

REPLACEMENT OF CFC SOLVENTS BY NEW "NO CLEAN" FLUXES OR NEW SOLVENTS FOR ELECTRONIC CIRCUIT CLEANING AFTER SOLDERING

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Abstract: Some "no clean" fluxes and solder pastes containing residueless fluxes were tested by ionic contamination measurements on circuits after soldering. The influence of ionic contamination on the reliability of circuit functioning was measured by insulation resistance measurements in humid conditions. The same measurements were used to evaluate some new organic solvents for possible substitution of trichlorotrifluoroethane (CFC) solvents in the cleaning of electronic circuits after soldering.

Zamenjava CFC topil z novimi fluksi "brez ostankov" ali pa z novimi topili za čiščenje elektronskih vezij po spajkanju

Ključne besede: vezja tiskana, proizvodnja vezij, čiščenje površin, čiščenje po spajkanju, vezja elektronska, topila organska, CFC topila klorofluorogljikova, fluksi čistilni "nečisti", CFC-113 triklorotrifluoretan, tehnologije debeloplastne, kontaminacija ionska, prevodnost ionska, zanesljivost delovanja, okolje vlažno, Montreal protokol, fluksi brez ostankov, odstranjevanje ostankov fluksov, kolofonija fluksi, fluksi vodotopni, fluksi sintetično aktivirani, spajkanje brez čiščenja, čiščenje vodno, čiščenje polvodno, preskušanje topil, paste spajkalne

Povzetek: Preizkusili smo nekatere flukse "brez ostankov" in pastozne spajke s fluksi "brez ostankov" s pomočjo meritve ionskih ostankov na vezjih po spajkanju. Vpliv ionskih nečistoč na zanesljivost vezij smo ugotovili s pomočjo meritve izolacijske upornosti v vlažni atmosferi. Enake meritve smo uporabili za ovrednotenje nekaterih novih topli kot možne zamenjave za triklorotrifluoretan (CFC) v postopku čiščenja elektronskih vezij po spajkanju.

INTRODUCTION

According to the Montreal Protocol the use of CFC-113 (trichlorotrifluoroethane) and 1,1,1 trichloroethane is to be reduced and phased out completely by the year 2000 /1,2/. Possible alternatives for replacing CFC solvents used for electronic circuit cleaning after soldering include new fluxes which do not need to be cleaned, or the choice of solvents other than CFC. Dependent on the type of fluxes used for circuit cleaning (rosin flux, water soluble, synthetically activated fluxes) suitable cleaning must be applied for flux residue removal. New fluxes, the so called "no residue" fluxes with very low solid content ($\leq 5\%$), have been developed which do not require cleaning, or when necessary it is possible to clean with organic solvents other than CFC. When rosin based fluxes are used for circuit soldering, new organic solvents other than trichlorotrifluoroethane must be chosen.

The attention of industry has been focused on four primary strategies for removing CFCs from use: HCFC as replacements for CFC, semiaqueous and aqueous cleaning and no-clean soldering. These are becoming available at increasingly attractive prices. When selecting a possible solution for circuit cleaning many aspects must be taken into consideration; material compatibility, energy consumption and also the selection of solvents, which are usually in the form of a mixture. Terpenes, water and other solvents are mixed with varying amounts of surfactants, detergents, saponifiers or other agents to maximize performance in specific applications.

In our work we have tested two solvents other than CFC for circuit cleaning after soldering, and which were selected on the basis of previous work on solvent testing /3,5,6/. Also five "no residue" fluxes were tested for circuit soldering without cleaning in comparison with

RMA flux, as well as two solder pastes containing "no residue" flux.

EXPERIMENTAL

Ionic residues after the soldering of circuits were determined by ionic conductivity measurements of the solvent containing dissolved contaminants, and by insulation resistance measurements on the test sample between closely spaced soldered conductors in humid conditions /3/.

The main characteristics of the fluxes and solder pastes tested are presented in Table I and Table II. The characteristic of RMA fluxes normally used for circuits soldering are also given in Table I for comparison. The characteristics of the new solvents A and B compared to Freon (CFC) are given in Table III.

Table I: Main characteristics of fluxes used for immersion or wave soldering

Flux	Solid content (wt%)	Flux activity	Halide content
A	<2	no residue	0
B	2	no residue	0
C	2	no residue	0
D	2.1	no residue	0
E	2	no residue	0
Alpha 611	37	RMA	0.1
Alpha GR8	40	RMA	0.1

Table II: Solder pastes characteristics

Solder paste	Alloy composition	Metal content (wt%)	Flux activity
A	62Sn36Pb2Ag	89	no residue
B	62Sn36Pb2Ag	90	no residue

Table III: Main characteristics of solvents

Solvent	Composition	Mol. weight	Boiling point (°C)	ODP* value
A	CCl ₂ F-CH ₃	117	32	0.1
B	alcohol mixture	-	78	-
Freon	CCl ₂ F-CClF ₂	187	48	0.8

* Ozon depletion potential

Ionic contamination measurement

Samples for ionic contamination measurements were soldered by circuit immersion in a solder pot when using fluxes A,B,C,D and E for hybrid circuit soldering, or wave soldered with fluxes A and B for printed circuits. Fluxes were preheated before soldering to the specified temperature, and after soldering circuits were not cleaned.

The dimension of hybrid circuit ceramic substrate were 2.5 cm x 2.5 cm and of the printed circuit 9 cm x 6 cm. Two circuits were used for each ionic contamination measurement. Ionic contamination on the circuits after soldering was measured by the static conductivity method in which the ionic conductivity of a mixture of 50 vol% distilled water: 50 vol% isopropyl alcohol was measured before and after immersion of the circuit in the solution for 10 minutes, using an Iskra MA 5964 Conductometer /3/.

The dynamic conductivity method was also used for ionic contamination measurements using two instruments; an Iskra Conductometer and an Omegameter 600 SMD in which the mixture of distilled water: isopropyl alcohol was circulated in the system after calibration with NaCl. The ionic contamination value measured is expressed in $\mu\text{g NaCl}/\text{cm}^2$ according to Standard MIL-P-28809A. To determine the quantity of ionic contamination on a specimen under test, the conductivity of a fixed amount of test solution used to extract and dissolve the contaminants was measured. The system detects and records the concentration of contaminants in the test cell at the beginning of the test to establish a base line. Subsequent calculation represents only the amount of contamination added to the extract solution during the test. A state of equilibrium is attained when all the contaminants have dissolved in the test extract solution. At the conclusion of the test the final contamination level in equivalent micrograms of NaCl/cm^2 are recorded. Before running another test, the solution is regenerated through a built - in deionising system to establish a clean solution and a new base line for the next test.

Insulation resistance measurement

The test circuits for insulation resistance measurements were prepared according to DIN-32513 and IPC-SF-818 as given in Fig.1 and Fig.2. On the DIN-32513 test sample the distances between lines are 1.3 mm and the line widths 0.7 mm, and on the IPC-SF-818 test sample the line spacing is 0.7 mm and the line width is 0.35 mm.

Ten test samples were soldered with the same fluxes on ceramic substrates and on printed circuits. The insulation resistance between closely spaced soldered conductors was measured before and after testing in a humid chamber under conditions of 93%RH, at 40°C with 50V DC applied. Ten samples were also soldered with a rosin flux for testing and the circuits cleaned with Freon and solvents A and B.

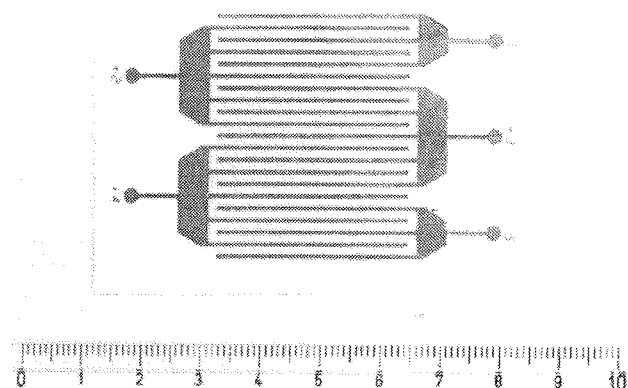


Fig.1: DIN-32513 test sample

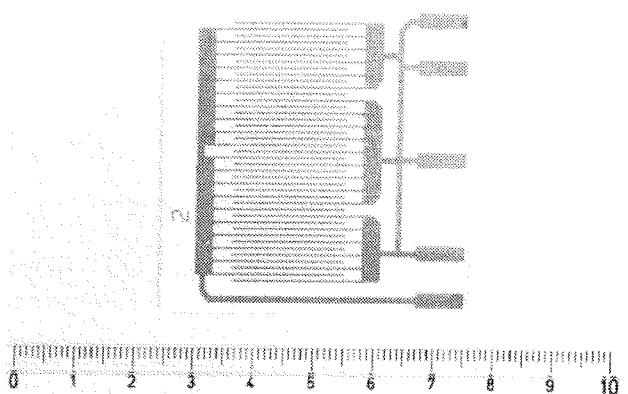


Fig.2: IPC-SF-818 test sample

RESULTS AND DISCUSSION

Ionic contamination measurement

The results of ionic contamination measurements are presented in Table IV for hybrid circuits printed on ceramic substrates and on printed circuits when the fluxes given in Table I were used for circuit soldering. The circuits were not cleaned after soldering. Visual inspection after soldering showed that the best appearance (clean, bright lines without solder balls) were obtained when fluxes A and E were used for soldering. For comparison the results when Alpha 611 was used for hybrid circuit soldering and Alpha GR8 for printed circuits soldering are also given.

The results of ionic contamination measurements when solder pastes were used for hybrid circuits or Alpha 611 for soldering in the solder pot and cleaned with Freon and the new solvents A and B are given in Table V. Ionic contamination was measured on hybrid circuits only, and by static and dynamic conductivity measurements

using the instruments mentioned earlier. The solvent volume used to dissolve flux residues from a circuit surface of 1 cm² after soldering was 3 ml/cm² for static conductivity measurements.

The results obtained from dynamic conductivity measurements were expressed in µg NaCl/cm², because the instruments were calibrated with NaCl.

Table IV: Ionic conductivity measurement results

Flux	Ionic conductivity (µS/cm)		Ionic content (µgNaCl/cm ²)		
	Iskra Conductometer		Iskra Conductometer		Omega-meter
	Ceramic	Printed	Ceramic	Printed	Ceramic
A	0.35	0.5	0.6	-	0.5
B	0.3	-	0.8	0.6	0.5
C	0.4	0.6	0.5	-	0.7
D	0.2	-	0.7	-	1.4
E	0.8	-	2.1	-	5.9
A 611	0.4	-	0.8	-	-
A GR8	-	0.6	-	0.7	-

Table V: Ionic conductivity measurement results

Solder paste	Ionic conductivity (µS/cm)	Ionic content (µgNaCl/cm ²)	
	Iskra Conductometer	Iskra Conductometer	Omega-meter
A	0.1	1.2	-
B	0.2	0.8	-
Flux Alpha 611 cleaned with:			
Freon	0.2	1.3	1.1
A	0.1	0.8	0.6
B	0.05	0.6	0.3

The results given in Table IV show that fluxes D and E leave more ionic residues on the circuits after soldering than fluxes A, B and C, and the results are comparable with results obtained for samples using Alpha 611 and Alpha GR8 rosin fluxes.

The highest of ionic residue after soldering was measured when flux E was used and is greater than the allowed limit of $1.3 \mu\text{gNaCl/cm}$ according to MIL-P-28809A. All other results are lower than the allowed limit of ionic content on circuits after soldering.

No great difference in ionic contamination left after soldering on ceramic substrates or printed circuits was observed. The measurements performed with the Iskra 5964 Conductometer were not so sensitive when the difference between the ionic contamination on the circuits were small.

The results given in Table V for solder pastes A and B containing "no residue" fluxes show comparable ionic residues on the circuits after soldering. When hybrid circuits were soldered with Alpha 611 RMA flux and the circuits cleaned with Freon and solvents A and B, the results obtained with three instruments show that highest of ionic residue left on the circuits was measured when the circuits were cleaned with Freon and only a very small quantity of ionic residues when the circuits were cleaned with solvent B.

Insulation resistance measurements

The results of insulation resistance measurements after humidity testing under conditions of 93% RH, at 40°C , 50 V DC are given in Table VI when measured on DIN 32513 test sample and in Table VII on IPC-SF-818 test samples.

Table VI: Results of insulation resistance measurements on the DIN-32153 test sample after humidity testing

Flux	Insulation resistance after humidity testing (ohm)					
	168 hours		500 hours		1000 hours	
	Ceramics	Printed	Ceramics	Printed	Ceramics	Printed
A	10^{12}	10^{12}	10^{12}	$5 \cdot 10^{11}$	$5 \cdot 10^{11}$	10^{11}
B	$8 \cdot 10^{11}$	$8 \cdot 10^{11}$	$5 \cdot 10^{11}$	$2 \cdot 10^{11}$	$6 \cdot 10^{11}$	10^{11}
A 611	$5 \cdot 10^{11}$	-	$5 \cdot 10^{11}$	-	10^{11}	-
A GR8	-	10^{12}	-	10^{11}	-	$0.2 \cdot 10^{11}$
Solder paste						
A	10^{12}	$0.8 \cdot 10^{12}$	$5 \cdot 10^{11}$	10^{11}	10^{11}	10^{11}
B		-	10^{11}	-	$5 \cdot 10^{11}$	-

The insulation resistance was measured on DIN 32513 test samples on both substrates when residueless fluxes and solder paste containing residueless fluxes were used for soldering. The insulation resistance was measured only on hybrid circuits when Alpha 611 flux

was used for circuit soldering and cleaned with the new solvents and Freon. The insulation resistance on the IPC-SF-818 test sample was measured on hybrid circuits only.

Table VII: Results of insulation resistance measurements on the IPC-SF-818 test sample after humidity testing (only on hybrid circuits)

Flux	Insulation resistance in humidity chamber; 93% RH, 40°C (ohm)	
	Before test	168 hours
A	10^{11}	$2 \cdot 10^8$
B	10^{12}	10^{10}
C	10^{11}	10^{10}
D	$6 \cdot 10^{10}$	10^7
E	$5 \cdot 10^{10}$	10^7
A 611	10^{12}	$5 \cdot 10^{11}$
Soldered with Alpha 611 and cleaned		
Freon	$8 \cdot 10^{11}$	$8 \cdot 10^{10}$
A	$8 \cdot 10^{11}$	$5 \cdot 10^{11}$
B	10^{12}	10^{11}

The results of insulation resistance measurements given in Table VI after humidity testing in the humid chamber at 93% RH, 40°C with a voltage applied to the test circuits show that after 500 and 1000 hours no significant reduction of insulation resistance was observed on all samples. The minimum value of insulation resistance measured after 1000 hours on hybrid circuits and printed circuits was 10^{10} ohm which is higher than the allowed value of 10^9 ohm according to Standard IPC-SF-818.

The results of insulation resistance measurements given in Table VII obtained on IPC-SF-818 test sample with very small distances (0.7 mm) between soldered lines (measured only on hybrid circuits) show a significant lowering of insulation resistance after 168 hours testing in the humid chamber. The lowest insulation resistance of 10^7 ohm was measured when samples were soldered with fluxes D and E. The same test samples soldered with Alpha 611 and cleaned with solvents A and B and Freon showed an insulation resistance of 10^{11} ohm which is higher than allowed according to IPC-SF-818.

CONCLUSIONS

Five "no residue" fluxes and two solder pastes containing "no residue" fluxes and two organic solvents for circuit cleaning after soldering as substitutes for CFC

solvents were tested by ionic conductivity measurements of dissolved flux residues and insulation resistance measurements on test samples between closely spaced soldered conductors in humid conditions.

The results for ionic contamination left on the hybrid and printed circuits after soldering, measured with three instruments for measuring the conductivity of the solution in which the circuits were immersed, show that the "no residue" flux E contains a higher ionic content than the other fluxes. The most sensitive measurements were obtained using the Omegameter 600 SMD instrument.

When using the new solvents A and B for cleaning Alpha 611 flux after soldering, a very low ionic residue was measured on the circuit.

The insulation resistance measurements show a very low decrease of insulation resistance when measured on DIN 32513 test sample in all cases when compared with the results obtained on IPC-SF-818 test samples. The lowest insulation resistance of 10^7 ohm was found when measured on IPC-SF-818 test sample for hybrid circuits soldered with fluxes D and E as compared with 10^{11} ohm measured on samples soldered with Alpha 611 and cleaned with the new solvents A and B. This value was higher than the 10^{10} ohm measured on samples soldered with Alpha 611 and cleaned with Freon (CFC).

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