A Novel Solution for No-Clean Flux Not Fully Dried Under Component Terminations

Fen Chen[1] and Ning-Cheng Lee[2]
Indium Corporation
1 fchen@indium.com; 2 nclee@indium.com

ABSTRACT
The miniaturization trend is driving industry to adopting low standoff components or components in cavity. The cost reduction pressure is pushing telecommunication industry to combine assembly of components and electromagnetic shield in one single reflow process. As a result, the flux outgassing/drying is getting very difficult for devices due to poor venting channel. This resulted in insufficiently dried/burnt-off flux residue. For a properly formulated flux, the remaining flux activity posed no issue in a dried flux residue for no-clean process. However, when venting channel is blocked, not only solvents remain, but also activators could not be burnt off. The presence of solvents allows mobility of active ingredients and the associated corrosion, thus poses a major threat to the reliability. In this work, a new halogen-free no-clean SnAgCu solder paste, Paste F, has been developed. This solder paste exhibited SIR value above the IPC spec 100 MΩ without any dendrite formation, even with a wet flux residue on the comb pattern. The wet flux residue was caused by covering the comb pattern with 10 mm × 10 mm glass slide during reflow and SIR testing in order to mimic the poorly vented low standoff components. The Paste F also showed very good SMT assembly performance, including voiding of QFN and HIP resistance. The wetting ability of Paste F was very good under nitrogen. For air reflow, Paste F wetted well on all surface finishes, and is better than paste C which is widely accepted by industry for air reflow process. The above good performance on both non-corrosivity with wet flux residue and robust SMT process can only be accomplished through a breakthrough in flux technology.

KEY WORDS
No-clean, flux, Surface Insulation Resistance (SIR), SAC305, halogen-free, soldering, low standoff components, wet flux residue

INDUSTRY TRENDS
The electronic industry is obviously driven by miniaturization and cost reduction.

The highly favorite thin, small portable devices such as smart phones are the strongest driving force pushing the continuous thinning down of devices, component profiles, and boards. In order to support the advancement in getting thinner, low standoff components such as QFN and LGA become a popular choice in product design, as shown in Figure 1, and exemplified in Figure 2. The shift toward a thinner profile is further augmented with designs encompassing components assembled in the cavity of substrate, as schematically shown in Figure 1 as well, and illustrated in more details in Figure 3 .

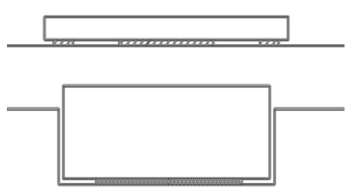


Figure 1 Schematic drawing of low standoff components and components assembled in the cavity of substrate.[1]

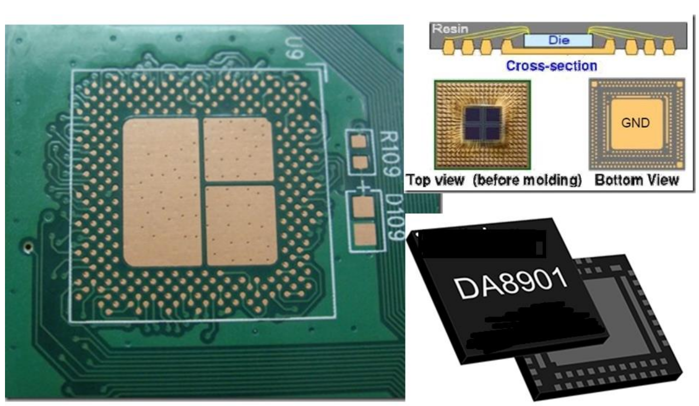


Figure 2 Examples of QFN components and PCB footprint

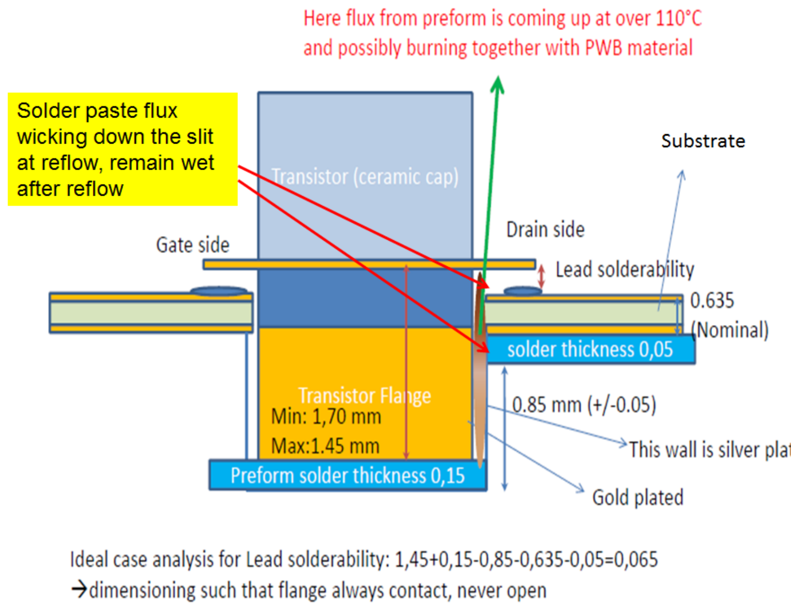


Figure 3 Schematic of transistor partially embedded in substrate

On the other hand, for telecommunication devices, in order to reduce the cost, the assembly of components often is conducted with the simultaneous assembly of electromagnetic shield with few or no venting holes on the shield, as shown in Figure 4, and exemplified in Figure 5. This way, the labor cost needed for assembly of clip-on type shield can be eliminated. For simultaneous assembly process, a proper number of venting holes on the shield are definitely needed for escape of flux fumes. Those holes often are tape-masked after reflow assembly for integral shielding effect.

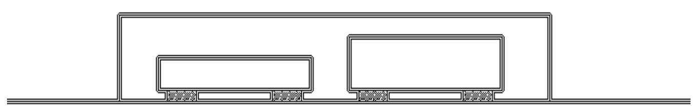


Figure 4 Components sealed within electromagnetic shield [1]

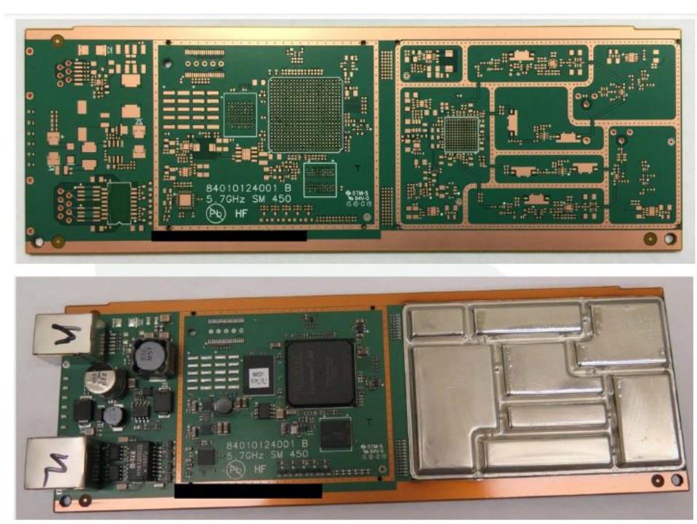


Figure 5 Bare board and assembled high frequency RF telecommunication board with components enclosed by shields

FLUX BEHAVIOR

The flux typically comprised of solvents, activators, resins, and rheological additives. Examples of activators may include organic acids, organic bases, and halogenated compounds. In the case of resins, depending on the nature of flux being water soluble or no-clean, the resin chemistry may be highly hygroscopic polar compounds or non-polar rosins or resins. At conventional SMT board reflow assembly, the flux residue typically dried out well. Figure 6 shows the flux vaporization behavior under open environment [2]. The solvent escaped first, and then followed by solid escape at a higher temperature.

In general, flux is formulated with sufficient flux capacity so that it can provide adequate fluxing performance over a wide processing window, such as what shown in Figure 7. A short profile (profile 1 in Figure 7) consumes less flux activity than a long profile (profile 2 in Figure 7) does. In other words, the flux will have more or less remaining activity or activators after reflow, depending on the reflow profile utilized.

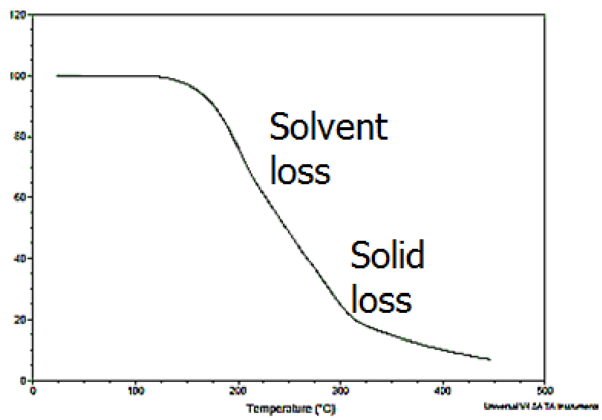


Figure 6 Flux vaporization behavior [2]

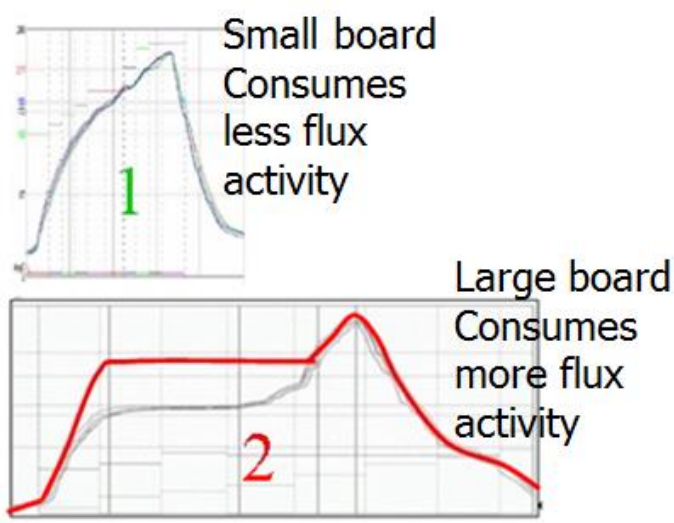


Figure 7 Flux activity consumption varies with profile type [3]

For a good no-clean system, any remaining activators are encapsulated within the non-polar rosin/resin, thus poses no reliability concern. For water soluble system, the flux residue can be easily removed by aqueous cleaners, hence also poses no issue on reliability.

CHALLENGE

The low standoff components and components in cavity are indispensable in manufacturing thin profile devices. However, a new issue emerged associated with those slimsy fashionable electronic gadgets.

The smaller clearance or holes would not allow easy access and removal of flux residues, thus results in immediate corrosion problem

The small clearance between components and substrates greatly hampered the venting of flux volatiles at reflow soldering. As a result, considerable amount of flux ingredients got entrapped under the components, including solvents, vaporized activators, rheological additives, and fluxing reaction products [4]. On the other hand, for many designs with components sealed within the electromagnetic shield, the venting whole number may be too few or the whole diameter may be too small, the venting of flux volatiles can be hampered as well.

When venting of flux volatiles is significantly impeded due to configuration factor described above, the reliability immediately becomes a concern. Obviously, for aqueous cleaning system, the smaller clearance or holes would not allow easy access and removal of flux residues, thus results in immediate corrosion problem.

Even for no-clean system, where the flux residue used to be benign, the entrapped solvents and activators start to create corrosion problems which were never experienced before. For instance, organic acid activators in dried flux residue are not capable of undergoing corrosion reaction when encapsulated by solid rosin. This holds true even under hot humid environment, since water cannot penetrate through the non-polar rosin protection layer. However, in the presence of entrapped solvent, the flux residue becomes liquid or semi-liquid, and activators can move around engaging corrosion reaction, particularly under hot humidity and biased condition.

Figure 8 depicts the behavior of activator RCOOH under different process conditions. When the venting path is open, not only the solvent can be dried out, but some of the activator can also be vaporized and escaped from flux residue. When the solvent is retained in the flux due to blocking of venting path, the wet flux residue is more prone to pick up moisture under humid environment, and consequently results in corrosion, particularly under elevated temperature and biased condition.

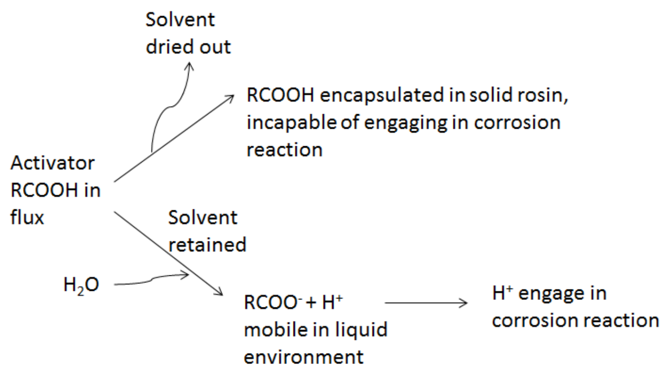


Figure 8 Activator RCOOH behavior under different process condition [1]

The corrosion problem caused by lack of venting path can be detrimental. Figure 9 shows dendrite formation around a large pad of a bottom-terminated component. The flux expelled from solder paste at large pad could not dry out due to very limited venting space. Figure 10 shows dendrite formation for chip capacitor covered by an electromagnetic shield without venting hole. The solvent was not able to vent out, consequently resulted in dendrite formation.

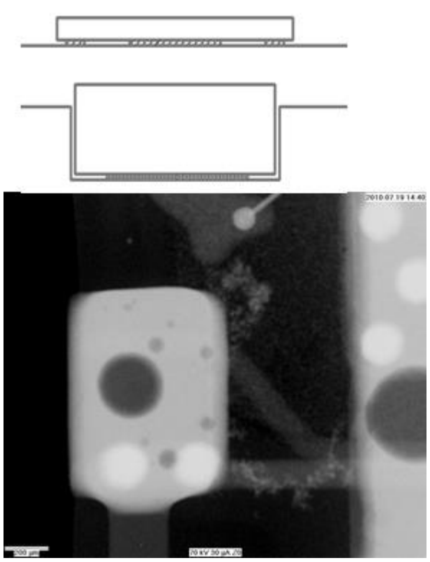


Figure 9 Dendrite formation around the large pad of a bottom-terminated component[1]

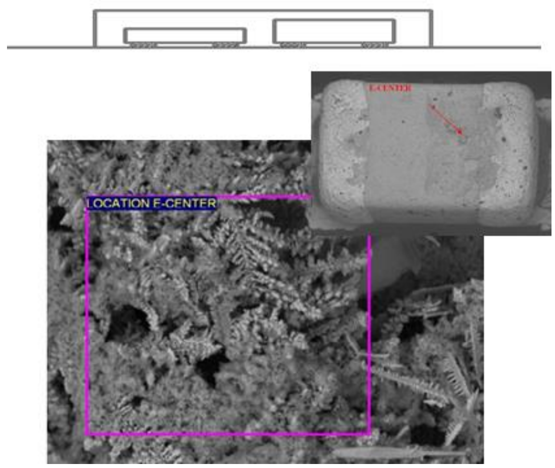


Figure 10 Dendrite formation for chip capacitor covered by a electromagnetic shield without venting hole

WHERE WE GO FROM HERE

The emergence of "low standoff components" or "components in cavity" is driven by the need for convenience. The assembly of components and concurrent sealing is driven by desire of cost reduction. The assembly of components and concurrent sealing is driven by desire of cost reduction. Apparently both driving forces are here to stay. Facing the resultant corrosion and dendrite formation, the question is: where we go from here?

The first potential solution is removal of flux residue. This will be very challenging, since the cause "small venting space" of having wet flux residue will also be the barrier for cleaner to remove the flux residue. To make situation worse, the residue is getting more and more difficult to remove with new flux chemistries needed for supporting further miniaturization [5].

The second potential solution is to develop flux which is non-corrosive and non-conductive even if flux residue drying is not possible. In other words, develop a flux which is benign wet or dry. However, in principle, a wet flux residue being non-corrosive and non-conductive should contain very low amount of activators and exhibit very low activity. Such type of flux would be poor in wetting, which in turn would be poor in voiding [6, 7] and HIP performance [8], hence would not be adequate for SMT assembly applications.

The challenge is: can a flux be developed, being benign with wet flux residue, but still perform well at SMT assembly process, including reflowed under air?

QUEST FOR BENIGH WET FLUX

A major developmental effort has been conducted for this quest. As a result, a new halogen-free no clean solder paste, Paste F, was developed. The performance assessment, including the SIR behavior with hampered venting of flux fume, wetting, voiding, and head-in-pillow, are presented and discussed below.

EXPERIMENTAL

1. **Materials**

Six solder pastes were tested, including the newly developed halogen-free no-clean solder paste Paste F and five conventional solder pastes as controls. The characteristics of those six solder pastes are shown in Table 1. All solder pastes employed 96.5Sn3.0Ag0.5Cu (SAC305), type 4 (20-37 microns) or type 4.5 solder powder. Pastes A, B, and C are standard products well received by market as SMT no-clean lead-free solder paste. Paste D and E are commercially available materials; the powder size of E was not available.

Table 1 Characteristics of solder pastes evaluated.[1]

Flux	Characteristics
A	Halogenated, no-clean, T4
B	Halogenated, no-clean, T4.5
C	Halogen-free, no-clean, T4
D	Halogen-free, no-clean, T4
E	Halogenated, no-clean
Paste F	Halogen-free, no-clean, T4

2. **Surface Insulation Resistance (SIR) Test**

Standard IPC B-24 SIR board was used for this experiment. The flux vehicle of each of the solder pastes was printed onto 3 of the 4 comb patterns in the SIR comb pattern using a 0.10 mm (4 mil) thickness stencil. A 10 mm × 10 mm glass slide was placed onto part of the printed flux of a comb pattern. Two comb patterns received this glass slide coverage treatment, as shown in Figure 11. Each of the glass slides was further secured onto the SIR coupon with a production high temperature tape to avoid slide movement during subsequent air reflow. The reflow was conducted via a convection oven with a peak temperature of 244ºC, with profile shown in Figure 12. Other than the coupon preparation, the SIR testing was performed in accordance with J-STD-004B.

Figure 11 Example of reflowed SIR board with glass slide, with 3 comb patterns printed with flux, and 2 of these 3 comb patterns were further covered with glass slides.[1]

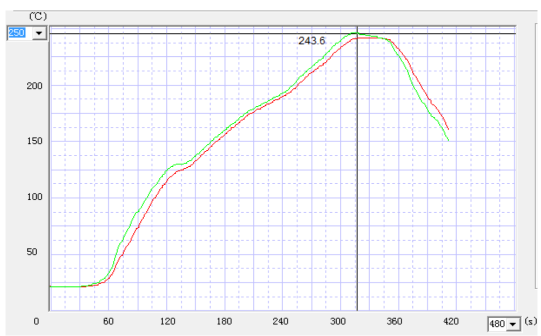


Figure 12 Reflow profile used for fluxed SIR boards with or withou glass slides attached.[1]

The SIR performance of those fluxes on SIR coupon without glass slide coverage (Standard SIR Test) was also evaluated for comparison purpose. Here all flux fumes vaporized with dry flux residue left behind on the comb pattern.

It should be noted that during the preliminary trials, solder paste was printed onto comb pattern followed by placing glass slide. After reflow, the flux residue under the glass slide was found to be dry despite the glass slide coverage. This was due to too high a standoff caused by the solder rim formed on comb pattern. In order to mimic the hampered venting of flux fume, printing flux vehicle instead of solder paste was found to be effective and resulted in wet flux residue.

3. Wetting Test

Use a three-hole stencil, with hole diameter of 6.35 mm (0.25 inch), and thickness of 0.12 mm (5 mil), print each paste onto 4 types of substrates with surface finishes described below: OSP substrate, Oxidized OSP (by pre-conditioning OSP substrate in 200ºC oven for 2 hours), Nickel and Alloy 42. The substrate with printed paste was then sent through oven both under air and under nitrogen atmosphere with reflow profile shown in Figure 13. The reflowed coupon was then examined for wetting behavior.

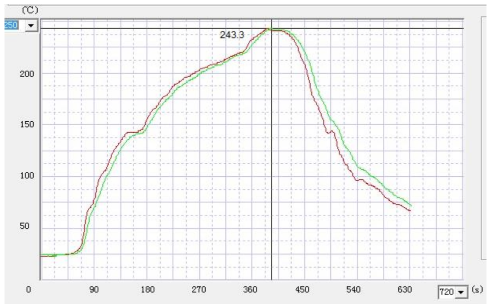


Figure 13 Reflow profile used for paste wetting test[1].

4. Voiding Test

A dummy coupon representing QFN was assembled as below (see Figure 14):

1) Prepare 30 mm x 30 mm FR4-OSP with 10 mm x 10 mm Cu pad in the center.
2) Print the paste onto the Cu pad using a 0.3 mm (12 mil) thick stencil with 10 mm x 10 mm aperture size.
3) Place a 12 mm x 12 mm QFN coupon with Immersion Ag surface finish onto the paste
4) Send the sandwich through convection oven with profile shown in Figure 15 and air reflow atmosphere
5) Examine the voiding with X-ray inspection equipment.

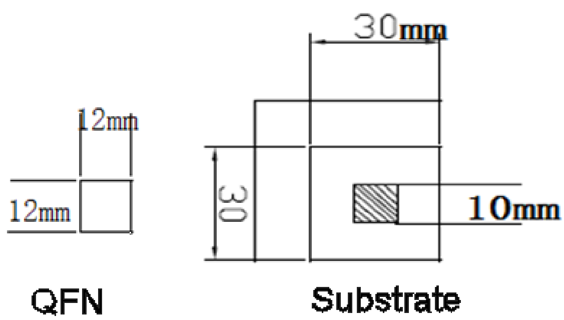


Figure 14 Schematic drawing of QFN coupon and substrate[1].

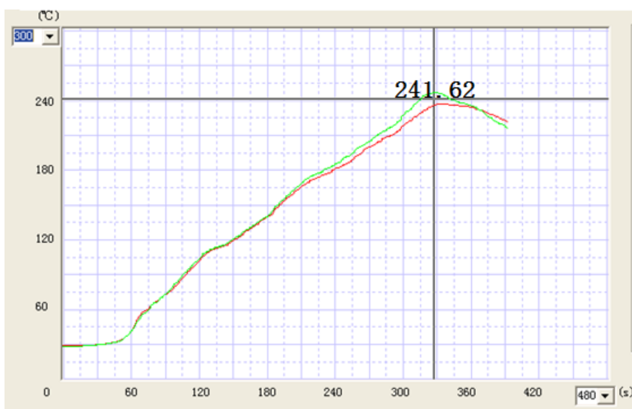


Figure 15 Reflow profile used for QFN voiding test[1].

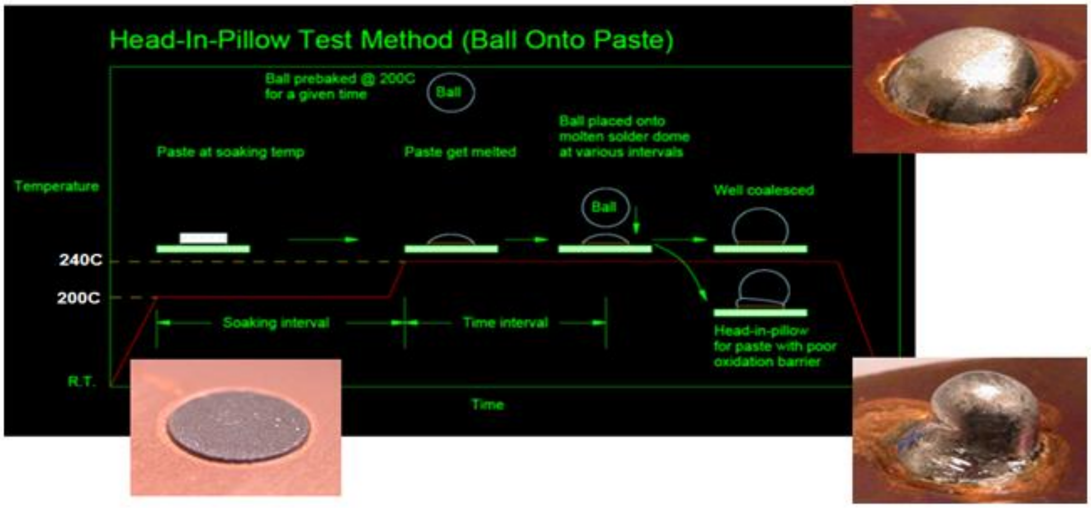
5. Head-In-Pillow (HIP) Test

The propensity toward HIP was evaluated with Ball-Onto-Paste method [8], as described below.

Ball onto Paste test

Ball onto Paste method is used to assess combined capability of oxidation resistance and excessive fluxing capacity of fluxes. In this method, both paste and solder ball are subjected to oxidation prior to putting them together. Figure 16 shows the schematic drawing about the test method, which can be described with the following procedure.

1) Precondition 2.3 mm diameter solder ball at 200°C under air for 30 min, then put it aside.



2) Print 3.0 mm diameter solder paste onto Cu coupon using a 125 µ thick stencil. Precondition the printed solder paste at 200°C on hot plate with 2 min under air.
3) Move the preconditioned specimen onto 240°C hot plate under air. Once the paste melted, hold the coalesced solder at 240°C, with time varies (e.g. 0, 20, 60, 80 seconds).
4) Drop a preconditioned solder ball onto the liquid solder dome. Hold the specimen on 240°C hot plate for 20 more seconds under air. Remove specimen from hot plate.
5) Examine the specimen under 40X optical microscope for incomplete coalescence, which reflects propensity of HIP (Head-in-Pillow).

Example of printed paste (lower left), full coalescence between ball and paste (upper right), and partial coalescence (lower right) are exemplified in Figure 16.

Figure 16 Ball Onto Paste method for HIP propensity evaluation[1].RESULTS

1. SIR

Table 2 shows the key data points on results of SIR standard test and SIR with glass slide on for all fluxes. Figure 17 shows the original data for SIR standard test, while Figure 18 shows the original data for SIR with glass slide on for all fluxes. F or standard SIR test, no significant difference can be discerned between various fluxes, with most of fluxes being above 10^9 Ω except flux A.

Table 2 SIR standards and SIR with glass slide on for various fluxes. Expressed as log of resistance ohm [1].

Flux	SIR standard				SIR with glass slide on			
	0	24 hours	96 hours	168 hours	0	24 hours	96 hours	168 hours
A	8.2	8.8	9	9.2	6	6	6	6
B	9.2	9.4	9.6	9.6	8.2	8.3	6.4	6.4
C	10.5	10	9.9	9.9	6	6	6	6
D	9.7	9.4	9.4	9.4	6.8	6.7	6	6
E	10.3	10.2	10.1	10	7.6	8.3	8.4	8.7
Paste F	9.4	9.5	9.5	9.6	8.1	8.2	8.2	8.2

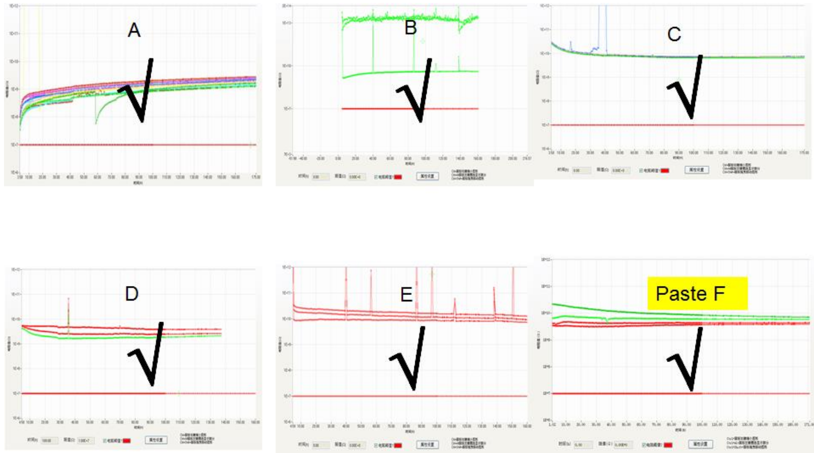


Figure 17 SIR standard test data of various fluxes shown in Table 1.

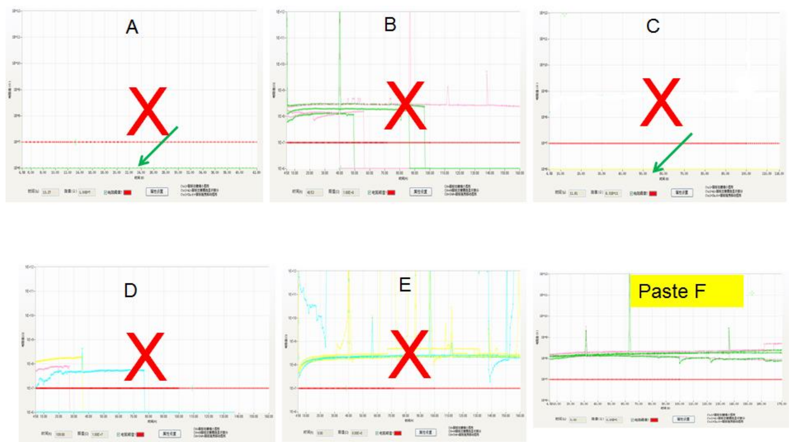


Figure 18 SIR data with glass slide on of various fluxes shown in Table 1.

However, when the glass slide was placed on test coupon, most traditional fluxes failed badly and the resistance was under 1 MΩ. Here all readings below 1E+6 Ω were reported as 1 MΩ due to the inserted current limiting resistor in the circuitry. Flux E was close to pass, with good portion reading above 100 MΩ, except at the beginning, near the end, and a number of blips. Flux Paste F was the only one exhibiting a clean pass through whole test.

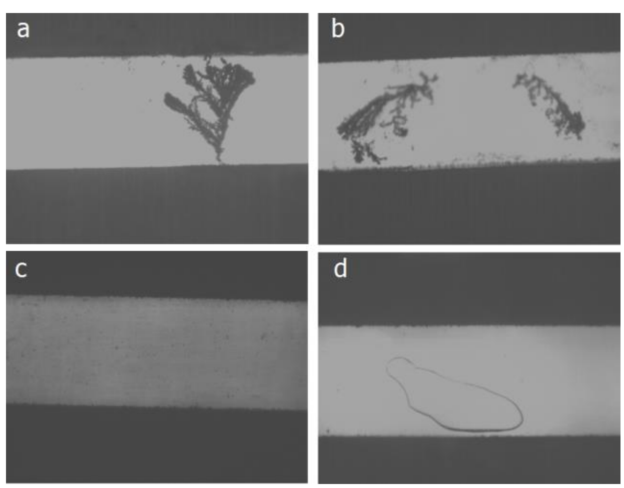


Figure 19 Close up look of SIR coupons after SIR test with glass slide on (50X), with a, b showing dendrites, and c, d free of dendrites [1].

The coupons with glass slide on were examined with 50X microscope. The dendrite was clearly observed in flux A, B, C and D, as exemplified in Figure 19 (a) and (b). No dendrite could be discerned for flux E and flux Paste F, as exemplified in Figure 19 (c) and (d).

Flux A, B and E are halogenated and flux C, D and Paste F are halogen-free. For the SIR test with glass slide on, with flux Paste F being the only one passed the spec, flux E nearly passed, and the rest fluxes all failed, it is obvious that removing halogen from flux did not promise a pass, and a major breakthrough in flux chemistry formulation is needed to accomplish this.

Wetting

When reflowed under nitrogen, all solder pastes wetted well on all substrates and no difference can be discerned.

When reflowed under air, the wetting behavior of those pastes can be differentiated. Figure 20 shows the solder spread appearance on various substrates. The halogenated pastes A, B and E showed full wetting of the prints on all 4 substrates. For the halogen-free solder pastes C, D, and Paste F, D showed dewetting on all substrates. C wetted regular OSP and oxidized OSP well, showed some dewetting on Ni and considerable dewetting on Alloy 42. Paste F wetted well on all four surface finishes. Considering that paste C is very well accepted by industry for air reflow process, Paste F wetted better than C, thus is expected to meet industry need for air reflow.

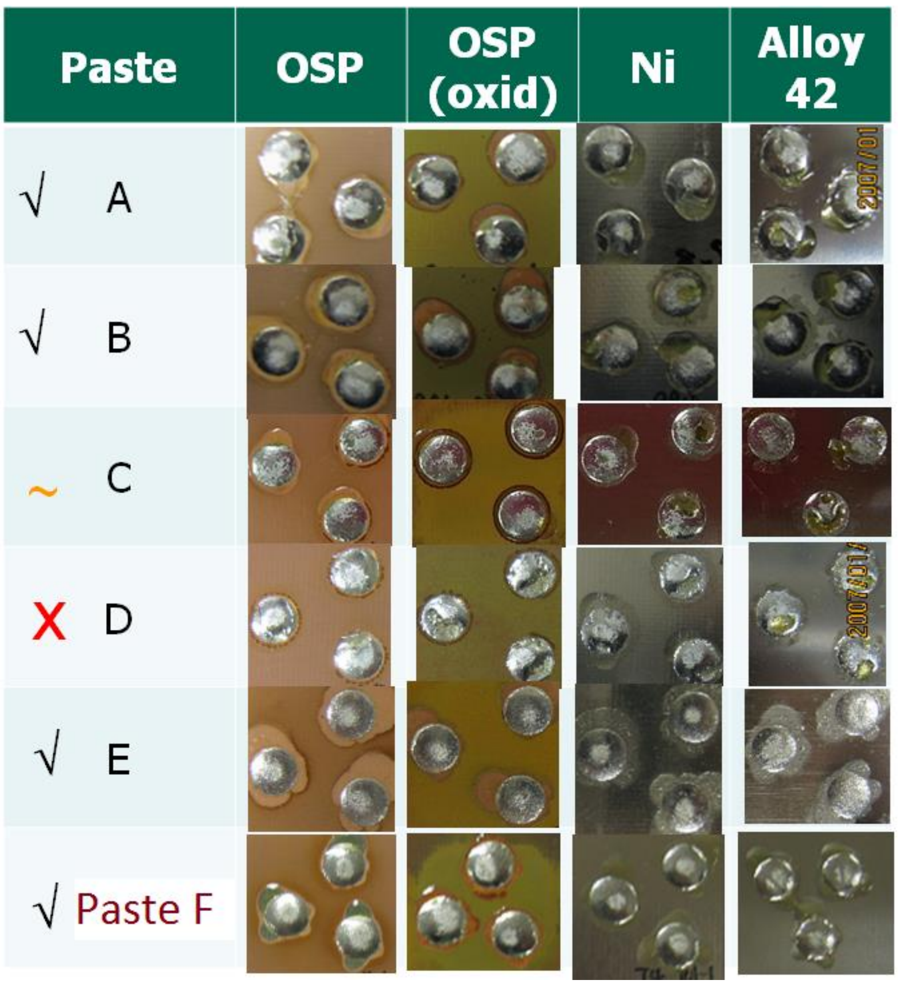


Figure 20 Wetting of solder pastes under air on various substrates[1].

2. Voiding

The voiding performance of each paste is shown in Table 3. The halogenated paste B shows the lowest voiding rate among all pastes studied. The halogen-free Paste F exhibits the second lowest voiding, and is better than all halogen-free pastes.

Table 3 Voiding performance (area %) of various solder pastes[1].

No.	Largest void (%)	SD	All voids (%)	SD
A	2.6	1.4	19.6	5.8
B	1.1	0.7	8.0	7.4
C	3.0	1.5	20.3	7.2
D	1.7	0.6	19.7	5.8
E	1.5	1.1	24.1	8.4
Paste F	2.3	1.4	9.4	5.7

3. Head-in-Pillow(HIP)

The head-in-pillow behavior of various pastes is shown in Table 4. The resistance against occurrence of HIP can be ranked below: B > A > Paste F > E > C > D. Paste F is not only better than all halogen-free pastes, but also better than the halogenated paste E.

Table 4. Head in Pillow Test for Various Solder Pastes[1]

Sample	After preheated at 200C/2 min, time of paste at 240C before placing ball						
	0 s	20 s	40 s	60 s	80 s	100 s	120 s
A					coalesced	marginal	HIP
B						coalesced	marginal
C	coalesced	HIP			—	—	—
D	marginal	HIP			—	—	—
E		coalesced	marginal	HIP			
F					coalesced	HIP	

Legend: coalesced; coalesced with oxide film impression discernible; failed to coalesce, HIP

DISCUSSION

The Paste F performed very well at voiding and HIP under air. Good voiding demands good wetting [6,7], and good HIP need good oxidation barrier capability plus good fluxing capacity [8]. The good wetting and good fluxing capacity is consistent with the wetting performance results observed. In the meantime, the good SIR performance with wet flux residue demands low activator concentration or low corrosively in the flux residue. The dilemma between good soldering performance and low corrosivity can only be resolved with a breakthrough in flux technology, as demonstrated by Paste F here.

The performance of those pastes can be summarized in Table 5. For SIR - glass slide on, Paste F was the only one which performed well. All solder pastes had at least two features unacceptable, except Paste F. This newly developed paste performed very well on all features, and marginally well for wetting under air. Even for that feature, Paste F still matched paste C which is widely accepted by industry for air reflow processes.

Table 5 Summary of solder paste performance[1]

Paste	SIR-G	SIR-Std	HIP	Void	Wet (air)	Wet (N2)
A T4	x	√	√	x	√	√
B T4.5	x	√	√	√	√	√
C T4	x	√	x	x	√	√
D T4	x	√	x	x	x	√
E	x	√	x	x	√	√
Paste F T4	√	√	√	√	√	√

Paste F (halogen-free) good overall under N2 and Air

good

acceptable

unacceptable

A	Halogenated NC
B	Halogenated NC
C	Halogen-free NC
D	Halogen-free NC
E	Halogenated NC
Paste F	Halogen-free NC

CONCLUSIONS

The miniaturization trend is driving industry to adopting low standoff components or components in cavity. The cost reduction pressure is pushing telecommunication industry to combine assembly of components and electromagnetic shields in one single reflow process. As a result, the flux outgassing/drying is getting very difficult for devices due to poor venting channels. This resulted in insufficiently dried/burnt-off flux residue. For a properly formulated flux, the remaining flux activity posed no issue in a dried flux residue for no-clean processes.

However, when the venting channel is blocked, not only do the solvents remain, but also activators could not be burnt off. The presence of solvents allows mobility of active ingredients and the associated corrosion, which poses a major threat to the reliability. In this work, a new halogen-free no-clean SnAgCu solder paste, Paste F, has been developed. This solder paste exhibited SIR value above the IPC spec. of 100 MΩ without any dendrite formation, even with a wet flux residue on the comb pattern. The wet flux residue was caused by covering the comb pattern with a 10 mm × 10 mm glass slide during reflow and SIR testing in order to mimic the poorly vented low standoff components. The paste Paste F also showed very good SMT assembly performance, including voiding of QFN and HIP resistance. The wetting ability of Paste F was very good under nitrogen. For air reflow, Paste F wetted well on all surface finishes, and is better than paste C which is widely accepted by industry for air reflow processes. The above good performance on both non-corrosivity with wet flux residue and robust SMT process can only be accomplished through flux technology breakthroughs.

REFERENCES

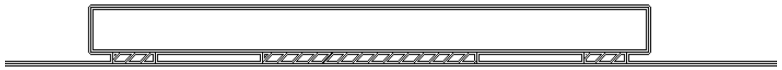
1. Fen Chen and Ning-Cheng Lee, "The risk and solution for no-clean flux not fully dried under component terminations", SMTA International, Chicago, IL, September, 2015..
2. Internal company data.
3. Ning-Cheng Lee, "Critical Parameters in Voiding Control At Reflow Soldering", Chip Scale Review, August-September 2005.
4. Eric Bastow, "The Effects of Partially Activated No-Clean Flux Residues Under Component Bodies and No-Clean Flux Residues Entrapped Under RF Cans on Electrical Reliability". IPC APEX, 2011.
5. Ning-Cheng Lee, "Flux Technology For Lead-Free Alloys & Its Impact On Cleaning", SMTA International, Chicago, IL, September, 2002.
6. Wanda Hance and Ning-Cheng Lee, "Voiding Mechanisms in SMT", China Lake's 17th Annual Electronics Manufacturing Seminar, 1993.
7. Ning-Cheng Lee, "Reflow soldering processing and troubleshooting SMT, BGA, CSP, and Flip Chip Technologies", Newnes, pp.288, 2001.
8. Yan Liu, Pamela Fiacco, and Ning-Cheng Lee, "Testing and Prevention of Head-In-Pillow". Surface Mount Technology Association (SMTA) China South Conference at NEPCON Shenzhen, August, 2010.

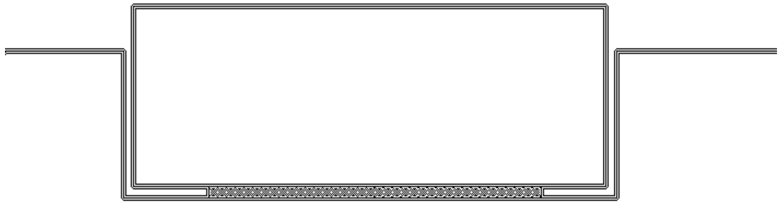
A Novel Solution For no-clean Flux Not Fully Dried Under Component Terminations

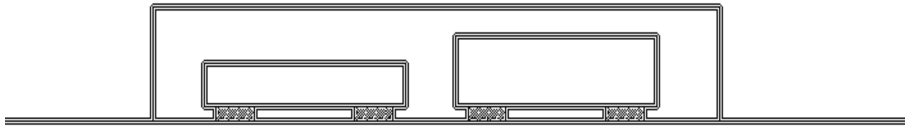
Ning-Cheng Lee & Fen Chen
Indium Corporation

Background – Insufficient Drying/Burnt-off

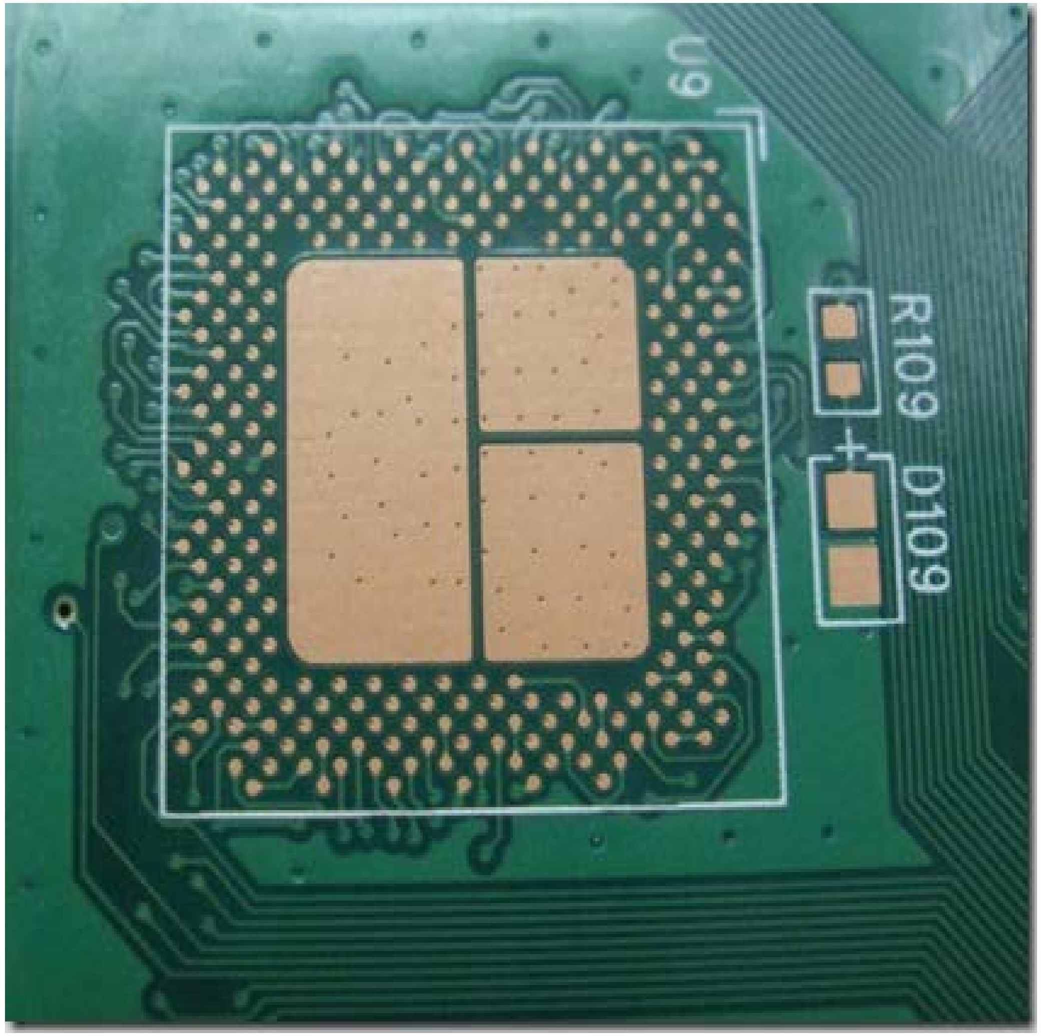
- At SMT assembly, flux outgassing/drying is difficult for devices with poor venting channel, and resulted in insufficiently dried/burnt-off flux residue for no-clean process. Examples including
  - Large low stand-off components such as QFN, LGA
  - Components covered under electromagnetic shield which has either no or few venting holes
  - Components assembled within cavity of board
  - Any other devices with small open space around solder joints

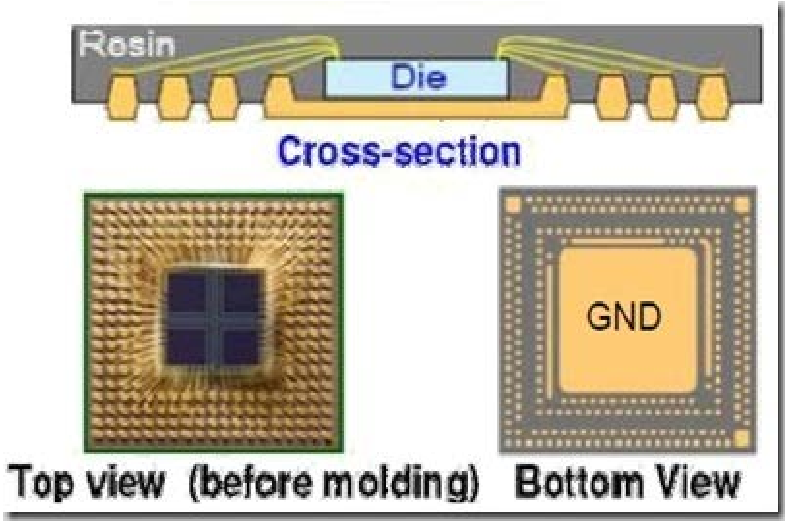


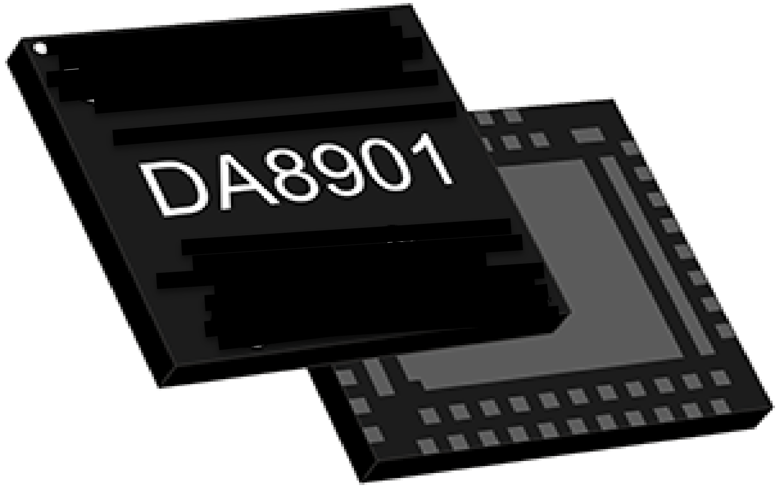




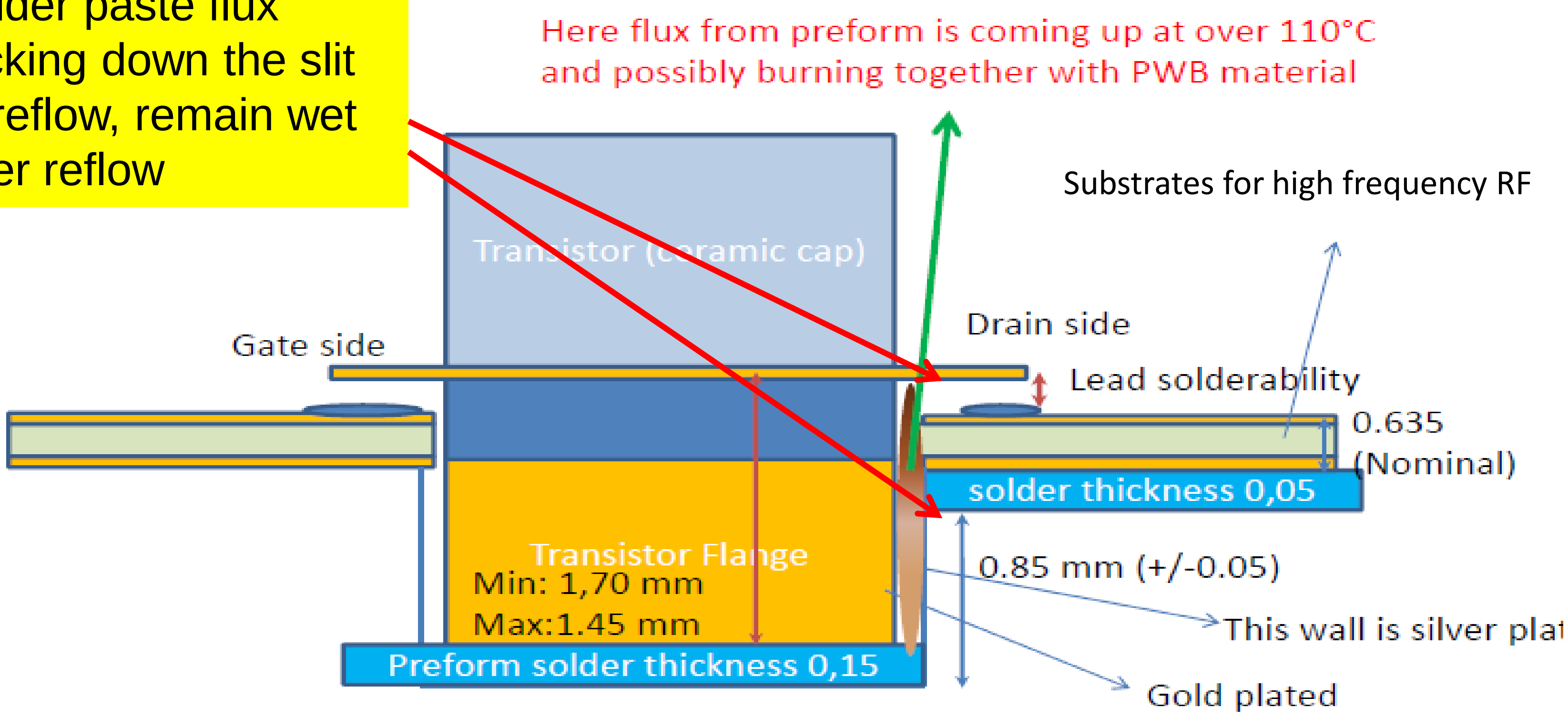
Land Pattern for aQFN





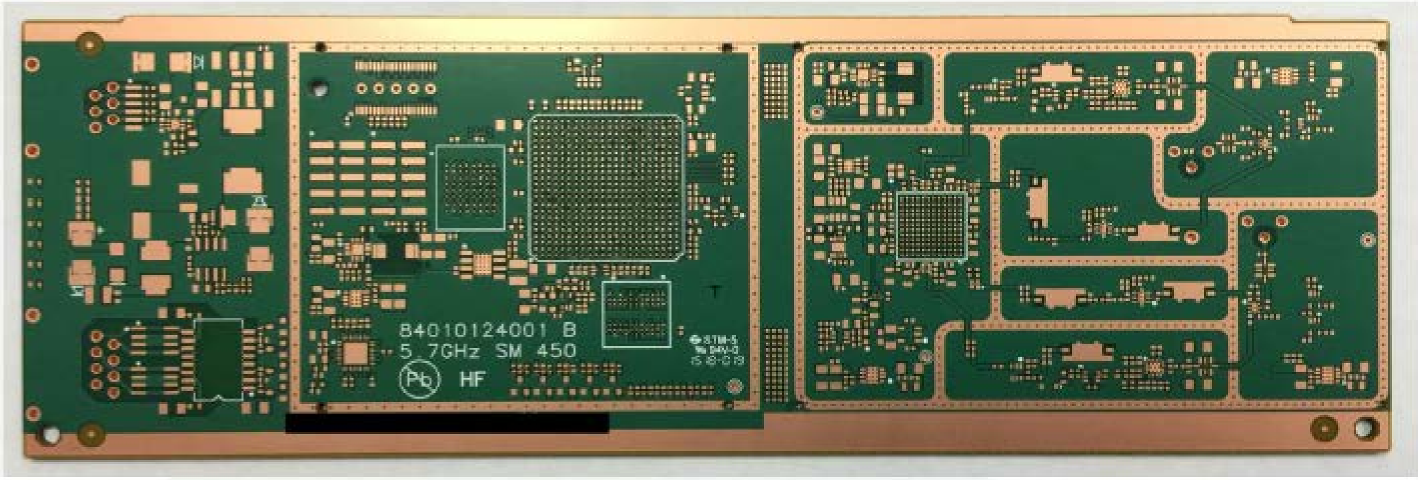


Solder paste flux wicking down the slit at reflow, remain wet after reflow



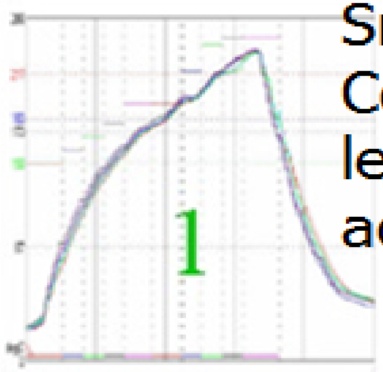
Ideal case analysis for Lead solderability: 1,45+0,15-0,85-0,635-0,05=0,065
→dimensioning such that flange always contact, never open

Bare & Assembled Boards



Flux Activity Typically Not All Consumed at Reflow

- Flux typically exhibits sufficient activity capacity to cover the need of wide range of reflow profiles. Thus generally, at end of reflow, not all flux activity is depleted.



Small board Consumes less flux activity

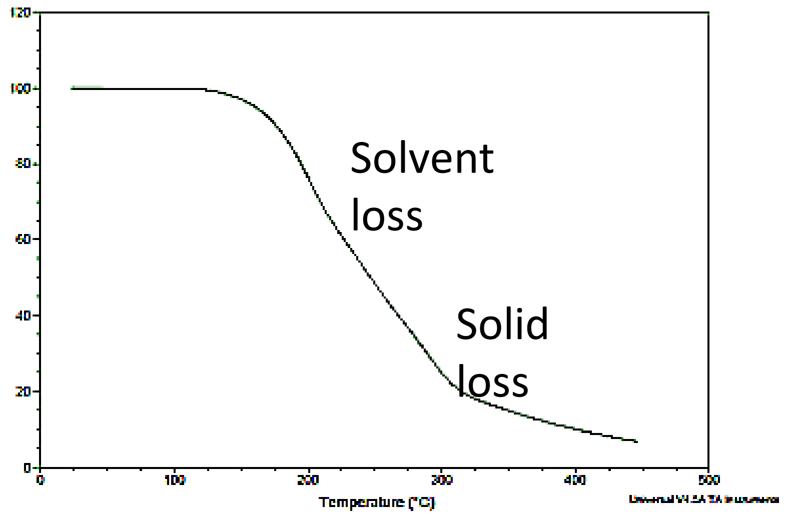
Large board Consumes more flux activity

Remaining Flux Activity No Issue

- For a properly formulated flux, the remaining flux activity posed no issue in a dried flux residue. Activators are embedded in solid rosin/resin matrix can not engage reaction and are benign.
- (Similar to some salt blended in vaseline cause no corrosion on nail in vaseline.)

Effect of Insufficient Dried/Burnt-off Flux Residue

- At typical SMT reflow condition, not only solvent dried out, but some solids also burnt off, including low molecular weight activators.
- However, when venting channel is blocked, not only solvents stay, but also less activators burnt off.
- Presence of solvents allows mobility of active ingredients, and the associated chemical reactions, thus increase the risk of corrosion
- Corrosion can be aggravated by bias, higher humidity and temperature



Behavior of Activator

Activator RCOOH in flux

Solvent dried out

RCOOH encapsulated in solid rosin, incapable of engaging in corrosion reaction

Solvent retained

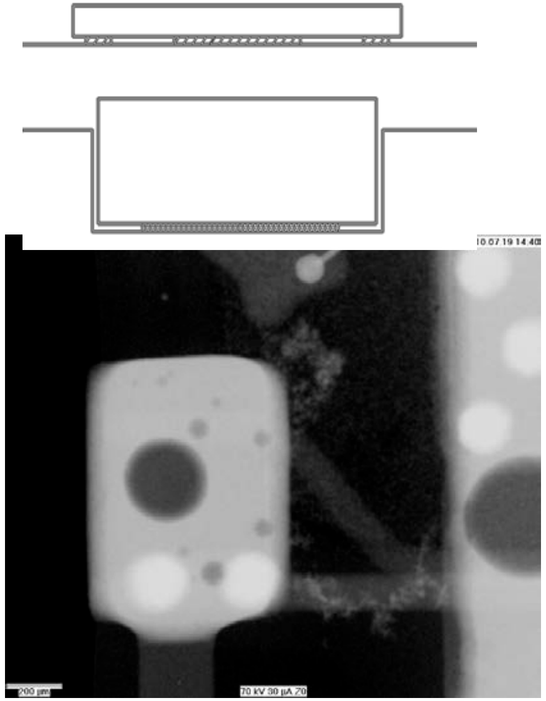
H_2O

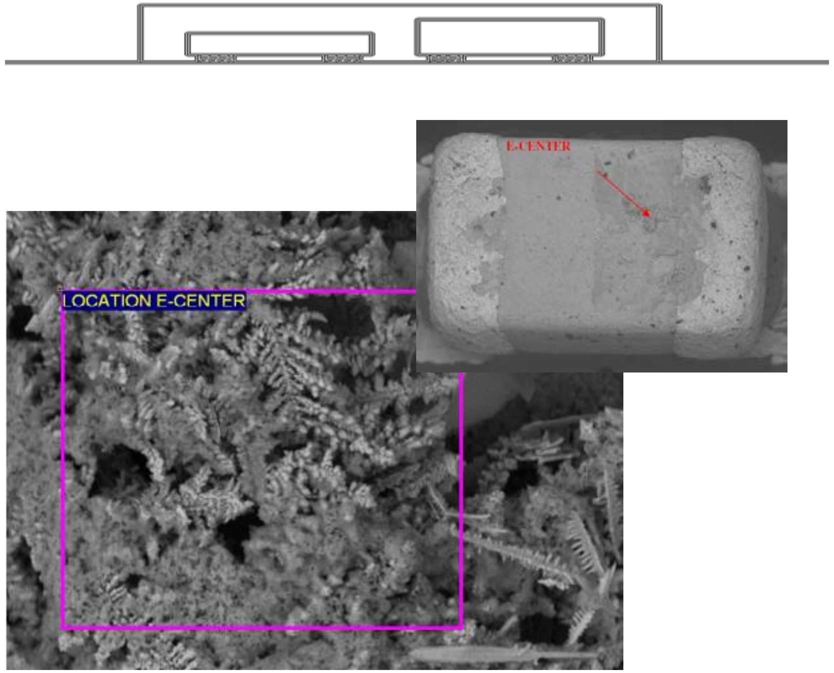
$RCOO^- + H^+$ mobile in liquid environment

H^+ engage in corrosion reaction

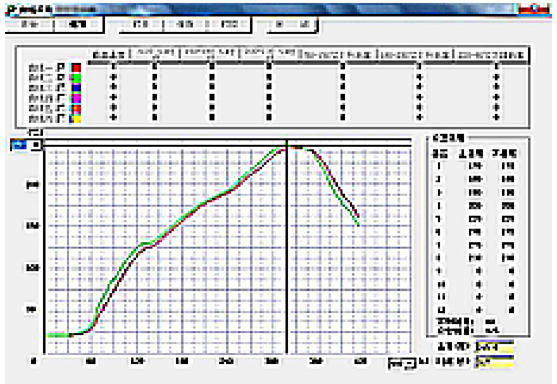
Dendrite Formation Caused by Poor Design – Flux unable to outgas

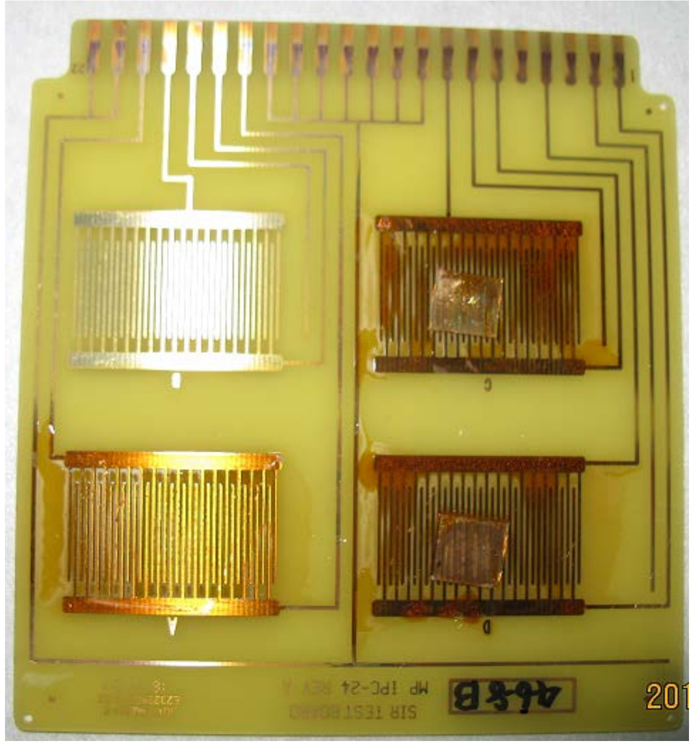
- **Dendrite** formation around the large pad of bottom-terminated-components. The flux expelled from solder paste for large pad could not outgas due to very limited open space for venting.
- **Dendrite** formation for chip capacitor covered by a electromagnetic shield without venting hole. Flux not able to vent out to dry out the solvent, thus result in dendrite formation.





SIR Test Setup to Mimic Poorly Vented Solder Reflow





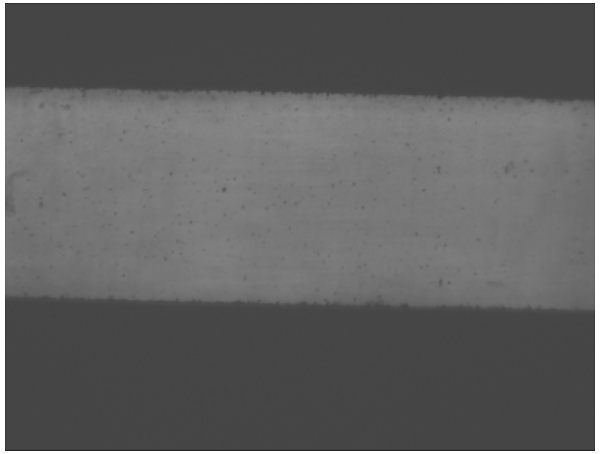
- To simulate the poorly vented reflow condition
  - Print flux on comb pattern
  - Place glass slide on top of flux
  - Reflow
  - Run SIR test

- Note
  - Print solder paste on comb pattern resulted in a higher standoff between glass slide and SIR coupon which still allow flux fume venting

SIR (Standard)

Paste	0 /log(Ω)	24 hrs /log(Ω)	96 hrs /log(Ω)	168 hrs /log(Ω)
A	8.2	8.8	9.0	9.2
B	9.2	9.4	9.6	9.6
C	10.5	10.0	9.9	9.9
D	9.7	9.4	9.4	9.4
E	10.3	10.2	10.1	10.0

No dendrites

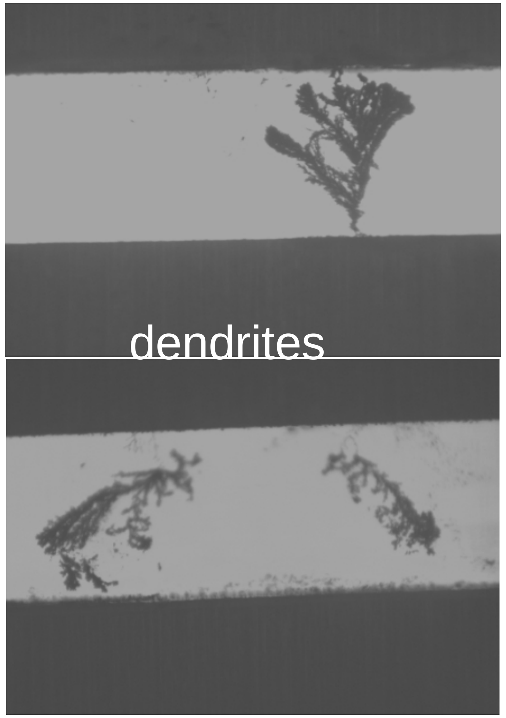


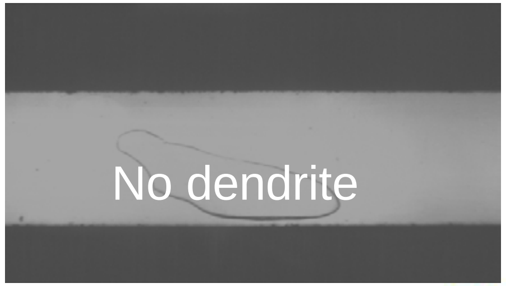
A	Halogenated NC
B	Halogenated NC
C	Halogen-free NC
D	Halogen-free NC
E	Halogenated NC

SIR with Glass Slide (SIR-G)

- With glass slide on, in most cases the SIR reading is low and dendrite formation observed.

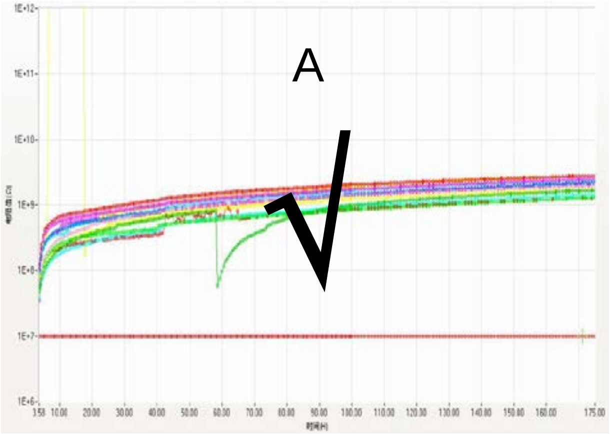
No.	0 /log(Ω)	24 hrs /log(Ω)	96 hrs /log(Ω)	168 hrs /log(Ω)
A	6	6	6	6
B	8.2	8.3	6.4	6.4
C	6	6	6	6
D	6.8	6.7	6	6
E	7.6	8.3	8.4	8.7

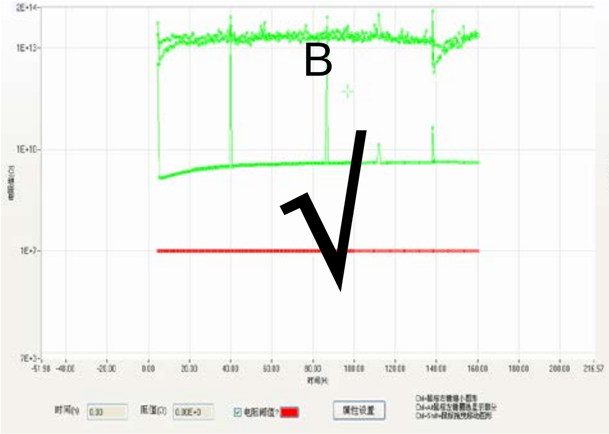


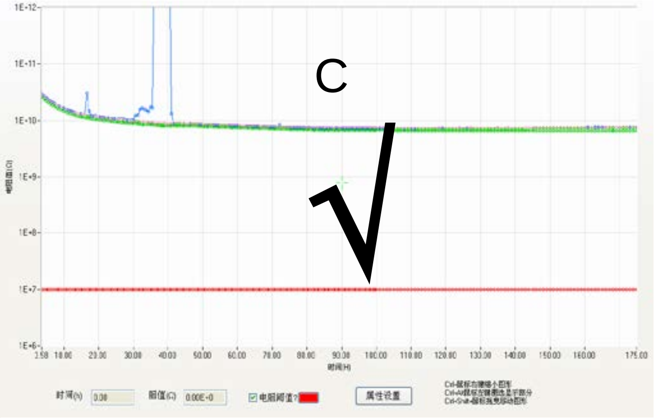


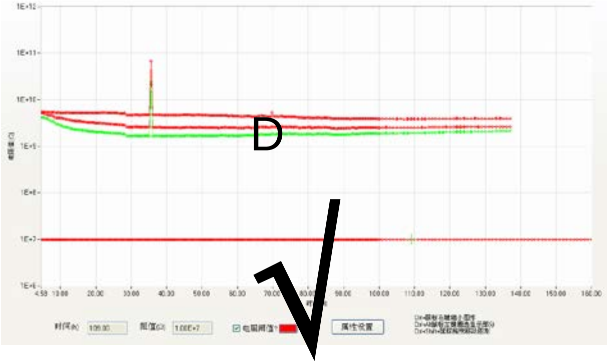
SIR – Standard

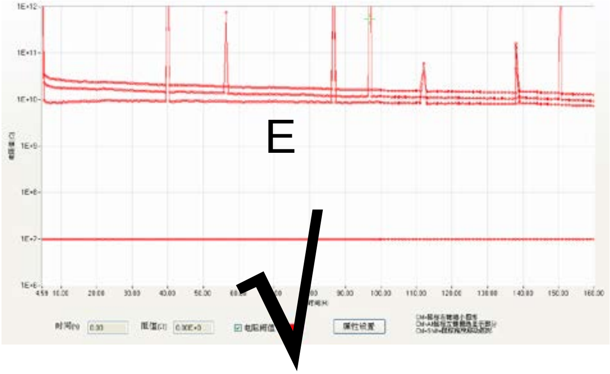
A	Halogenated NC
B	Halogenated NC
C	Halogen-free NC
D	Halogen-free NC
E	Halogenated NC





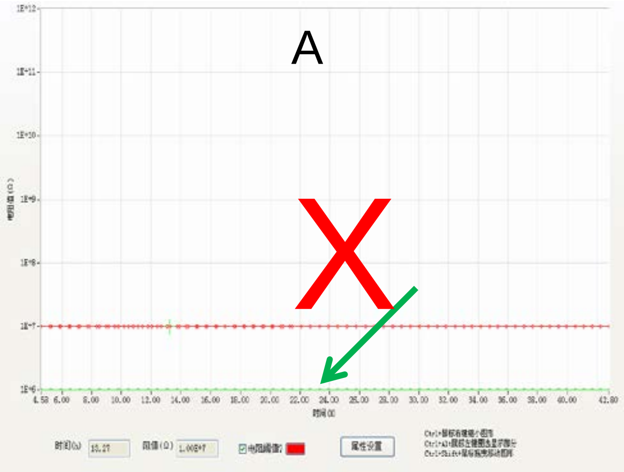


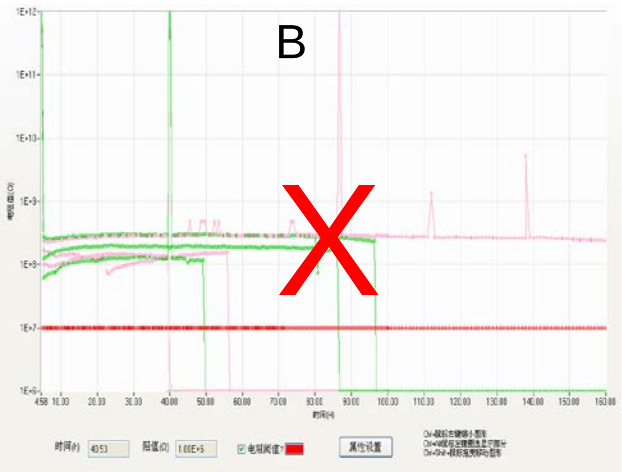


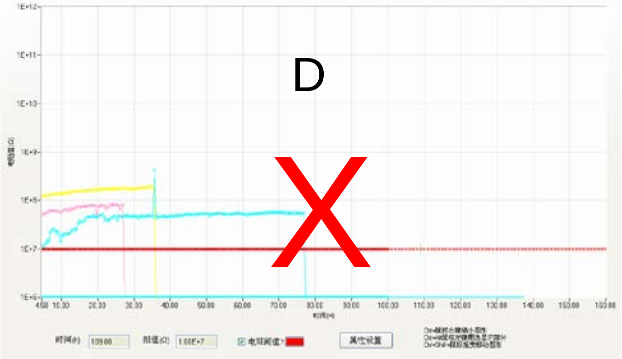


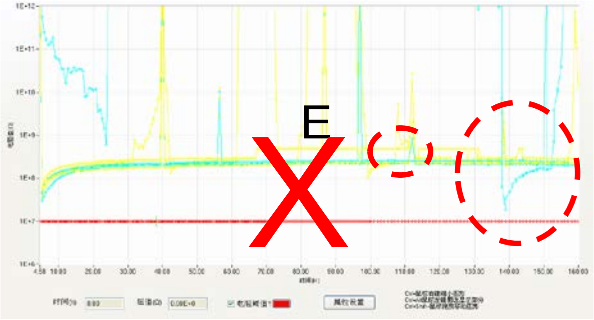
SIR with Glass Slide

A	Halogenated NC
B	Halogenated NC
C	Halogen-free NC
D	Halogen-free NC
E	Halogenated NC







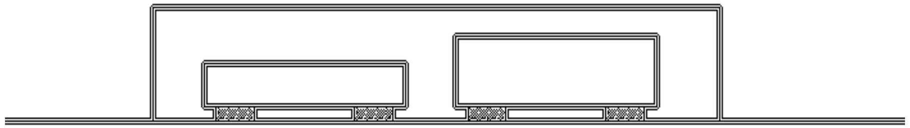


Solution through Design?

- For QFN, provide through-hole via under QFN to facilitate flux outgassing
- For electromagnetic shielding,
  - provide venting hole on shield at reflow, then followed by tape masking the holes
  - Solder assemble the shield side frame, followed by attaching the clip-on shield onto the side frame.

Solution through Process?

- One solution would be flux residue cleaning after reflow. This will solve the problem in many cases. But, for some designs, cleaning is either difficult or not feasible, as shown below



Solution through Material?

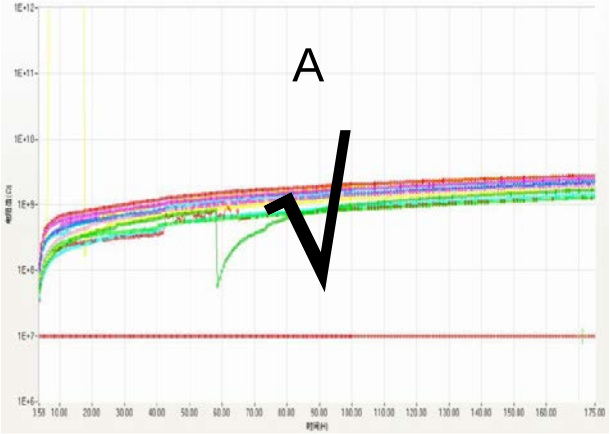
- Another solution is development of fluxes which perform well even when it is insufficiently dried
- However, in principle,
  - A wet flux residue being non-corrosive and non-conductive should contain very low amount of activators and exhibit very low activity.
  - Such type of flux would be poor in wetting, which in turn would be poor in voiding and HIP performance, hence would not be adequate for SMT assembly applications.

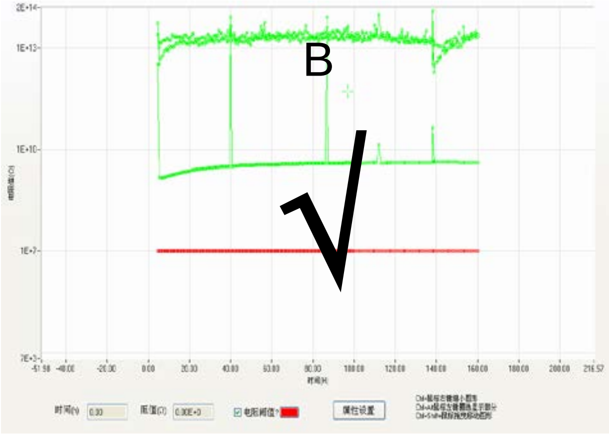
Challenge

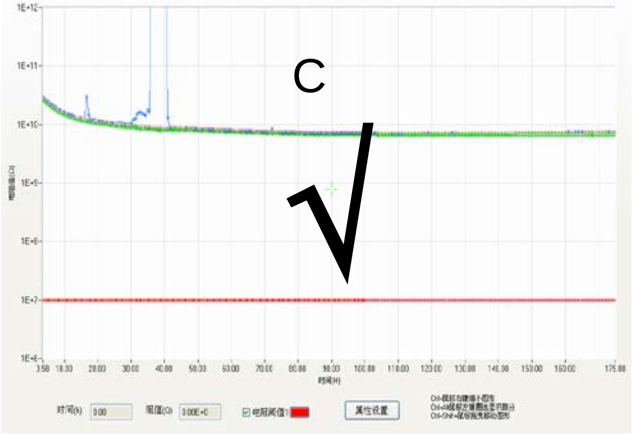
– Can a flux be developed, being benign with wet flux residue, but still perform well at SMT assembly process, including reflowed under air?

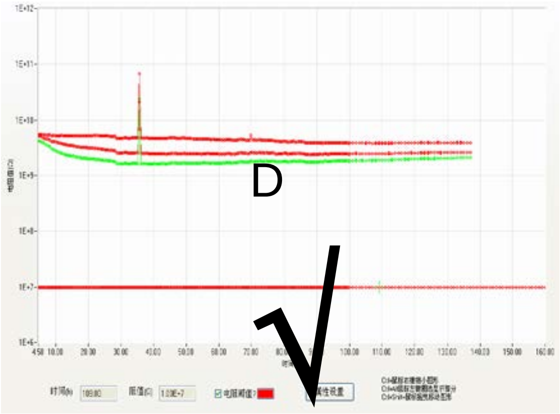
New Flux F
SIR – Standard

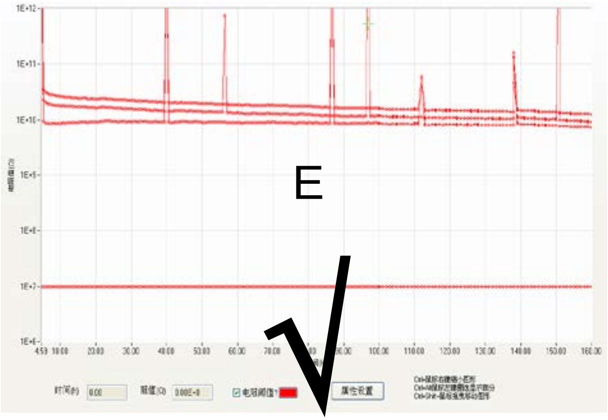
A	Halogenated NC
B	Halogenated NC
C	Halogen-free NC
D	Halogen-free NC
E	Halogenated NC
F	Halogen-free NC





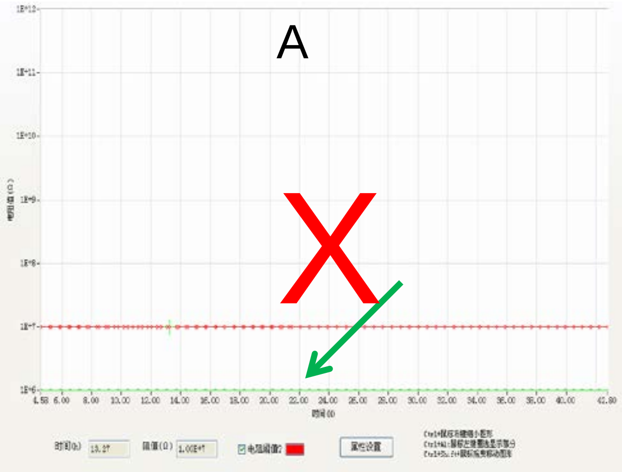


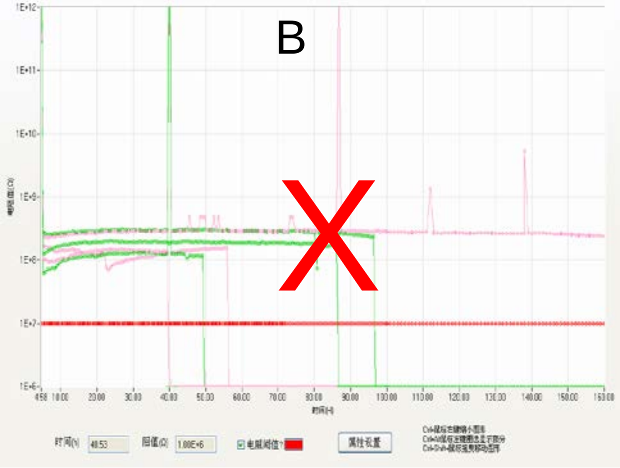


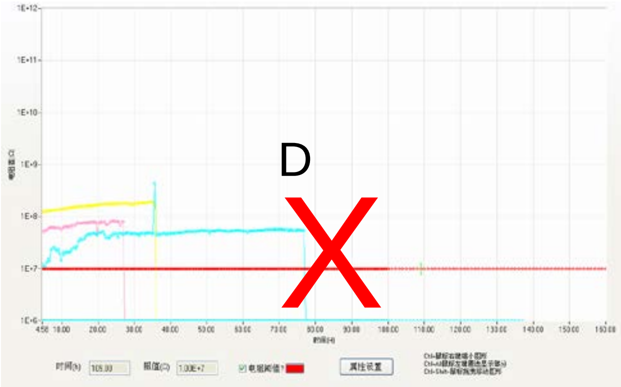


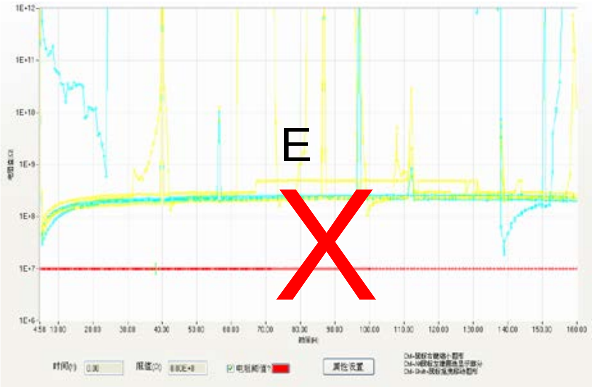
New Flux F
SIR with Glass Slide

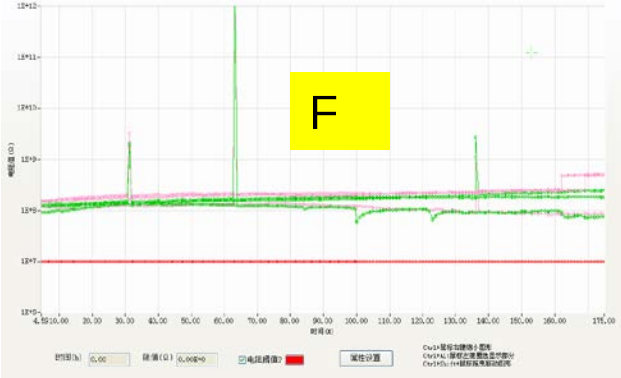
A	Halogenated NC
B	Halogenated NC
C	Halogen-free NC
D	Halogen-free NC
E	Halogenated NC
F	Halogen-free NC









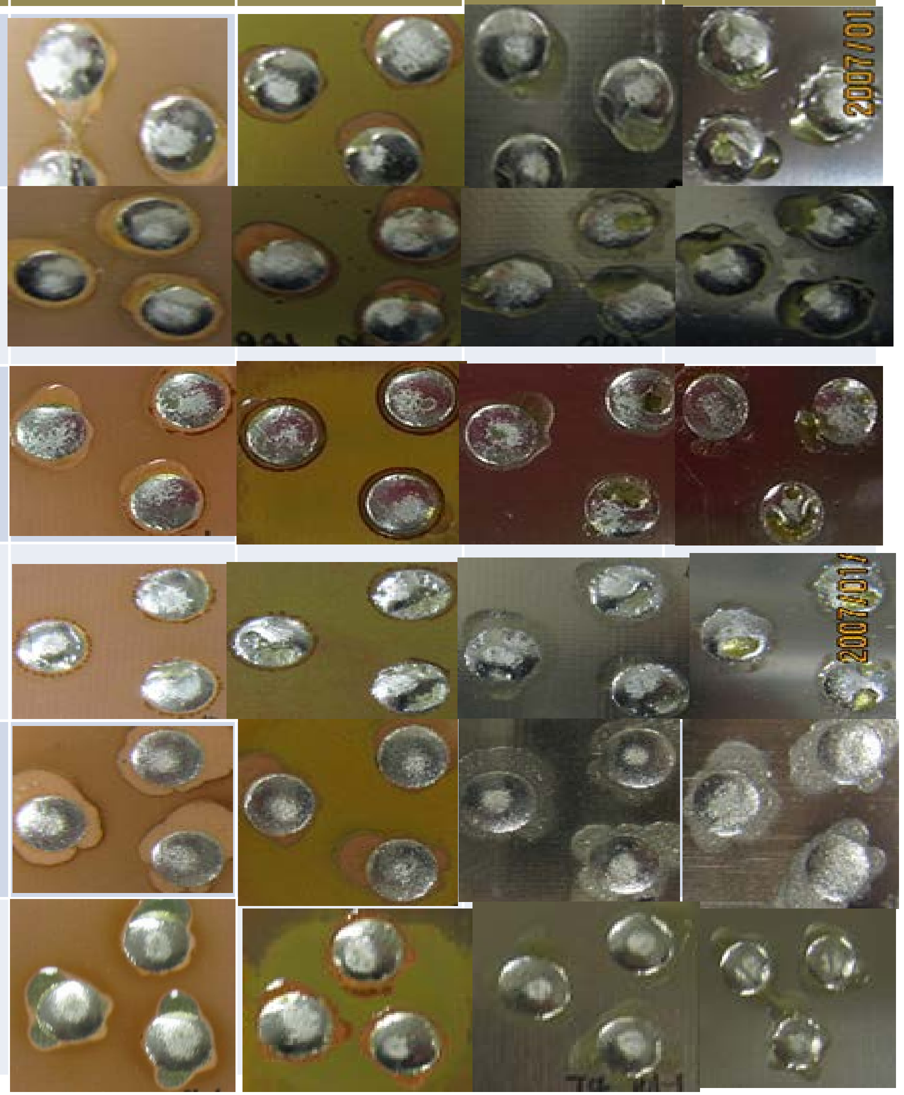


Wetting (air)

(Wetting at N2 all good)

A	Halogenated NC
B	Halogenated NC
C	Halogen-free NC
D	Halogen-free NC
E	Halogenated NC
F	Halogen-free NC

Paste	OSP	OSP (oxid)	Ni	Alloy 42
√ A				
√ B				
~ C				
X D				
√ E				
√ F				



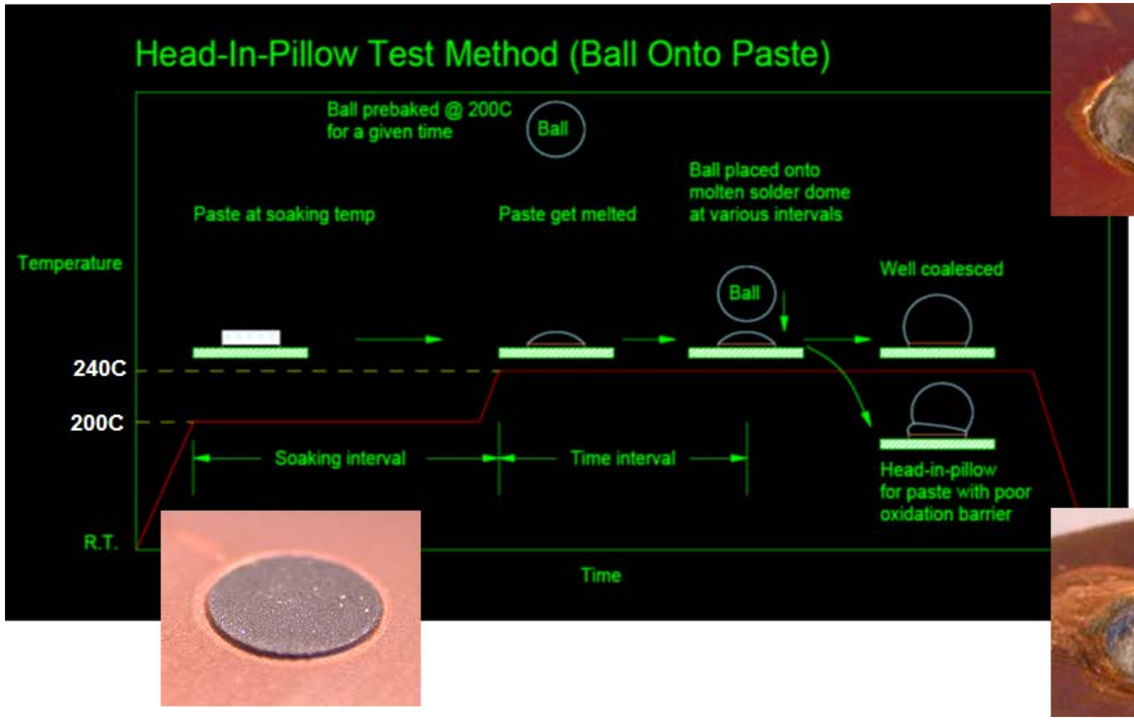
Voiding

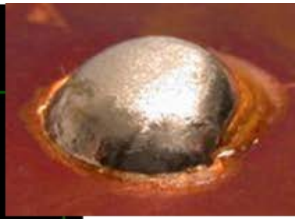
(QFN 0.30mm thickness stencil)

	No.	Largest void (%)	SD	All voids (%)	SD
X	A	2.6	1.4	19.6	5.8
√	B	1.1	0.7	8.0	7.4
X	C	3.0	1.5	20.3	7.2
X	D	1.7	0.6	19.7	5.8
X	E	1.5	1.1	24.1	8.4
√	F	2.3	1.4	9.4	5.7

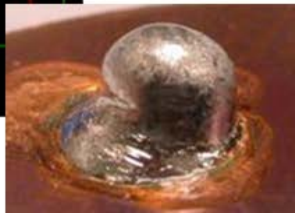
A	Halogenated NC
B	Halogenated NC
C	Halogen-free NC
D	Halogen-free NC
E	Halogenated NC
F	Halogen-free NC

HIP test method





Full coalesece
(HIP)



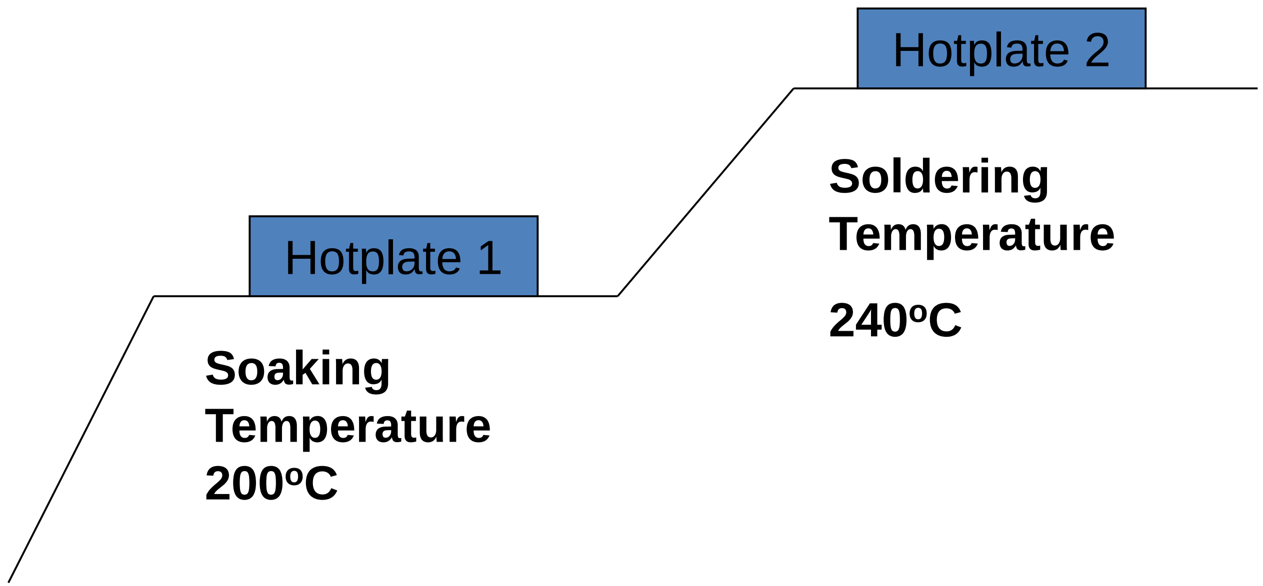
Non-coalesece
(HIP)

HIP test method

Solder Ball stay at 200°C/30 min.

Paste stay at 200°C, with 2 min.

Coalesced paste stay @ 240°C (before ball drop) with time varies.



HIP

Table 4 Head-in-pillow test for various solder pastes.

Sample	After preheated at 200C/2 min, time of paste at 240C before placing ball						
	0 s	20 s	40 s	60 s	80 s	100 s	120 s
√ A					coalesced	marginal	HIP
√ B						coalesced	marginal
X C	coalesced	HIP			—	—	—
X D	marginal	HIP			—	—	—
X E		coalesced	marginal	HIP			
√ F					coalesced	HIP	

Legend: coalesced (green); coalesced with oxide film impression discernible (orange); failed to coalesce, HIP (red)

A	Halogenated NC
B	Halogenated NC
C	Halogen-free NC
D	Halogen-free NC
E	Halogenated NC
F	Halogen-free NC

APEX EXPO IPC 2016

Performance Summary

Paste	SIR-G	SIR-Std	HIP	Void	Wet (air)	Wet (N2)
A T4	x	√	√	x	√	√
B T4.5	x	√	√	√	√	
C T4	x	√	x	x	√	√
D T4	x	√	x	x	x	√
E	x	√	x	x	√	
F T4	√	√	√	√	√	√

F (halogen-free) good overall under N2 and Air

good

acceptable

unacceptable

A	Halogenated NC
B	Halogenated NC
C	Halogen-free NC
D	Halogen-free NC
E	Halogenated NC
F	Halogen-free NC

FORWARD THINKING FOR TOMORROW'S TECHNOLOGY

Conclusions

- No clean flux residue is prone to pose corrosion risk if not properly dried/burnt-off
- The risk may be prevented through residue cleaning or redesigning in some cases
- Alternative solution
  - New flux chemistry F was developed which provides good SIR without proper venting at reflow.
  - This flux also exhibit good wetting performance and other critical features.
  - The above can co-exist only through a breakthrough in flux technology