INTRODUCTION

EXAR's chip-scale package (CSP) is a bare die integrated circuit (IC) with solder balls as its electrical and mechanical interconnections to the printed circuit board (PCB) pads.

The bump structure of this package type is shown in Figure 1. Table 1 lists the key attributes for EXAR CSP packages.

CSP packages have the following advantages:
- Smallest footprint per I/O resulting in significant PCB space savings.
- Very good electrical and thermal performance compared to plastic over molded packages.
- Utilizes standard surface mount assembly technology.
- Proven board level reliability (BLR)

CHIP SCALE PACKAGE (CSP) DESIGN, FABRICATION & ASSEMBLY

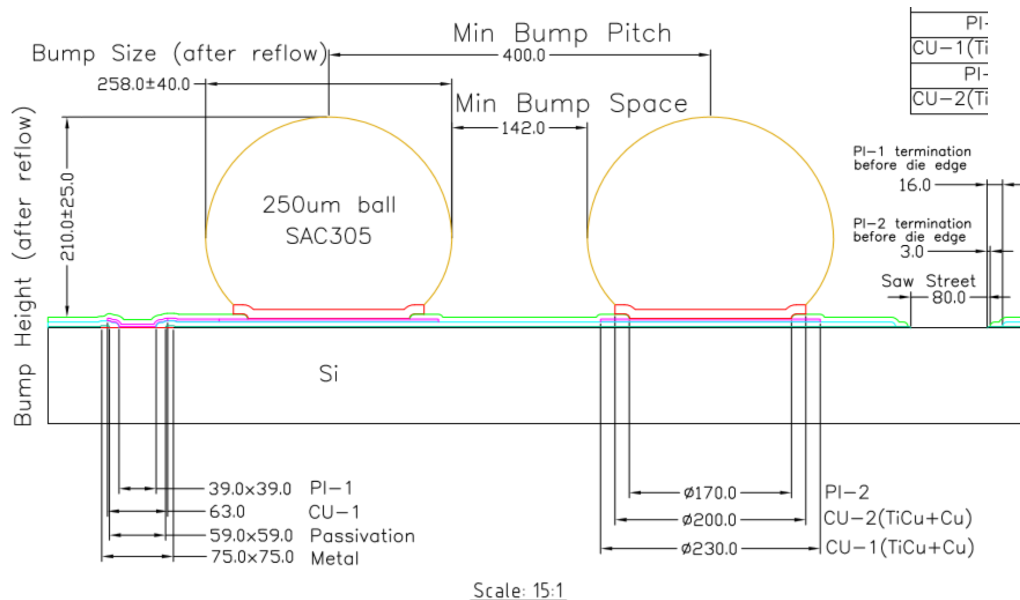

Figure 1 – 0.4mm Pitch CSP Structure

Table 1: Key Attributes for EXAR CSP Packages	
Typical Pitch	0.4mm
Ball Diameter	250um
Ball Height	210um
Ball Coplanarity	0.050mm Max
Moisture Sensitivity Classification	Level 1 @ 260°C

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CSP Package Construction

Figure 2 illustrates the construction of the CSP. It has solder balls on a 0.4mm pitch located in a matrix layout on the active side of the silicon IC.

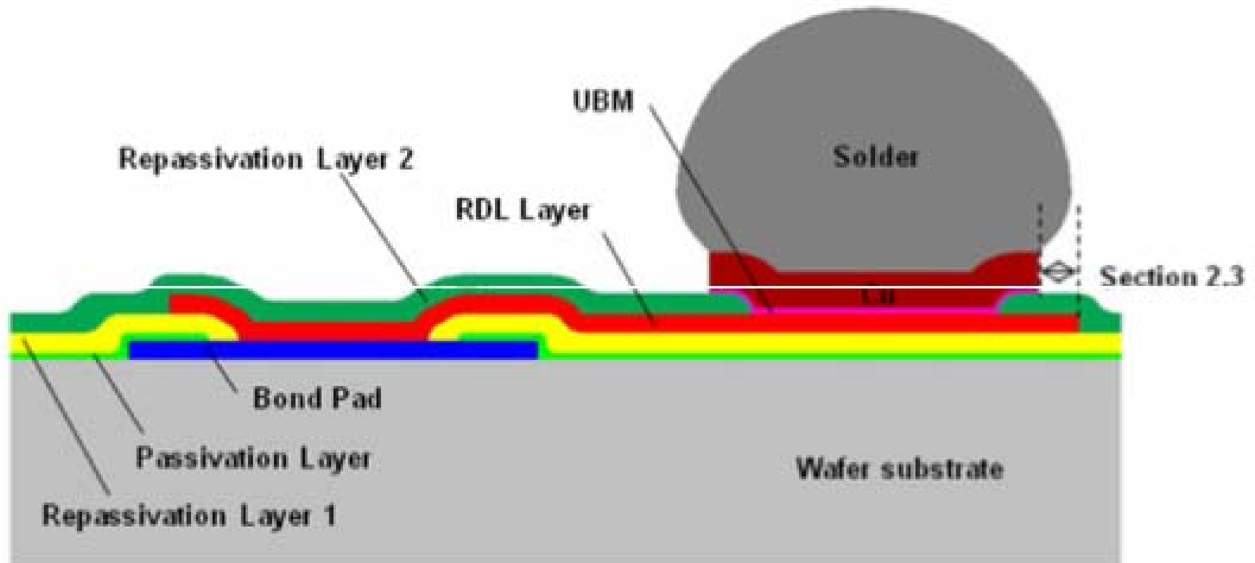

Figure 2 – CSP Construction

The wafer backside is coated with organic material to serve as protection from mechanical damage. Each individual package is laser-marked on the backside. After wafer level processing, the wafer is subjected to final test (at wafer level) followed by dicing, inspection, pick and place into tape and reel. The package is assembled on a PCB using standard surface mount assembly techniques.

CSP transportation media

The CSP is shipped in standard polycarbonate conductive carrier tape with pressure sensitive adhesive cover tape. The carrier tape pocket size comply with EIA-481 guidelines. The tape and reel is sealed inside an Electrostatic Sensitive Device (ESD) bag. A flat cardboard box is used to store the sealed bag and EXAR's standard labeling is applied outside the box.

PCB pad design

A well-designed and manufactured printed circuit board is required for optimum performance. To achieve maximum reliability and thermal performance, special care should be taken in the design of the PCB pads for the CSP.

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Two types of land patterns are used for surface mount devices:

1. Solder mask defined (SMD) pads have solder mask openings smaller than the metal pads
2. Non-solder mask defined (NSMD) pads have metal pads smaller than the solder mask openings.

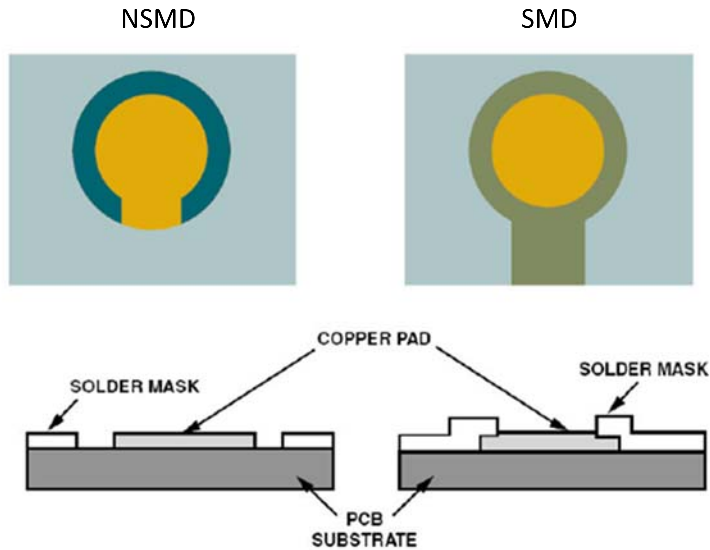

Figure 3 – NSMD & SMD Land Patterns

EXAR recommends the use of NSMD pads for optimum reliability specifically for fine pitch CSP's. They have the advantage of tighter copper dimensions, compared to solder mask dimensions, and the uniform coverage is better at the solder melting temperature.

There should NOT be any mixture of SMD and NSMD pads within the same CSP footprint. The recommended NSMD pad diamater is 250um (0.010 inch). Maximum copper trace width is 100 um (0.0039 inch).

Because of the fine pitch nature of these components, EXAR recommends the inclusion of fiducial marks in proximity to the CSP package to facilitate component alignment & placement.

An outline of the CSP should be printed on the PCB to aid the post-reflow visual inspection for CSP misalignment.

PCB Finish

Selection of an appropriate PCB surface finish is essential to ensure correct manufacturing of the final board assembly. Table 2 compares several popular surface finishes and summarizes industry recommended guidelines.

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Table 2: Surface Finish Options

Finish Name	Description	Recommendation	Comments
Copper OSP	Organic Solderability Preservative (OSP)	Very Good	Recommended for high volume manufacturing
Silver Immersion	Thin layer silver electroless plated	Very Good	Silver immersion thickness must be controlled to 0.150 – 0.625µm to minimize micro voids at the solder joint
Gold Immersion	Thin layer gold electroless plated	Good	Very flat. Ideal for quick-turn prototype
HASL	Hot Air Solder Leveled	Acceptable	Process must be controlled to provide solder coverage of small solder mask opening
Tin Immersion	Thin layer tin electroless plated	Not recommended	Oxidizes in relatively short time

Stencil Design

The stencil thickness and pattern geometry determine the precise volume of solder paste deposited onto the device land pattern. Stencil alignment accuracy and consistent solder volume transfer is critical for uniform solder reflow. Stencils are usually made of brass or stainless steel, with stainless steel being more durable and preferred.

To enhance solder paste release, the walls of the apertures should be as smooth as possible.
The general recommendation for the aperture geometry is a square aperture with slightly rounded corners. The aperture should be slightly tapered or trapezoidal in the vertical axis. Smooth walls, rounded corners, and a trapezoidal cross-section enhance the release of solder paste from the aperture.

EXAR recommends that the CSP stencil aperture must meet the industry standard area ratio of > 0.66. In some applications, a step-down stencil is recommended for the regions where the CSP pads are located.

A 5° tapered, trapezoidal square solder stencil aperture opening with rounded corners using a laser-cut process followed by electro-polish process is highly recommended.

Solder paste

A low residue, no clean solder paste is used commonly in mounting CSPs. Most paste manufacturers provide a recommended thermal profile for their solder paste. These reflow profiles should be closely followed. Solder pastes that exhibit low voiding in the solder joint are highly recommended for CSP.

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EXAR's lead-free CSP uses a SAC305 solder alloy which is composed of 96.5% Sn, 3% Ag and 0.5% Cu. No significant changes are required for the lead-free solder paste printing process.

A Type 3 or finer solder paste is recommended for 0.4mm pitch printing.

Solder paste printing

An automatic or manual stencil/screen printer can be used to distribute the solder paste onto the PCB lands. A Design of Experiments (DOE) should always be used to establish optimum printing parameters. Most assemblers find these parameter ranges to offer good starting points:

- Print head speed: 1-6 inches/sec.
- Squeegee pressure: 0.75-1.5 pound per inch of squeegee
- Under-stencil wiping: Every 3 boards
- Temperature: 23-28°C
- Humidity: 30-60 percent RH

A stainless steel squeegee should be used.

Multiple printing of solder paste should be avoided for fine pitch devices as it could cause smearing of the solder paste.

CSP placement

The CSP exhibits a strong self-centering effect and can self-align during solder reflow even when it is placed up to 50% off the PCB land pad. As a result, conventional placement systems can be employed in most cases, using either the CSP outline or the position of the solder balls as a placement guide.

Vision systems on some placement systems may introduce problems if not chosen or configured properly. The vision system should have a resolution of less than 1 mil/pixel. Since the color of the active side of the CSP may vary from lot to lot, the threshold or acceptance level of the vision system may require adjustment whenever varying colors are encountered.

Solder Reflow process

The EXAR CSP is compatible with all industry standard solder reflow processes. There are no special requirements necessary when reflowing CSPs. As with all surface mount devices, it is important that profiles be checked on all new board designs. In addition, if there are tall components mixed on the board, the profile must be checked at different locations on the board. Component temperatures may vary because of surrounding components, locations of parts on the PCB, and package densities.

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The reflow profile guidelines are based on the temperature at the actual solder ball to PCB land pad solder joint location. The actual temperature of the solder joint is often different than the temperature settings in the reflow system. It is important that reflow specific profiles be done using thermocouples at the actual solder joint locations and characterized by using the reflow guidelines in Table 3 and Figure 4 respectively.

Table 3: Lead-free Solder Reflow Temperature Profile Guidelines

Reflow Profile	Description of Characteristics	Process Windows
Preheat	Initial heating of component solder balls	2.0^0C to $2.5^0C/sec$
Thermal Soak	Solder paste dries out and flux activates	150^0C to 200^0C +/- 5^0C 95 to 105 sec
Reflow	Time above 217^0C Peak Reflow temperature	50 to 55 sec ~260^0C
Cooling	Cooling rate	Max -$4^0C/sec$

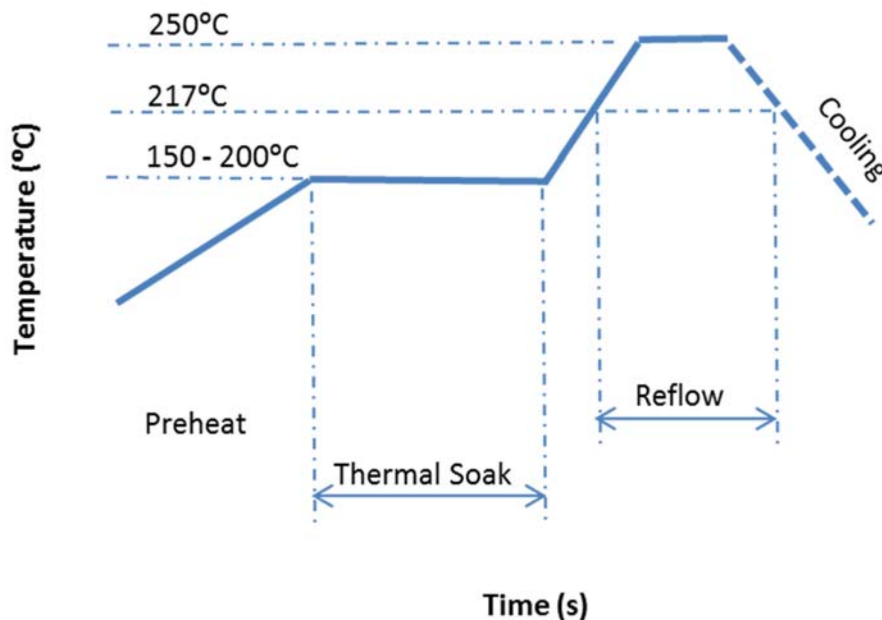

Figure 4– Typical Lead-free Solder Reflow Profile

Note the peak reflow temperature applies to the temperature of the balls in the solder joints, not the temperature of the component package itself.

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Whenever possible, Nitrogen (N2) inert atmosphere at reflow oven is preferred. N2 inert atmosphere reduces oxidation of the solder paste during the reflow process, improves wetting and reduces voiding. The inert N2 environment results in improved wetting and reduced voiding due to the lack of oxide film on surface on the molten solder. All of these positive attributes improve both time zero yield and solder joint reliability.

For lead-free soldering, the increased amount of tin in the solder heightens its tendency to oxidize, dross and to react with other metals. With a nitrogen inert environment, lead-free solder achieves similar wetting to a eutectic tin/lead composition.

The recommended Oxygen level must be between 20~50PPM.

PCB Cleaning

If a low residue no-clean solder paste is used, PCB cleaning is not required.

If for any reason PCB cleaning is required, care must be taken to make sure the backside of the package is free from mechanical contact during the cleaning process. For instance, for CSPs assembled in various module configurations, each module must be isolated and secured before going into the aqueous cleaning system.

If water-soluble flux is used, water-cleaning systems are required for cleaning the boards. Surfactants can be introduced to improve water penetration and flow.

CSP Rework

Rework is performed using processes analogous to those used for BGA rework. In order to maintain component and PC board integrity and to obtain reliable solder connections, the rework process should duplicate the original reflow profile. The rework process starts with part removal using a convection nozzle and bottom-side preheater. Once the solder becomes liquid (190^0C for SnPb solder, and 220^0C for SnAgCu solder), the CSP can be lifted off the board using a nozzle.

After part removal, the site is prepared by tinning the pads with a temperature-controlled soldering iron. A gel flux is then applied to the solder pads using a small brush or swab. The component is placed onto the tinned site. Finally, using the same convection nozzle and bottom-side preheater the part is reflowed using a profile that matches the original reflow profile as nearly as possible.

Solder Joint Inspection

Post-reflow inspection of CSPs on PCB is typically accomplished by using transmission type X-ray equipment. X-ray can be used for reflow process monitoring and as a failure analysis tool.

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This method is used to establish process parameters, and then to monitor the production equipment and process since 100% X-ray is not economical for high volume production. Transmission X-ray can detect bridging, shorts, opens and solder voids.

2-D XRAY system with OVHM (Oblique View at Highest Magnification) is highly recommended as it can detect solder bridges, opens and voids.

Handling of assembled products with CSP

CSP are susceptible to mechanical damage from mishandling. Bending, flexing, impacting, or dropping of loaded board should be avoided.

Handling of CSP

Since the CSP is a bare silicon die with solder balls, care is required in handling this device:

- Use vacuum absorb pens to pick the CSP from its backside.
- Use soft tip tweezers to pick the CSP from its edges
- Avoid using metal tweezers
- Avoid contact on the active side of the CSP
- Avoid dropping the CSP on any hard surfaces
- Do not re-ball the CSP
- Do not use discarded CSP’s from a pick-and-place machine

It is important to note that minor chip outs & slight discoloration on the backside of the package are sometimes evident but not necessarily rejectable per EXAR’s workmanship’s standards.

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