Wafer Direct Technology for Mini LED Flip Attachment

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Abstract. We would like to introduce the mechanism structure of our wafer direct die attachment technology for mini LED. Wafer direct technology is structured from two parts of that one is adhesive one shot dipping and other is pinhole free chip shooting. 1st, we developed “One shot wafer dipping” which can transfer the adhesive to around 30,000 chips of mini LED on a wafer at once. Second section is to take about die mounting. Common die bonder use an ejector pin to pick up mini LED chip. Ejector pin makes a pinhole on wafer and lead air into between wafer and mini LED chip. This air is effective to remove mini LED chip from wafer by the pick up nozzle. Ejector pin of die bonder leaves a broken piece of wafer on chip. We developed wafer direct chip shooting technology. Wafer direct chip shooter also use an ejector pin for shooting down mini LED chip. But wafer direct does not make any pinhole on wafer that means no broken piece of wafer exists. Our wafer direct technology maximize productivity of mini LED die bonding and minimize faulty ratio of mini LED die bonding.

1. Introduction [1] Wafer direct dipping.
We considered to sandwich a wafer between pusher head and dipping stage. See figure 1 “method of wafer dipping”, 1. Squeegeeing of ACP for flattening and control thickness. 2. ACP is flatten in targeted thickness. 3. Dipping stage comes to bottom side of wafer. 4. Pusher head comes down and dipping stage goes up. 5. ACP is transferred to mini LED chips on wafer by one shot. We use a round plate for the pusher head as like a wafer expander. Dipping stage rise 5mm up and pusher head push 1mm down a wafer for dipping. We set the matching point of wafer and ACP as zero height level. We keep 3 seconds dipping time at zero height level to transfer ACP to wafer by surface tension. Then we keep pusher head at zero height level and dipping stage comes down in slow speed of [0.01mm per second] for optimization of dipping volume of ACP. It takes 60 seconds as one dipping cycle that is too slow speed for common LED production. (See figure 2. “Timing chart of dipping”). But more than 30 thousands mini LED chips are existing on single wafer which means to take only 0.002 seconds per chip. So wafer direct dipping can meet to huge demand of mini LED bonding. It is easy to optimize supply volume of ACP or any adhesive in wafer direct dipping. Wafer direct dipping does not occur any offset of ACP or adhesive supply position as like often happen on solder printing. We use stretching of wafer for making flatness. But we have to keep return tension ability of wafer until next chip mounting process. So we minimize a distance of extension to push a wafer down for dipping. Minimum extension of wafer for flattening is 1mm.
Wafer direct one shot dipping can transfer 60% depth of ACP pool to mini LED chips on wafer by surface tension. We can control dipping volume by depth of ACP pool and dipping time profile. See Figure. 2 dipping volume control and Figure. 3 time chart of dipping. We can control depth of ACP pool from 10μm up to 500μm by squeegeeing. We can also control dipping volume by shorten or extend of waiting time and separating speed of wafer and ACP pool.

**Figure. 1.** Method of wafer dipping

2. Consideration and result [1] Wafer direct dipping.

We prepared a drilled pusher head with 380 mini vacuum holes which has for flattening of wafer. Unfortunately, drilled head couldn't get complete flatness of wafer which couldn’t transfer ACP to half of 30,000 mini LED chips on wafer. We checked dipping condition of mini LED chips and found that dipping of mini LED chips at around vacuum hole area are done well. But mini LED chips at far from vacuum hole area are not stable condition. We found that many airspace existed between vacuum hole and vacuum hole which disturbed flatness of wafer. See Fig. 4 Airspace.
One of the most important issues of wafer direct dipping is how to keep flatness of wafer. It is necessary to vacuum a wafer by area not at pinpoint. We estimated needful additional number of drilling hole is around 80,000. It is quite difficult to meet such huge number of holes in technically as well as cost wise. So we looked for replacement technology of drilling holes and found out porous metal for pusher head. New porous head have 141,000 micro vacuum holes which enlarge vacuum area size from 12[mm2] to 1,628[mm2]. See Table 1. comparison of drilled and porous. Total vacuuming power is -10.9kPa which is same between drilling and porous due to use same vacuum pomp.

|                  | Drilled head | Porous head |
|------------------|--------------|-------------|
| Number of hole   | 380          | 144000      |
| Mm2 per hole     | 0.031        | 0.011       |
| Vacuum area size | 12           | 1628        |
| Proportion       | 1            | 136         |

Figure 4 Airspace

Porous is made from continuous cracks and gaps, not holes. See Fig. 5 porous metal. Thousands vacuum cracks and gaps of Porous improved vacuum condition which stabilized vacuum power and brought high level flatness. So we solve existing oversupply or shortage of ACP volume and provide even volume of ACP or other adhesive to thousands mini LED chips. It was removed remaining air between wafer and pusher head by porous which led flatness of wafer see Fig. 6 porous vacuum and F Fig. 7 dipping marks on ACP pool and evenly ACP dipped to mini LED chips on wafer. We could confirm very highly versatility of wafer direct dipping.
3. Introduction [2] Wafer direct chip shooting.
We would like to introduce you method of movement of shooting head of wafer direct dies attachment.
Common die bonder pick chip up by vacuum nozzle, then move to substrate and place it there.
Wafer direct chip shooting does not have any pick up motion and no travel to substrate. Ejector pin and plunger are on the same axis but ejector pin is controlled by motor and plunger is controlled by solenoid. We make a pinhole on wafer by ejector pin. Pinhole leads air flow which reduces stickiness of wafer. An adhesive dipped mini LED chip sticks to substrate and transferred it from wafer by return tension of wafer. See Fig. 7 of head unit
1. Ejector pin comes down to top surface of wafer
2. Ejector pin and plunger pushes wafer down and makes a pinhole
3. Transfers mini LED chip to substrate
4. Then ejector pin goes up to home position
4. Consideration and result [2] Wafer direct chip shooting
We had two technical issues with die attachment process of wafer direct that one is contamination of a broken piece of wafer and other is shift of chip address on wafer due to loosen tension of wafer. Both of them are made by making pinhole. It is appeared a broken piece of wafer on surface of mini LED chip when mount mini LED chip to substrate by making pinhole. This broken piece disturbs lighting of mini LED which must be removed at cleaning process later. Other is shift of chip position. We recognize X, Y axis position of all chips on wafer by camera before starting chip mounting. We use this X, Y coordinates as target position each chip for chip bonding. But chip location is shifted one by one after making pinhole. Because pinhole loosens tension of wafer which shifts original X, Y coordinates of chip. If we recognize X, Y position of chip again during mounting which drastically disturb the productivity. We considered to find the algorithm of loosen tension of wafer by pinhole for prediction of position change. But we could find after test of thousands chip mounting that loosen of tension of wafer is in random and no algorithm is available. We understood that we can’t control shift of chip position by tension change of wafer and have to find the condition of pinhole free chip mounting. If we push down mini LED chip by ejector pin only, ejector pin penetrates wafer. We do not get any pinhole when we push down mini led chip by ejector pin and plunger together, but it is not possible to transfer mini LED chip from wafer to substrate due to that adhesion of wafer is stronger than adhesion of ACP or solder. Ejector pin and plunger together to push down mini LED and keep it for 5milliseconds. Wafer leaves from mini LED by return tension except holding area by ejector pin when plunger goes up. Ejector pin still stays at bottom further 4milliseconds to well transfer mini LED to substrate by surface tension of adhesive without making any pinhole. See Fig. 9 structure of pinhole free chip shooting.

![Figure. 9 Structure of pinhole free chip shooting](image)

Ejector pin, plunger and solenoid are assembled on Z axis which is under control by Z axis motor. Plunger is assembled on Z axis but is under controlled by solenoid. Key technology of pinhole free mini LED chip mounting is movement of plunger and waiting time. See below Fig. 10 timing chart of plunger and ejector pin.
We could confirm that both of ACP and solder paste well separated and aggregated under wafer direct dipping technology. We had no solder bridge and no remaining solder ball at gap. See Fig. 11 X-ray after reflow. ACP is mixture of solder and epoxy resin which has “self-alignment” function. Melted solder in ACP flows to P electrode and N electrode of chip and substrate in even volume under reflow. This flow power is strong as called as “self-alignment” which corrects mounting offset of mini LED chip. Solder paste in screen printing has same function but it has weak offset correction due to that screen printing supplies minimum volume of solder to electrodes of substrate which does not flow. But wafer direct dipping supplies ACP in the center of mini LED chip that solder flow from center to edge in long distance which enlarges self-alignment” function. See Fig. 12 wafer direct dipping result. So we can see good “self-alignment” function with solder paste to be supplied by wafer direct dipping. This is advantage of wafer dipping to screen printing.

Figure 10 Timing chart of plunger and ejector pin

Figure 11 X-ray after reflow
It is not suitable to use ACP in screen printing due to that epoxy resin of ACP is sticky which is not removable from the stencil. But it is possible to use both of ACP and solder paste in wafer direct dipping. See Fig. 12 wafer direct dipping result. So we can say that wafer direct dipping technology can optimize supply volume of any adhesive. Wafer direct dipping can replace existing screen printing of solder paste on mini LED die bonding.

**Table 2. Comparison chart**

|                     | Die bonder | Wafer direct |
|---------------------|------------|--------------|
| Pinhole             | Yes        | No           |
| Pin damage          | Yes        | No           |
| Contamination       | Yes        | No           |
| Touch electrode     | Yes        | No           |
| Flip chip           | No         | Yes          |

Common die bonder for mini LED bonding is still having not escapable several potential problems such as damage to electrodes of mini LED chip by ejector pin and remaining debris of wafer on electrodes. Wafer direct chip shooting with pinhole free technology can solve existing such two problems of die bonder in the same time. See Table. 3 comparison chart. Wafer direct chip shooting can achieve the speed of 0.098 seconds per mini LED chip, and X, Y axis accuracy is ±0.01 mm after reflow. See Table. 3 bonding accuracy.

**Table. 3 Bonding accuracy**

| After reflow | Sn-Bi solder X | Y | ACP X | Y |
|--------------|----------------|---|-------|---|
| Ave.(mm)     | -0.004         | 0.000 | 0.003 | 0.000 |
| 3 sigma(mm)  | 0.013          | 0.016 | 0.012 | 0.011 |

You can see Figure. 13 [10,050] chips placed on lighting module. We do not have any unlit chip on this module. We can say that yield rate of wafer direct technology is high that our mini LED chip mounting rate is 99.7% or more. We would like to introduce details of our wafer direct technology for improvement of die attachment technology of mini LED flip chip.
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5. References
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[2] Patent No. US9633883B2 dated 20170425 “Apparatus for transfer of semiconductor devices” owned by Rohinni LLC, USA.
[3] Patent No. JP6603412 “Mounting method, mounting head and mounting apparatus” owned by T. Tatsuiwa, Japan.
[4] Patent No. JP6543421 “Transfer method and mounting method” owned by T. Katashio, Japan.
[5] Patent No. JP6603412 “Optimization and quantification of “mini LED flip chip on board (COB) package” by self-alignment with anisotropic conductive paste (ACP) and pinhole free wafer direct technology” on November 25, 2020 for “PROCEEDING(SSLCHINA & IFWS 2020). Published by China solid state lighting alliance and China advanced semiconductor industry innovation alliance. Page No. 194 by K. Hiraki.