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Development of a New Surface Insulation Resistance (SIR) Test Method

by

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ABSTRACT

In a previous part of this work the functional dependence of the SIR parameters has been studied. A draft SIR test method has been produced here. The method is significantly different to the existing standard in a number respects and reflects the advances in electronics manufacturing and the improvements in the instrumentation. The work has involved evaluating the effects of a number of parameters (e.g. test time, test bias, test temperature and humidity, board pattern and board finish) and recommending suitable test conditions for the SIR measurements. The method represents a major step forward in improving the sensitivity of the test and its ability to predict reliability. This method has been tested and validated as part of an intercomparison, the results of which confirmed that the viability of the method.

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1. Introduction

Reliability is a key issue impacting on today's electronics, and the Surface Insulation Resistance (SIR) technique has been widely used to assess the effect of contaminants on the reliability of assemblies. The SIR is a measurement of an electrochemical process between two metallic conductors on a substrate surface. Its value is dependent on a number of test parameters, primarily electrical field strength, test patterns, board finish and test environment. The current SIR method described in international standards is based on 30 year old technology. However, instrumentation capability, assembly and flux technology, have significantly improved over the intervening period, and the time is ripe to update the method to meet today's electronic industry requirements.

The test result analysis report from previous part of this work predicted how SIR is affected by different field strengths, test patterns, test temperature and humidity, and soldering heat in combination with fluxes and board finishes^(1, 2, 3). Recommendations concerning these parameters were made, and now a new draft SIR method has been developed and is detailed below.

The following draft SIR method details the sample preparation and SIR measurement procedure.

2. Materials and Apparatus Requirements

Boards

The test board is shown in Figure 1. The board finish is AuNi, and the pattern is 400/200µl track and gap. The four comb patterns in the board shall be fluxed with test flux.

2.2. *Wiring*

Halogen-free 0.05 in. pitch cable with 34 conductors, with a configuration suitable for wiring the board.

2.3. *Connectors*

0.1 in. pitch single sided, 32-way gold connector

Drying oven

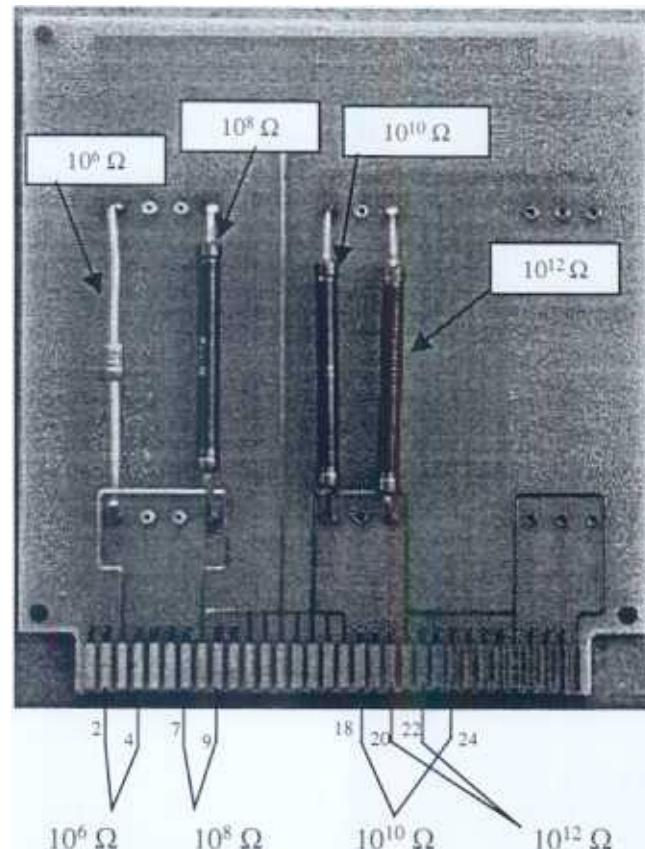


Figure 2. The calibration board

3. Test Procedure

Preparation of the test boards

Preparation of test board

a) Cleaning the test board and assessing the cleanliness of the board

- (1) Hold the board vertically and spray de-ionized water for 10 seconds, then spray with IPA for 10 seconds. Bake the test board in the oven for 16 hours at 125°C.
- (2) An alternative cleaning method. Place the test board in an ionic contamination tester containing 75% v/v propan-2-ol, 25% de-ionized water solution, and process until the measurement indicates a value of less than $0.1 \mu\text{g}/\text{cm}^2$ NaCl equivalent.

- b) A test and bias voltage supply capable of providing 5 volts dc ($\pm 2\%$).
- c) A sample selection system capable of individually selecting all the test patterns in the measurement experiment. The system shall incorporate an in-line limiting resistor of 10^4 ohm or greater in each current pathway.
- d) The tolerance of the total measurement system shall be $\pm 5\%$ up to 10^{10} ohms, $\pm 10\%$ between 10^{10} to 10^{11} ohms, and $\pm 20\%$ above 10^{11} ohms.
- e) The measurement system shall be calibrated by substituting a calibration board (see section 2.7). An example is shown in Figure 2. The calibration board should be substituted for the usual test coupons in the chamber at ambient conditions.
- f) The data sampling rate should be every ten minutes.

Calibration board

Calibration of the complete system using a calibration board with known resistors shall be carried out every three months. The calibration board is shown in Figure 2. The calibration board shall be of the same general size as the test board, and should have one of each 10^6 , 10^8 , 10^{10} and 10^{12} ohm resistors in specific current pathways.

Test board holders

The test board holder is an arrangement of equally spaced (minimum of 15 mm spacing) edge connectors (see section 2.3) mounted on a stainless steel frame. The cabling from the test holder to the outside of the humidity chamber should be accomplished using suitable cables from (see section 2.2). The cleanliness of the test board holder, the connector block and the cables should be assured. A possible procedure is discussed in 3.1.1.(a) (2), i.e. cleaning in a contamination tester.

- (3) Set up clean boards in the humidity chamber, by insertion into the edge connector arrangement.
- (4) Take an initial SIR measurement @ 23°C/50%RH (room conditions). Take the chamber to 65°C and 85% RH. Increase the temperature first and then the humidity.
- (5) Take SIR measurements every 10 minutes during 16h exposure under test conditions.
- (6) If the SIR value is stable and greater than 10^{10} ohms the boards are satisfactory for fluxing. If the SIR does not meet this criterion, the boards should be rejected.

b) Fluxing the test board

- (1) Flux the test board at room temperature with 50 µl flux. If using the diluted flux, do not use a flux solution older than 4 weeks.
- (2) Dispense the flux slowly in a number of drops initially onto the centre of the comb pattern and ensure a uniform coverage by dispensing further drops in areas of low coverage. The aim is to achieve a uniform thickness of the flux over the SIR pattern. The flux may spread outside the pattern
- (3) Flux drying condition. Lay the board flat, fluxed pattern side up, on a pre-heated metal plate (aluminium is ideal) in a fan oven at 100 °C for 5 minutes.

3.2. *Method for connecting the test board to the SIR measurement system*

The connections from the test patterns which come out on the tabs for the test board are listed in Table (see Figure also

Carefully slide the test board edge into the connector. Do not handle the boards with bare hands, wear clean-room gloves and only handle the edges of the board. Ensure that the gold tabs of the board engage with gold contacts in the edge connectors.

Table 1. Tab connections to test board

Test pattern	Identification	Tab connection
Comb pattern 1	SIR1	29
Comb pattern 2	SIR2	16
Comb pattern 3	SIR3	8
Comb pattern 4	SIR4	2
	Bias	5, 12, 20, 24
	Earth	3, 6, 9, 13, 14, 15, 17, 21, 27, 31

3.3. *SIR measurement procedure*

Sample size

Four test boards and two control boards for each test. The control board shall be cleaned (see section 3.1.1 a)) but not fluxed.

SIR measurement for test board

- a) High resistance measurement system calibration: Prior to connecting the test board to the measurement system, the calibration board (see section 2.7) shall be connected to the system and a measurement taken. If any channel does not conform with the tolerance of the total measurement system ($\pm 5\%$ up to 10^{10} ohms, $\pm 10\%$ between 10^{10} to 10^{11} ohms, and $\pm 20\%$ above 10^{11} ohms), then this must be rectified. If there are concerns over the cleanliness of the connector, it shall be cleaned or replaced. If there is any concern over the accuracy of the instrument, it shall be calibrated using standard resistors. The calibration of the whole system shall be carried out every three months.
- b) Test board measurements: Carefully mount the test boards, in the vertical plane in the humidity chamber, and connect the wiring loom from the boards to the outside of the measuring chamber. Subsequently bias can be applied .

A single test voltage of 5V should be used throughout the experiment. If an automatic monitoring system is used, start the monitoring at room temperature, and use a 10 minute cycle time.

The test conditions are identified as: 65°C and 85%RH, or 40°C and 93%RH. The temperature should be ramped up first and allowed to equilibrate, before the humidity is increased. The humidity should be increased slowly enough to avoid condensation on the board. This may be best achieved by setting 5%RH below the required humidity, with a small hold to allow stabilising and then a further increase to the required humidity. At the end of the test, remove the humidity first, then decrease the temperature, and stop SIR acquisition at room temperature. The temperature and humidity of the chamber should be checked with calibrated instruments. The test period is 168 hours. The acquired data should be stored for future trend analysis.

4. Assessment

If a board exhibits intermittent electrical failure or anomalous performance during SIR testing, carry out visual inspection for the presence of dendrite formation or corrosion products. SEM/EDX analysis should be carried out where necessary, and the following conditions recorded.

- a) Presence of dendrites. If present, count and record the number of dendrites. A dendrite should only be counted when its length exceeds 200 μm . Multiple dendrites in a cluster that are interconnected should only be counted as one dendrite. A picture or SEM image for the tested sample shall be taken.
- b) Presence of corrosion products. If present, record the percentage of the spacing between the conductors bridged by the worst-case corrosion products. A picture or SEM image for the tested sample shall be taken.
- c) Presence of discolouration between conductors (discolouration on conductors is acceptable). If present, discolouration shall be recorded as a colour image and included in the test report.

If the resistance measurements taken on the control boards fall below 10 G Ω and the test boards with the candidate material fail, a new control and test boards must be prepared and the test repeated.

Any reason for deleting values (scratches, condensation, solder bridged conductors, outlying points, etc.) must be noted. Rejection of results for more than 2 test patterns for a given condition shall require the test to be repeated.

5. Test Report

The test report shall include the following information:

- a) Identification and preparation of the flux. The flux concentration must also be recorded.
- b) Test conditions; temperature, humidity and bias voltage.
- c) The individual charts or graphs showing the average log SIR value with time for four test boards and two control boards; the standard deviation should be given as well.
- d) If any results show a rapid change in resistance of one order of magnitude in less than one hour, then these occurrences should be tabulated.
- e) The number of dendrites formed during the SIR test. The picture or SEM image of the discolouration between conductors for the test boards.
- f) The fractional area coverage of corrosion products, in terms of the interelectrode spacing should be recorded.
- g) Simple explanation and conclusion about the test results.

6. Intercomparison

To test the method developed above three laboratories conducted a joint set of tests. The laboratories were NPL, Siemens in Berlin, and the National Microelectronics Research Centre (NMRC) in Cork.

The intercomparison test was based around two experiments:

1. Test boards prepared by Siemens and sent to all the partners by post for testing at their laboratories.
2. The samples prepared and tested by each partner at their own laboratory.

The test board, fluxes and test conditions are listed in Table 2. The preparation and testing of samples were carried out according to the test method detailed above.

Table 2. The test board, fluxes and test conditions

Flux	Flux A (ISO1.1.2)	Flux D (ISO2.3.3)
Flux formulas (% W/W)	Isopropyl alcohol 64,805	Isopropyl alcohol 62,010
	Denatured Ethyl alcohol 30,000	De-ionized water 5,000
	Adipic acid 2,000	Malic acid 4,000
	Bromo-Carboxylic acid 0,195	Citric acid anhydrate 6,000
	Midified rosin 0,900	Alkyl polyglycol 16,000
	De-ionized water 2,000	Defoamer 2,000
	Fatty alcohols 0,100	Esters of carb. Acids 4,990
Dilution with IPA (times)	4	200
Test condition	40°C/93% RH	65°C/85% RH
Number of test boards	4 test boards and two control boards	
Board pattern	200µm gap and 400µm track with NiAu finish	

7. Results and Discussion of Intercomparison

The results are presented as an average value from all test boards for each condition. The number of test boards are shown in table 1. The standard deviation of the log SIR is less than 0.2 decade ohms. The SIR value with time on the control boards prepared by Siemens and each partner, and tested by each partner are shown in Figures 3 and 4 for the two sets of environmental conditions. Similarly the SIR values with time on the fluxed test boards are shown in Figures 5 and 6. The nomenclature of the results in the figures refers firstly to where the boards were prepared, and secondly to where they were tested.

The results from Figure 3 and 4 clearly shows that the SIR value on the control boards tested at both conditions are very close. An excellent agreement was also achieved with the Flux D results

presented in Figure 6. The small systematic difference between laboratories may be due to errors in the chamber calibration. This is discussed below.

These results validated the technique using samples prepared at each laboratory and samples prepared only at Siemens. Each laboratory testing both sample sets achieved the same results. This indicates that the reproducibility for individual sample preparation and SIR measurement according to the procedure at different laboratory is very good, and demonstrates that the draft SIR method is both appropriate and feasible.

The largest variation in the results occurred for the boards with Flux A. This is probably a function either of the property of flux A, which volatilises more easily, or of the high test humidity. Small changes in humidity at this high level, which are still within the accuracy of the machine, may cause significant changes in the adsorbed water layer thickness and hence the SIR value. This question mark over the accuracy of the chamber at this humidity level has led to all project partners to check the calibration on their equipment. Some experiments using Flux A gave inconsistent results, irrespective of which laboratory prepared the board. Whereas with Siemens and NPL there is close agreement with the Siemens prepared boards. The NPL test of the NPL prepared boards produced intermediate results, indicating a variance in the preparation procedure that affected the flux residues on the test pattern.

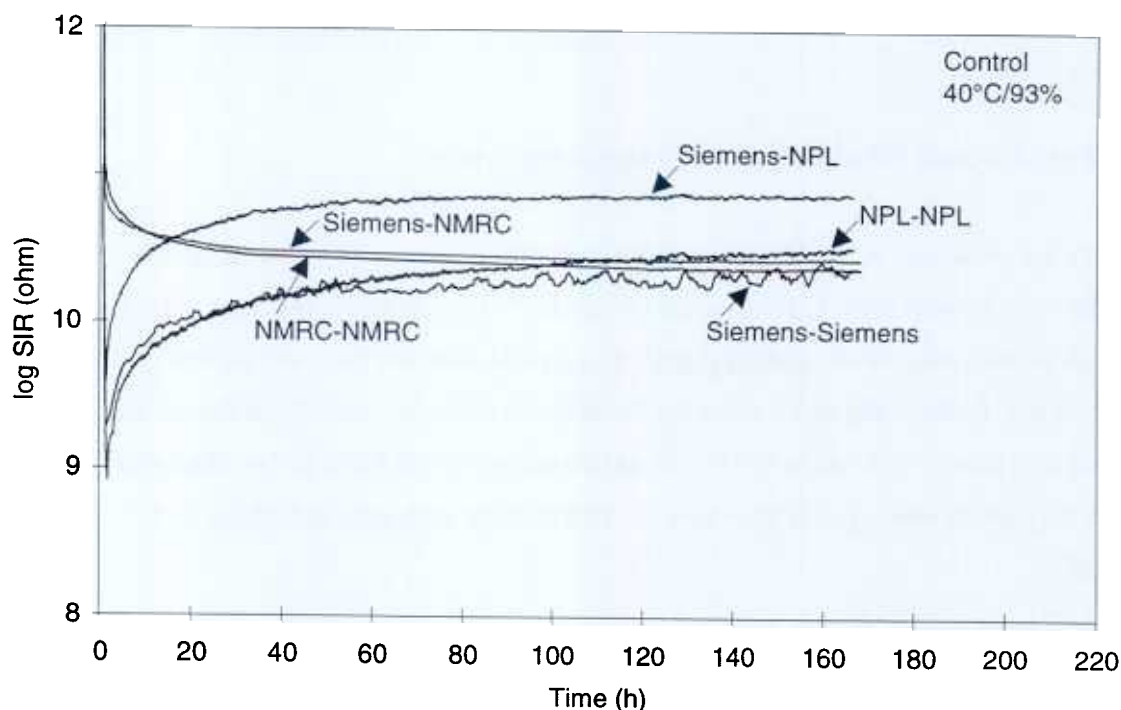


Figure 3. The SIR value with time on the control boards tested at 40°C/93%RH

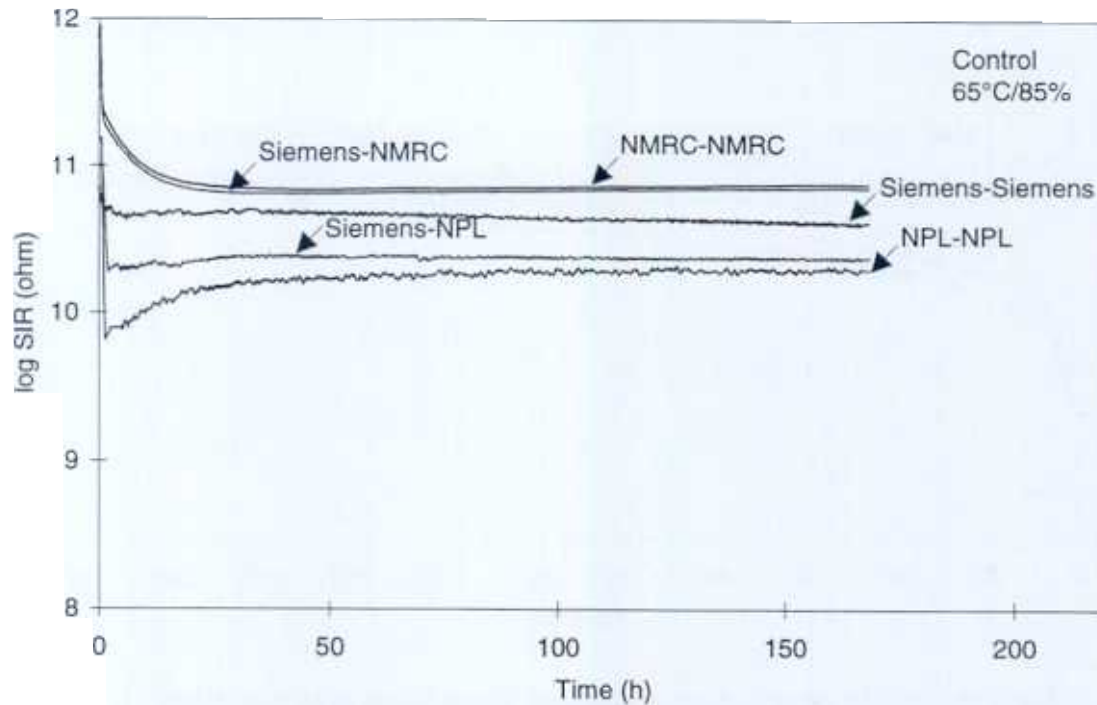


Figure 4. The SIR value with time on the control boards tested at 65°C/85%RH

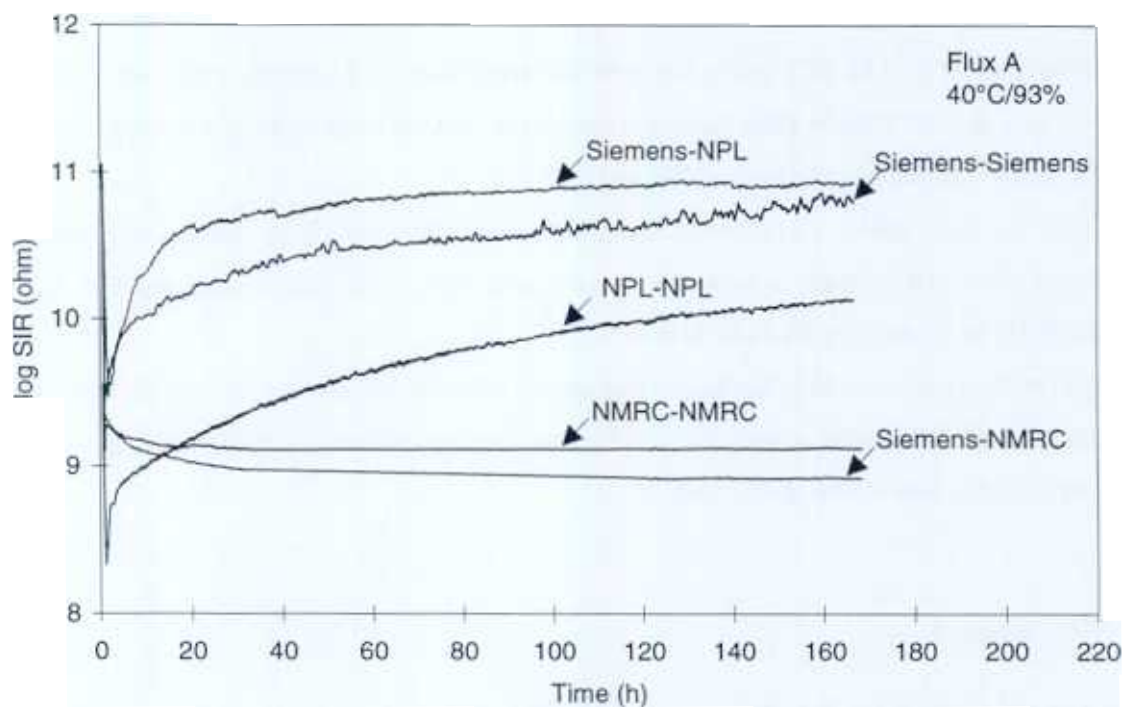


Figure 5. The SIR value with time on the test boards tested at 40°C/93%RH

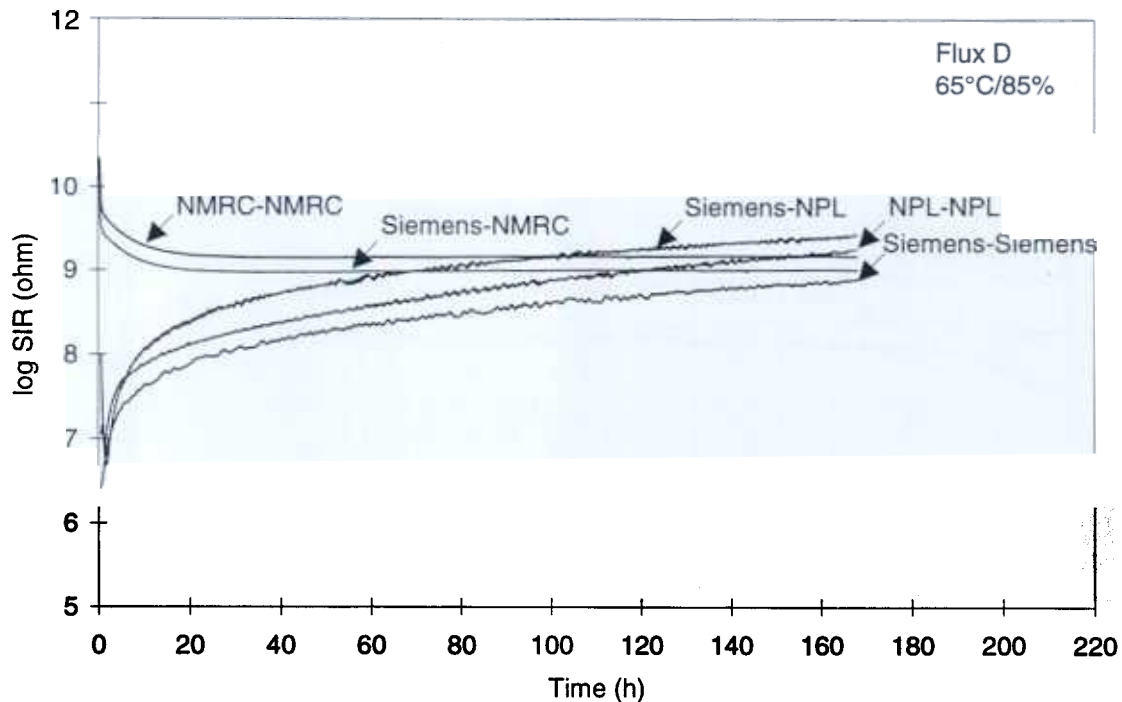


Figure 6. The SIR value with time on the test boards tested at 65°C/85%RH

8. Conclusions

- A new detailed method for SIR testing has been developed here, and a complete procedure given.
- The new test method reflects both the improvements in measurement techniques/instruments and the demands of current board design philosophy.
- This new method differs significantly from previous SIR methods in calling for frequent monitoring, low test voltage, a new test pattern with fine pitch, and reinforcing the use of 40°C/93%RH as appropriate for volatile fluxes.

The new method proposed here has been validated by different laboratories, with good agreement demonstrated. However, the results for one flux and test conditions, 40°C/93%RH, gave some cause for concern, and are being checked.

9. References

- (1) Ling Zou and Christopher Hunt NPL Report CMMT(A) 222.
- (2) John Barton "Assess influence of environmental condition" Work package WP2 European Contract SMT4-CR97-2155

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