Abstract— ATSLP, a package in QFN type family, was introduced by Infineon using Molded Interconnect Substrate (MIS) leadframe. The MIS leadframe contain materials such as, copper, pre-mold, solder mask, and etc. With combination of MIS leadframe and high temperature flip chip die bond cause high CTE mismatch, thus, effect in higher warpage. The higher warpage affects the processability along the assembly processes which has direct relation with productivity performance and quality concerns. Stress relieve concept is introduced to improve productivity and quality, whereby warpage was reduced by separating the pre-mold and copper materials. By doing this, shrinkage of the materials was separated from each other along the change of assembly process temperature.

Laser is selected as the source to perform cutting of pre-mold array. Polyimide tape is attached to the leadframe to hold the separated pre-mold array. Laser with non-contact cutting method, low thermal influence as well as having clean cut edges without burr or dust formation is ideal solution for this separation method. Through the laser precut on array method, productivity, material consumption, and output quality were improved as the warpage is significantly reduced. This paper further describe the selection of laser type, reaction of laser to polyimide tape, cutting process methods, and as well as the challenges faced along the assembly process.

I. INTRODUCTION

Assembly process starts with lamination of polyimide tape on to leadframe, UV laser used to separate polyimide tape according to array size. Then, IR Laser used to separate pre-mold and substrate. Through the slot opening at pre-mold, outcome from laser cut, stress relief concept is introduced. With this, stress relief on the leadframe, warpage is reduced even heat expansion induced from flip chip die bond and mold process.

This paper discuss the effect of laser type on polyimide tape during cutting process, the array pre-cut method, as well as the resultant leadframe warpage after going through the assembly process, whereby the thermal expansion and stress relieve concept is inter related.

II. METHODOLOGY

From the material properties of the MIS leadframe, a big difference of CTE mismatch can be observed from table 1, which is the combination of 4 major materials. This resultant the idea of using laser pre-cut as one of the potential solution to eliminate the warpage level, in order to improve the assembly processes and rejects reduction during manufacturing.

Table 1. Major components of MIS leadframe and its material properties

<table>
<thead>
<tr>
<th>Component</th>
<th>Tg (°C)</th>
<th>CTE 1 (ppm/°C)</th>
<th>CTE 2 (ppm/°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mold compound</td>
<td>175</td>
<td>11</td>
<td>42</td>
</tr>
<tr>
<td>Solder Mask</td>
<td>160</td>
<td>32</td>
<td>95</td>
</tr>
<tr>
<td>Copper stud/trace</td>
<td>NA</td>
<td>NA</td>
<td>17</td>
</tr>
<tr>
<td>Substrate carrier</td>
<td>NA</td>
<td>NA</td>
<td>12</td>
</tr>
</tbody>
</table>

The target process improvements for the evaluation are die bond and mold as the output respond of the warpage level at the two processes are higher due to the exposure to high temperature during processing. The manufacturing area tends to face issues such as manual handling during on/off load at machine and inconsistent vacuum suction on leadframe during die bond. While at mold process, pick and place error is common due to the high warpage level that affects the detection of leadframe in the station. These stoppages affect the smoothness of the process and process cycle time.

Leadframe design plays an important part on the improvement of the warpage level. Referring to Figure 1, the changes made on the leadframe was the original pseudobar was removed as the design was to control the warpage level to the minimum level. With the original pseudobar design, 3 columns from left and right of the array had to skipped die bond in order to achieve the acceptable warpage level for die bond and mold process, else there will be a risk of array crack due to excessive tension in between the array to leadframe.

Fig. 1. Pseudobar and Non-Pseudobar design of ATSLP Leadframe
Solder mask design was next to make changes as more opening slot is connected, and the slot extended to the pre-cut line. The changes can be viewed and compared from Figure 2. This enables the improvement on the overall ventilation system. This design changed is critical for the lamination process whereby adhesion between the tape and pad surface must be well taped to prevent array drop after laser pre-cut on array, die bond, as well as prevent the mold bleed into the active area.

The method to laminate the polyimide tape on the pad surface is important as it plays a part on the resultant warpage level, in addition to maintain the quality of the leadframe before proceed to array pre-cut process. The lamination of tape only on the pre-mold area was selected due to the fact that only this surface area is critical to the subsequent processes. Besides, defects such as bubble and incomplete tape on the bottom of whole leadframe can be prevented as such minor gap might cause air to trap in between the pre-mold and leadframe surface. The pre-mold area which was laminated can be referred in Figure 3.

The selection of the area for laser pre-cut on array is important as this is the point which enables the array to expand to the extent that will not induce higher warpage onto the leadframe. The line in between the two round pads has been identified as the laser pre-cut area, for instance, the cut through of the pre-mold and solder mask layer as an opening slot for the heat expansion during die bond and subsequent processes. The accuracy and the power control of the laser in this case is vital, as the two layers (Pre-mold and solder mask) must be cut through before the polyimide tape layer is damaged. Figure 4 shows the laser pre-cut side view of the laser cutting depth through pre-mold and solder mask layers.

![Fig. 2. Original solder mask design and improved solder mask design for tape lamination](image)

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![Fig. 4. Side view of the laser pre-cut on array without cut through polyimide tape](image)

**Fig. 4. Side view of the laser pre-cut on array without cut through polyimide tape**

### III. RESULT AND DISCUSSION

Different types of laser sources were selected to perform the cutting of polyimide tape at the array’s edges after lamination process. CO2 and UV laser were selected for tape cutting as both are the most industrial laser type use in the market. The same leadframe batch was used and laminate process was done in the same time frame to prevent any external factors that will influence the result on tape cutting. From the comparison Table 2, with the usage of CO2 laser, burnt residue (Figure 5) was observed after laser cut on tape. The burnt residue was in fact from the tape which is melted due to the laser source, which contains carbon, contacted the polyimide tape and with the present of oxygen [1]. The burnt residue has the potential to affect the downstream processes as it might transfers to the contact surface.

![Full Lamination vs Lamination only on pre-mold area](image)

**Fig. 3. Comparison of full lamination of tape on leadframe and lamination of tape on pre-mold surface only**

<table>
<thead>
<tr>
<th>Laser Source</th>
<th>CO2 (1064nm)</th>
<th>UV (355nm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wavelength</td>
<td>1064nm</td>
<td>355nm</td>
</tr>
<tr>
<td>Beam Size</td>
<td>120µm</td>
<td>50µm</td>
</tr>
</tbody>
</table>

- **Problem Encountered:** Burnt residue found after tape cut which affected subsequent process
- **Improvement Action:** Re-optimize laser parameter (power setting) to reduce the burnt residue
- **Result:** No significant improvement on burnt residue observed

![Cleanliness comparison](image)

**Table 2. Comparison of laser source, wavelength, and result**

As for the UV laser, it carries the wavelength of 355nm, complete the laser cut on the polyimide tape at the array edge without leaving any burnt mark (Figure 6). The overall cleanliness on the array edge has a clean cut compare to using CO2 laser.
Next, with the usage of fibre laser on the pre-mold array cut, we could observe that the thermal expansion of the array after die bond process did not affect the whole leadframe. The cutting width of 50um-80um on pre-mold is sufficient and the power control does not cut through the tape (Figure 6), which will later contribute to mold bleed during mold process. A comparison of the physical frame and warpage level after die bond for Non Laser pre-cut and laser pre-cut on array, found to be significant as the warpage level was reduce around ~60% (Figure 7 & 8).

The comparison made in die bond process was carried on to the mold process. As seen in Figure 9, the comparison has been made between the non-laser pre-cut array frame and the laser pre-cut array frame, whereby both were full bonded frames. From the result and observation, the crossbow warpage level of the strip with laser pre-cut was significantly reduced and able to sit flatly on the bottom of the mold cavity, which has a temperature of 180˚C. This indicated the risk of possible array crack due to warpage can be reduced. Hence, in mold process, more arrays can be prevented from such defect and enhance the productivity during manufacturing. After mold completed, the leadframes were placed on the table to compare the post mold leadframe warpage. Through laser pre-cut on array method, the warpage level was lesser compare with the non-laser pre-cut frame (Figure 10). The strips were taken for warpage measurement (Figure 11), and the result taken from sample size measurement observed that the crossbow warpage level was reduced from around 2mm to less than 1mm. From the overall engineering evaluation done in assembly process, the warpage level was reduced by ~60%, hence, the earlier risk of earlier defects seen can be reduced, as well as the productivity can be increased by 50% through this method.
Fig. 10. Physical leadframe condition after mold for Non Laser Pre-cut and Laser Pre-cut

Fig. 11. Comparison of leadframe warpage level after mold process

IV. CONCLUSION

From the result, leadframe warpage is influenced by the introduction of laser pre-cut process. The different CTE between the solder mask, pre-mold layer, and substrate proved to be the main contributor of the high warpage level seen in ATSLP. By using laser pre-cut method and the QFR-331 support tape, the chain between the layers were separated and the thermal expansion of the array along the processes reduce the warpage level seen on the leadframe. This can be validated whereby the result showed the difference in warpage level between the two samples, which were the ATSLP and the ATSLP with Laser Pre-cut. Through the introduction of this process, the product quality is improved as consistent vacuum and less handling of leadframe in assembly process, as well as the throughput was raised by 50% as the skipped bond and pseudobar were eliminated.

REFERENCES