# Deca Technologies Wafer Level Chip Scale Package (WLCSP) Assembly Guidelines

## Introduction

WLCSP is one of the most rapidly growing packaging technologies. This application note is for engineers who design and develop surface mount technology (SMT), printed circuit boards (PCB), or flexible printed circuits (FPC) incorporating wafer-level chip scale package (WLCSP) devices.

These guidelines document the best practices for WLCSP assembly and PCB/FPC design to ensure good manufacturing yield and reliable performance. Because many factors impact manufacturing, performance, and reliability of the final electronic products, including PCB and solder material selection, manufacturing equipment, and application specification requirements, you are encouraged to validate these best practice guidelines through your own product development and qualification process.

## Why WLCSP Instead of Conventional Packages (QFN or FBGA)

WLCSP is a true die-size package and therefore provides the smallest footprint of any standard IC package. For example, the footprint of a 32-pin QFN package is typically 25 $mm^2$ (5.0 mm x 5.0 mm) while an equivalent WLCSP with 30 balls can be only 5.1 $mm^2$ (2.2 mm x 2.32 mm), which results in an 80 percent reduction of footprint area on the PCB.

WLCSP eliminates most of the first-level package materials found in traditional packages (lead frame or substrate, die attach, wire bonds, and mold compound). It reduces the weight and three-dimensional space consumed by a lead frame-based package or laminate-based CSP. Also, elimination of leads and wires results in better electrical connectivity and conductivity.

Similar to BGA, WLCSP has an array of solder balls or bumps with available ball layouts in 0.5 mm or 0.4 mm pitch. The ball array design will vary by specific product design and application requirement.

Deca’s WLCSP structures are 100 percent green and Pb-free in compliance with RoHS.

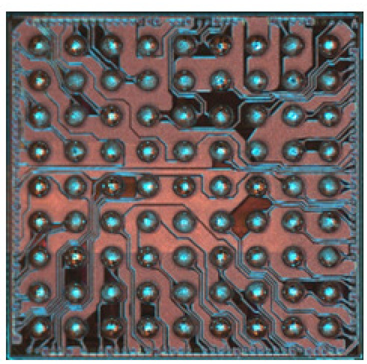


**Figure 1: 4-Series WLCSP**

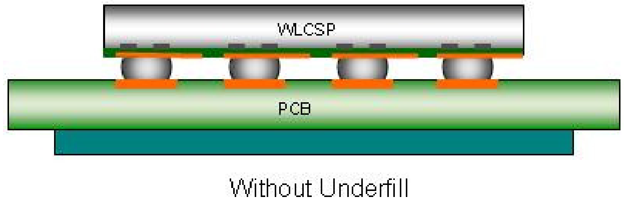



**Figure 2: WLCSP Mounted on PCB**

## 4-Series WLCSP

Deca's 4-Series WLCSP provides superior board level reliability and electrical performance. The 4-Series WLCSP structure is fabricated by applying 4 patterned layers (Via 1, RDL, Via 2 and UBM) on the semiconductor wafer. The 4-Series process begins with the application of a polymer layer (via 1) over the semiconductor wafer. Openings, or vias, are formed to allow access to the aluminum pads on the die surface. For die that are designed for wirebond interconnect, bond pads are typically positioned on the perimeter of the die. Next, a patterned copper redistribution layer (RDL) is formed over the via 1 layer. This creates electrical connections between the die bond pads and the array of solder ball pads. A second polymer layer (via 2) is applied over the copper RDL layer. Vias are formed in the 2nd polymer layer to expose via capture pads on the RDL layer. A copper under bump metallization (UBM) is then formed over the via 2 layer. Solder balls are then attached to the UBM pads to form a ball grid array, as shown in Figure 3

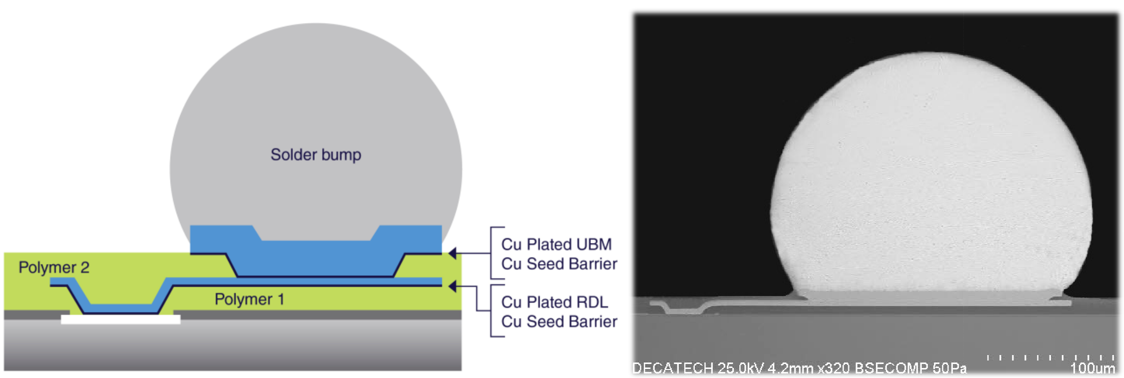



**Figure 3: 4-Series WLCSP Construction**

## Bump-On-Pad (BOP)

BOP is another type of WLCSP in which the fan-in routing is performed during the fabrication of the IC wafer, typically in the final metal layer. Bond pad openings are positioned directly under the BGA array ball locations rather than at the periphery of the die. The BOP process begins with the application of a polymer layer in which vias are formed to expose the die bond pads. A copper UBM layer is formed directly over the first via layer, then BGA balls are attached to the UBM pads. The BOP WLCSP structure is shown in Figure 4.

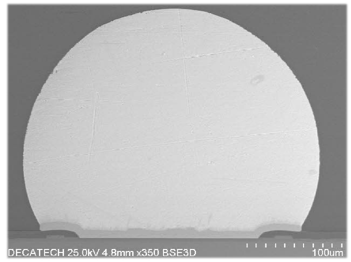



**Figure 4: BOP WLCSP Package Structure**

Deca's standard solder ball alloy is SAC405. Deca's WLCSP structures are compatible with a variety of wafer fabrication processes, including advanced low-K and ELK CMOS technologies.

## WLCSP PCB Layout Guidelines

### Land Pattern Recommendations

PCB fabrication uses two types of land pad patterns during surface mount assembly (see figure 5).

- Non-solder mask defined (NSMD) – The metal pad on the PCB (to which a package pad or pin will be attached) is smaller than the solder mask opening.
- Solder mask defined (SMD) – The solder mask opening is smaller than the metal part.

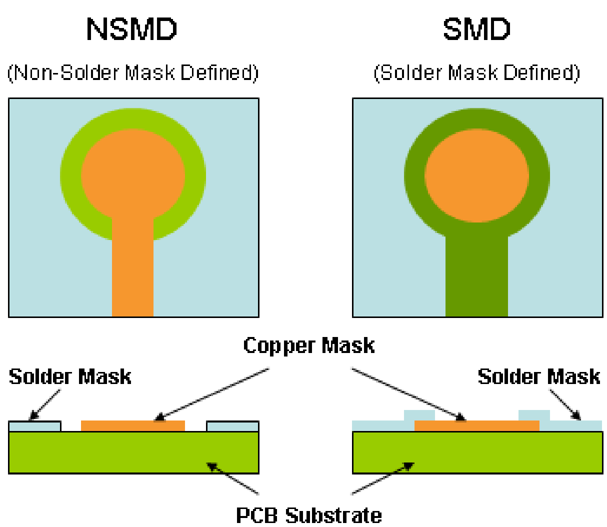



**Figure 5: NSMD and SMD Land Patterns**

NSMD and SMD each have their pros and cons, as shown in Table 1. Deca recommends NSMD pads be used when mounting WLCSP to rigid PCBs.

**Table 1 : Pros and Cons of NSMD and SMD**

| NSMD | | SMD | |
|---|---|---|---|
| PROS | CONS | PROS | CONS |
| Solder ball wets on the side-wall of the exposed copper pads thus improving solder joint reliability | Solder mask opening creates moats that allows underfill deposits.This irregular distribution of underfill may introduce stress on the solder mask and copper trace | Copper pads are stronger since the solder mask overlaps the copper thus improving bond adhesion between the pad and the laminate | Less space is formed in between pads when routing signal traces |
| Wider space is formed when routing signal traces due to small copper pad area | Potential underfill voiding as the solder mask opening provides challenges on the underfill's capillary action | Copper pads has a bigger area thus improving pcb to pad chemistry during flexing and excessive thermal exposure | Solder joint reliability failures during thermal cycle stress due to absence of copper pad sidewall |
| | Prone to pad lift due to fully exposed copper pad without solder mask overlap | | |

If non-soldermask defined pads are used, the NSMD pad diameter should be approximately 90% of the UBM diameter on the package. If solder mask defined pads are used on the motherboard, the SMD pad diameter should be equivalent to the diameter of the UBM on the WLCSP package.

For flexible printed circuit (FPC) board applications where underfill is required, Deca recommends SMD pads. NSMD is not recommended when the PCB applications require potential rework because NSMD is prone to pad lift at multiple thermal exposure. However, in terms of solder joint reliability, NSMD produces a more reliable solder joint during thermal cycle stress due to the available copper sidewall to which the solder can wet.

Deca strongly suggests that you carry out a complete DOE and reliability testing to determine the most suitable pattern for the given PCB application.

## Board Material Selection and Thickness

Standard glass/epoxy substrates are compatible with Deca's WLCSP structures. High-temperature FR4 laminate is preferred over standard FR4 for enhanced package reliability. This is because the CTE of high-temperature FR4 laminate (12–16 ppm/$^{o}$C) is lower than that of standard FR4 (14–18 ppm/$^{o}$C) and is closer to that of silicon (~2.5 ppm/$^{o}$C).

The actual CTE of a board is design-dependent. Numerous factors, such as number of metal layers of the PCB, the trace density, laminate material, the mounted component's population density, and the operating environment affect the thermal expansion. For the greatest reliability, the PCB laminate glass transition temperature should be above the operating range of the intended application (Tg > 170 $^{\circ}$C recommended).

Board thickness values currently used in the industry range from 0.4 mm to 2.3 mm. Thinner boards are more flexible, resulting in greater reliability during thermal cycling and improved thermal fatigue life in comparison to thicker boards.

Similarly, thinner packages also contribute to improved package thermal fatigue performance at the board level. FPC is another commonly used substrate for WLCSP assembly, especially for mobile and consumer electronics applications.

There are multiple factors in FPC material selection and design; for example, flex polymer material and thickness, copper thickness, and stiffener material and thickness. SUS304 (stainless steel) is a recommended stiffener to enhance the thermal and mechanical strength of WLCSP devices. When using a metallic stiffener, the additional parasitic capacitance of the stiffener must be taken into account.

Depending on the application, WLCSP can be board mounted on different board pad surface finishes with matching solder paste to form a complete joint. The surface finish on the PCB land pads can have a significant effect on yield and reliability. Cu OSP is a recommended finish for use with Deca’s 4-Series WLCSP. Electroless Ni immersion gold (ENIG) is an acceptable alternative, but Au thickness is recommended to be limited to < 0.5 micron.

Other pad finish alternatives include immersion Ag, immersion Sn, and solder-on-pad (SOP).

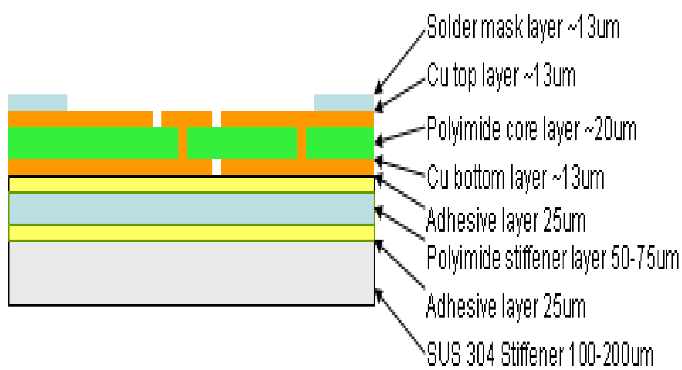



**Figure 6: Typical FPC Structures**

## WLCSP SMT Guidelines

WLCSP board assembly starts with solder paste screen-printing on the board prior to component pick and place. Consider the following recommendations for all WLCSP applications:

- Stencil design guidelines
- Solder paste
- Package placement
- Reflow
- Underfill
- SMT Rework

## Stencil Design Guidelines

The stencil design guidelines outlined in the IPC-7525 should be followed for all assemblies. It is essential to use good quality stencils to achieve good quality solder-paste printing. Better solder stencil performance is achieved using laser cut or electroformed stencils instead of chemically etched stencils. For tight pitch components on the board, Deca recommends laser cut stencils because they give better paste release action, resulting to consistent solder paste volume. The solder stencil opening should be identical for all solder pads in the WLCSP array to prevent unbalanced solder ball height.

Laser-defined apertures or electroformed stencils provide the crispest printing results. Aperture area ratio is defined as the ratio of stencil aperture cross-section to the aperture wall area. Aspect ratio is defined as the ratio of stencil aperture diameter to the aperture height. To get the best solder paste transfer, an area ratio of ≥ 0.66 or an aspect ratio of ≥ 1.5 are recommended. Square stencil apertures provide the most consistent paste transfer. For a 400 µm pitch, the recommended stencil alignment accuracy is ±50 microns at 3 sigma.

One of the most critical aspects of SMT is achieving a robust and consistent solder paste printing process. This requires several process monitors, such as paste volume control and stencil inspection to ensure equal amounts of solder paste are deposited on the PCB pads. Overprinting can result in solder bridging while non-uniform printing could result in opens after reflow due to a coplanarity issue. On the other hand, marginally insufficient solder paste can create a narrow solder joint after reflow, which can result in reliability failures in the field.

X-ray inspection is highly recommended after reflow to ensure proper placement and solder wetting. Stencil cleaning is also required periodically for consistent paste printing.

## Solder Paste

The solder paste printing process involves transferring solder paste (typical industry standard Pb-free solder paste containing Sn-Ag-Cu) by squeezing the paste over the predefined stencil mask. Deca recommends that an auto stencil underside cleaning is done periodically during screen printing as this may improve solder paste volume uniformity and result in better paste release. Avoid doing manual cleaning because it may dent and damage the stencil and degrade its paste printing quality.

The best board-level reliability performance is achieved when maximum device stand-offs exist under the WLCSP, which is obtained by using the maximum manufacturable solder paste volume. Solder paste volume is the best predictor of the finished board quality, and a thorough inspection for solder volume uniformity is highly recommended. A no-clean solder paste with a particle size no larger than 40 µm (Type 3) is recommended.

## Package Placement

Typical surface mount pick and place equipment can assemble WLCSP devices to a PCB or FPC when the equipment is properly optimized for WLCSP parts.

WLCSP technology provides robust self-alignment with screen-printed solder paste when the solder-ball height is greater than 0.15 mm. When solder ball stand-off is less than 0.15 mm, more caution is required for self-alignment. The ratio between pick and place tool and package size should be a minimum of 80 percent to provide uniform distribution of stress on the package during placement.

Additional recommendations concerning placement force for best success with component placement processes are as follows:

- Placement Z-height on the board should be set to zero or to a critical distance between the PCB and WLCSP before it is dropped or placed. It is recommended that you avoid setting a bond force, which can overdrive the package to the surface of the board. This is a common setup mistake, which eventually leads to MOS when the resultant force drives back the solder ball toward the top side of die, which damages it.
- Maximum component placement force depends on WLCSP structures as well as mounting board materials. Although each solder ball is manufactured to withstand a load force of 35 grams, Deca recommends avoiding any force applied on the WLCSP by simply setting the Z position to zero as minimum. Exceeding this force may reduce reliability because of excessive mechanical stress on the device causing top side damage on the surface of the WLCSP.
- During component transfer via conveyor there is a possibility of component displacement or skewing prior reflow. Conveyor speed and transfer must be optimized to avoid jerking and fast motion. If realignment of the package is required on the board prior to reflow, do not use metal tweezers in correcting the component placement. Instead, use a soft tool such as a vacuum pen or equivalent.

### Pick and Place Process

During component pick-up from carrier tape, Deca recommends a Z-height distance between the WLCSP and the pick-up tool. Vacuum pressure is then defined at around 60-70 kpa to lift the WLCSP from the pocket of the carrier tape. This practice prevents direct contact and MOS on the WLCSP during pick-up.

Z-height distance between the WLCSP and the pick-up tool should be set to zero or with minimal gap as shown in Figure 7. The vacuum lifts out the package from the pocket of the carrier tape.

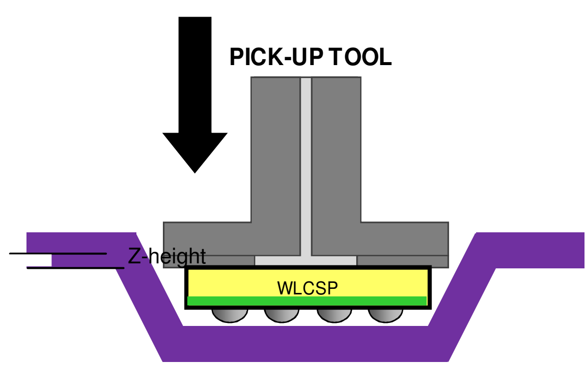



**Figure 7: WLCSP – Pick-Up Tool**

Similarly, Z-height during placement should be set to zero or with a minimum gap height to avoid overdrive during board placement as shown in Figure 8.

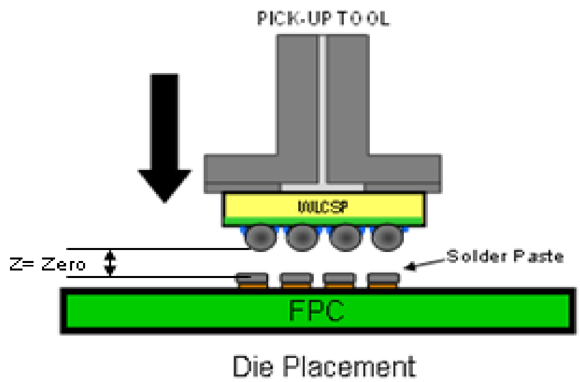



**Figure 8: WLCSP on FPC Board**

## Reflow

All Deca WLCSP devices use Pb-free solder balls. Therefore, Pb-free solder paste with a Pb-free reflow profile is recommended.

- The reflow furnace should have a nitrogen purge with oxygen content below 50 ppm.
- Actual reflow temperatures are determined by the end user based on thermal loading effect measurements within the furnace, including the complexity of the components on the board and the board size and thickness. Well-constructed profiling tools must be available to achieve accurate temperature settings.
- For Pb-free (Sn-Ag-Cu or Sn-Ag) solder, the reflow profile is critical. The Sn-Ag-Cu solder alloy melts at ~220 ℃, and the reflow temperature peak at joint level should be 15 to 20 ℃ higher than melting temperature. See Table 2 for more details about maximum reflow temperature.
- All of Deca's WLCSPs are qualified at 260 ℃ reflow with MSL1. Typical temperature profiles for the lead-free (Sn-Ag-Cu or Sn-Ag) solder and the corresponding critical reflow parameters are shown in Figure 9 and Table 2.

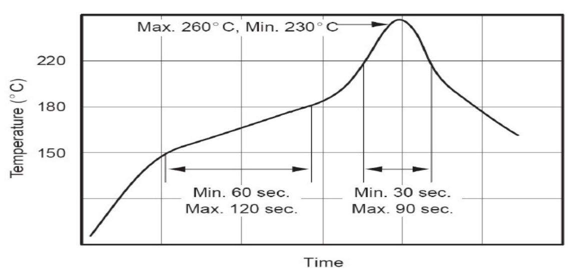



**Figure 9: Recommended Reflow Profile for Sn-Ag-Cu Paste**

| Process Step | Lead-Free Solder |
|---|---|
| Ramp Rate | 3℃/sec |
| Pre-Heat | 150℃ to 180℃, 60 to 180 seconds |
| Time above Liquidus, 220℃ | 30 to 90 seconds |
| Peak Temperature | 255℃ ±5℃ |
| Time within 5℃ of Peak Temperature | 10 to 20 seconds |
| Ramp Down Rate | 6℃/sec Maximum |

**Table 2: Recommended Reflow Parameters for Sn-Ag-Cu Paste**

Dwell time in the soldering zone (with temperature higher than 220 °C) should be kept as short as possible. Peak temperature must not exceed 260 °C. Controlled atmosphere (N2 or N2H2) is recommended during the whole reflow profile, especially above 150 °C.

Ramp-down must not be abrupt and should not exceed the recommended rate. Similarly, avoid installation of high-speed air Ionizers at the exit of the reflow because this has the potential to result in excessive cooling rate.

A solder joint is considered of good quality when the entire solder land pad has been wetted by the solder from the WLCSP solder ball. The surface of the joint should be smooth and the shape symmetrical. The soldered joints on a chip should be uniform. Voids in the solder joint after reflow can occur during the reflow process when the reflow profile is not properly tuned based on the recommended profile. Solder joint inspection after reflow can be done with X-ray to monitor defects such as bridging, open circuits, and voids. A common failure associated with poor reflow process and oxidation is the head and pillow effect. This can be reduced or eliminated by proper storage and handling of components and reflow profile optimization.

**Underfill Process**

Deca's WLCSP are typically designed to be mounted to rigid PCB without board level underfill. However, underfill may be desirable in some customer specific applications. Underfill is recommended for WLCSP mounted on FPC regardless of die size. Rigid stiffeners such as SUS304 (stainless steel) enhance board level reliability with respect to thermal and mechanical stress.

A reliable underfill evenly encapsulates the solder joint and absorbs the CTE mismatch between the WLCSP device and the board. This behavior of the underfill protects the solder joint from excessive solder fatigue, as a result of thermal cycling, mechanical shock, and vibration.

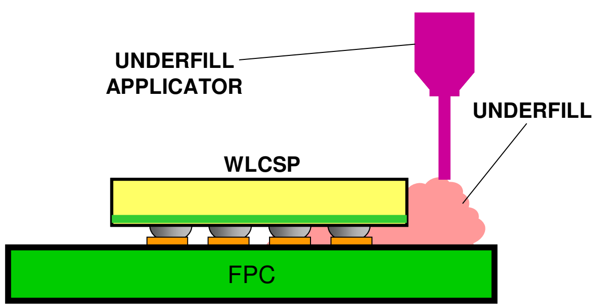



**Figure 10 : Underfill Process**

Underfill selection depends on several factors such as the combination of WLCSP size, WLCSP construction material and dimensions, circuit board structure and materials, and reliability requirements. Contact Deca Support for further details on underfill (www.decatechnologies.com/contact).

Underfill CTE should be close to the CTE of the solder joint. High CTE epoxy is not recommended as an underfill material because CTE mismatch will cause higher stress on WLCSP products. Likewise, silicone does not provide the enhanced mechanical support needed for an underfill material.

Significant differences in performance have been observed from different underfill types and suppliers. Deca strongly recommends using optimized underfill material derived from an actual DOE.

## WLSCP Underfill Process Requirements

### Needles

Needles are very important in manipulating underfill flow. Many types and sizes of needles are available in the market, such as conventional metal shafts, plastic tips or shafts to prevent possible scratching on the substrate, and tapered plastic tips to reduce back pressure in the pump.

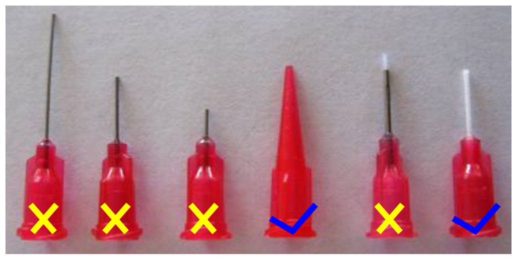


**Figure 11: Needles for Underfill Dispense**

Deca recommends soft plastic needles without metal to reduce impact force of the needle if it collides with the WLCSP die edge due to manual underfill dispense.

A 0.25” needle is recommended to keep back pressure on the pump low. Needle diameter controls the line width during dispensing. Twenty-two gauge needles, with a 410 µm inner diameter, are recommended for dispensing underfill at a rate of 10–20 mg/s. Lower-gauge needles are used when minimal underfill is dispensed on very small packages. Twenty gauge needles with a 610 µm inner diameter enable good control at larger flow rates. For manually dispensed underfill, use a plastic conical tip to reduce contact on the edge of the die, which reduces mechanical damage.

### Pre-Bake

Substrates should be free from moisture for a good and reliable underfill. Pre-bake is necessary to prevent voiding and delamination during cure. Plasma cleaning improves flow rate, improves fillet height and its uniformity, and promotes effective interface adhesion. As a result, plasma treatment prevents delamination and void formation that can result in a shortened lifetime for microelectronic devices.

### Dispensing

It is recommended that you use an auto-dispensing machine for underfill dispense to reduce mechanical damages caused by manually dispensing the underfill on the edge of the die. Underfill volume is controlled to optimize reliability and appearance. Ideal underfill should be dispensed to completely fill the solder ball area of the die and provide good fillet that covers greater than 50 percent of the edges of the die but not more than 75 percent. Dispense volume variations will lead to undesired fillet size variations. Estimation of volume is possible with simple calculations; while the final volume is accomplished by trial and error. This is achieved by processing a number of assemblies using different volumes of underfill and reliability testing. A change of substrate supplier or substrate manufacturing process or solder ball type will require another volume evaluation.

Because the total bond area of the solder ball is always much smaller than the respective areas of the die and the substrate, the stress on an individual solder ball is relatively large. By absorbing energy during thermal cycling, the underfill reduces this stress by a factor of about 10.

Underfill also prevents solder extrusion during thermal cycling. Successfully applied underfill functions as an isotropic compression container around each solder ball and prevents them from extruding to form shorts within each other. At the same time, the underfill prevents the initiation of cracks in solder balls by eliminating free surfaces at grain boundaries where cracks could propagate.

To some degree, underfill also serves as a heat sink to dissipate heat from the die. However, for this to happen all regions of the cured underfill must have the same thermal characteristics, because variations can cause overheating in the die.

The space to be occupied by the fluid underfill consists of the under-die volume and the fillet surrounding the die. The entire volume of fluid to be dispensed can be calculated by:

**V = VC - VB + VF**
Where:

VC - Volume under the die = die length x die width x underfill G=gap

VB - Volume of the interconnect solder balls = area of cross section of solder ball x underfill gap x number of solder balls

VF - Volume in the fillet

The volume (VC) can be calculated easily, but must take into account the anticipated variation in the underfill gap. The underfill gap will vary if the size of the solder balls varies. The goal is to dispense accurately a volume that is an average of the solder balls' size.

Accurate calculation of the volume of the fillet is critical because the fillet acts as a reservoir that compensates for normal variations in the under-die volume. The fillet's volume can be calculated by getting the desired area of the fillet and multiplying it by four. Underfill fillets typically have a low contact angle, which in turn will speed underfilling and lower the viscosity of the underfill material. Speed will increase if the distance or vertical height of the gap under the die is large. Similarly, smaller and rounder filler particles increase the speed of underfill.

Making the fillet wider effectively increases the volume of the reservoir, and is one method to increase the dispensing tolerances. It must be kept in mind; however, that widening the fillet increases the X-Y dimensions of the underfill as well. Since stresses resulting from thermal mismatch are most severe at the corners because they are farthest from the center, increasing the height and width of the fillet more than 50 percent of the die thickness generally increases the opportunities for corner cracks, side chipping, and delamination (see Figure 12).

Figure 12. Underfill Fillet Layout

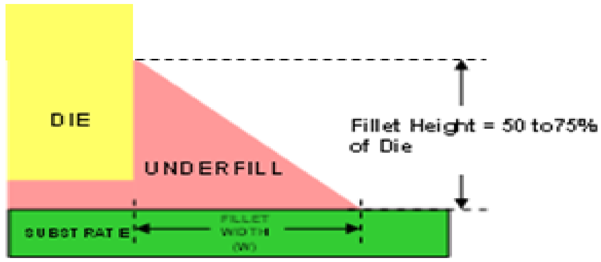
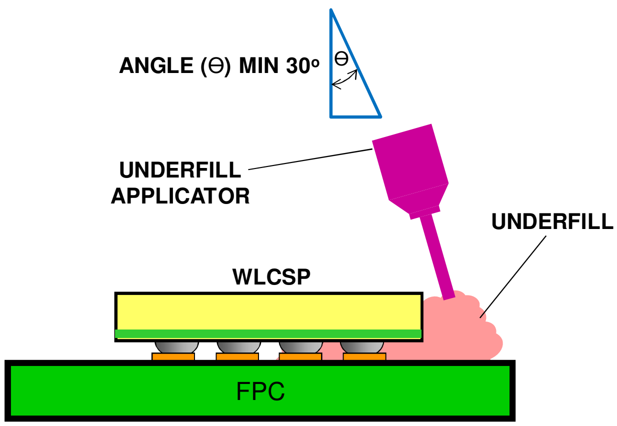



Figure 13 shows the recommended manual dispensing of underfill with a slanting angle of 30º minimum. This reduces contact between the needle and the edge of the die thus minimizing damage of the WLCSP die edge.

The recommended fillet height is around 50 percent to 75 percent of the die thickness to reduce flexural stress on the corner and edge of the die. The needle for manual dispense should be made of soft plastic material.

Figure 13. Manual Underfill Process




## Dispense Pattern

The dispense pattern is the two-dimensional step made by a needle as underfill is dispensed onto a WLCSP assembly. Several patterns may be dispensed, but the goal is to achieve a void-free, underfilled assembly with a small fillet, requiring a minimum flow time and minimum time in the dispenser. In this way, reliability is maximized, assembly real estate is conserved, and time expenditures are controlled. Developing a pattern for a properly designed flip chip assembly requires a trade-off between dispenser time and the area covered by the fillets Flow time is quite high for larger die. A straight line or "I-shape" along one edge of the die is very simple to implement for die where a relatively small dispense fillet and control of air entrapment is needed. Dispense along the longer side to minimize flow time. The pattern length generally varies from 50 percent to 125 percent of the die edge length. The greater lengths minimize the dispense fillet but increase the probability of trapped air at the far edge of the die. The "L-shape" dispense pattern along two adjacent die edges produces the smallest dispense edge fillets and shortest flow times.

Figure 14 shows 100 percent and 60 percent line-shaped or “I-shape” dispense patterns. Faster flow along the die edges may necessitate a shorter dispense length to prevent void formation at the midpoint of the opposite side.

**Figure 14. Line-shaped or “I-shape” Dispense Patterns**

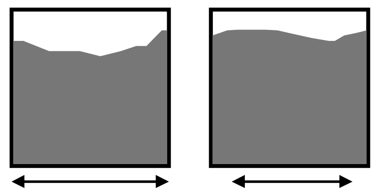
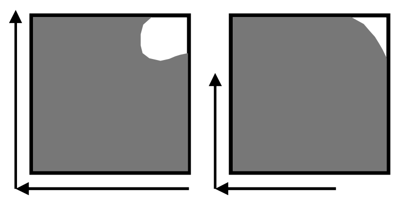


Figure 15 shows 100 percent and 65 percent L-shaped dispense patterns. Faster flow along the die edges may necessitate a shorter dispense length to prevent void formation in the opposite corner.

**Figure 15: L-shaped Dispense Patterns**



If self-filleting is not acceptable or if you want very symmetric fillets, then the initial pattern is completed with a “seal pass.” The “I-shaped” dispense is followed with a U-shape or an initial L-shape is followed with another L-shape to dispense underfill along the remaining die edges to complete the gap. Dispense parameters are manipulated to control the quality of dispensing. To dispense an even line of underfill commonly requires that the dispensing pump start before pattern motion begins. This gives the viscous underfill time to touch the substrate before the needle starts moving.

The distance from the die should be sufficiently great that the needle never strikes the die and that no underfill spills onto the die during dispensing (a potential reliability issue). This generally requires a spacing of 250 µm at least. The needle height should be controlled to provide a uniform line of underfill along the die. A 250 µm height between the board and needle tip is generally recommended, especially if the underfill tends to string.

### Post-Dispense Staging

It is recommended that staging or exposure of uncured underfill to the ambient atmosphere be limited to one hour. Properly cured, bulk underfill is unlikely to be affected by absorption of moisture at atmospheric pressure.

However, absorption of moisture by liquid underfill prior to cure can be very damaging. The moisture chemically reacts with the underfill to degrade cured properties. Moisture can come from a moist assembly or from the atmosphere. Surface appearance and surface physical properties are affected the most since moisture enters the liquid mass by diffusion and convection.

Underfill that is contaminated by moisture prior to cure often exhibits a spotted white or milky appearance after cure. Underfill that is cured while it contains moisture may exhibit very poor solvent resistance or depressed thermal stability.

**Cure Process**

Cure is the process by which the liquid underfill, composed of fillers, resins, cross-linking agents, catalysts, and so on, is deliberately converted to a desired solid form that is chemically and physically stable. Usually, curing involves heating the underfill for a predetermined time at one or more temperatures. This section describes typical curing processes in more detail, including techniques that reduce the extent of unintended reactions.

The underfill must remain at the specified temperature for the required time. Ramp rates of greater than 10℃ per minute are recommended to reduce loss of anhydride curing agents.

A variety of oven types are acceptable for curing underfills, including box and belt-style convection ovens, IR ovens, and conduction (non-convection) ovens. Use of ovens under vacuum is not recommended because of the possibility of inducing voids from minute quantities of dissolved gases or trapped air. Ensure that the oven provides a uniform, consistent temperature at all times. IR ovens may require extra attention to ensure uniform temperatures. Slow heating in non-convection ovens may require extra attention to assure the required dwell time at temperature.

Cures that have two or more steps (see Figure 16) may be recommended for a given underfill if voiding under the die or excessive stress or warp is observed. With multi-stage underfill cure units are partially cured, or gelled at a lower temperature, and then heated again to a higher temperature to achieve full cure. This produces a final solid with less overall shrinkage than that produced at the higher temperature alone and enables initial hardening (gelling) of the underfill at a temperature less likely to evolve gases that cause voids.

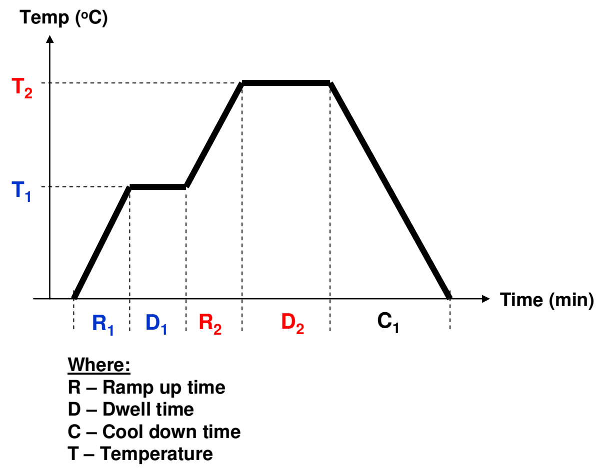



**Figure 16: Two-Step Cure Process**

Any of the equipment discussed previously is acceptable for performing multi-stage curing. Belt-style ovens are probably the most convenient because the stages are easily programmed into succeeding zones of the oven.

Exercise caution when modifying a cure schedule from the recommended time at temperature.

### Pot Life

The period during which the underfill can be processed (excluding thaw time) is called the pot life. Underfill whose pot life is exceeded must be discarded.

Because the demands on the flow properties of underfills vary considerably from one application to another, the pot life also varies. The real pot life in a given application is determined experimentally.

The time required for a doubling of the viscosity is commonly quoted as the pot life on underfill datasheets. This number is valid for comparison of similar underfills and as a starting point for real pot life determinations. Higher temperatures greatly impair pot life because temperature accelerates the chemical cross-linking reactions. Advancement, the term given to undesirable chemical cross-linking of underfills, accelerates after thawing and more quickly in a warm environment.

Eventually, the viscosity will exceed that which provides acceptable processing (flow speed or distance), rendering the underfill useless. Shielding a syringe from the substrate heaters or a warm dispensing environment may extend pot life significantly. Pot life is roughly doubled for every 10 °C drop in underfill temperature. It should be noted that aging of the underfill in its original cartridge or syringe does not significantly affect its properties after a proper cure. Only flow and viscosity are affected. If the underfill processes properly, then final, cured properties are unaffected.

## Jet-Underfill Machine Process

The key element of a jet dispensing system is a valve that meters and ejects fluid droplets. Air pressure retracts an internal spring-driven plunger, allowing a precise amount of fluid from the reservoir to enter the chamber under pressure. The spring-driven plunger then returns to its seat, ejecting the fluid as a droplet though the nozzle.

### Jetting Advantages

*Component Density* – Placing a needle safely between components requires more space than jetting a small drop between them. For small PCB board with high component density Jet Underfill is the best dispense system recommended.

*Fillets* – Because of the narrower fluid edge, the 100 micron droplet stream creates smaller fillets than needle dispensing, allowing die to be placed closer to a board edge or to bond pads.

*Speed* – Jet dispensing is faster than needle dispensing because the needle must be lifted vertically away from the substrate between dispensed dots or lines, while the non-contact jet travels in the x-y plane without being lifted between dots or lines, and can dispense "on the fly" without stopping.

*Contact-Free* – The jet nozzle is positioned well above any die. Needles may strike an adjacent chip, causing damage to the needle and possibly to the die. Die clipping creates a yield loss for needle dispensing. Jet dispensing eliminates that risk.

*Lower Cost* – Jet dispensing of flip chip underfills allows denser component spacing, greater throughput, contact-free dispensing, and higher yields than needle dispensing, resulting in 50 percent to 66 percent lower operating costs than for needle dispensing.

*Die Stacking* – 3-D packaging with stacked, wire-bonded die requires a minimum wetted area to bring bond pads close to the die. Jetting stacked die underfill also eliminates the risk of needle contact with the bond wires.

## SMT Rework

Rework of WLCSP devices is similar to that of ball grid array (BGA) packages, but more difficult because of the exposed silicon substrate and possible presence of underfill. Rework should be carried out using a controlled and qualified process. Following a qualified process will prevent mechanical and ESD damage to the device.

The ability to rework components with underfill depends on the characteristics of the underfill being used. There are underfills in the market that are reworkable by simple application of heat and proper cleaning.

Prior to attempting any rework, ensure that the assembly is moisture-free, to prevent moisture damage to the board or other components during rework. Under-board preheating is required at 100 °C to 125 °C for eutectic solder and 150 °C to 170 °C for Pb-free solder.

For cured underfill, removal of conventional underfill for repair of a flawed assembly is not practical or recommended. Conventional underfill encapsulants are practically impervious to everything except concentrated acids. Removable underfills are available for chip mount and CSP assemblies. Concentrated acids plus heat is applied to underfilled units in removing underfill. Another one is the use of heat and light abrasion. After this, the die or CSP is then pulled off during heating. See

for recommended rework flow for a reworkable underfill SUF1577-15.

Focused infrared technology is recommended, over traditional hot-gas rework to remove the solder balls of WLCSP devices. Focused IR allows more accurate removal and replacement of WLCSP devices without heating the adjacent components on a PCB/FPC.

Deca recommends component replacement for parts that are removed from the board and to avoid reuse as the latter may have reduced reliability. If the component must be reused, a three-stage (ramp up - hold - ramp down) reflow profile is required for component removal. Otherwise, a direct ramp-up can be used for faster device removal. The peak temperature is in the range of 240–250 °C for up to 90 seconds with Pb-free solder balls.

The temperature delta across the solder joints should be less than 10 °C. The temperature around the component undergoing rework should be less than 150 °C. The component top temperature should be less than 260 °C for Pb-free devices. Flux is not recommended because it adds a process step and additional cost.

Air velocity should be as low as possible to avoid component skew (for example, 500 FCH for top heater, 100 FCH for bottom heater). A nitrogen atmosphere is recommended for better heat distribution and removal, and to limit oxidation of conductor surfaces. A zero-force vacuum pick-up is required during the transition to cool down to avoid bridging of reflowed solder balls.

After reflow, X-ray inspection is recommended for verification of alignment, bridging, voids, die shear, and/or die pulling.

Note: The surface of the substrate should be carefully cleaned and all solder and flux residues and underfill removed. See

for details.

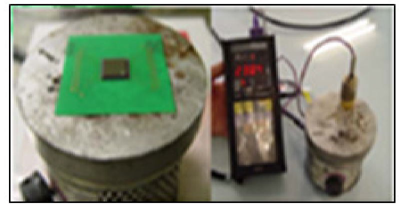
### Component Replacement

The rework site must be cleaned with solvent prior to component replacement to remove any surface contamination and oxides as shown in Figure 17.

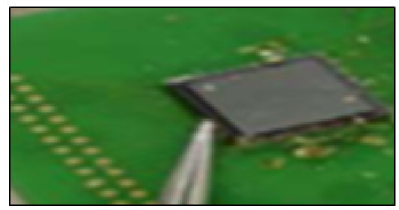
For solder paste/flux application, use a mini-stencil with a squeegee of the same width as the stencil. Aligning the apertures with the solder pads under 50–100X magnification is recommended. The device placement machine should allow fine adjustment in X, Y, and rotation axes. Do not use tweezers when manually mounting the WLCSP on the rework area. Instead, use a vacuum pen to place a new WLCSP unit on the board.

Follow the paste manufacturer's recommendation for reflow

profile, with the maximum temperature not exceeding the package qualification level. Reflow profiles developed for initial

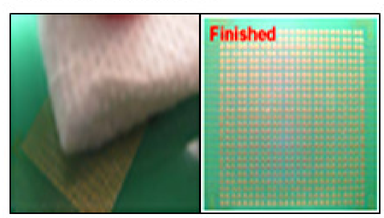


1.Heat the WLCSP at 230degC Max with a Focused IR, hot air blow gun or plate depending on the component density on top and backside of the board.



2.Using a plastic tweezer gently scrape off the fillet of the Underfill. At this point the solder has also melted and the WLCSP can also be lifted away from the board.

3.Using a soldering iron with a flat tip (paper knife type) gently scrape off the remaining solder and Underfill material. A solder wick in tandem can also be used to surgically extract any excess solder




4.Wipe the board with a lint free cloth soaked in a cleaning solvent like alcohol and inspect for any pad lift or damaged copper pads.( SMD is recommended for applications which may require frequent rework due to component density)

**Figure 17: Component removal and site redressing**

placement or rework can also be used. A three-stage (ramp-up, hold, ramp-down) profile may result in smaller temperature distribution across the site.

## WLCSP Reliability

Deca's WLCSP qualification procedures and requirements comply with various industry standards including JEDEC/IPC and MIL-STD-883. Standard stress tests for component-level and board level reliability are listed in Table 3.

**Table 3. WLCSP Qualification Stress Tests**

| Test | Condition | Duration | Sample Size |
|---|---|---|---|
| **MSL Level 1** | 260ºC peak | 3x reflow | 150 units |
| **Component Temp Cycle*** | -55ºC to 125ºC | 1000 cycles | 77 units, 3 builds |
| **HAST*** | 130ºC, 85% RH | 96 hours | 77 units, 3 builds |
| **High Temperature Storage*** | 150ºC | 1000 hours | 77 units, 3 builds |
| **Board Level Temp Cycle** | -40ºC to 125ºC | 500 cycles | 60 units |
| **Board level Drop** | 0.5 ms, 1500G | 150 drops | 60 units |
| ***With precondition** | | | |

Additional reliability stress tests have been performed based on specific customer requirements. Contact Deca Support for further details on reliability test methods and results (www.decatechnologies.com/contact).

## WLCSP Handling during Packing, Shipping and SMT

WLCSPs are vulnerable to oxidation, contamination, and mechanical damage. Open and handle boxes, moisture barrier bags, and reels only at approved workstations. Loose units that are outside their original carrier tape packing are considered compromised. They cannot be recovered by picking them up with tweezers and loading them on the carrier tape.

The original packing materials were selected to provide adequate protection to the WLCSP units through a normal distribution and manufacturing process. WLCSPs are delivered in tape and reel to be fully compatible with standard high-volume packing.

All reels should have the following:

- Manufacturing label for device lot identification.
- ESD warning label (it is not necessary to place an ESD sticker in the lock reel with an embossed ESD label).
- Humidity indicator card.

- Desiccant pack — Use one 60 g desiccant pack for each bag. If 30 g packs are being used, place two packs for each MBB.

The moisture sensitivity level (MSL) of a component indicates its floor life and storage conditions after the original container has been opened. Deca WLCSP products are classified as moisture sensitivity level 1 (MSL1) at 260 °C peak reflow temperature in accordance with JEDEC standard J-STD-020.

CAD fit simulation between unit and tray pockets is done during carrier tape selection to test proper fit.

Standard carrier tape selection should be in accordance with EIA-481-D-2008. All conditions stated on this standard must be met to ensure proper handling of WLCSP.

Figure 18 shows the EIA-481-D-2008 standard for maximum component rotation and lateral movement on the tape pocket.

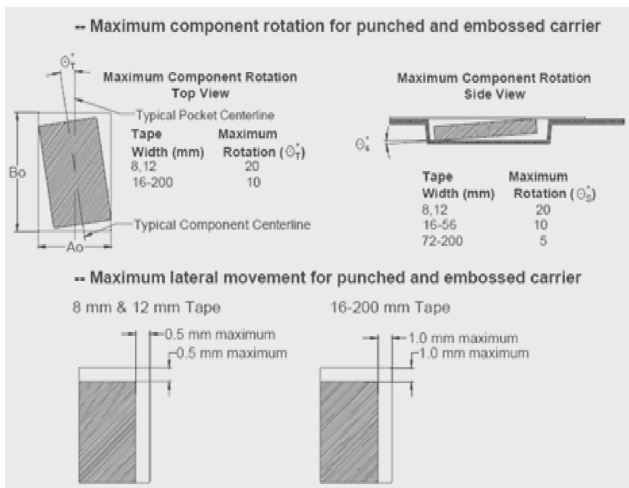



**Figure 18 : EIA-481-D-2008 Standard**

An example of a standard carrier tape drawing for a WLCSP device with the dimensions 3.215 mm x 3.215 mm x 0.51 mm (± 0.5 mm) is shown in Figure 20.

A hole on the pocket of the carrier is available to prevent air buildup during WLCSP placement on the pocket. This prevents misplacement from backflush and mechanical damage from stress during placement of units. Carrier tape designs may also incorporate corner stress relief areas.

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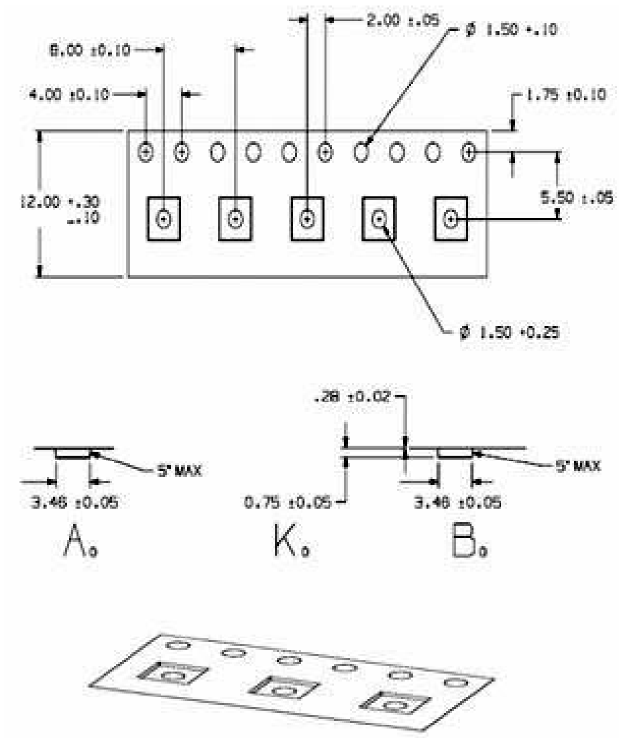


**Figure 19 : Standard Outline Drawing for WLCSP Packing Tape**

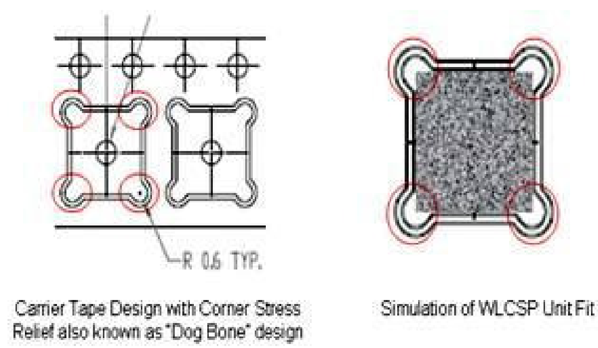


**Figure 20: Dog Bone Carrier Tape Design**

## Reference Documents

[1] Cypress Semiconductor, "Design, Manufacturing, and Handling Guidelines for using Cypress Wafer Level Chip Scale Packages "

[2] Cypress Semiconductor, "Design and Manufacturing with Summit Microelectronic's WLCSP Products," Summit
Microelectronics Corp. Pages 2-3, April 2, 2010