

REPORT

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

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Round robin test results and validation a New Surface Insulation Resistance (SIR) Test Method

by

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ABSTRACT

In a previous part of this work the draft SIR test method was produced ⁽¹⁾. The method was verified using conventional fluxes and solder paste in a full production environment ⁽²⁾. The final SIR test method has been released 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 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 validate using the commercial flux and solder paste as part of an intercomparison. The results confirmed that good agreement would be achieved by different laboratory. Both the commercial flux and solder paste passed the criterion in the new SIR measurement method. Therefore the new method is very successful at evaluating the reliability of modern electronic circuit board.

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Approved on behalf of Managing Director, NPL, by Dr C Lea,
Head, Centre for Materials Measurement and Technology

CONTENTS

1. INTRODUCTION	1
2. MATERIALS AND APPARATUS REQUIREMENTS.....	1
2.1. BOARDS	1
2.2. WIRING	1
2.3. CONNECTORS.....	1
2.4. DRYING OVEN	2
2.5. HUMIDITY CHAMBER	2
2.6. HIGH RESISTANCE MEASUREMENT SYSTEM.....	2
2.7. CALIBRATION BOARD.....	3
2.8. TEST BOARD HOLDERS	3
3. TEST PROCEDURE.....	4
3.1. PREPARATION OF THE TEST BOARDS	4
3.1.1. <i>Preparation of test board</i>	4
3.2. METHOD FOR CONNECTING THE TEST BOARD TO THE SIR MEASUREMENT SYSTEM.....	5
3.3. SIR MEASUREMENT PROCEDURE.....	6
3.3.1. <i>Sample size</i>	6
3.3.2. <i>SIR measurement for test board</i>	6
4. ASSESSMENT	7
5. TEST REPORT	8
6. INTERCOMPARISON	11
7. RESULTS AND DISCUSSION OF INTERCOMPARISON	11
8. CONCLUSIONS	14
9. REFERENCES	14
10. ACKNOWLEDGEMENT	15

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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 new 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 method represents a major step forward in improving the sensitivity of the test and its ability to predict reliability

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

2. Materials and Apparatus Requirements

2.1. Boards

The test board is shown in Figure 1. The board finish is Cu, and the pattern is a 400µm track and a 200µm gap. The patterns are guard banded, and the SIR pattern is 25 x 25 mm. The four comb patterns on the board shall be fluxed with test flux, or printed with test paste.

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

2.4. *Drying oven*

Suitable for use up to $130^{\circ}\text{C} \pm 1^{\circ}\text{C}$

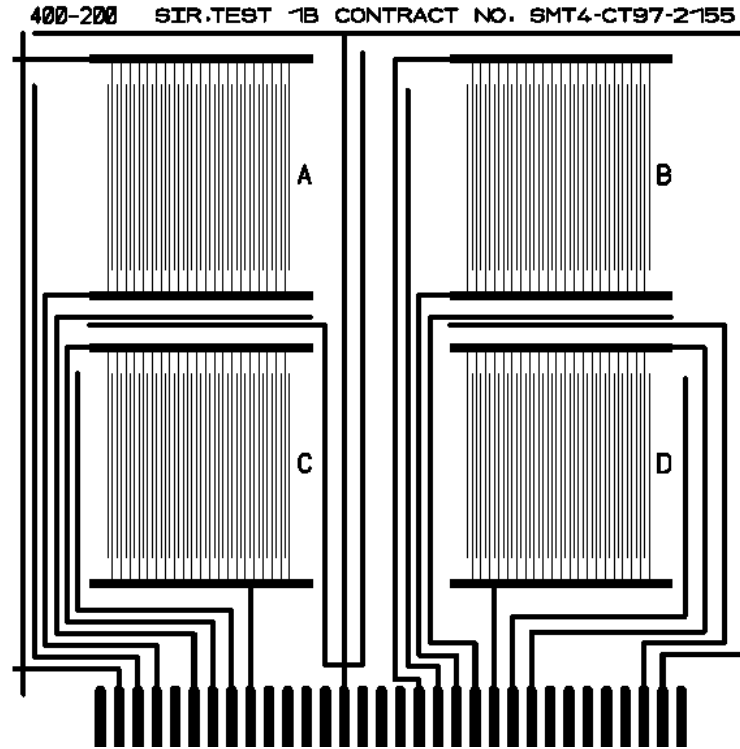


Figure 1. Lay out of the test board

2.5. *Humidity chamber*

Capable of programming environments up to 90°C with temperature control of $\pm 0.2^{\circ}\text{C}$, and relative humidity up to 93% with control of $\pm 5\%$ at a specific RH. The chamber should be constructed with stainless steel inner surfaces and be well insulated. The temperature and humidity measurements should be taken using sensors such as dry and wet bulb thermometers. Solid state sensors cannot tolerate high temperature and humidity. The temperature humidity levels of the test chamber shall be recorded throughout the test, preferably with independent control sensors.

2.6. *High resistance measurement system*

The measurement system shall comprise

- a) A measuring device capable of measuring surface insulation resistance (SIR) in the range of 10^6 ohms to 10^{12} ohms.

- 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.

2.7. 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.

2.8. 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.

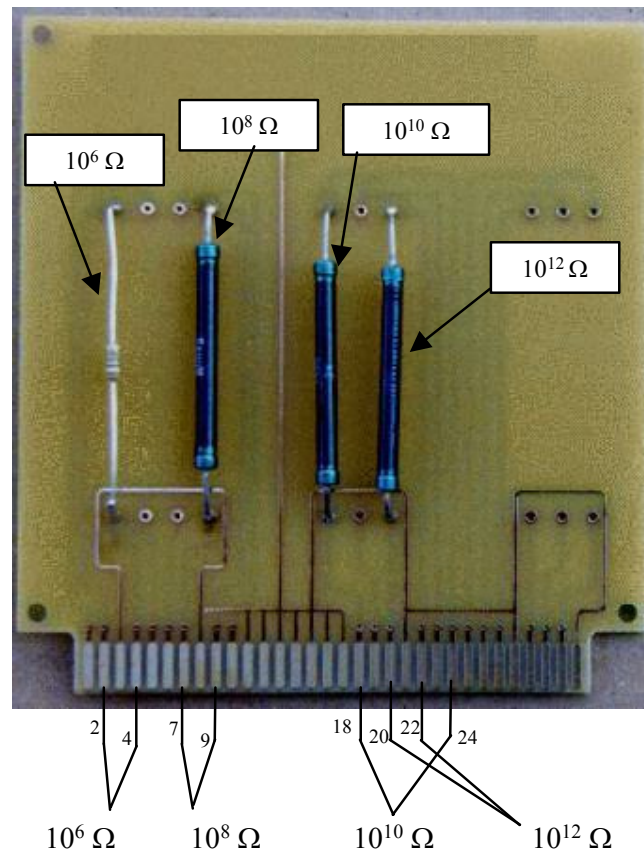


Figure 2. The calibration board

3. Test Procedure

3.1. Preparation of the test boards

3.1.1. 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.

- (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 40°C and 93% 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.

c) Printing the test board

- (1) Print the test board using test paste with 150 µm thickness stencil.
- (2) Reflow the board using the standard reflow profile or the profile, which is recommended by paste supplier.

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 1 (see Figure 1 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 A	SIR A	4
Comb pattern B	SIR B	20
Comb pattern C	SIR C	9
Comb pattern D	SIR D	22
	Bias	2, 7, 18, 24
	Earth	3, 8, 14, 19, 21, 23, 30

3.3. *SIR measurement procedure*

3.3.1. Sample size

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

3.3.2. 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: 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

Minimum SIR value over whole test for each test pattern should be $\geq 10^8 \Omega$. There is no evidence of dendrite formation during the test (Rapid drop in SIR).

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 20 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 GΩ 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.

Surface Insulation Resistance Measurement Report

Material Identification

ID Number:	
Flux Classification (flux type)	
Flux Form*	
Manufacturer's Identification	
Manufacturer's Batch Number	
Date of Manufacture	
Original Use by Date	
Solder Alloy (if used)	

*Form of flux refers to: liquid, paste, cored wire, preform, etc.

Flux heating method

Oven ☐ Wave soldering ☐ Reflow soldering ☐

If reflow or wave soldering method will be used. The processing parameters need to be record.

Processing Parameters

Reflow soldering	
Maximum Preheat Temperature (°C)	
Time Above Liquidus or Solder Contact Time	
Cleaning Method, Materials and Parameters	
Wave soldering	
Temperature of wave	
Preheat/flux temperature	
Contact time	
Cleaning Method, Materials and Parameters	

Testing Parameters

Date Original Qualification Tests Complete	
Tested By	
Interconnect Attachment Method*	
Test Anomalies Noted	
Number of Coupons Tested	
Test environment	
Test voltage	

* Refers to method used to interconnect coupons : hard wire solder vs. connectors or dedicated fixtures.

Visual Examination

Parameter	Observations	Pass/Fail
Dendritic Growth		
Corrosion		
Other Visual Effects		

SIR measurement results

Pattern Board	A	B	C	D	Mean Log SIR (ohm)	Standard deviation	Pass/Fail
	Final Log SIR (ohm)						
Flux1							
Flux2							
Flux3							
Control							
	Minimum Log SIR (ohm)						
Flux1							
Flux2							
Flux3							
Control							

Note: Individual graphs showing the measured resistance in log SIR with time for each test pattern are required.

6. Intercomparison

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

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, flux, paste and test conditions are listed in table 1. The preparation and testing of samples were carried out according to the Final SIR Test Method.

Table 2 The test board, fluxes, paste and test conditions

Test flux and paste	Flux 1 (ISO2.2.3.A)	Paste1 (ISO1.1.2.C)
Board finish	Cu	NiAu
Test condition	40°C/93% RH	
Number of test boards	3 test boards and 1 control board	
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. The number of test boards is shown in table 2. The standard deviation of the log SIR is less than 0.2 decades ohms. The SIR value with time on the control boards prepared by Siemens and each partner, and tested by each partner are shown in Figure 3 and Figure 4. Similarly the SIR values with time on the test boards for the flux and the paste are shown in Figure 5 and Figure 6. The results nomenclature in the figures refers firstly to where the boards were prepared and secondly to where they were tested.

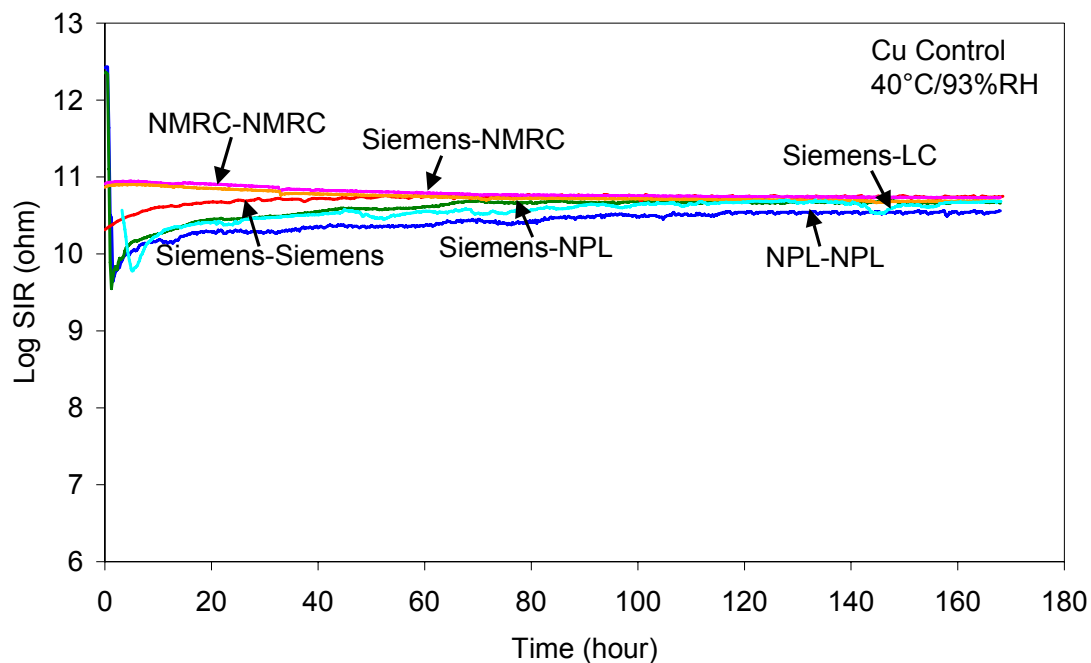


Figure 3. The SIR value with time on the control boards tested at 40°C/93%RH

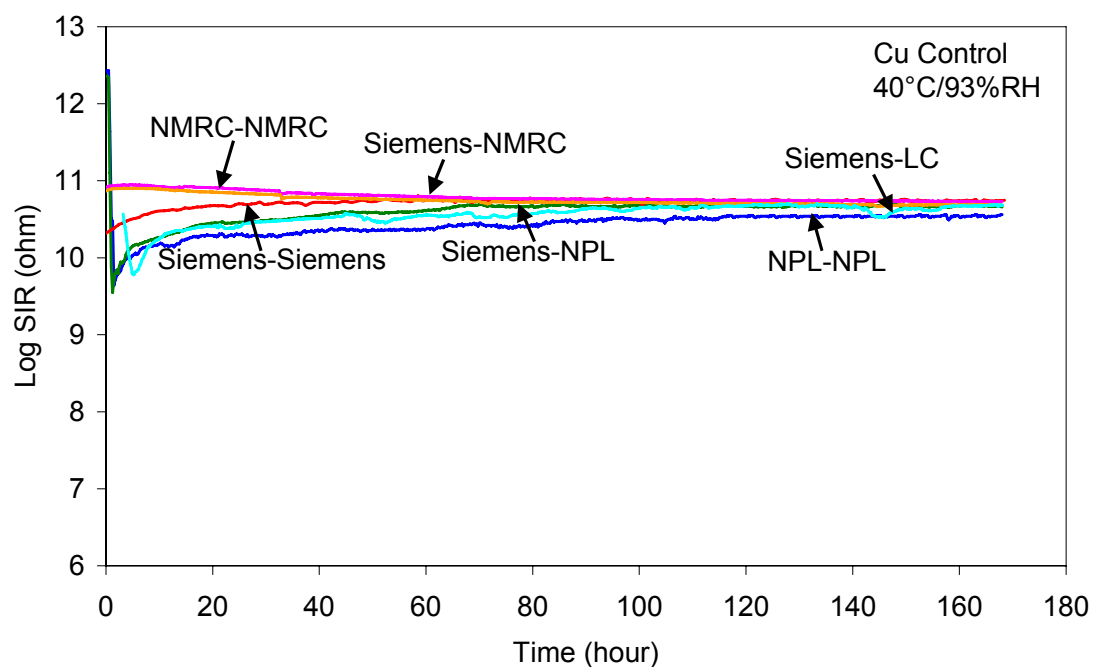


Figure 4. The SIR value with time on the control boards tested at 40°C/93%RH

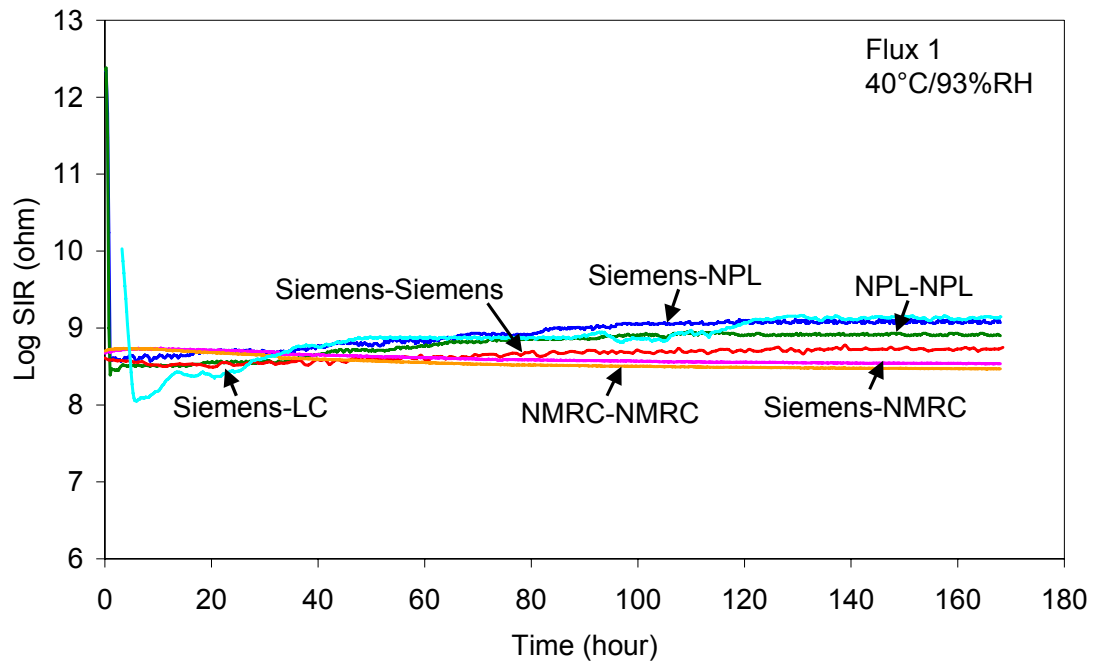


Figure 5. The SIR value with time on the test boards tested at 40°C/93%RH

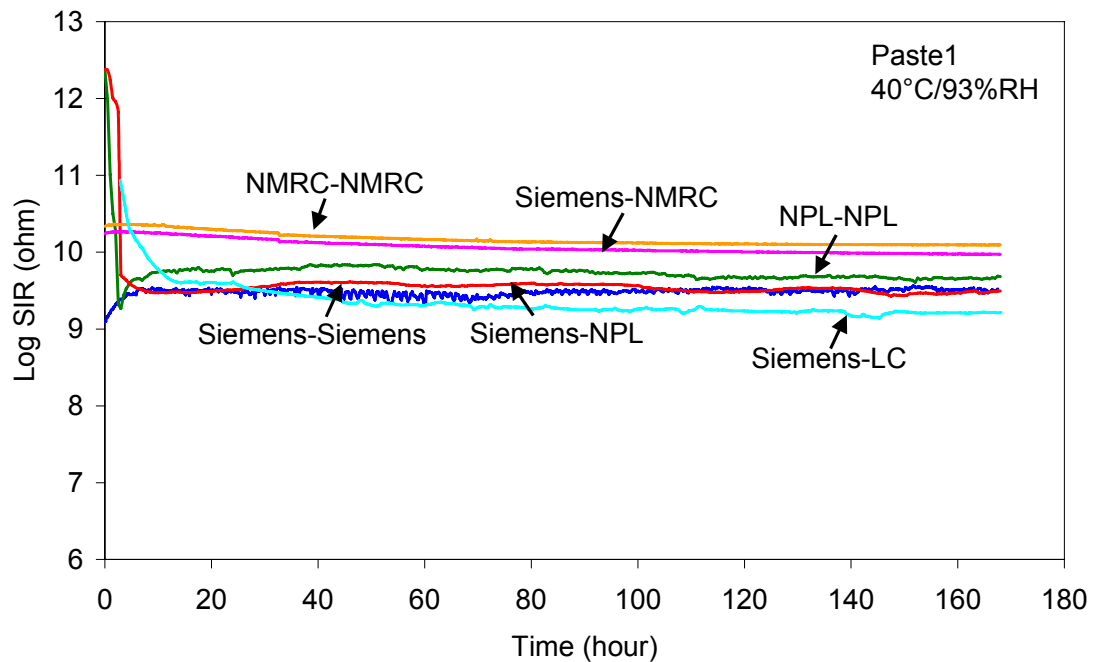


Figure 6. The SIR value with time on the test boards tested at 40°C/93%RH

The results from Figure 3 and Figure 4 clearly show that the SIR value on the control boards, Cu for the flux and AuNi for the paste, are very close. An excellent agreement was also achieved for fluxed

and printed test boards, which presented in Figure 5 and Figure6. This verified the technique and the ability of the partners to achieve the same results. This was achieved for samples being prepared at each laboratory and for samples being centrally prepared at Siemens. Each laboratory testing both types of sample got 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. Both the flux and the paste passed pass/fail criterion in the final test method. Therefore the new SIR measurement method is very successful at evaluating the reliability of modern electronic board.

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 modern flux.
- The new method proposed here has been validated using the commercial flux and solder paste by different laboratories, with good agreement demonstrated. Both the flux and the paste passed pass/fail criterion in the final test method, and the results show a significant difference between the flux and solder paste. Both the flux and the paste passed pass/fail criterion in the new test method. Therefore the new SIR measurement method is very successful at evaluating the reliability of modern electronic board.

9. References

- (1) Chris Hunt and Ling Zou NPL Report CMMT(A) 235.
- (2) Hartmut Meier and Klaus-Peter Galuschki “Application of SIR-method to industrial context ” Final Report for European Contract SMT4-CR97-2155

10. Acknowledgement

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