Selection of Dip Transfer Fluxes and Solder Pastes for PoP Assembly

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ABSTRACT
Consideration and selection of dip transfer flux and solder paste for PoP assembly are described, based on process consideration. The crucial properties vital for successful dip transfer include homogeneity, open time on flux/paste bed, volume and consistency of dip transferred material, open time after dip transfer before reflow, and solder joint formation. For each property, one or more practical test methods recommended are described. Overall, this work should provide the assembly house an easy way to select a flux or solder paste adequate for dip transfer PoP assembly applications.

Key Words: PoP, Package-on-Package, flux, solder paste, dip transfer, soldering, SMT

INTRODUCTION

The trend of electronic industry toward smaller, faster, more functions, and cheaper incubated the emergence of 3D packaging. Package-on-package (PoP) design combines pre-tested discrete logic and memory in array configured packages vertically. Being one of many solutions for 3D packaging, PoP prevails due to its efficiency and flexibility [1-3]. The process flow of PoP assembly mainly comprised of (1) stencil print solder paste, (2) pick and place bottom PoP, (3) pick top PoP, (4) dip top PoP in gel flux or paste, (5) place dipped top PoP onto bottom PoP, (6) reflow, (7) underfill PoP, and (8) cure underfill. At dipping step, the bonding materials used include gel fluxes or solder pastes, although epoxy fluxes may also be considered. Depending on the design and application, underfilling may or may not be required.

Successful assembly of PoP requires the proper selection of printable SMT solder paste as well as materials used at dip transfer step. Although many articles have covered PoP in terms of design and general process, none of those has touched on how to select soldering materials for PoP assembly. In this work, the fluxes or solder pastes for dip transfer will be the focus. The assembly process can be either clean or no-clean, with the latter being the dominant choice of industry.

DIP TRANSFER

Properties of materials critical for a successful dip transfer process include the homogeneity, open time on flux/paste bed, volume and consistency of dip transferred material, open time after dip transfer before reflow, and solder joint formation.

General Description

The gel flux is a creamy and tacky flux. A solder paste for dip transfer has similar feature, with solder powder content typically ranging from 80 to 85% w/w.

Homogeneity

The first feature important for consistent dip transfer is homogeneity of materials. Perhaps the easiest way to check the consistency is to spread the material on a glass slide, then inspect under optical microscope. An even and creamy texture is the desired feature. Presence of wavy or grainy appearance, or few large particles or conglomerate is evidence of non-homogeneity. Depending on the size of solder bump on PoP, the requirement on homogeneity may vary. No particulate with a diameter larger than 1/3 of the bump diameter is recommended. In the event a particulate is picked or missed, the impact on volume transferred should be no more than 10% of the volume transferred, therefore is estimated to be tolerable for soldering performance.

Open Time on Flux/Paste Bed

For dipping process, the flux/paste is typically dispensed onto a rotating disk with film thickness regulated by doctor blade. Due to the moisture pick-up and drying, the material may gradually deteriorate and result in inconsistent performance. An open time long enough to cover one shift, or 8-10 hours, is desired for minimizing change time and material waste. The open time can be determined with the use of actual dipping device, with consistency of dipped PoP monitored.

Alternatively, the tack of flux/paste can be measured by following test procedure in IPC-TM-650 method 2.4.44 at a given exposure time after print. A print thickness of 200-250 microns is recommended for this testing.

Volume and Consistency of Dip Transferred Material

Perhaps the most tricky issue is the assessment of the volume and consistency of dip transferred materials, particularly for flux.

For both flux and solder paste, the overall volume on each package can be assessed by determining the weight of flux/paste pick up by measuring the weight of component before and after dipping. For consistency, the paste can be assessed by flipping over the dipped PoP, and examining the consistency of paste coverage under optical microscope, particularly with an angled view. Figure 1 and 2 shows the angled view and top view of PoP with satisfactory and unsatisfactory dip transfer performance, respectively. An adequate dip transfer solder paste should yield a consistent coverage for every bump, besides sufficient overall volume pick up.

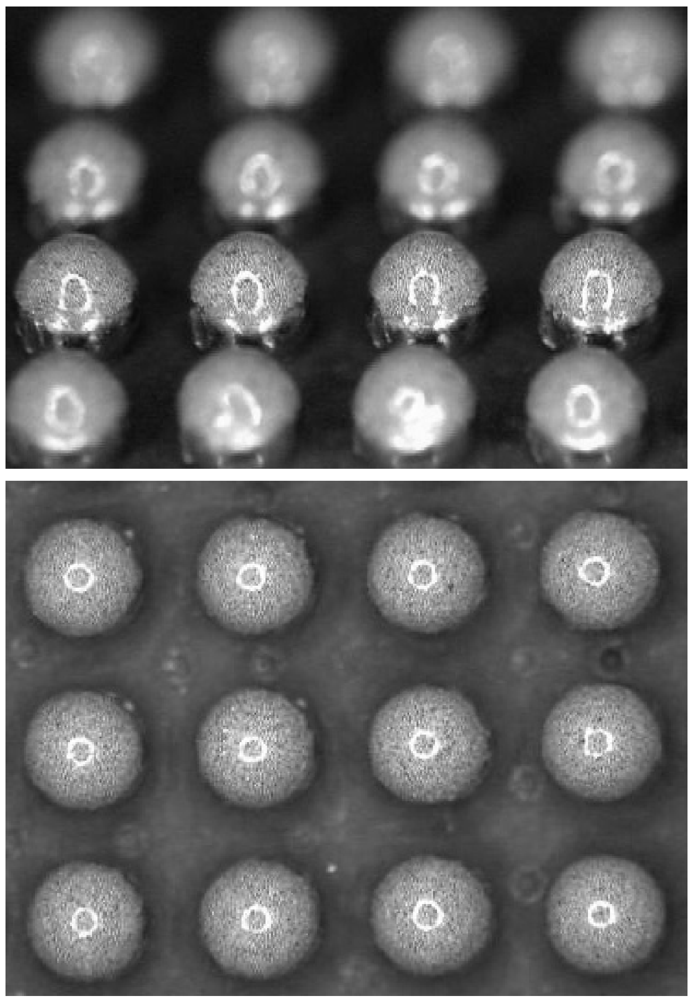


Fig. 1 Angled view (top) and top view (bottom) of PoP after paste dipping process using a solder paste with proper rheology.

However, for gel flux, the consistency assessment becomes a challenge due to the translucent nature of flux itself. The following procedure developed at Indium is recommended for this purpose.

- Flux was placed in a rotating flux bath with a fixed squeegee to ensure consistent height.
- Pick and dip the PoP into the flux.
- The dipped PoP was then placed onto a copper coupon, followed by lifting off to leave a flux print on the copper.
- The copper coupon was then examined under a microscope at 45x magnification.

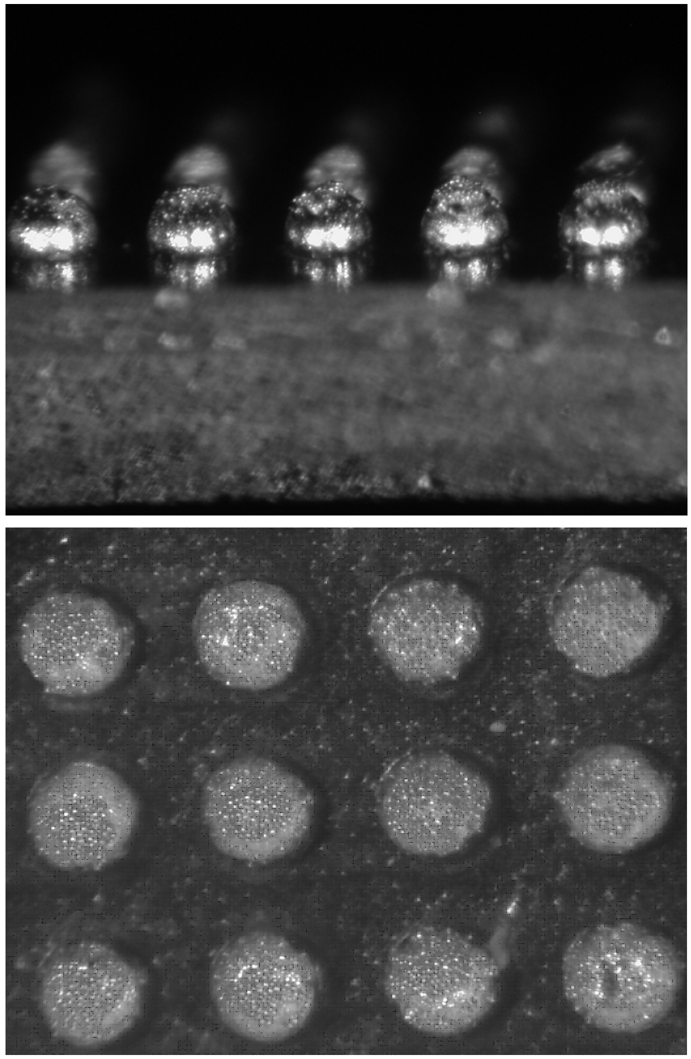


Fig. 2 Angled view (top) and top view (bottom) of PoP after paste dipping process using a solder paste with inadequate rheology.

Figure 3 shows the satisfactory print of a fluxed PoP on copper coupon. The close-up look shows a fairly uniform flux deposition. On the other hand, Figure 4 shows that of a non-uniform flux deposition. The contrast between flux and copper background allows easy assessment of the uniformity of deposit size.

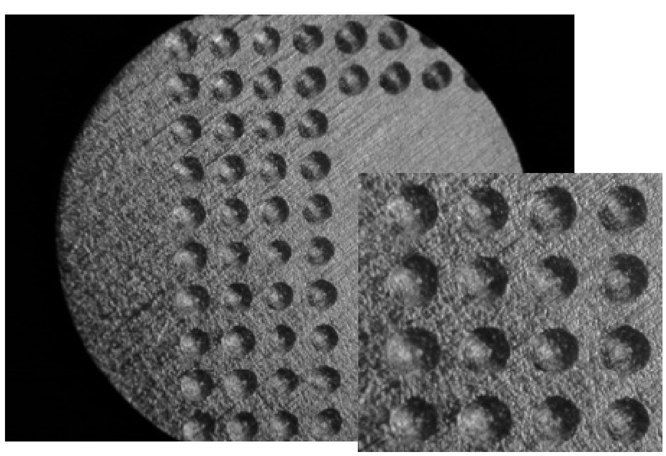


Fig. 3 Flux print of fluxed PoP on Cu coupon. Uniform flux deposits can be seen.

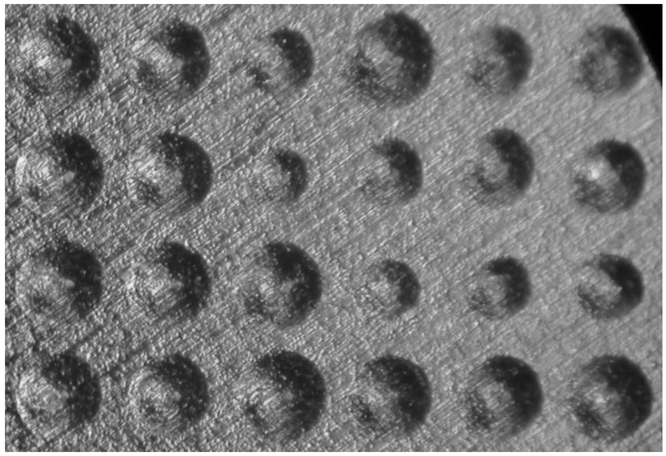


Fig. 4 Flux print of fluxed PoP on Cu coupon, exhibiting non-uniform flux deposits.

The flux transferred at dipping may also be assessed by pressing the fluxed PoP against a glass slide, with flux in contact with glass. This PoP is then secured onto slide with a tape. This glass slide with PoP mounted is then flipped over, and examined under a microscope. A halo of flux can be seen pressed against the glass slide. However, although the flux is clearly visible under microscope, the contrast is not high enough to be photographed, as shown in Figure 5.

If the gel flux is colored, assessment of consistency may be slightly easier. However, due to the tiny volume of flux deposited, the effect of color often is negligible. On the other hand, UV tracer does enhance the visibility under UV light..

<u>Open Time After Dipping Before Reflow</u>

In general, the performance of gel flux is not sensitive to the time elapsed after dipping but before reflow. Even if the flux dried up somewhat, the soldering performance often is still adequate. However, same can not be said to be true for solder paste, mainly due to the possible oxidation of solder powder. Regardless, reflow performance should be checked in order to identify the acceptable open time.

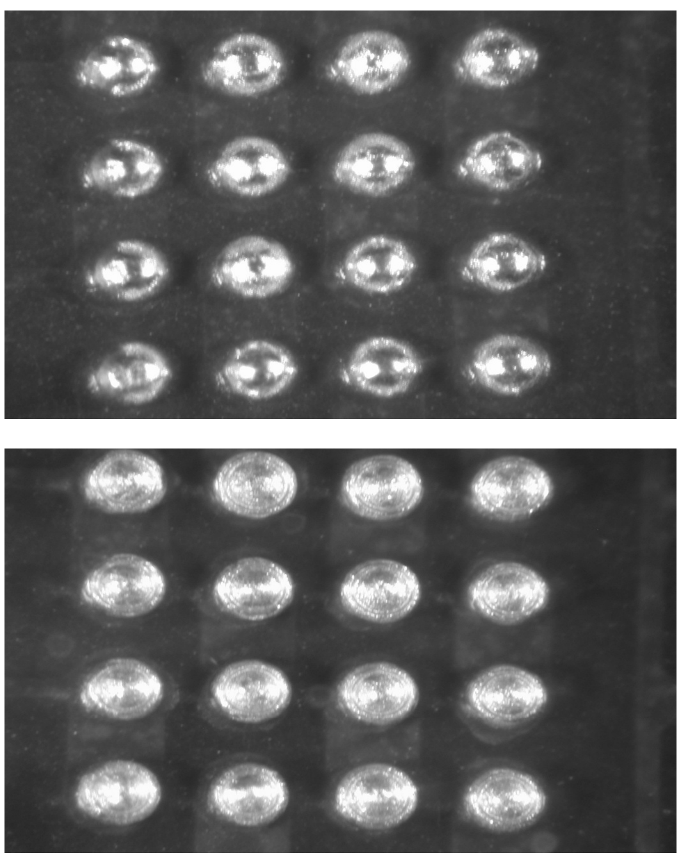


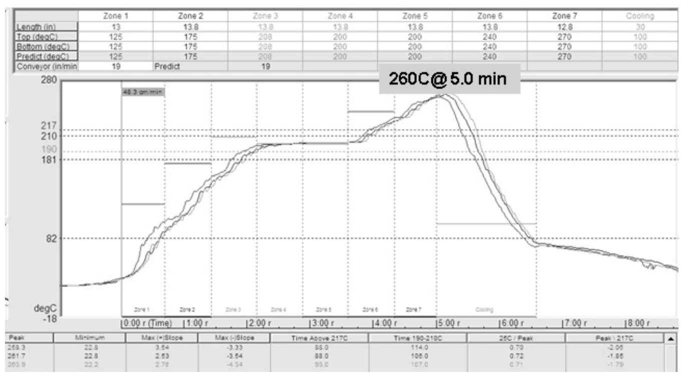
Fig. 5 View of PoP through a glass slide under microscope before flux dipping (top) and after flux dipping (bottom).

Solder Joint Formation

The ultimate goal of dip transfer process is to form an adequate solder joint. In most instances, use of a robust gel flux is good enough to get this job done. Since soldering involves removal of metal oxide before a solder joint is formed, the testing should include aggravated process conditions to find out whether the flux can tolerate the oxidation induced under such situation. Examples of aggravated conditions include (1) high humidity exposure, (2) long time and/or high temperature exposure under air prior to solder joint formation. The solder joint formed should be checked for wetting, voiding, solder balling, bridging with the use of X-Ray equipment. Additional tests may apply depending on the requirement.

Example of high humidity exposure includes conditioning of dipped PoP at 90% relative humidity for a given time, such as 2, 4, and 8 hours. At conditioning, the dipped PoP should be held upside down so that the flux/paste coating will not be disrupted.

The long time and high temperature exposure under air prior to solder joint formation can be introduced through the use of a long, hot soaking profile, such as that shown in Fig. 6. A regular profile is also shown for comparison.



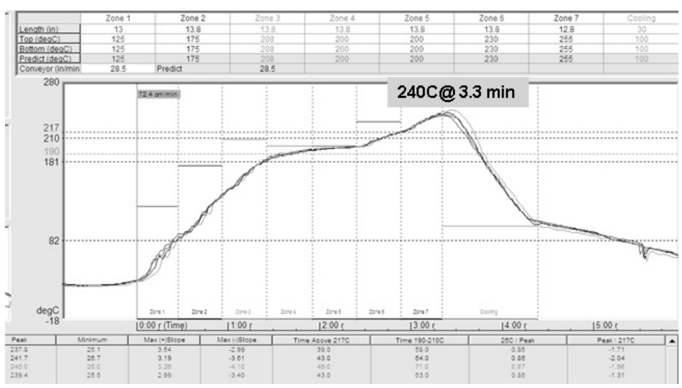


Fig. 6 An aggravated reflow profile (top) with high temperature and long soaking time. A regular profile (bottom) is also shown for comparison.

When dealing with PoP exhibiting warpage, use of solder paste instead of gel flux is recommended for dipping process. Here the solder powder should be Type 5 or finer, although Type 4 may be acceptable in some applications. The metal load typically is 80-85% w/w.

Use of solder paste provides continuity of solder between bump and pad, hence reduced the potential of open symptom. Use of fine powder not only enhances the homogeneity, but also slows down the melting process due to higher solder oxide. Upon reflow, wicking of solder paste onto solder bump may occur due to the higher temperature of top PoP [4]. This behavior may still result in open even in the presence of solder paste. Use of slow melting solder paste allows a better chance for both bottom and top PoP to reach the same temperature, thus prevented wicking phenomenon. The potential trade-off of using fine powder is the slightly higher chance of solder balling.

DISCUSSION

In this work, the focus is on the process side of dip transfer of PoP assembly. Materials desired for this process, and test methods for selection of materials are described. There are also other factors such as corrosion, SIR, environmental issue, and safety, should also be considered in selecting a material, but are beyond the scope of this work.

CONCLUSION

Consideration and selection of dip transfer flux and solder paste for PoP assembly are described, based on process consideration. The crucial properties vital for successful dip transfer include homogeneity, open time on flux/paste bed, volume and consistency of dip transferred material, open time after dip transfer before reflow, and solder joint formation. For each property, one or more practical test methods recommended are described. Overall, this work should provide the assembly house an easy way to select a flux or solder paste adequate for dip transfer PoP assembly applications.

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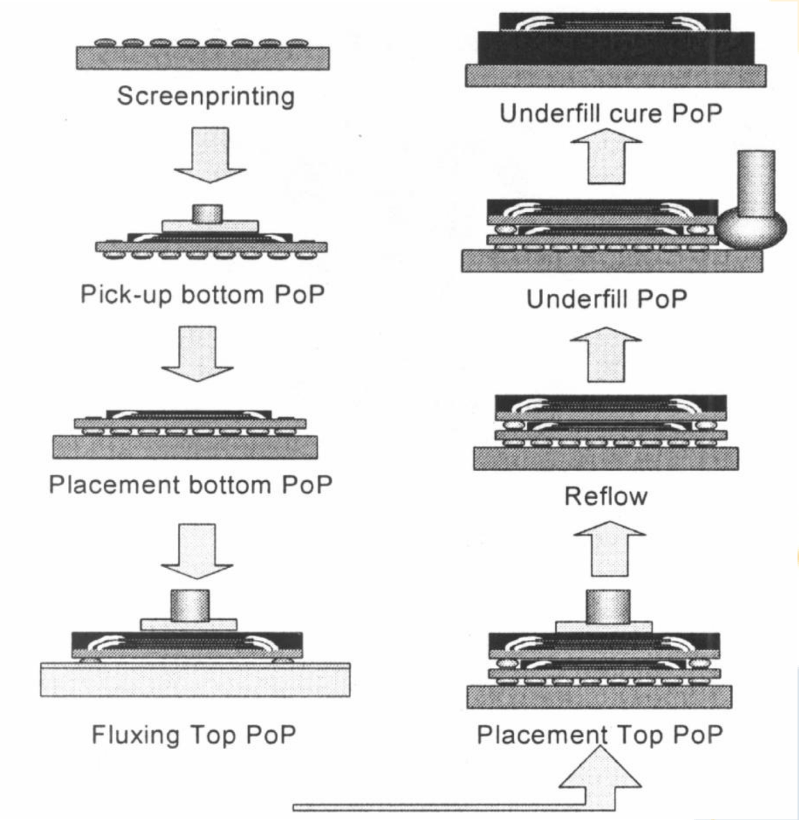
PoP Process

- Flux, solder paste, & epoxy flux can be used for dip transfer of PoP assembly
- Underfilling may or may not be needed
- Knowledge on how to select flux/paste desired



Crucial Properties of Flux/Paste

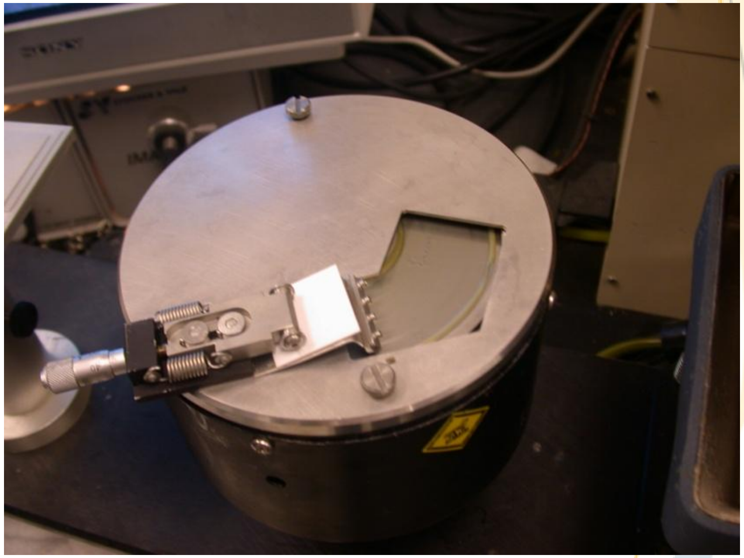
- Homogeneity
- Open time on flux/paste bed
- Volume & consistency of dip transfer materials
- Open time after dip transfer, before reflow
- Solder joint formation

Homogeneity

- Spread the flux/paste on a glass slide, inspect under microscope
- Wavy, grainy appearance, large particles, bubbles, or conglomerate not desired.
- Particles or conglomerate > 1/3 bump diameter not desired (may induce >10% change in volume transferred)

Open Time on Flux/Paste Bed

- Open time > 1 shift (or 8-10 hrs) desired for minimizing change time & material waste.
- Can be determined on actual dipping device.
- Can also be determined via tack measurement procedure (IPC-TM-650, 2.2.44)
- Print thickness 200-250 microns recommended.

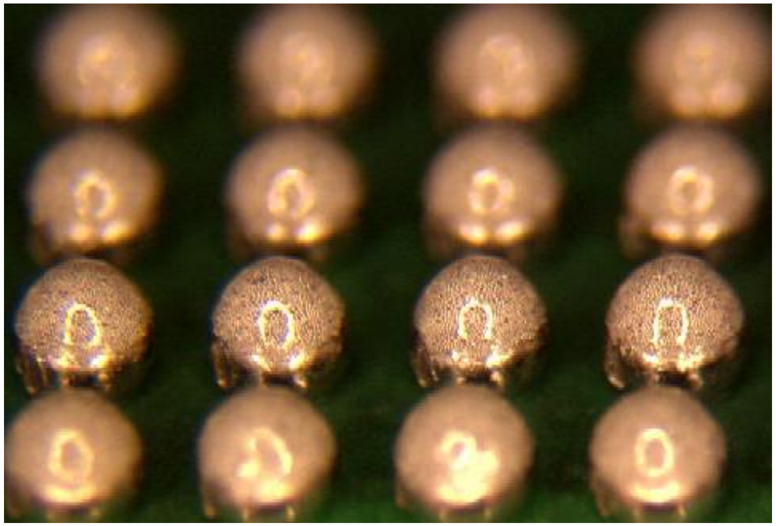


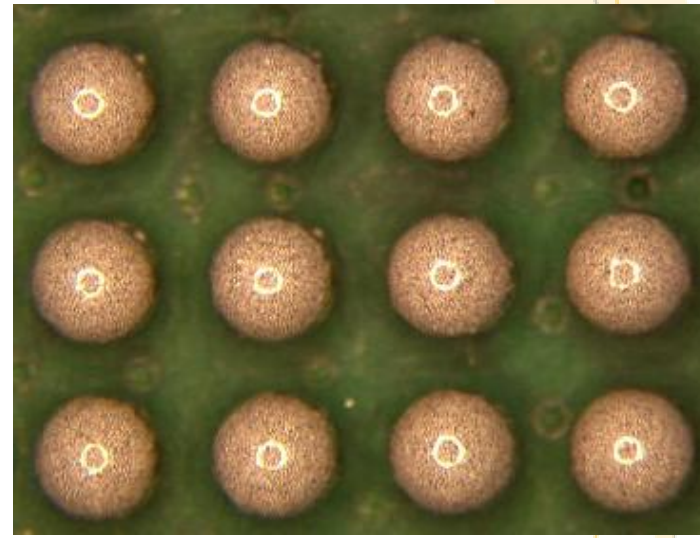
Volume & Consistency

- Overall volume can be determined by measuring the weight of PoP before & after dip transfer.
- For consistency, paste can be assessed by examining the bump surface.

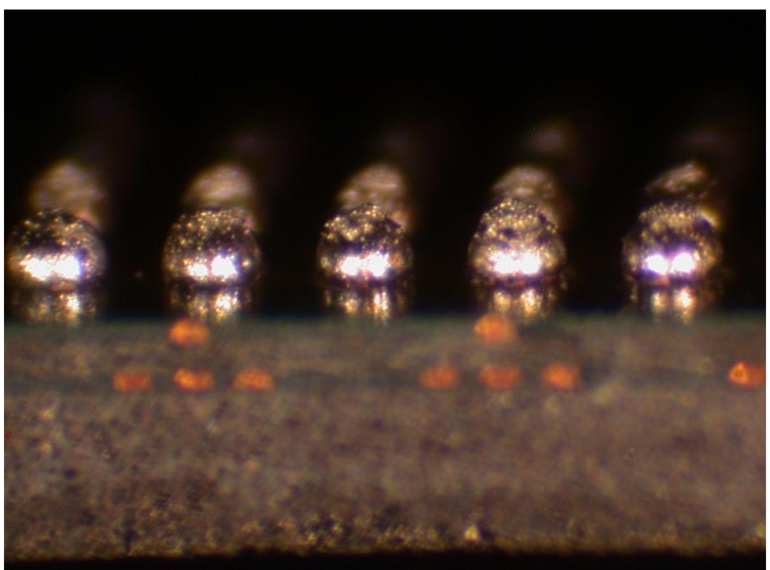
Paste Consistency Check

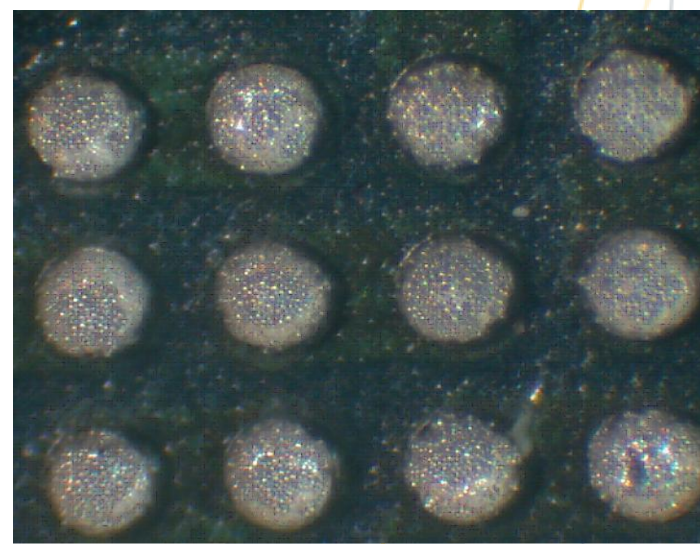
Consistent





Inconsistent





Flux Consistency Check

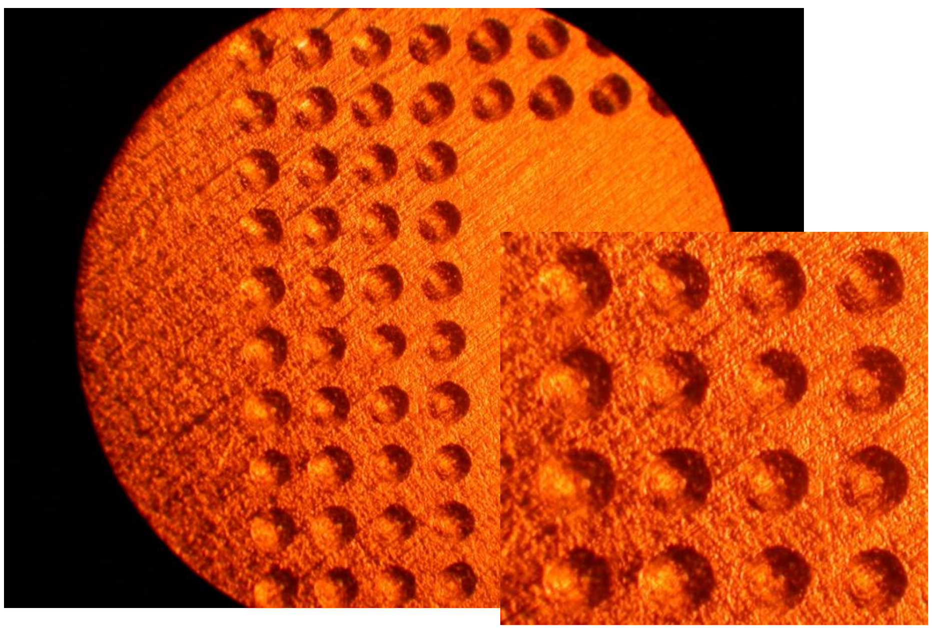
- Flux visibility is much poorer than paste.
- Although the total volume can be determined by weighing method, the consistency can not be judged easily under microscope.

Flux Consistency Check - 1

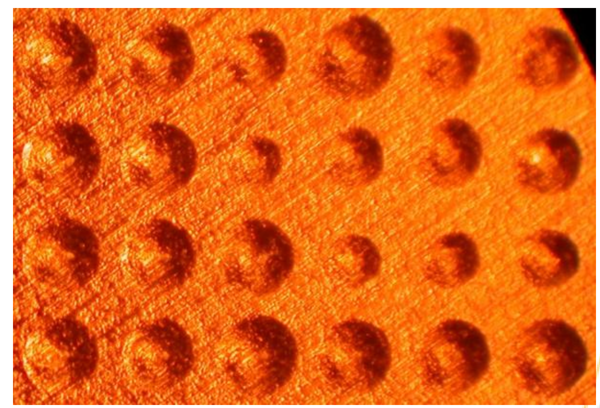
Visual inspection of the flux print onto a copper coupon

Materials: BGA coupon, flux, copper coupon

- Flux was placed in a rotating flux bed with a doctor blade to ensure consistent height.
- Pick and dip PoP into flux.
- The dipped PoP was then placed onto a Cu coupon, followed by lifting off to leave a flux print on Cu.
- The copper coupon was then examined under a microscope at 40x magnification.



Flux print of fluxed PoP on Cu coupon. Uniform flux deposits can be seen.

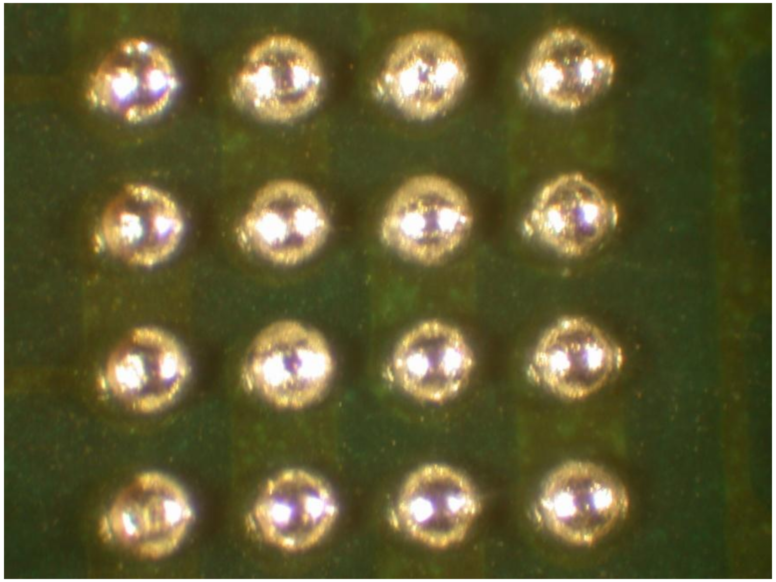


Flux print of PoP on Cu coupon, with non-uniform flux deposits.

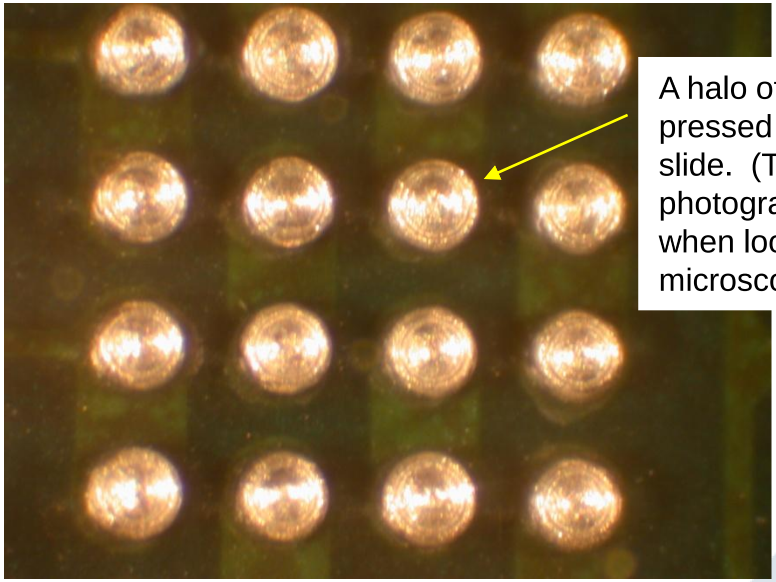
Flux Consistency Check - 2

Visual inspection of the balls through a glass slide.

- Flux was placed in a rotating flux bed with a doctor blade.
- Pick PoP and dip into the flux.
- The fluxed PoP was placed onto a glass slide. Tape PoP in place.
- The glass slide was flipped over and examined under a microscope at 40x total magnification.



Without Flux



A halo of flux can be seen pressed against the glass slide. (The halo is hard to photograph but is clear when looking through a microscope).

Dipped in Flux

Flux Visibility Enhancement

- Dyed flux has negligible effect on visibility due to tiny volume
- Flux with UV tracer is more visible under UV light. But, the rheology may be affected.

Open Time After Dipping Before Reflow

- Gel flux typically is not sensitive to open time. Solder paste may be more sensitive due to possible oxidation of solder powder.
- Reflow performance should be checked for open time window.

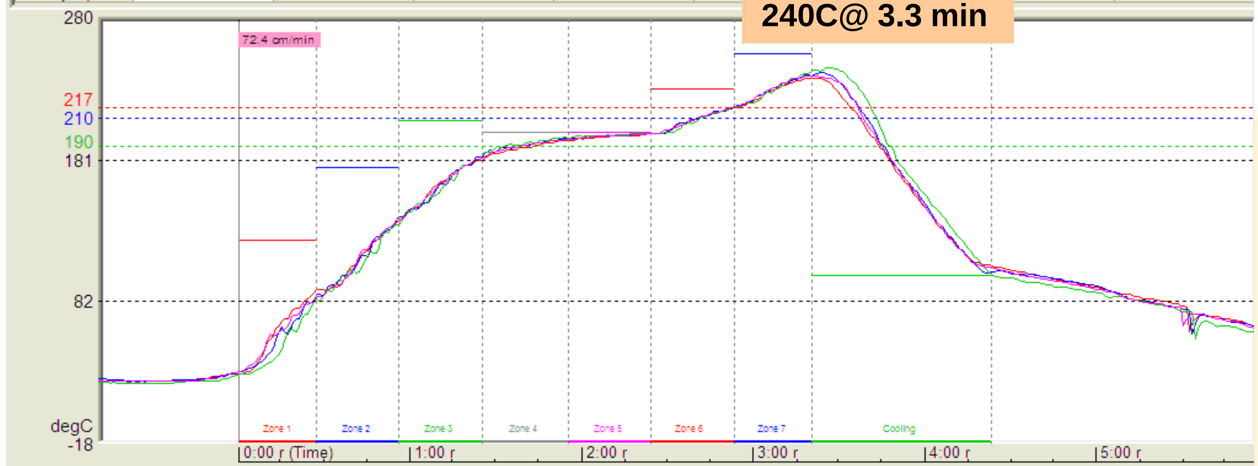
Solder Joint Formation

- Use aggravated test condition for fluxing performance assessment
  - high humidity exposure
    - 90%RH/2,4,8 hrs
    - Fluxed bump facing up at conditioning to avoid disruption
  - long time and/or high temperature exposure under air prior to solder joint formation.
- Check for wetting, voiding, solder balling, bridging with the use of X-Ray equipment. Additional tests may apply depending on the requirement.

Reflow Profiles

Regular profile

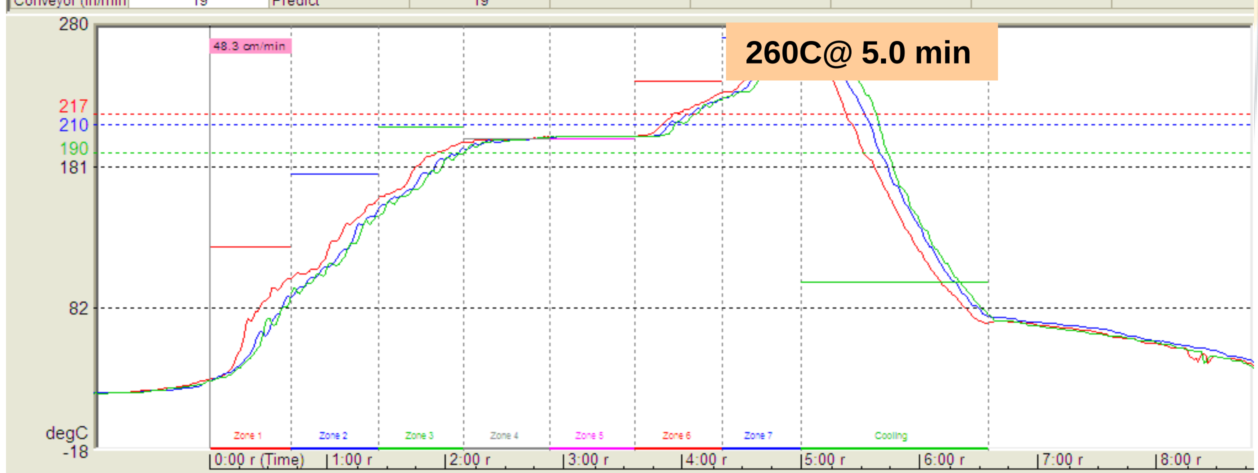
	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Cooling
Length (in)	13	13.8	13.8	13.8	13.8	13.8	12.8	30
Top (degC)	125	175	208	200	200	230	255	100
Bottom (degC)	125	175	208	200	200	230	255	100
Predict (degC)	125	175	208	200	200	230	255	100
Conveyor (in/min	28.5	Predict	28.5					



Peak	Minimum	Max (+)Slope	Max (-)Slope	Time Above 217C	Time 190-210C	25C / Peak	Peak \ 217C
37.8	26.1	3.54	-2.99	39.0	58.0	0.86	-1.71
41.7	26.7	3.19	-3.61	43.0	64.0	0.86	-2.04
45.0	25.0	3.26	-4.10	49.0	71.0	0.87	-1.98
39.4	25.6	2.99	-3.40	43.0	63.0	0.86	-1.31

Long time/high temp exposure under air prior to joint formation

	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Cooling
Length (in)	13	13.8	13.8	13.8	13.8	13.8	12.8	30
Top (degC)	125	175	208	200	200	240	270	100
Bottom (degC)	125	175	208	200	200	240	270	100
Predict (degC)	125	175	208	200	200	240	270	100
Conveyor (in/min	19	Predict	19					



Peak	Minimum	Max (+)Slope	Max (-)Slope	Time Above 217C	Time 190-210C	25C / Peak	Peak \ 217C
58.3	22.8	3.54	-3.33	88.0	114.0	0.70	-2.06
51.7	22.8	2.53	-3.54	88.0	106.0	0.72	-1.85
53.9	22.2	2.78	-4.34	93.0	107.0	0.71	-1.79

Solder Paste or Flux?

- PoP with warpage - use solder paste
  - Type 5 or finer, although Type 4 may be OK
  - Metal load typically 80-85% w/w.
- Solder paste provides continuity of solder between bump and pad, hence reduced the potential of open symptom.
- Fine powder
  - Enhances the homogeneity
  - Slows down the melting process due to higher solder oxide.
  - At reflow, prone to have wicking due to the higher temperature of top PoP. This behavior may still result in open even in the presence of solder paste.
  - Slow melting solder paste allows both bottom and top PoP to reach the same temperature, thus prevents wicking.
  - The potential trade-off of using fine powder is the slightly higher chance of solder balling.

Conclusion

- Consideration and selection of dip transfer flux and solder paste for PoP assembly are described, based on process consideration.
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