APPLICATION NOTE

XThin™ Sn Die Attachment Recommendations

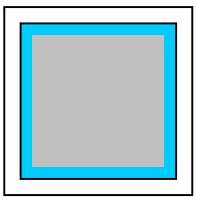
This applications note provides the user with a basic understanding of Cree's new low temperature attach version XThin™ chips, information on the recommended packaging, and an overview of some constraints to be considered when packaging the chips.

Cree's XThin™ LEDs are the next generation of solid state LED emitters that combine highly efficient InGaN materials with Cree's proprietary G•SiC® substrate to deliver superior price performance for high intensity LEDs. These LED chips have a geometrically enhanced Epi-down design to maximize light extraction efficiency, and require only a single wire bond connection. These vertically structured LED chips are approximately 115 microns in height and require a low forward voltage.

Applications for XThin include next generation mobile appliances for use in their LCD backlights and digital camera flash where brightness, sub-miniaturization, and low power consumption are required.

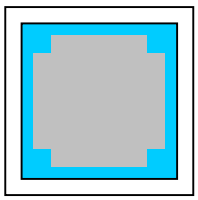
Cree has developed two versions of XThin which utilize tin (Sn) as the contact metallization. These chips are designed for die attach process temperatures at or below 270 °C, enabling the use of XThin chips in surface mount packages which utilize plastic materials in the leadframe substrate. The product designations for these chips are as follows:

- **C*xxx*XT290-S*xx*00-C**
  2.0um thick Sn for *Flux Eutectic Attach*:
  - Die placement with flux
  - Sn reflow with no pressure applied
  - Chip visibly identified by square pattern of Sn contact metal pad:



Bottom View for -C

- **C*xxx*XT290-S*xx*00-D**
  0.5um thick Sn for *Eutectic Attach*:
  - One step Thermal Compression die bonding.
  - Chip visibly identified by cross pattern of Sn contact metal pad:



Bottom View for -D

NOTE: C*xxx*XT290-S*xx*00-C and –D are not intended for use where extended reliable operation in high temperature and high humidity environments is required. For this condition or for use in a leaded radial lamp, use C*xxx*XT290-S*xx*00-A (AuSn version).

A cross-sectional diagram of the die attach side of XThin™ LEDs is shown in Figure 1 with nominal dimensions. During the wafer fabrication process a highly reflective layer is added to the bottom of the chip to increase luminous intensity. Outside the reflector metal a die attach metal layer is added. This die attach layer is composed of metals which act as a barrier to protect the reflector and terminates with tin. Although passivation protects the edge of the epi layer, it should be noted that the distance from the bottom of the chip to the Silicon Carbide substrate is 5 microns as shown in Figure 1. See "Schottky or Shunt Formation" section for additional information.

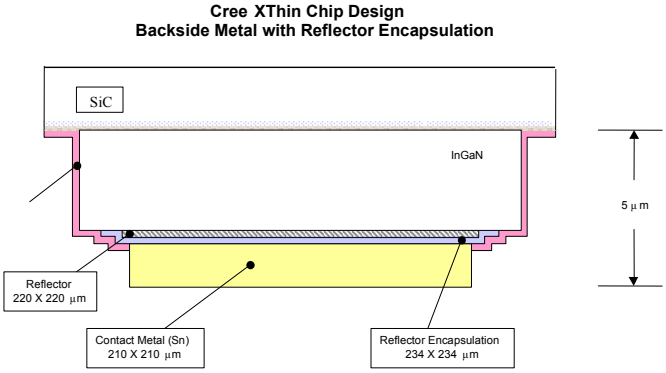


Figure 1: XThin™ Design

"FLUX EUTECTIC" DIE ATTACH

A robust die attach process is critical to achieve low electrical resistance, low thermal resistance and good mechanical and electrical integrity. The "Flux Eutectic" die attach method is one recommended method for packaging XThin™ LED's. In this attach method, there is no external force applied during the contact metal reflow process. The advantage of this method is that no squeeze-out of the die attach metal occurs, reducing the risk of forming a Schottky contact to the n-substrate of the device.

The low-temperature Xthin LED version C*xxx*XT290-S*xx*00-C has a 2.0um Sn layer deposited on the bottom of the chip. The nominal melting temperature of this metal is 232°C. During assembly, a very small volume of flux is placed on the package substrate by pin transfer / stamping, or other precision dispense method, and the chip is placed into the flux.

For example, a no-clean flux (such as Alpha Metals UP78) is dispensed into the package via pin transfer with a dot size of approximately 200um. After die placement, the leadframe is heated to 265deg C for 5-8 seconds to reflow the Sn contact metal and form a bond to the package leadframe. Subsequent cleaning in Isopropyl Alcohol in an ultrasonic bath for 15 minutes removes flux residue prior to wirebond and encapsulation.

When using the Flux Eutectic die attach process, the user should take into account the following recommendations and precautions:

- Careful control of flux dispense volume is critical to minimize risk of die movement during reflow.
- To ensure a good metal bond and minimal die movement during reflow, the chip should be placed through the flux and in good contact with the package substrate prior to reflow. Die place tooling should be controlled to ensure good coplanarity of the chip and the package leadframe. Cree recommends coplanarity be controlled within 5° of parallel.
- The peak temperature of the reflow process should be 20-30°C above the melting temperature of the contact metal – in the case of Sn contact metal the peak temperature should be in the range of 255 – 265°C.

- An RMA flux results in good die shear strengths however using too much flux causes poor melting of the solder.
- When packaging XThin™ chips with the Flux Eutectic method, a flux clean after reflow is highly desirable – even if a "no-clean" flux is used. The flux clean will ensure optimum lamp brightness and reduce the potential for leakage currents to form due to ionic contamination from flux residue. A 15 minute ultrasonic isopropyl alcohol clean is recommended.

In summary, as with any solder process the type of flux, the amount of flux used, and the reflow time and temperatures are critical factors that must be fully understood and controlled by the user to optimize die attach results and long term reliability of the packaged LED.

NOTE: The 2.0um Sn contact chip is not suited for bonding with pressure applied to the chip during reflow (when the Sn melts). Excess metal "squeeze out" will occur, with potential formation of shorts or shunts as noted under "Other Considerations" below.

EUTECTIC DIE ATTACH

An alternative die attach method is the Eutectic (or thermal compression) bonding process. A special version of the XThin™ chip has been developed for Eutectic bonding, with 0.5um Sn thickness to reduce the amount of metal "squeeze out" beyond the epi mesa, reducing the likelihood for formation of Schottky or Shunt defects and subsequent leakage currents and related problems.

Commercial equipment is available from multiple LED packaging equipment suppliers for eutectic bonding of LED chips. The equipment integrates a heated bonding station, along with appropriate pre-heat and cool-down zones. This equipment has been successfully used to bond Cree's X-class LED's in a single step thermal-compression process.

For the 0.5um Sn XThin™ version C*xxx*XT290-S*xx*00-D, typical processing conditions are as follows:

- Bonding temperature 255 – 265 °C
- Leadframe pre-heat: 10 sec
- Bonding time: ~300 msec
- Bonding force 50 +/- 10 g

Customization of the equipment is required to match the user's leadframe design. Specifically the "heat tunnel" must be precisely configured to work with the leadframe. Therefore, precise process settings must be determined and optimized by the user in conjunction with the equipment supplier, but the above conditions are provided as a baseline for initial process trials and a starting point for optimization experiments.

For additional information, see **Cree X-product Applications Guidelines,** document **# CPR3-AN03.**

When using the Eutectic die attach process, the user should take into account the following recommendations and precautions:

- Only the 0.5um Sn version XThin™ chip (C*xxx*XT290-S*xx*00**-D**) is designed for Eutectic die attach using pressure during the heated bonding process. The 2.0 um Sn version, as well as the 1.7um AuSn versions, of XBright™ and XThin™ chips, are not intended for eutectic bonding with pressure because of the risk of metal "squeeze out" and related failure mechanisms.
- Careful attention should be paid to the pickup collet, and the coplanarity of the chip's bonding surface to the metal

package leadframe. Cree recommends coplanarity of these surfaces be controlled within 5° of parallel to ensure a good bond, minimum metal "squeeze out" and to avoid contacting the leadframe with the N-SiC side of the device. Cree recommends the user routinely monitor leadframe samples after die shear, inspecting the metal residues for good bonding, acceptable metal squeeze out, and inspecting for evidence of gouging on leadframe surface by the SiC chip. See document CPR3-AN03 for representative images.

OTHER CONSIDERATIONS

Schottky or Shunt Formation

The close proximity of the edge of the Silicon Carbide substrate to the metal on the bottom of the chip (~5 microns) must be considered when packaging XThin™. A conductive path will be created if residual die attach material (i.e. Sn) extends up the edge of the chip and contacts the silicon carbide. The Flux Eutectic Attach process was developed to minimize the likelihood of this defect occurring. However, it is still recommended that the customer verify that no shunt or Schottky contact has formed. A simple measurement of the forward voltage of a lamp at low current can easily determine if this problem exists. As can be seen in Figure 2, an acceptable lamp has a forward voltage, Vf, of ≥1.9V at 1 µA, while an "unacceptable" device has a Vf < 1.9V at 1 µA. **It is highly recommended that the user perform this test in both product (reliability) qualification and production phases to verify acceptable packaging process control.**

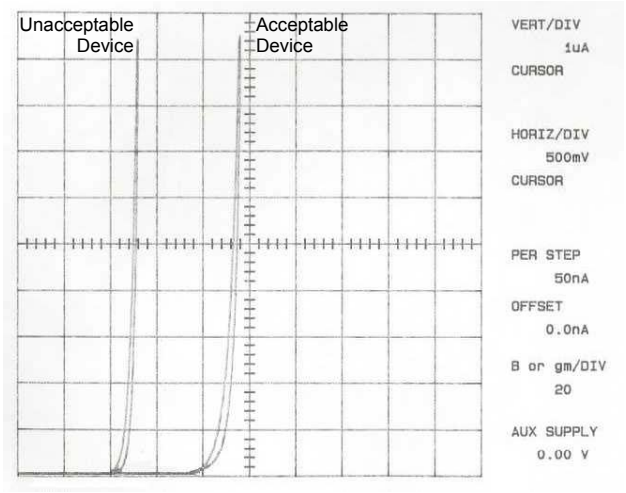


Figure 2. XThin™ criteria for Schottky formation.

Maintaining Barrier Layer Integrity

As noted previously, the backside metal layers act as a barrier to prevent tin from migrating into the reflector and reducing light output. When using automatic pick and place equipment during packaging operations, damage to the backside metal must be avoided to insure this barrier remains intact. **Ejector pin pressure must be kept at a minimum, and the Ejector pin travel should be synchronized to the pickup collet, to ensure the metal is not damaged.**

Post-Attach Processing Temperatures

Post packaging assembly temperature conditions must be controlled. Although the XThin™ chips themselves are capable of withstanding temperatures of up to 325°C for 5 seconds, long exposure of assembled lamps to temperatures above the melting temperature of the die attach material can cause the die to separate from the package leadframe. This could in-turn cause cracks in the die attach and ultimately failure of the product.

NOTE: All die attach process conditions listed in this document, for both Flux Eutectic method and Eutectic method, are provided only as an initial baseline. As each package and assembly system is unique, the user should thoroughly characterize their process conditions to optimize the performance of their product.