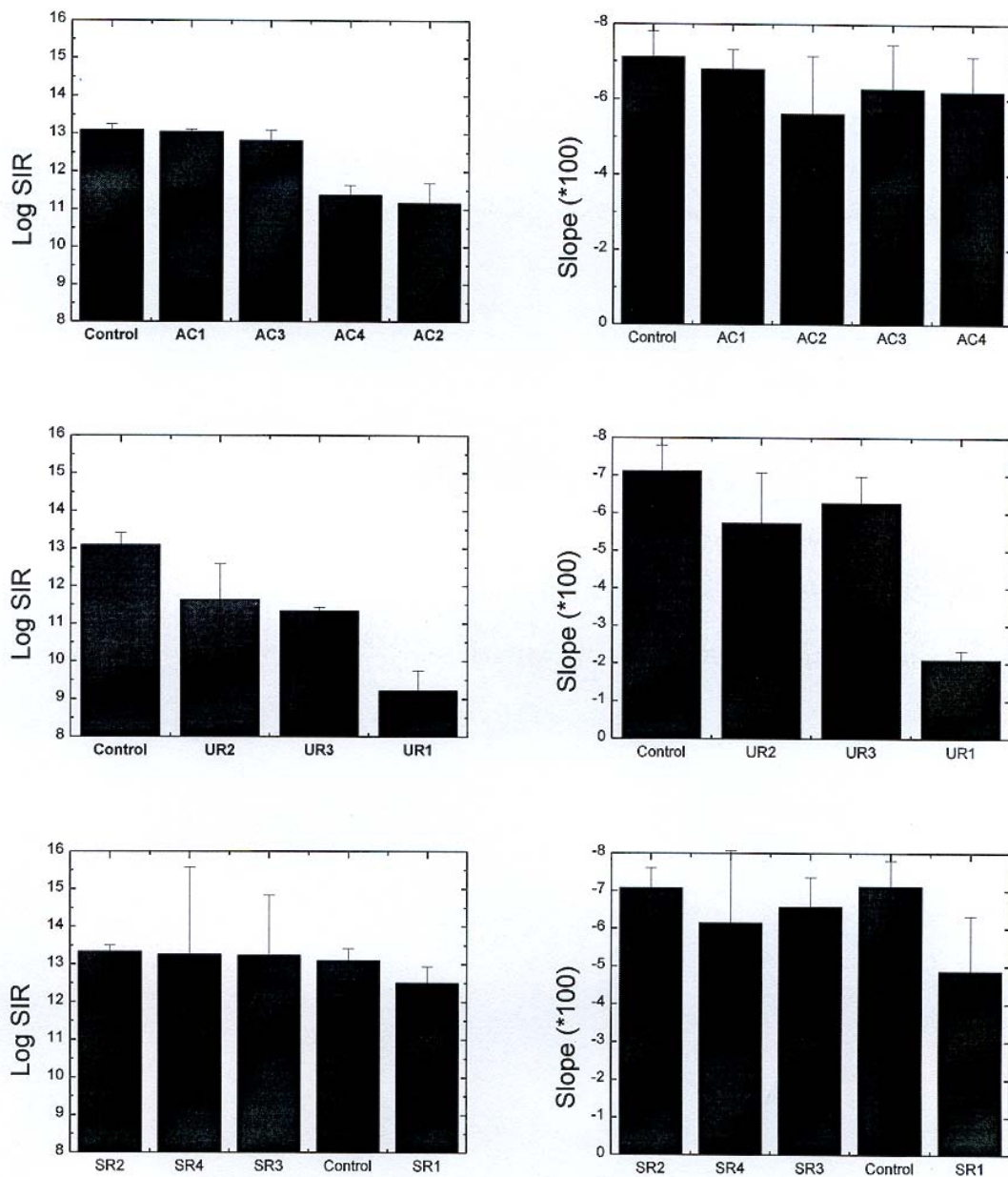


Figure 4: A comparison of log SIR (50°C) (intercept) and its temperature dependence (slope) for different coatings deposited on Cu-OSP FR-4 laminate.

In interpreting the data shown in Figure 4 note that optimum performance is indicated by a high value for log SIR at 50°C coupled with a low or zero value for slope.

5 ACKNOWLEDGEMENTS

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Details of the study that led to the derivation of the SIR temperature indices can be found in National Physical Laboratory Report entitled 'Surface Insulation Resistance and the Properties of Conformal Coatings', P. Tomlins and L. Zou, CMMT (A) 270, May 2000.

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