High Reliability LED Chip-on-Board Assemblies

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LED chip-on-board applications (COB) typically involve assembling an LED die stack directly on to a substrate such as Metal Core PCB (MCPCB), FR4 etc. This schematic is shown in Figure 1 and compared to a typical LED Package-on-Board stack.

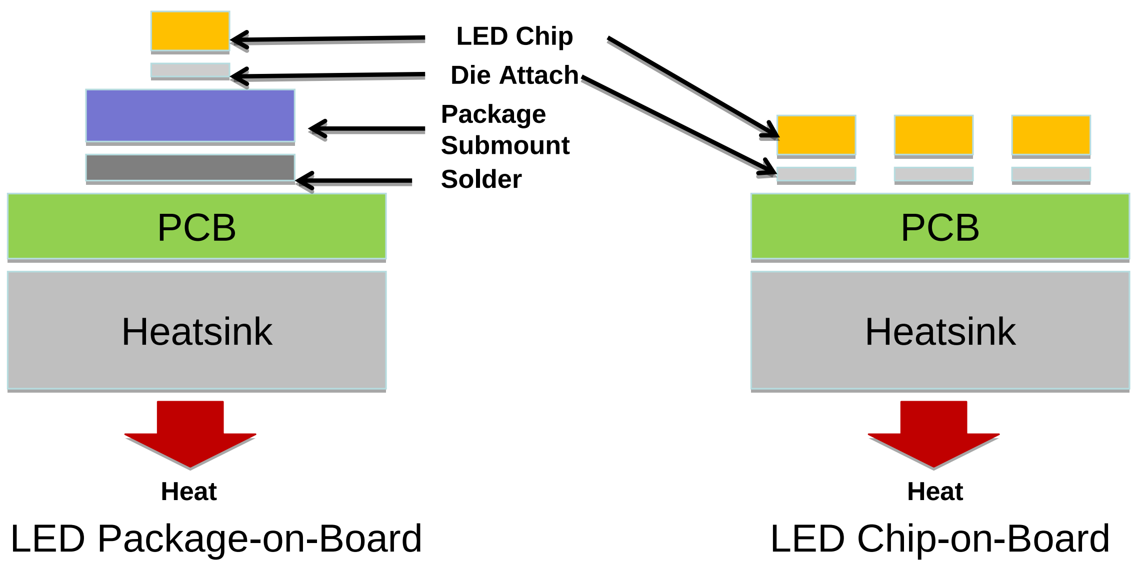

Figure 1: LED Chip-on-Board Structure vs Package-on-Board Structure

LED Chip-on-Board structures have several advantages including:

- Lower thermal resistance – since one packaging layer is eliminated
- COB designs can scale effectively based on lumen output required
- COB platforms provide higher design flexibility and can be tailored for module size and power level, especially for wide area lighting applications.
- COB designs can lower system costs.

Consequently, the LED COB segment is growing rapidly, and as shown in Figure 2, all LED chip structures (lateral, flip chip, and vertical) can be utilized in designing LED COB products.

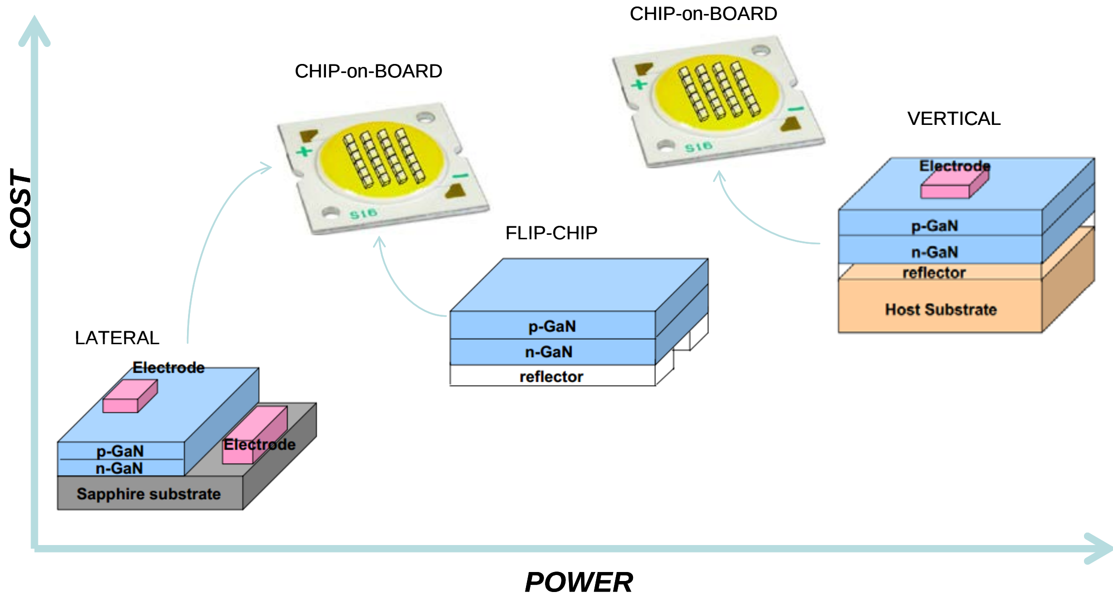

Figure 2: LED Chip Structures Used for Chip-on-Board Designs

A variety of die attach materials, including solder, conductive adhesive, or sintered materials can be used to bond the LEDs to the substrate, depending on the specific requirements, and the tradeoffs involved.

In certain COB designs, SAC-based die attach solder paste is a convenient form factor to use, given the fact that existing equipment sets can be used to implement a high throughput process, and since second reflow is not needed in COB applications.

Reliability of the COB assembly in a given application generally depends on:

- The material stack selected (LED submount, solder, board material and dielectric, and respective geometries),
- The manufacturing process conditions and
- The use environment (temperature swings and harshness of conditions)

In selecting the appropriate solder alloy to be used, one needs to consider the reliability requirements. In doing so one needs to specifically focus on the power level, operating temperature and cycling conditions and CTE mismatch between the LED die stack and the MCPCB, and consequently, its impact on thermal cycle-induced creep fatigue of the solder material.

In the case of a high power LED assembly on aluminum MCPCB, the ΔCTE between the LED and the MCPCB is 18-20, which is quite high, as shown schematically in Figure 3. During thermal cycling experienced by the COB assembly in applications such as outdoor lighting or automotive, the high ΔCTE causes significant strain energy build-up in the solder joint between the LED die and the MCPCB, during the thermal cycling experienced in use. This is shown schematically in Figure 4. This strain energy buildup causes micro-cracking, and eventually, failure of the joint.

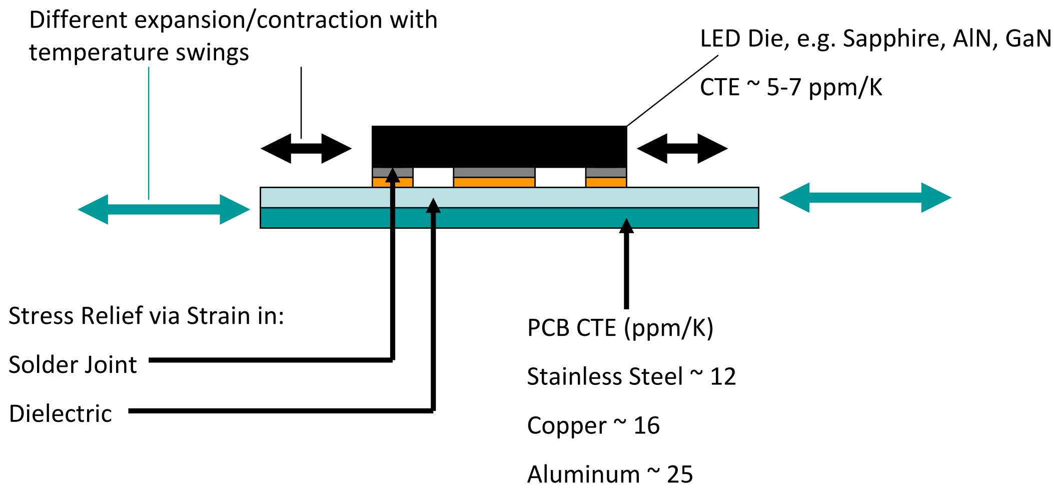

Figure 3: Schematic of Chip-on-Board Stack with CTE Mismatch

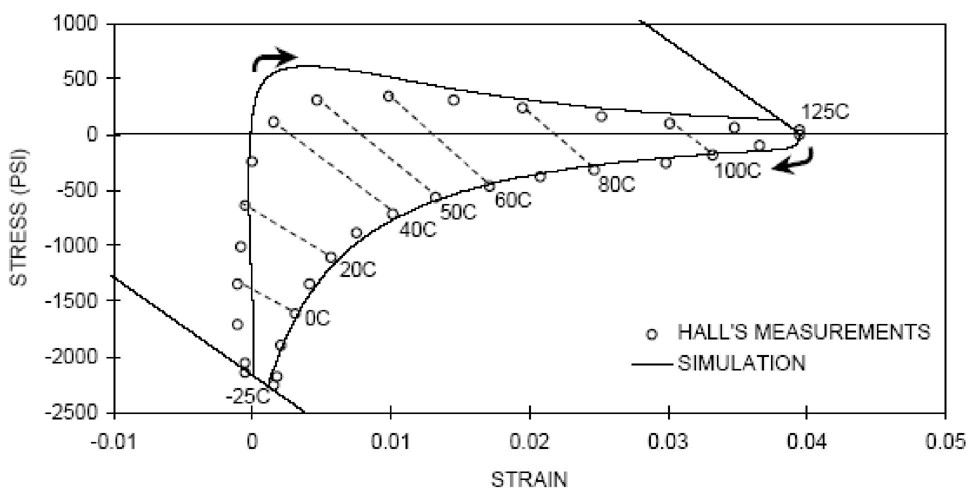

Figure 4: Schematic of Stress-Strain Hysteresis Showing Strain Energy Build-Up Due to CTE Mismatch in LED COB Die Stack

Thus, for a given LED chip structure and board material used, it is beneficial to use solder joints with improved mechanical and thermal fatigue/creep and vibration resistance. Alpha has accomplished this by developing the Maxrel™ family of alloys, via a micro-structural control approach. These advanced alloys have been developed with special additives for improved thermal stability for high temperature operation and higher thermal fatigue and vibration resistance. The first commercially released Maxrel alloy is available in solder paste, preform, and wire format. Alpha's Lumet™ P39 solder paste with Maxrel™ alloy, has been commercially implemented for high power LED assembly.

Figure 5 shows component shear data for a high power ceramic based LED assembled on a Metal Core PCB using Lumet™ P39 with Maxrel alloy with two different reflow profiles, over 1000 thermal cycles from -40C to 125C. It is clear that the Maxrel™ alloy maintains excellent shear strength even after 1000 thermal cycles under high CTE mismatch conditions.

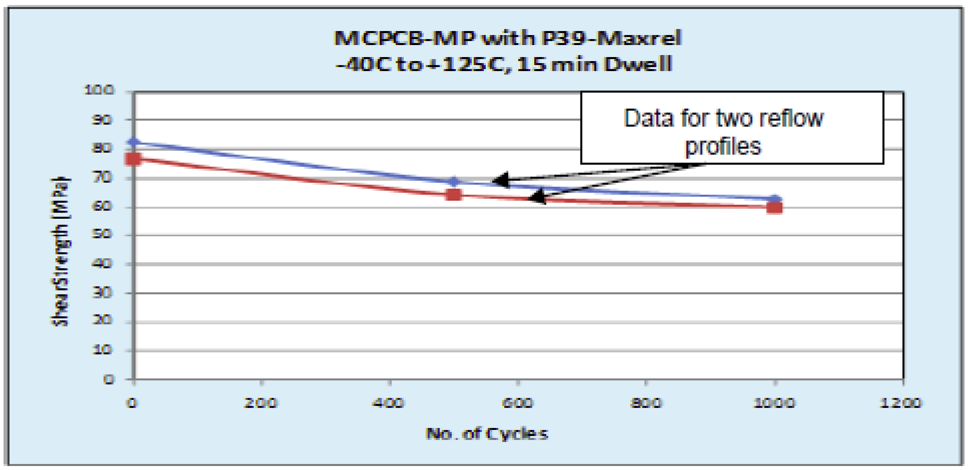

Figure 5: Component shear data for ceramic based LED on MCPCB using Lumet™ P39 with Maxrel alloy, over 1000 thermal cycles

In conclusion, creep resistance of the solder alloy used is a significant determinant of solder joint reliability in high CTE mismatch assembly stacks under thermal cycling conditions. Solder joints with improved mechanical and thermal fatigue/creep and vibration resistance and bond line uniformity, are possible by using micro-structural control approach. Alpha has developed the Maxrel™ alloys for improved thermal stability. Solder pastes such as Lumet™ P39 with Maxrel alloy can be used for LED COB assemblies on MCPCB to enhance the reliability of such assemblies.