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Advanced Rework Technology and Processes for Next Generation Large Area Arrays, 01005, PoP and QFN Devices

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Abstract
BGA Rework is now largely mature, although new supplemental processes that provide improved process control such as Solder Paste Dipping and Non-Contact Site Cleaning can now be integrated into existing processes if the rework technology that is used allows.

So what are the next set of challenges that will need to be addressed in regard to Area Array and SMT Rework? The International Electronics Manufacturing Initiative or iNEMI has recently published its 2013 Technology Roadmap for the global electronics industry which includes a section dedicated specifically to rework and repair. Of particular interest and importance is iNEMI's gap analysis which identifies future specific gaps and challenges that will result from such factors as government regulations, disruptive technologies and new product requirements.

This paper will review five of the key rework gaps and challenges identified by iNEMI including:

1) Reworking very large, next generation area arrays on large high thermal mass assemblies.
2) Development of hand soldering processes for reworking 01005 components.
3) Development of industry-standardized processes for reworking Package-on-Package (PoP) devices.
4) Development of industry-standardized processes for reworking Quad Flat, No Lead (QFN) devices.
5) Development of site redressing processes that prevent lifted pads, solder mask damage and copper dissolution [(1)]

The objective of this paper is to discuss the five iNEMI rework gaps and challenges including identification of the key technical/process challenges, outlining in detail the efforts-to-date aimed at addressing these new challenges as well as the next steps required for complete resolution of these challenges.

Introduction

The five major rework gaps and challenges identified in the rework and repair section of the 2013 iNEMI Technology Roadmap requires a combination of new thinking, new and innovative technology and a lot of good old fashioned hard work.

BGA Rework Systems, which have successfully handled the requirement to rework lead-free BGA's for ten plus years will now be required to handle a number of new technical challenges including the ability to align next generation extra large (70-100mm), high I/O (>1000) components as well as having the thermal capacity to reflow these large components while meeting the current stringent standards for both maximum package temperature and the maximum joint temperature Delta which are based on much smaller, current generation components. Other machine/process challenges related to next generation large devices will include such "simple" things as vacuum-holding capability as well as more complicated issues such as component warpage and site preparation. In addition, these XXL components will most often be found on very large, high thermal mass assemblies for server, telecommunications and networking applications which means that the BGA Rework System must also have the capability to hold and preheat these very large, high thermal mass assemblies.

BGA Rework Systems will also be required to handle new challenges associated with PoP Rework including controlled solder paste/flux dipping, the accuracy to place 0.3-0.4mm pitch devices and the force control necessary to place a dipped top device on an unreflowed bottom device so both packages can be reflowed together. QFN rework requires the integration of pasted or pre-pasted and reflowed devices as well as the process-know how to control voiding in the center ground pad area.

The rework industry's reluctance to replace wick-based site redressing with non-contact methods is beginning to change. The industry's view of solder wick as a fast and easy solution for preparing a site must be tempered by the fact that wick-based cleaning lacks process control, thereby subjecting the PCB to a higher potential incidence of pad or solder mask damage.

The pros and cons of various flux/paste application methods including dipping, paste-on-device, paste-on-board, stay-in-place stencils and multi-up stencils are reviewed and summarized.

Finally, the topic of 01005 rework is analyzed in detail including the potential use of hand tools, BGA Rework Systems and combined (man/machine) technology systems.

Next Generation Large Area Array Rework

Some of the largest Area Arrays in use today include CCGA's, as well as BGA sockets and connectors with lead patterns approaching 50mm. iNEMI forecasts component sizes of 60-75mm, however future rework requirements for 80-90mm components have already begun to surface.

These next generation large area arrays may have high thermal mass issues such as metal BGA sockets. Further complicating this issue is the fact that these large, thermally challenging devices will typically be found on large, high thermal mass PCB's.

iNEMI's major concern is the ability to reflow these next generation large devices on large, high thermal mass PCB's based on the current stringent specifications as shown in Table 1.

Table 1: Large Area Array Rework (2)

Soldering Process	Parameter	Units	2011	2013	2015	2017	2023
Pb-free	Maximum package sizes	mm	50	50	55	60	75
	Maximum package temperature (dependent on component body size)	°C	245-260	245-260	245-260	245-260	245-260
	Target solder joint temperature	°C	235	235	235	235	235
	Target delta T across solder joints	°C	<10	<10	<10	<10	<10
	Time Above Liquidus (TAL)	Sec	60-90	60-90	60-90	60-90	60-90

The challenge will be that next generation area arrays will increase in size by 50-100% and will typically be found on large, high thermal mass PCB's, however the reflow specifications are the same as for today's standard BGA's.

Large Area Array Thermal Profiling

A 114mm (4.5") square BGA with 10,000 I/O was thermally profiled. Seven (7) thermocouples (TC's) were used to instrument the test vehicle. Six (6) TC's measured joint temperature and one measured package temperature. The PCB was the same size as the device so preheating the joints to 150°C represented the board preheat stage.

Significant development effort was done in regard to optimizing the thermal distribution of the nozzle required for this very large device. The nozzle design is proprietary at the time of this writing and therefore cannot be photographed or illustrated in detail.

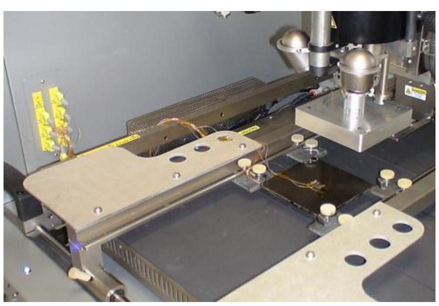

Figure 1. Instrumented 114mm BGA on BGA Rework System

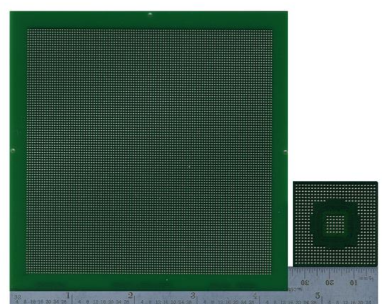

Figure 2. 114mm BGA (10,000 I/O) with 35mm BGA shown for scale

This extremely large device required significant thermal energy and time to reflow it. The PCB was preheated to 150°C with a high power, indirect IR bottom heater. The top heater setting after preheat was 495°C at 2.5 scfm flow for 150 seconds. The top heater setting of 495° is very high compared to the 300-325°C setting typically used for BGA's. However the large size of the component and the nozzle required significantly more thermal energy. A Board Cooling System was used to cool the part down after reflow which is critical to achieving targeted Time Above Liquidus (TAL). The results are shown in Table 2.

Table 2: 114mm BGA (Ph 150°C, 495C @ 2.5 scfm, 150 sec)

		Max Temp (°)		Delta T (°)		TAL (sec)	
TC #	Location	Actual	Spec	Actual	Spec	Actual	Spec
1	Top of Package	260	260		-	-	-
2	Joint (corner)	235	235	6	‹ 10	52	60-90
3	Joint (corner)	235				55	
4	Joint (corner)	239				72	
5	Joint (corner)	238				68	
6	Joint (corner)	237				69	
7	Joint (corner)	241				75	

All specifications were met except the TAL for two joints fell short of the target. The volume of air used to cool down the component can be easily reduced to correct this. However the bigger issue is that the maximum package temperature was 260°C, which leaves no margin for error.

A modification was made to the rework system that allowed significantly higher flow rates to be used. The thermal energy transferred to the component is a combination of temperature and flow so the higher the flow rate, the lower the temperature required. A low temperature/high flow approach typically reduces package temperature, however it can negatively impact the delta T of the joints if the flow is too high, so the optimum balance of temperature and flow must be found for each application.

Increasing the gas flow from 2.5 scfm (current maximum) to 3.0 scfm (25% increase) allowed the nozzle heater temperature to be reduced from 495°C to 350°C (30% reduction). The results of the temperature and flow modification are shown in Table 3.

Table 3: 114mm BGA (Ph 150°C, 350C @ 3.0 scfm, 167 sec)

		Max Temp (°)		Delta T (°)		TAL (sec)	
TC #	Location	Actual	Spec	Actual	Spec	Actual	Spec
1	Top of Package	250	260		-	-	-
2	Joint (corner)	240	235	6	‹ 10	75	60-90
3	Joint (corner)	240				78	
4	Joint (corner)	241				92	
5	Joint (corner)	241				88	
6	Joint (corner)	235				76	
7	Joint (corner)	239				86	

The lower temperature/higher flow approach reduced the maximum package temperature from 260°C to 250°C, well below the current guidelines with no negative impact on the delta T of the joints. All joints except one met the TAL target of 60-90 seconds using this approach.

It is important to note that the 114mm BGA is attached to a 114mm test board with no layers. The thermal settings required to reflow a device of this size on a large, high thermal mass assembly will be significantly higher. It will be critical for the BGA Rework System to have the nozzle temperature/flow and board heating/cooling/handling capability required to rework these next generation large devices on high thermal mass assemblies (Figure 3).

Next generation large component technology will also provide additional challenges not cited by iNEMI including alignment capability, warpage issues, component/site preparation, large board handling capability and nozzle vacuum requirements. It is anticipated that the vision system on rework machines of the future must be able to align components at least up to 75mm and perhaps as large as 100mm or more (Figure 4). Warpage/coplanarity issues will be a major issue for next generation large devices, especially as the pitch decreases over time. Non-Contact Site Cleaning technology must include large size nozzles that provide safe, effective and fast cleaning of the residual site solder. Finally, the vacuum capability of the nozzle must be sufficient not only to hold large devices in place, but also to lift and remove them out of reflowed solder.

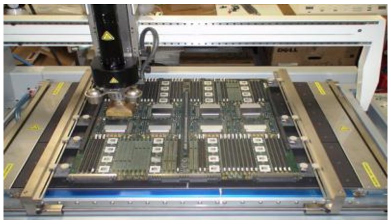

Figure 3. 22x24 high thermal mass PCB on large board rework system (board courtesy of IBM)

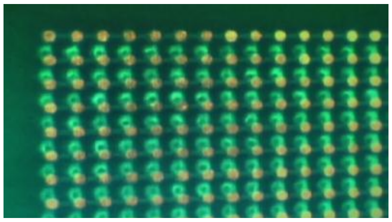

Figure 4. 114mm BGA Corner Viewing in Vision

One major roadblock to the development of effective rework technology and processes for next generation large devices on thermally challenging assemblies is access to and the cost of these devices and assemblies. Cooperative effort is needed between OEM's/CM's and rework equipment suppliers in this area to address the critical issues outlined above.

01005 Rework

Small enough to pass through the eye of a needle and multiple times smaller than a pepper flake, 01005's are nearly invisible to the human eye. These microscopic devices pose significant rework challenges including component handling, site preparation and reflow.

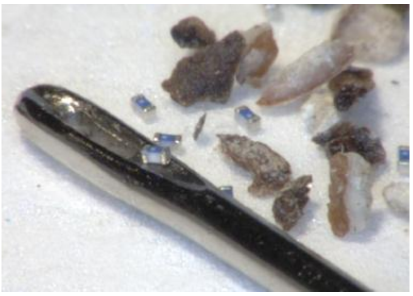

Figure 5. 01005 in eye of Needle and Next to pepper flakes

01005's are not yet used in widespread high volume production, however it is believed that current users are performing hand soldering rework when required. iNEMI's view is that hand soldering rework of 01005's is difficult but possible for a skilled operator.

These are conflicting industry views regarding 01005 rework with the majority of views indicating that 01005's can not be reworked. On the other hand, manufacturers of both hand tools and BGA rework equipment indicate that they have equipment capable of reworking 01005's. Web based research found several hand tools said to be capable of 01005 rework, however, no hand tool-based video of 01005 rework was found. On the other hand, several 01005 rework videos were found using BGA rework machines, but many have limitations or issues including high capital cost, low throughput, lacking ease of use, and the ability to rework 01005's with adjacent spacing of 0.2mm or less.

Another issue is the inability of most machine-based systems to handle almost half of the cases where the residual site solder can not be reused due to paste printing defects such as insufficient solder (Figure 6). Some rework machines do provide paste dispensing capability, however the complexity and efficiency of dispensing microscopic dots in a repeatable fashion in a hot rework environment is a major concern.

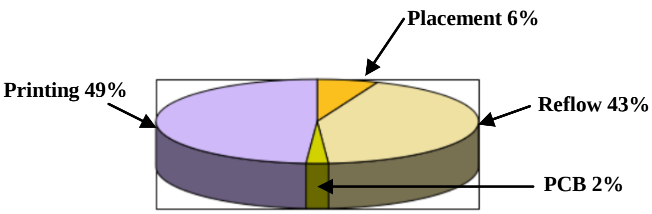

Figure 6. Root Cause of Defect (3)

One other alternative for 01005 rework is to combine the best features of hand soldering and BGA-type machine rework into a "Man" (ie: man or woman)/Machine Rework Interface (MMRI). In this approach, the operator has manual control of all processes which are done directly at board level without using slower, more expensive and often complicated beamsplitter-based systems. The board level rework approach also eliminates "Z" axis accuracy issues that exist with most beamsplitter-based systems. If the beamsplitter is not calibrated accurately and often, the nozzle will not properly contact the 01005 during removal, and the positioning will be off during placement. In addition, some BGA Rework Systems do not have the accuracy necessary for placing micro-discretes regardless of how often the vision system is calibrated. Remember that we are talking about microscopic devices, so minor placement errors which had no impact in the past on BGA rework, now become significant.

Figure 7. "Man"/Machine 01005 Rework Interface (MMRI)

In addition to manual control, the MMRI approach also provides the operator with numerous machine-related advantages, including inspection quality microscope-based optics, integrated top and bottom heating technology and perhaps most importantly, elimination of the precise manual dexterity required for hand soldering rework.

The 01005 removal throughput with the MMRI approach is multiple times faster than beamsplitter-based systems, and as fast as hand tools.

The 01005 replacement process is greatly simplified when the residual solder on the pads can be reused. A stereo microscope with high magnification zoom lens assists the operator in picking the replacement device from the tape holder, eliminating any manual handling of the part. The site is fluxed with a micro syringe to minimize over application of flux which is a key iNEMI concern. Indium 30B halide-free flux is used as it does not contribute any ionic species which can create a conductive pathway for dendritic growth that can cause electrical failure if not properly heat activated. Unlike hand soldering, the MMRI process includes full board preheat which should eliminate any flux non-activation concerns however the use of halogen-free flux is recommended as an additional safeguard.

Alignment is done easily and quickly at board level using the inspection-quality stereo microscope with high magnification zoom lens, fine adjust X/Y Table and Theta Rotational Adjustment. Another advantage of the MMRI process is that a misaligned 01005 can be removed, aligned and replaced in a single step.

The 01005 replacement process becomes far more complicated when the residual solder can not be used. First, any solder remaining on the pads must be removed with a micro-site cleaning nozzle, which provides both heat and vacuum. The Board Cooling System and the nozzle cool air bypass are activated and continue until the board temperature drops to 70°C. The Board Cooling System is powerful and the PCB's that 01005's will be used on will have low thermal mass so the cooldown will occur quickly. A proprietary micro-dipping tool is used in conjunction with a precision depth dip tray to transfer solder paste to the pads. The stereo microscope with zoom lens allows the operator to view the paste application process and to inspect the paste prior to proceeding. 01005 rework throughput can be increased by using a batch approach where all 01005 defects are removed and site cleaned and then all sites are pasted and replaced separately.

The nozzle is heated at low temperature and the replacement component is picked from the tape pocket. Static electricity and paper dust are two tape-related concerns. The replacement device is aligned with the pasted pads, placed and reflowed. Force feedback is provided to the operator during manual placement, which is important as assembly-based placement testing indicates that placement force in excess of 2 newtons (200 grams) can cause component cracking. Another significant advantage of the MMRI System compared to both hand soldering and BGA Rework Systems is that after the replacement component is placed on the pasted pads, the operator can retract the nozzle slightly and reflow the device with convective heating. This allows the 01005 to self center which is not possible when the device is held in place with a conductive heating tip. Using the IR bottom heater in conjunction with the convective heating nozzle provides the gradual ramp up desired for replacing ceramic capacitors which cannot be accomplished with conductive heating tips. Nitrogen is recommended for the convective reflow process to improve wetting and reduce oxidation of the fine grain solder particles.

- Tip Contact Time : 7 seconds
- Heating Slope : 13° / second
- Max 01005 Temp : 242°C
- Heating Cycle : 7 seconds

01005 Removal (Combined Conductive / Convective Heating)

- Tip Contact Time : 0 seconds
- Heating Slope : 2° / second
- Cooling Slope : -5° / seconds
- Max 01005 Temp : 242°C
- Heating/Cooling Cycle : 60 seconds

01005 Replacement (Convective-only Heating)

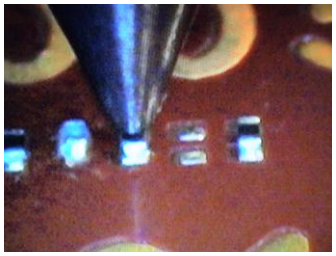

Figure 8. 01005 Micro-Tip Nozzle

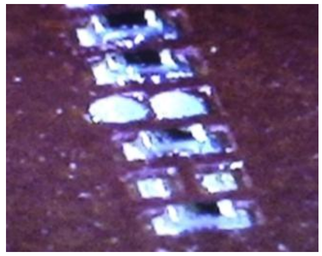

Figure 9. Paste Transfer onto 01005 Pads

Figure 10. 01005 Replacement (left) Site Cleaned Pads (right)

The cleanliness of the micro-tip is critical to insure consistent vacuum removal of these microscopic devices on an ongoing basis. The operator periodically uses an ultra-fine gauge cleaning tool to keep the micro-vacuum tip clean.

Package on Package (PoP) Rework

PoP is two or more fine pitch components stacked on top of one another in an effort to save board space. The bottom package is typically a high performance logic device and the top package is typically a high capacity memory device. Warpage of the bottom package caused by the CTE mismatch between the die, molding compound and substrate is by far the most common PoP issue. Warpage is a key issue for PoP due to the fact that the packages are extremely thin and typically fine pitch. PoP warpage typically manifests itself as a Head-in-Pillow (HiP) defect, which is defined as the incomplete coalescence of the solder joint between the PoP sphere and the printed solder paste. Other contributors to HiP defects include flux exhaustion, poor wetting and incorrect solder paste chemistry.

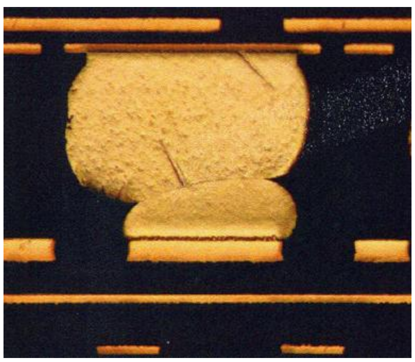

Figure 11. Head in Pillow Defect [4]

PoP Rework mimics standard BGA Rework with a few modifications. PoP devices can either be removed separately with a standard nozzle that requires zero clearance (Figure 12) or together with a vacuum-activated tweezer nozzle, which requires some adjacent clearance (Figure 13). Some companies glue the two packages with adhesive so they can be removed together with a standard nozzle. PoP removal should not include any downward nozzle pressure during the removal process as this can result in solder ball migration to adjacent components. Vacuum-based component removal using a vacuum sensor accomplishes this task.

Figure 12. Standard Nozzle (Removes 1 Package at a time)

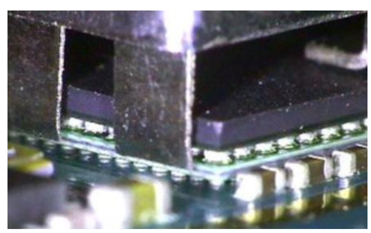

Figure 13. Tweezer Nozzle (Finetech) (Removes both Packages together)

After the components are removed, the residual site solder must be removed. The "stone age" practice of removing the residual solder with a soldering iron and wick should be replaced by non-contact solder removal to eliminate the potential for lifted pads and solder mask damage. The cautionary verbage associated with using solder wick (ie manual site dressing is very dependent on operator skill, damage often occurs when operators do not tin the bit, do not apply pressure to the pads, the speed of the wicking process is critical, etc. etc.) should serve as a wake-up call to companies who continue to allow wick-based site cleaning to be used because their operators prefer it or because it is fast. Higher lead-free reflow temperature and the continued drive toward finer pitch devices should signal the end of wick-based cleaning, however iNEMI estimates that wick is still currently used 80% of the time for site preparation. Every operator can detect a damaged pad and knows how to fix it, however determining if the solder mask has been damaged by the solder wicking process is far more difficult.

Some BGA rework equipment manufacturers' claim to have a non-contact site cleaning system, however they really have a heated nozzle with a metal vacuum tip that is moved across the site with manual "x", "y" and "z" controls. A true non-contact site cleaning tool incorporates a vacuum sensor that automatically and continuously adjusts the vacuum tip height. The most advanced systems go one step further by using a high temperature composite vacuum tip rather than a metal tip to completely eliminate the possibility of a heated metal tip contacting the board or the pads (Figure 14).

Users are demanding faster non-contact site cleaning solutions in order to switch from solder wick. Some BGA rework manufacturers' have already developed larger, site specific cleaning tools designed to clean the site in a single pass (Figure 15).

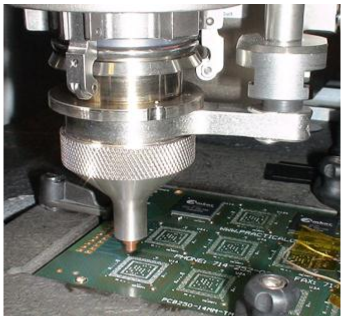

Figure 14. Non-Contact Site Cleaning System

Figure 15. Large Site Cleaning Nozzle (Zevac AG)

PoP replacement is more complicated than replacing a BGA. First, the bottom package is picked and is typically dipped in a controlled volume of flux or dippable solder paste, using force control to insure repeatability. Ideally, the dipping process can have multiple programmable dip locations so that the dip tray does not have to be re-prepared after each process (Figure 17). Dipping the bottom package in solder paste helps to address the warpage/HiP issue discussed earlier. Using a dippable solder paste chemistry with a higher temperature activation will help reduce flux exhaustion and improve wetting. If the beamsplitter has independent top and bottom lighting, camera zoom and the ability to move to all areas of the component, the solder paste on the spheres can be inspected during alignment in vision (Figure 18). This allows the operator to terminate the process if the paste has bridged or is missing from any spheres.

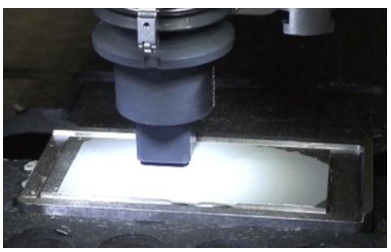

Figure 16. Force-Controlled Solder Paste Dipping

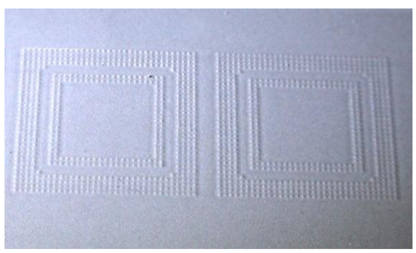

Figure 17. Multiple Imprints in Solder Paste

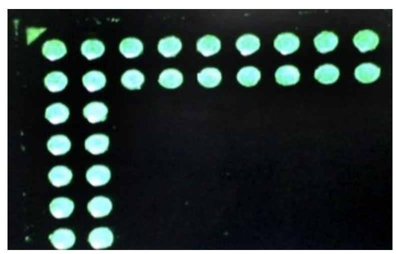

Figure 18. Inspecting Paste on Spheres in Vision

The top package can be dipped in either solder paste or tacky flux as the top package will have a lower CTE mismatch and therefore less warpage. If the top package is dipped in solder paste, it can be inspected in vision. If the package is dipped in tacky flux, inspection in vision will not be possible, however, the imprint of the spheres into the flux tray can be inspected to insure that all spheres have flux on them. Some flux manufacturers are now adding a color dye to the tacky flux so inspection is possible.

The top package is aligned with the top side of the bottom package and placed onto the bottom package. Force control (1-2 newtons) is recommended. Both packages are then reflowed together. Some BGA rework manufacturers' recommend reflowing the packages separately. It is not clear why this approach is recommended as it results in an additional complete reflow cycle for the bottom package and the PCB. Nitrogen is recommended for the reflow process to improve wetting and reduce oxidation of the fine grain solder particles.

Through-Mold Via (TMV™) PoP (Figure 19) is Amkor's next generation 3D packaging solution which uses a laser ablation process to create recesses within the dielectric material as opposed to current photolithographic techniques where the signals are formed on the surface of the dielectric [5]. TMV PoP utilizes a balanced, fully-molded structure which improves warpage control and allows bottom package thickness reductions. Thermal Shadow Moiré testing demonstrates that the TMV PoP exhibited a dramatic improvement in warpage compared to the conventional PoP package as shown in Table 4.

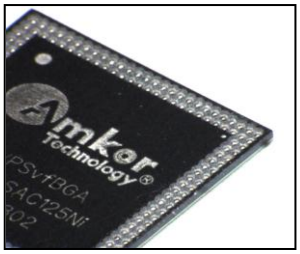

Figure 19. Amkor TMV™ PoP

Table 4: Thermal Shadow Moiré Results [6]

Package/Substrate	TMV/0.30	FC PoP/0.30
Max Warpage (μM)	-51.8	-136.8

TMV™ PoP Solderability Testing

A 77x132mm test board (8 layers, 1.0mm thick) and 14mm TMV™ PoP devices were used for solderability testing (Figure 20). The bottom package is 0.65mm pitch with 620 I/O while the top package is 0.5mm pitch with 200 I/O. A typical preheat/soak/ramp/reflow/cool soldering profile was developed on a BGA Rework System by instrumenting one TMV PoP.

No thermal changes were made to the reflow process throughout the study. The only thing that was changed was the component/site preparation method and material as summarized in Table 5.

Figure 20. TMV PoP Test Vehicle

Table 5: TMV™ PoP Solderability Testing

	Bottom Package				Top Package		
Placement #	**Paste Dip**	**Flux Dip**	**Flux Site**	**Flux Top of Pkg**	**Paste Dip**	**Flux Dip**	**Nitrogen**
1-2		✓				✓	
3-4			✓	✓			
5-6			✓			✓	
7-8	✓				✓		
9-10	✓		✓	✓	✓		
11-12			✓		✓		
13-14		✓				✓	✓
15-16	✓				✓		✓
17-18			✓	✓			✓

The objective of the study was to see if the component/site preparation method/material had any significant impact on the TMV™ PoP in regard to warpage, HiP or any other defects.

PoP Solderability Testing Results

Cross sectioning results of the PoP solderability testing indicates that the biggest factor influencing good joint formation is the liberal use of flux. Best results for both top and bottom joints resulted when flux was brushed on both the site and top side pad surface on the bottom PoP. Flux dipping produced reasonable results but joints were not always as well formed as when flux was brushed on the pads. Solder paste dipping showed the poorest results with some cases of complete opens and at best only partial wetting of solder sphere to pad. Nitrogen also appears to produce better overall results than air and appears to help in marginal soldering situations.

One thought is that the small size of the PoP solder spheres limits the volume of flux or solder paste that can be applied during the dipping process to levels that are not sufficient to produce good solderability results. However, the sample size in the study was relatively small and should be verified by follow up testing using a larger sample size.

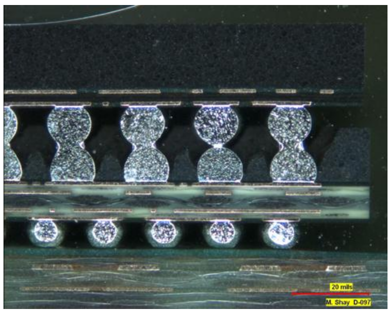

Figure 21. Cross Section showing poor results (solder paste dipping)

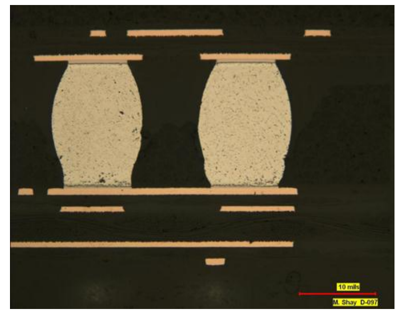

Figure 22. Cross Section showing good results (flux brushed on)

QFN/MLF Rework

Amkor, calls them MLF's (micro lead-frame) while many others refer to these components as QFN's (quad flat, no leads). IPC refers to these devices as BTC's (bottom terminated components).

The MLF is a plastic encapsulated package with a copper lead frame substrate. The package uses perimeter lands on the bottom of the package to provide electrical contact to the PCB. The package also has a large center pad on the bottom of the package to provide an efficient heat path to the PCB.

The two major issues associated with QFN technology are excessive voiding in the thermal pad area and out gassing which may cause solder balling and/or splatter. Both issues are caused by flux entrapment due to the low component standoff height. IPC-A-610 allows voiding levels of up to 25%.

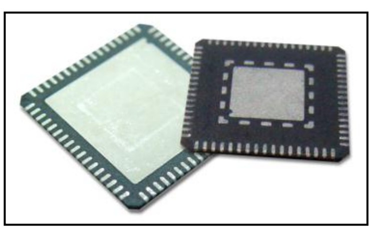

Figure 23. QFN / MLF Devices

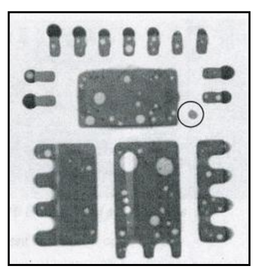

Figure 24. Example of Voiding and Solder Balling under a Power QFN [7]

The QFN/MLF rework process mimics the PoP process explained earlier except that solder paste dipping is not possible with QFN's due to package flatness. Solder paste must be applied to either the component or the pads prior to replacement. There are a number of processes for applying solder paste, including solder preforms, polyimide or metal site stencils, polyimide or metal component stencils, stay-in-place stencils or multi-up stencils.

The stay-in-place stencil approach applies a tacky polyimide stencil to the device (Figure 25a). Paste is applied and the excess removed with a doctor blade. The device is then reflowed and the stencil is removed leaving a bumped device (Figure 25b). A second stencil is applied to the pads and paste or flux is applied (Figure 25c). The bumped QFN/MLF is placed in the site stencil and reflowed. The site stencil remains on the board permanently. Reliability testing by NASA/DOD indicates that the stay-in-place stencil performed at the same level as traditional board paste printing.

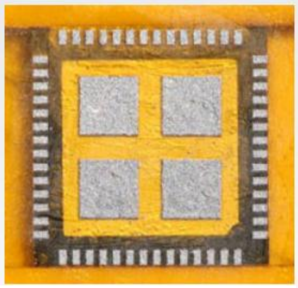

Figure 25a
QFN with Stencil [8]
And Solder Paste

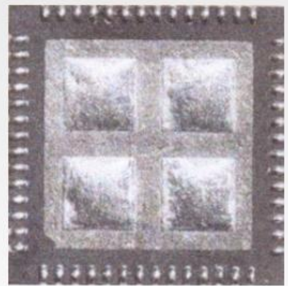

Figure 25b
Bumped QFN after [8]
Reflow and Removal of Stencil

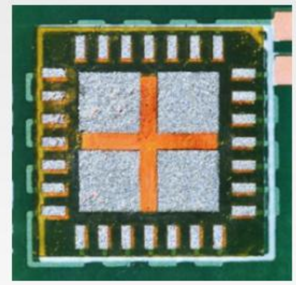

Figure 25c
Stay-in-Place Site [8]
Stencil

Another pasting methodology is the multi-up method where a multi-up stretched metal stencil is used instead of a single component stencil (Figure 26). Typically twenty devices can be stenciled together depending on size. After the components are stenciled, a vacuum table is activated to hold the components in place as the stencil is lifted. The pasted components are reflowed and stored as bumped components for later use. Tacky flux is applied to the site prior to placement.

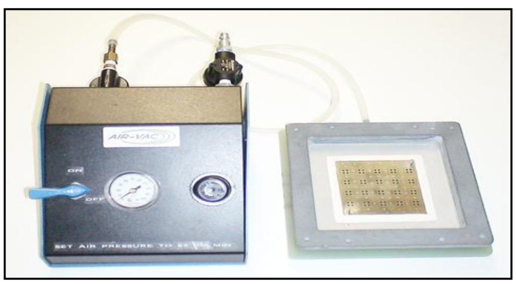

Figure 26. Multi-Up Stenciling System

The design of the solder paste stencil for the thermal pad on a QFN is critical to help minimize voiding and out gassing. Amkor recommends that the stencil have multiple smaller openings instead of one large opening which will typically result in 50% to 80% solder paste coverage. Amkor also recommends a stencil thickness of 0.125mm for 0.4 and 0.5mm pitch parts and 0.15-0.2mm thickness for coarser pitch parts [9] .

QFN Solderability Testing

A 203x140mm (8"x5.5") 0.062" thick test vehicle along with 10mm square MLF components with 0.5mm pitch were used for solderability testing. Two (2) thermal profiles were developed; a short soak/ramp profile and a longer soak/ramp profile.

Three paste-on-device metal stencils with different center pad designs and paste coverage were used as shown below. All stencils used were 0.125mm (.005") thick.

Center Pad #1

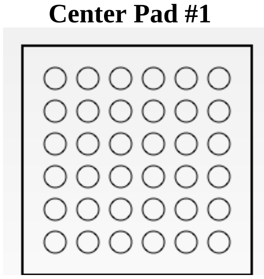

Figure 27a
1.00mm diameter [10]
circles @ 1.2mm pitch
– 50% coverage

Center Pad #2

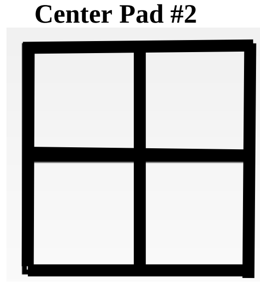

Figure 27b
3.10mm squares [10]
@ 3.95mm pitch
– 60% coverage

Center Pad #3

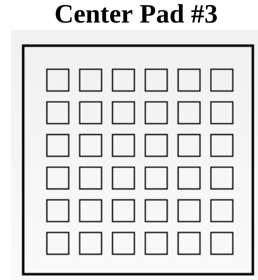

Figure 27c
1.35x1.35mm squares [10]
@ 1.5mm pitch
– 81% coverage

In addition, the Multi-Up Stencil System described previously was used in conjunction with the center pad #2 stencil design. The MLF devices were stenciled and reflowed prior to use in the test. Indium 9.0A No Clean solder paste (type 4 mesh) was used with all stencils.

The objective of the solderability study was to determine which stencil design provided the best results in regard to minimum voiding in the center pad region. A second objective was to determine if the pre-reflowed QFN's from the multi-up stencil performed as well as pasted QFN's with the same stencil design.

Results

Voiding results using the various center pad stencil designs and short versus long soak/ramp cycles are summarized in Table 6.

Table 6 : QFN Voiding Summary

				Voiding (Center Pad)	
Stencil	**Location**	**% Coverage**	**Profile**	**Total**	**Largest Single**
36 Circles	1A	50%	Short Soak/Ramp	11.5%	1.6%
36 Circles	1B	50%	Long Soak/Ramp	6.5%	0.6%
4 Windows	2A	60%	Short Soak/Ramp	17.9%	2.0%
4 Windows	2B	60%	Long Soak/Ramp	10.5%	1.9%
25 Windows	3A	81%	Short Soak/Ramp	13.4%	2.4%
25 Windows	3B	81%	Long Soak/Ramp	11.3%	1.8%
4 Windows (1)	4A	60%	Short Soak/Ramp	13.3%	1.1%
4 Windows (1)	4B	60%	Long Soak/Ramp	16.1%	1.4%

(1) Using Multi-Up Stencil, Reflowed in Advance of Use, Flux Added to Site

All of the QFN's had total percent voiding well below the IPC specification of 25%. The long soak stage provided less voiding than the short soak stage with all three stencils. The long soak stage with the lowest percent solder paste coverage yielded the best results. Finally, the QFN's that were pre-bumped with the multi-up stencil approach yielded similar results to the standard pasting approach.

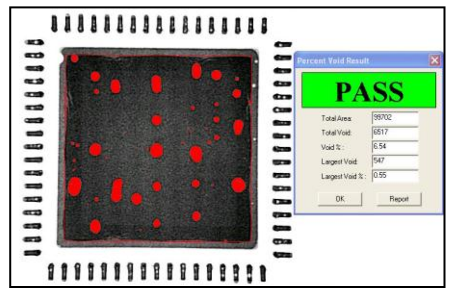

Figure 28. QFN with acceptable void levels

Conclusion

Large area arrays (>50mm) on large, high thermal mass PCB's will create rework challenges including meeting the current strict reflow and package temperature guidelines that were established for much smaller BGA's. Other challenges that will need to be addressed include alignment capability, warpage, large board handling and safe/fast/effective site cleaning. Access to next generation large area arrays on high thermal mass PCB's is required to develop effective rework solutions.

Methodologies must be developed for reworking microscopic 01005's in a cost effective, practical manner than provides high throughput capability. The ability to clean the site and prepare it with solder paste will be important as 50% of 01005 defects are created by the paste printing process. A "Man"/Machine Rework Interface (MMRI) approach was proposed as a possible solution.

Packaging innovations such as Amkor's TMV™ PoP will help resolve Head in Pillow (HiP) issues that are found frequently with current PoP packaging technology. A PoP solderability study showed that manual flux application and the use of nitrogen yielded the best results.

Several MLF/QFN solder paste application methods were discussed including two new and innovative methods: stay-in-place stencils and the multi-up stencil. The design of the stencil for the center pad area is critical to minimize voiding caused by flux entrapment from the low package stand-off height.

Modifications to existing BGA rework equipment as well as new equipment and processes will be required to meet the challenges associated with reworking next generation SMT applications.

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I would like to acknowledge Mario Scalzo, Senior Technical Support Engineer at Indium Corporation for providing all of the solder pastes and fluxes used in this paper as well as for the insight he provided regarding the various solder alloys and flux chemistries.

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- Based on only a few test samples subjected to thermal cycling and visual inspection, it appears that re-columned CGA60 package with no interposer is a viable rework solution from an assembly perspective only. Further work is required to substantiate these test results for an active-die version.
- All CGA1144 assemblies with re-columned packages passed 200 severe thermal cycles (–120°/85°C) with no apparent visual damage or daisy chain failures.
- Based on limited thermal cycle test results and visual inspection during thermal cycling, it appears that re-columning of CGA1144 is a viable option from a solder attachment perspective only.

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