A COMPARATIVE STUDY OF BALL GRID ARRAY AND ULTRA FINE-PITCH QFP TECHNOLOGIES USING SOLDER PASTE STENCIL PRINTING

Roger Rörgren, Per Carlsson and Johan Liu
IVF - The Swedish Institute of Production Engineering Research
Argongatan 30, S-431 53 Mölndal, Sweden

ABSTRACT

The present miniaturization trend toward higher-performance, smaller and lighter products has resulted in an increasing demand for smaller component packages and/or higher pin counts. This paper addresses some important properties of solder pastes for assembling BGA and ultra fine-pitch QFP components. Viscosity measurements and analyses using Differential Scanning Calorimetry are presented, and give some insight into the complex rheology and thermal behavior of solder pastes. Gold plated test boards were assembled using nitrogen reflow of 1.5 mm pitch BGAs and QFPs with a pitch range from 0.3 mm (11.8 mil) to 0.65 mm (25.6 mil), and the yield in terms of solder defects and solder balls was studied. A fractional factorial experiment to study the solder balling phenomenon was carried out using IR reflow in air and pretinned boards.

INTRODUCTION

The Quad Flat Pack (QFP) and the Ball Grid Array (BGA) packages today both offer a large number of I/Os, as required by modern IC technology. The BGA concept has received much appreciation owing to its inherent, potential benefits to surface mount production. In order to accommodate the increasing number of I/Os needed, the peripheral QFP technology is forced to an ever finer lead pitch with thinner and more fragile leads. The BGA, taking advantage of the area under the package for the solder sphere interconnections, satisfies the I/O demand using a far coarser pitch. Additionally, the package size and the board real estate required are usually smaller. The relationship between BGA and QFP packages' size and I/O count is illustrated in Figure 1. A typical 0.65 mm (25.6 mil) fine-pitch QFP with 160 leads measures 28x28 mm. Modern portable electronics asking for the same number of leads in a package 14x14 mm ends up at 0.3 mm (11.8 mil) pitch with a space between the leads of only 0.15 mm (6 mils). Alternatively, increasing the number of I/Os while retaining the 0.65 mm pitch, means e.g. 232 leads in a 40x40 mm body. A 27x27 mm plastic BGA (PBGA) houses 225 I/Os with a coarse 1.5 mm pitch. The distance between adjacent solder spheres is approximately 0.8 mm. The more I/Os needed, the better off with the BGA in terms of package size since the dimensions only grow as the square root of the I/O count for a given pitch, and not linearly as is the case for QFPs.

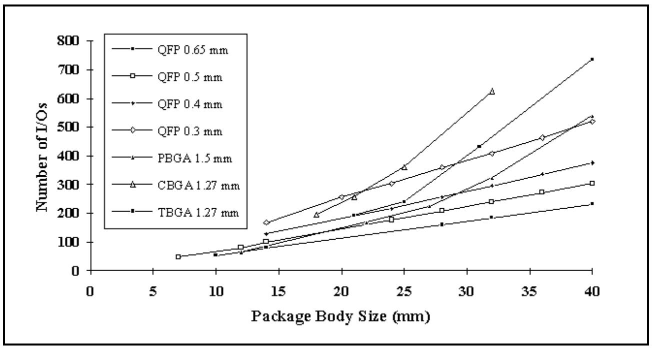


Figure 1. Size comparison of square QFP and BGA packages of different types and with different I/Os.

Replacing QFPs with BGAs not only means that higher pin counts or smaller packages can be achieved, but also that a considerably higher manufacturing process yield can be reached. Today, the manufacturing aspects seem to be the major driving forces for the BGA technology, although issues like cost, reliability, and rework and inspection will probably soon push the technology further. Even though a choice between the BGA and QFP technologies seems easy from a production point of view, as illustrated in Figure 2, the alternatives still have to be considered and pertinent issues should be scrutinized.

Figure 2.A 0.3 mm (11.8 mil) QFP placed on a grid of 1.5 mm pitch solder spheres (bottom side of PBGA225)

Purpose

The purpose of this work is to evaluate the suitability of existing manufacturing processes for production using BGAs and/or ultra fine-pitch QFPs. Since a key to success is believed to be the solder paste printing process, much effort has been devoted to different solder pastes and their properties. Test boards were fabricated using stencil printing on flash gold boards and assembly of QFP packages with component lead pitch ranging from 0.3 mm to 0.65 mm. Optimization of the processes for e.g. 0.3 mm pitch QFP or BGA has not been included, but rather the comparison of existing processes for the two technologies. Particular emphasis was put on the print quality and on the process yield in terms of shorts and solder balls after reflow. A factorial experiment was designed and carried out using IR reflow in air of pretinned boards to find the factors influencing the solder balling rate under the BGA package and its consequences to the technology. The solder pastes included in the tests are described in more detail at the end of the paper.

SOLDER PASTE CHARACTERIZATION

The properties of the solder paste is of great importance for the final result of the surface mount assembly, especially when component lead pitches below 0.65 mm (25.6 mil) are addressed. A solder paste may typically contain up to 20 ingredients providing separate functions, e.g. a binding agent, a fluxing agent, rheology controllers and modifiers, which unfortunately most often are interrelated with respect to performance. A typical paste contains 85 to 95 % (by weight) of solder particles and 5 to 15 % of fluxing and other agents or additives and solvents making up the final product. The paste viscosity is different for different application methods: stencil printing requires about 1 000 Pa·s (=1 000 000 cps), screen printing 800 Pa·s and dispensing approximately 500 Pa·s according to Brookfield measurements

Table I.*Size classification of solder paste (IPC-SP-819).*

Class (according to IPC-SP-819)	Particle Size (µm)	Mesh Cut (1/inch)
IPC Type 1	75-150 µm	-100+200
IPC Type 2	45-75 µm	-200+325
IPC Type 3	20-45 µm	-325+500
IPC Type 4	20-38 µm	-400+500

For fine-pitch SMT assembly, it is also important that the size of the solder particles is sufficiently small and the that its distribution is tightly controlled. The IPC type 3 is usually recommended for fine-pitch applications. Type 3 implies a particle size with 80 % (by weight) of the sample ranging from 20 to 45 µm (mesh -325+500), see Table I. For ultra fine-pitch, which involves stencil apertures on the order of 0.15 mm (6 mils), even 3 or 4 solder particles in a row are sufficient to effectively block the aperture and cause a meagre print. There are modern pastes available containing very fine powder-like solder particles less than 20 µm in size. It should be noted, however, that such pastes are more likely to oxidize due to their larger surface area. What is gained in printability may thus be lost in inferior wetting and an unacceptable soldering performance.

The viscosity is perhaps the single most important parameter relating to the rheology and the printing performance of a paste. For instance, from a production point of view, the paste should be easily printed in a standard stencil printing process through very small apertures while still not sagging. This is sometimes described in a more elaborate way in terms of shear thinning, thixotropy, and yield point. Furthermore, the paste must not dry out on the stencil, which also would block the apertures, but retain its tackiness in order to keep the components in place in the wet paste between placement and reflow. During reflow the boards are first heated to evaporate solvents and to activate the solder paste flux system. The flux then removes oxides on the solder particles and the metal surfaces to be soldered while preventing their re-oxidation. Pastes are generally affected by changes in ambient temperature and humidity and the viscosity also changes with time as the material is being used in a normal stencil printing operation.

Viscosity is commonly measured using dedicated equipment such as the Brookfield or the Malcom viscometers. However, different operating principles of different equipment as well as different measurement parameters often make it impossible to compare the values. Under these conditions, values from single-point measurements, i.e. taken at one shear rate only, are not of any use. In this study, a Brookfield DV-II viscometer with a reversible helipath stand was used with a T-spindle (TF) at different shear rates to register the pastes' dynamical viscosity, η, at 5 RPM and to calculate a Thixotropy Index, T.I.=Log[η (1 RPM)/η (10 RPM)]. To investigate the pseudo-plastic and thixotropic behavior of the pastes, a circular spindle (no.7) was employed using shear rates between 0.5 and 10 RPM. A rheology profile was recorded by shearing for 15 s at each shear rate prior to measuring and without allowing the material to recover between the measurements. The viscosity was also measured under constant shear stress conditions for 5 minutes at each shear rate used.

Using Differential Scanning Calorimetry (DSC), it is possible to study the thermal properties of a solder paste, simulating a soldering process. During DSC measurements, phase transformations and chemical reactions causing heat generation (exothermic reaction) or absorbtion (endothermic reaction) can be identified by reference spectra obtained using known substances. When the solder particles melt, for instance, a very large endothermic peak is registered. However, when a conventional rosin-based flux system reacts with oxidized solder particles during reflow, forming carboxylate complexes as e.g. tin succinate, heat is generated and hence an exothermic peak is expected. The strength of the reactions (i.e. the height of the peaks registered) and the temperature at which they occur not only provide a finger-print of the paste tested but also a means to modify or optimize the reflow profile. In this study, DSC analyses were carried out on the selected pastes and on reference samples made up of solder particles, solvents and well known concentrations of abietic, adipic and succinic acids in different blends. The heating rate during the DSC measurements was 10 °C/min using a Mettler-Toledo TA8000 analyzer.

The tackiness of the paste after printing should be sufficient to allow a reasonable amount of handling of the boards with components placed but not yet soldered in the reflow process. This is especially important for fine-pitch SMT assembly, in which case even a minor displacement of a component during e.g. conveyor transportation to reflow might lead to bridging and short circuits. Quite often, though undesired, there is a time delay between paste application and component placement on the board. During this time the tackiness of the paste is affected as solvent is evaporated. This delay should therefore be kept to a minimum to avoid inconsistent results and possible solder failures. Even so, it is worthwhile to measure the tackiness of solder pastes and its change under aging conditions to simulate time delays that may occur during normal operation in a production environment. The time needed for the tack force to decrease to 80 % is usually defined as the tack time (also referred to as open time). This parameter varies significantly between different manufacturers and values typically range from a few hours to several days or even weeks.

The method used for measuring the tackiness is described in IPC-SP-819. A circular probe with a well-defined surface and area is slowly lowered into a pool of freshly deposited solder paste and subjected to a certain pressure for a given time. The probe is thereafter retracted at a well-controlled speed while measuring the force necessary to break contact between the probe and the paste, see Figure 3. This measurement is repeated using new samples that have been stored a stipulated time after paste application and the data can be used to generate a diagram showing the tack force versus storage time. The storage conditions used were 22 °C and 40 % relative humidity.

Figure 3. Paste tackiness measurement (IPC-SP-819).

Unfortunately, there is some disagreement on what parameters should be used in the tackiness measurements. The IPC specifies that a Ø 5.1 mm circular stainless steel probe be dipped and retracted at a speed of 2.5 mm/min. A force corresponding to a 300±30 gram weight should be applied for 5 seconds immediately prior to withdrawal of the probe. The paste deposit should be 6.5 mm in diameter and 0.25 mm thick. The Japanese Industry Standard JIS Z 3284 is claimed to simulate a high-speed chip-mounting process and thus specifies a lower pressure, corresponding to 50 grams, during 0.2 seconds before the probe is retracted at a considerably higher speed of 10 mm/sec. The probe, the dimensions of which are identical to that specified by IPC, is also to be lowered more slowly into the paste deposit: 2.0 mm/sec.

SURFACE MOUNT TEST ASSEMBLY

The test board used in the investigation is shown in Figure 4. It is a double-sided 1.6 mm thick FR-4 board, 178 by 222 mm, with a flash gold finish (0.1 µm electroless immersion Au on 5 µm of Ni). The board was designed for quad flat packages with lead pitches between 0.3 mm (11.8 mils) and 0.65 mm (25.6 mils) and 1.5 mm BGA225s as well as a number of chip components. The BGAs used were internally connected in a Daisy Chain configuration and thus allowed continuity testing of the connections by measuring the total resistance formed by the 225 solder joints. The QFPs used were without electrical function but had electrically isolated leads which permitted easy checking of shorts after reflow. For this purpose, they were mounted in the second and fourth columns of the test board (Figure 4).

Figure 4. Layout of the test board used in the study.

The solder pastes were applied in an automatic printer with two different thicknesses of the nickel-plated, additively electroformed stencils: 0.1 mm (4 mils) and 0.13 mm (5 mils). The stencil apertures were designed 10 % smaller than the corresponding pad size, both in width and length, to provide better gasketing between board and stencil. The apertures were slightly tapered with approximately 1 mil larger openings on the PCB side. Metal squeegees were used in all tests since they were found not to cause any scooping of the paste deposit. The stencil printing parameters are summarized in Table II.

Table II. Stencil printing parameters used.

Parameter	Value
Stencil thickness	4 or 5 mils
Squeegee width	250 mm
Squeegee angle	60° with PCB
Squeegee speed	17 mm/s
Squeegee pressure	1.0-1.5 kg/cm^2

The components used to populate the test boards are described in Table III. The QFPs all had pretinned copper leads, whereas the OMPAC BGA connections consisted of 30 mil diameter solder spheres of 62/36/2 Sn/Pb/Ag.

Table III. Components used for test board assembly.

Package Type	I/O	Pitch	Body Size	No./PCB
PBGA225	225	1.5 mm	27x27 mm	2
PQFP160	160	0.65 mm	28x28 mm	2
PQFP208	208	0.5 mm	28x28 mm	3
MQUAD256	256	0.4 mm	28x28 mm	2
TQFP160	160	0.3 mm	14x14 mm	1

Non-soldermask defined pads with a nominal diameter of 30 mils were used on the PCB. The test boards were assembled each with two PBGAs, two 0.65 mil pitch PQFPs, three 0.5 mm pitch PQFPs, two 0.4 mm pitch MQUADs and one 0.3 mm pitch TQFP. Placement was carried out in a fully automated pick-and-place machine with a mounting pressure corresponding to 150-250 grams. Soldering was performed in a nitrogen atmosphere with a combination of convection and IR. The oxygen levels were monitored continuously during reflow and stayed below 22 ppm in the peak zone at all times. In total, 24 boards were fully populated and soldered in the final assembly test run using Paste D and Paste I. This translates to 10,800 BGA joints, 7,680 0.65 mm QFP joints, 14,976 0.5 mm, 12,288 0.4 mm and 3,840 0.3 mm QFP joints

In order to study the phenomenon of solder balls and the influence of process parameters, a fractional factorial experiment was designed. The formation of solder balls under intentionally chosen harsh conditions was studied, using IR reflow in air of pretinned boards. With a two-fold reduction, five possibly provocative parameters were varied in the test, according to Table IV below. Thus, 16 pretinned boards were populated with two PBGA225s each. Unfortunately, the low-level solder paste was not available in a halide-free version, so the difference in flux activity must also be taken into account when comparing the results.

Table IV. Parameter variation in the solder ball study.

Parameter	Low Level	High Level
Paste Particle Size	< 20 µm (0.2 % Halide)	25 - 45 µm (Halide Free)
Oxidation Exposure	No exposure	48 h @ 22 °C, 40 % RH
Paste Amount	0.20 mg/joint	0.50 mg/joint
Moisture Exposure	No exposure	1 h @ 30 °C, 80 % RH
Temperature Profile	Preheat < 120 °C	Preheat 150 °C

RESULTS AND DISCUSSION

Viscosity and Calorimetry

Table V below summarizes the viscosity measurements of the solder pastes tested using Brookfield spindle TF at 5 RPM and 25 °C. The measurement procedure is based on IPC-SP-819 but slightly shorter in time. Two solder pastes designed for dispensing were included here for reasons of comparison. Moreover, an index of thixotropy is calculated in Table V as the logarithm of the ratio of the viscosity at 1 RPM to the viscosity at 10 RPM, both measured at 25 °C. The thixotropy index (T.I.) is a measure of the viscosity change of a material being exposed to agitation or some other shearing effect, as in the stencil printing operation. A T.I. close to zero indicates a minor change with increasing RPM and thus a smaller thixotropic behavior under these conditions.

Table V. Measured viscosity η at 25 °C and 5 RPM, and thixotropy index, T.I., here defined as the logarithm of the ratio η (1 RPM)/η (10 RPM) at 25 °C.

Solder Paste	Particular Characteristics	Viscosity η_5 (Pa·s)*	T.I.
Paste A	Low Residue	1 020	0.60
Paste C	Dispensing	510 D	0.61
Paste D	Reference	1 010	0.63
Paste E	Water Soluble	1 050	0.55
Paste G	Ultra Fine-Pitch	790	0.49
Paste H	UFP Dispensing	610 D	0.67
Paste I	For Nitrogen	1 040	0.81
Paste J	Halide Free	1 210	0.45

* The letter "D " denotes paste designed for dispensing.

The rheology profiles depicted in Figures 5 through 7 are examples of the "memory effect" of three selected solder pastes. This means that the instantaneous viscosity of a paste is dependent on the history of the material, or more specifically any shearing the material has been exposed to. In this case, the viscosity was measured after constant shearing for 15 seconds before the shear rate was increased (or decreased) and the measurement repeated. When returning to the initial lowest shear rate used in the measurement, the viscosity had generally dropped some amount. This effect can be more or less temporary, depending on the composition of the paste. The viscosity of the reference, Paste D, was 12 % lower at 0.5 RPM after having measured at higher shear rates. The effect was hardly noticeable for Paste H (dispensing paste) in this test, whereas the water soluble Paste E exhibited a 35 % drop at 0.5 RPM as well as a considerably lower overall viscosity.

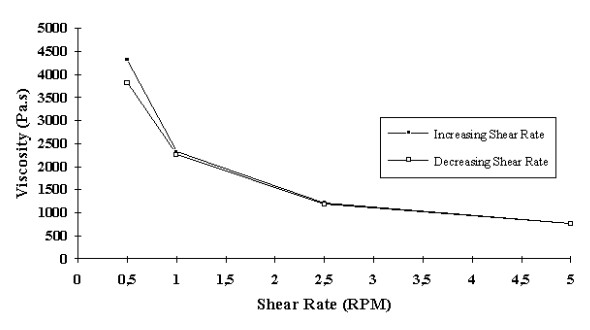


Figure 5. Rheology profile measured for Paste D.

Figure 6. Rheology profile, Paste E.

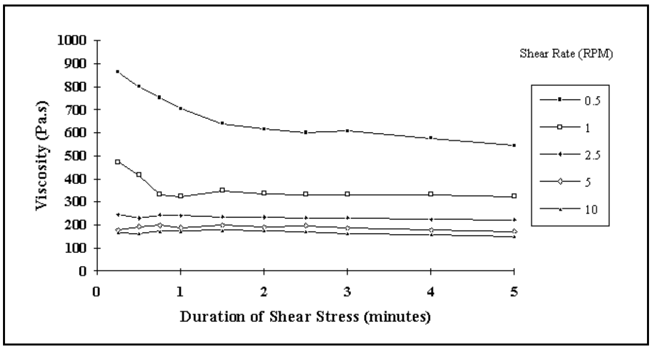
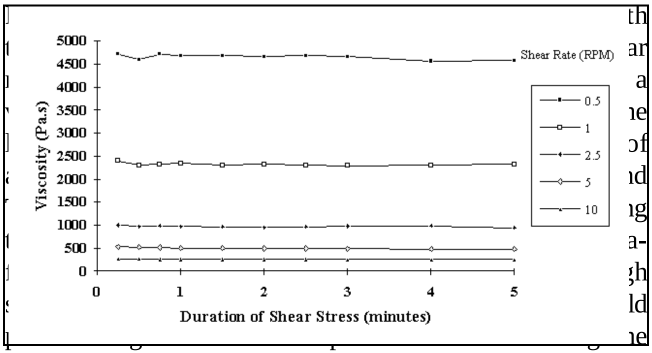


Figure 9. Rheology profile, Paste H

Figure 7. Viscosity versus duration of constant shear stress for different shear rates, Paste E.



th ar a ne of nd ng a- gh ld ne

Figure 10. Viscosity versus duration of constant shear stress for different shear rates, Paste H.

high viscosity state after printing to prevent slumping. The top *horizontal* line in the diagrams represents the lowest shear rate still giving consistent results.

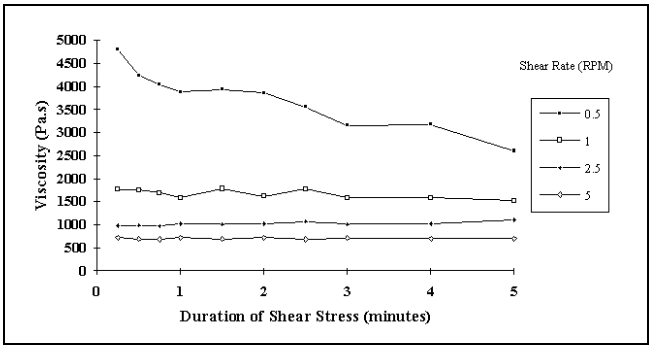


Figure 8. Viscosity versus duration of constant shear stress for different shear rates, Paste D.

A typical example of a DSC spectrum is shown in Figure 11, below, obtained using Paste A. It shows a large endothermic peak at the melting point of the solder and a smaller exothermic reaction at 147 °C. This peak could be identified using a reference sample containing adipic and abietic acid (and solder spheres), showing an exothermic peak at the same temperature, Figure 12. The water soluble Paste E does not show any peaks above 60 °C, except at the melting point of the alloy.

Figure 11.DSC spectrum of solder paste A.

Figure 12.DSC spectrum of reference sample, adipic and abietic acid mixed with solder spheres and solvents.

Tackiness

The results from the tackiness measurements have been summarized in Figure 13 for six selected solder pastes. The most conspicuous feature is the very large spread in tack force after some time despite the fact that the initial values are approximately the same! The dispensing paste H exhibits a dramatic *increase* with time and the tack force has nearly doubled in 48 hours. This particular behavior is most likely due to the higher flux content of this paste, 14 %, as compared to about 10 % for the other pastes, which prevents this paste from drying out too quickly. The water soluble Paste E and the long-tack Paste B both show slightly higher values after 48 h but then seem to stabilize. The shortest tack time was found for Paste I, which had dried out completely after only 8 h.

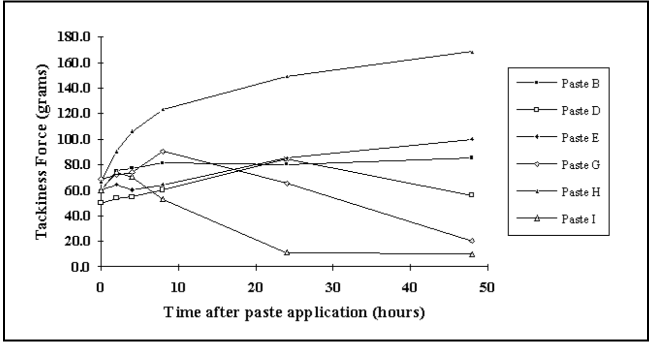


Figure 13. Tack force versus time after paste application.

Solder defects

The bridging rate (shorts) of QFP leads after soldering, using the two different stencil thicknesses, is summarized in Figure 14 below. Only joints where the components were perfectly positioned in the first place were examined, thus excluding possible positioning errors. No bridges were found using any of the stencils for 0.65 and 0.5 mm QFPs or using the 4 mil stencil for 0.4 mm QFPs. Using the 5 mil stencil for 0.4 mm QFP the bridging rate was 5000 ppm in this non-optimized test run. The 0.3 mm pitch QFPs suffered from severe bridging using the 4 mil thick stencil, due to the apertures being only 0.15 mm wide. The 5 mil stencil was actually too thick to allow proper paste deposit and caused blocked apertures, which resulted in many open joints (but no bridges) after soldering. Printing tests carried out using even smaller aperture widths of 0.13 mm resulted in almost complete blocking of the apertures using both 4 and 5 mil thick stencils.

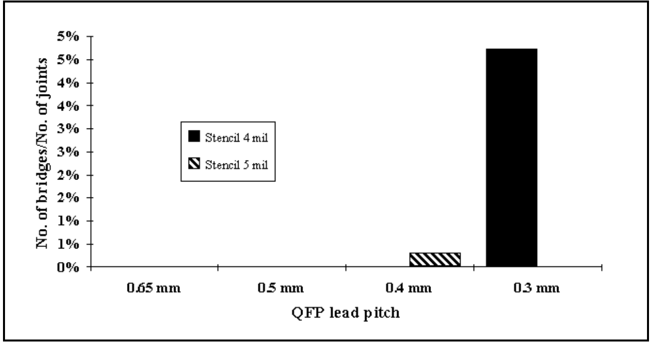


Figure 14. Bridging rate for QFPs using Paste D.

After having verified that all BGA joints were electrically conducting in the Daisy Chain-circuit, they were examined using real-time x-ray microscopy. More than 5,000 joints were inspected *without any trace* of solder balls. This result is attributed to both the choice of Au PCB finish and the use of a well-established temperature profile in a nitrogen atmosphere. Only very few solder balls were found between the QFP leads. Figure 15 below shows an example where 2 very small solder balls were encountered between the pads of a 0.5 mm pitch QFP208. The paste used was reference paste D and the stencil thickness was 4 mils. The size of the solder balls is less than 50 µm.

Figure 15.X-ray micrograph revealing 2 solder balls between pads of 0.5 mm pitch QFP208. Paste D at 50X.

Solder Ball Formation Study

The solder balling rate, measured under BGA packages, is summarized in Figure 16. The chart gives the number of solder balls found per 100 BGA joints for packages assembled on pretinned boards and reflowed in air. The factor having the most prominent influence on the solder ball formation was found to be the volume of paste deposited on the PCB. Increasing the amount of (wet) paste from 0.2 to 0.5 mg/joint resulted in an increase of the solder balling rate from 140 to 460 solder balls per 100 joints. The overall average was 300 solder balls/100 joints. Also oxidation and moisture exposures clearly affect the solder balling rate. The confidence level for these three parameters is at least 94 %.

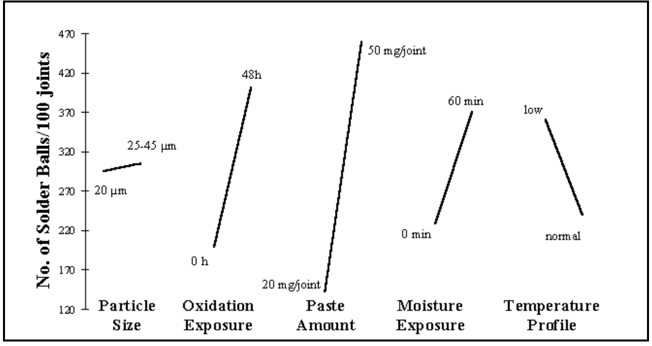


Figure 16. Parameter influence on solder ball formation under BGA packages assembled on pretinned boards.

Cross-sections of BGA and QFP joints are shown in Figures 17 through 21. The stencil thickness used was 5 mils and the solder paste was Paste D. Figure 17 shows how the BGA solder connection has collapsed during reflow giving a stand-off of about 0.48 mm. The shape of the joint is not symmetrical since a soldermask-defined pad was used on the BGA substrate (top) whereas a non-soldermask defined pad was used on the PCB. A symmetrically shaped joint is generally believed to provide better mechanical strength, which thus requires the non-covered area of the two pads to be equal. Crack propagation is expected to initiate at the BGA substrate/solder sphere interface unless non-soldermask defined pads are used on both PCB and BGA substrate. The QFP solder joint cross-sections are found in Figures 18-21.

Figure 17. Cross-section of 1.5 mm BGA225 joint (72X).

Figure 18. Cross-section of 0.3 mm QFP joint (143X).

Figure 19. Cross-section of 0.4 mm QFP joint (143X).

Figure 20. Cross-section of 0.5 mm QFP joint (72X).

Figure 21. Cross-section of 0.65 mm QFP joint (72X).

CONCLUSIONS

Characterization of solder pastes by viscosity measurements can be a helpful tool both for finding the best process parameters and for quality control. However, since there are many different ways of measuring viscosity, it is necessary to be able to critically judge and repeat measurements presented by manufacturers and other users. DSC can be used as a complementary analysis tool, which in some cases can provide valuable information about the thermal properties of solder pastes.

The surface mount test assemblies showed that it was possible to combine 1.5 mm pitch BGAs and QFPs with lead pitches down to 0.4 mm (16 mil) on the same PCB using stencil printing with a stencil mask thickness of 4 mils. In this test, Paste D was successfully printed and reflowed in a nitrogen atmosphere. Using 0.3 mm pitch (12 mil) packages with the same stencil thickness, severe problems with bridging were encountered in the printing process and short circuits occurred frequently after soldering. The process window for 0.3 mm pitch production seemed quite narrow. Stencils 3 mils or thinner may be required if this pitch is targeted. X-ray inspection of the BGA joints revealed that no solder balls had formed under the BGA packages when assembled on gold plated boards in a nitrogen reflow process. Both 4 and 5 mil thick stencils worked well with BGAs since the amount of solder forming the joint mainly comes from the melting of the eutectic solder spheres of the package. Thicker stencils would only be required to overcome bow or warpage problems with the PCB and/or the PBGA package, or if high-temperature 10/90 Sn/Pb solder spheres are used.

Using pretinned boards reflowed in air, the factors with the most flagrant influence on solder ball formation were found to be exposure to moisture and oxidation of the solder particles, and excessive paste deposited on the pads. However, the solder balls formed under the circumstances were very small and may not present any major problem to the BGA technology itself owing to the course pitch of the packages.

ACKNOWLEDGMENTS

This work has received financial support from NUTEK, the Swedish National Board for Industrial and Technical Development and VI, the Association of Swedish Engineering Industries. Special thanks are given to Mr. Joakim Anjeby, Saab Ericsson Space AB, and Mr. Sten-Åke Nilsson, Ericsson Microwave Systems AB, who made the assembly tests possible. ABB Industrial Systems AB are greatfully acknowledged for providing the CAD layout.

REFERENCES

A. I. Attarwala and R. Stierman, *Failure mode analysis of a 540 pin plastic ball grid array*, Proceedings Surface Mount International, San Jose, Ca, 1994

R. J. Chronoes, D. Mallik and S. D. Prough, *Packaging alternatives for high lead count, fine pitch, surface mount technology*, IEEE Transactions on Components, Hybrids and Manufacturing Technology, June 1993

H. Cole and E. Westerlaken, *The control of solder ball formation during wave soldering using No Clean fluxes and inert gas atmospheres*, Proceedings Nepcon West, Anaheim, Ca, 1993.

J. S. Hwang, S*older Paste in Electronics Packaging,* Van Nostrand Reinhold, New York, 1992

J. C. Ivankovits and B. M. Adams, *Controlled atmospheres on solder wetting,* Surface Mount Technology, October 1993

P. Mescher and G. Phelan, *A practical comparison of surface mount assembly for ball grid array components*, Proceedings Surface Mount International, San Jose, 1994

J. R. Morris, *Characterizing solder pastes for the 1990s*, IPC Technical Paper IPC-TP-901

M. Xiao, K. J. Lawless and N.-C. Lee, *Prospects of solder paste in the ultra-fine pitch era*, Soldering and Surface Mount Technology, October 1993

Table VI. Solder pastes used and some important data according to the manufacturers.

Solder Paste	Alloy	Metal Content	Flux	Viscosity* (Pa.s)	Particle Size	Particulars
Paste A	63/37	90 %	RMA	900	20-45 µm	Low Residue
Paste B	62/36/2	90.3 %	RMA	800	20-45 µm	Long Tacklife
Paste C	63/37	85 %	RMA	450 D	25-45 µm	Halide Free
Paste D	62/36/2	90 %	RMA	1150	25-45 µm	Reference
Paste E	62/36/2	88 %	WS	900	25-38 µm	Water Soluble
Paste F	62/36/2	90 %	RMA	220	25-45 µm	Fine-Pitch
Paste G	62/36/2	90 %	RMA	200	20-30 µm	Ultra F.-P.
Paste H	63/37	86 %	RMA	165 D	< 20 µm	0.2% Halide
Paste I	63/37	90.5 %	RMA	900	25-37 µm	For Nitrogen
Paste J	62/36/2	90.5 %	RMA	310	38-45 µm	Halide Free

* A "D" denotes paste designed for dispensing