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Design of Alignment Mark Stamper Module for LED Post-Processing

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ABSTRACT

Light emitting devices (LEDs) are widely used in the liquid crystal display (LCD) industry, especially for LCD back light units. Therefore, much research has been performed to minimize manufacturing costs. However, the current process does not process LED chips from broken substrates even though the substrate is expensive sapphire wafer. This is because the broken substrates lose their alignment marks. After pre-processing, LED dies are glued onto blue tape to continue post-processing. If auxiliary alignment marks are stamped on the blue tape, post-processing can be performed using some of the LED dies from broken substrates. In this paper, a novel stamper module that can stamp the alignment mark on the blue tape is proposed, designed, and fabricated. In testing, the stamper was reliable even after a few hundred stamps. The module can position the stamp and apply the pattern effectively. By using this module, the LED industry can reduce manufacturing costs.

1. Introduction

The yield of light emitting device (LED) process is important to make lower the cost of liquid crystal display (LCD) because one-dimensional or two-dimensional array of LEDs are widely used in the back lightening as light source[1]. The LED dies are processed on an expensive sapphire wafer that the effective usage of the substrate is essential to save the cost[2].

The bare LED substrate in Fig. 1(a) is pre-processed in lithography, development & washing and then the substrate with LED dies are glued on blue tape in Fig. 1(b). The substrates originally have alignment marks as presented with the small red "+". The blue tape is expanded to the radial direction for post-process in Fig. 1(c) and (d). This expansion makes gaps among the dies for easy handing. The following post-processes are usually handling, sorting, packaging and etc. Despite the expensive substrate, the chipmakers have given up the partially broken substrate in Fig. 1(e) because, in part, they have lost the alignment marks of the substrate. The alignment marks are important to carry out the following post-process[3]. The broken substrate in Fig. 1(e) can be post-processed if auxiliary alignment marks are printed on the blue tape. The chipmakers can easily register the auxiliary marks for their equipment system's software before the post-process.

This concept is shown in Fig. 2. The auxiliary alignment marks, "+", is patterned on the blue tape in addition to the original alignment marks on the substrate in Fig. 1(e). In the figures, the marks are exaggerated to show up.

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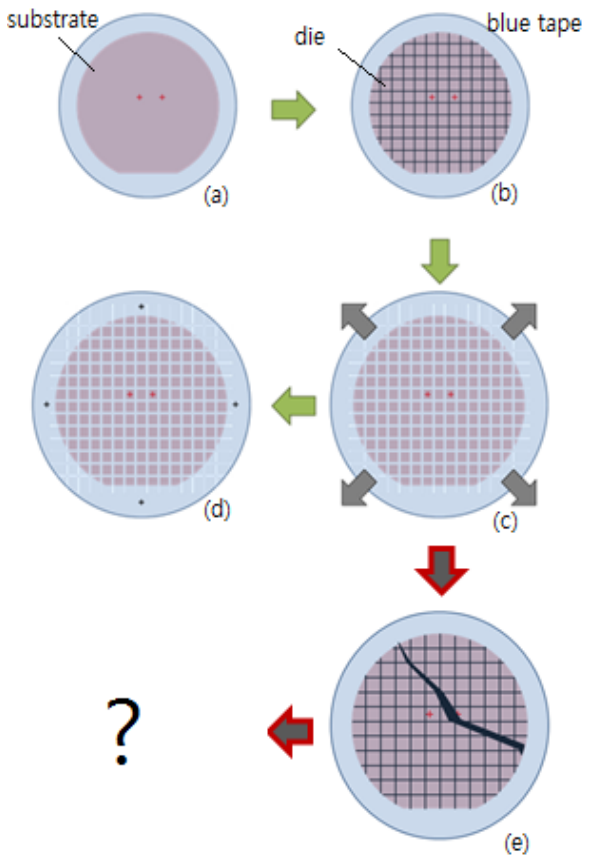

Fig. 1 Preparation for LED post-process with dies and blue tape (Tape frame is omitted for understanding)

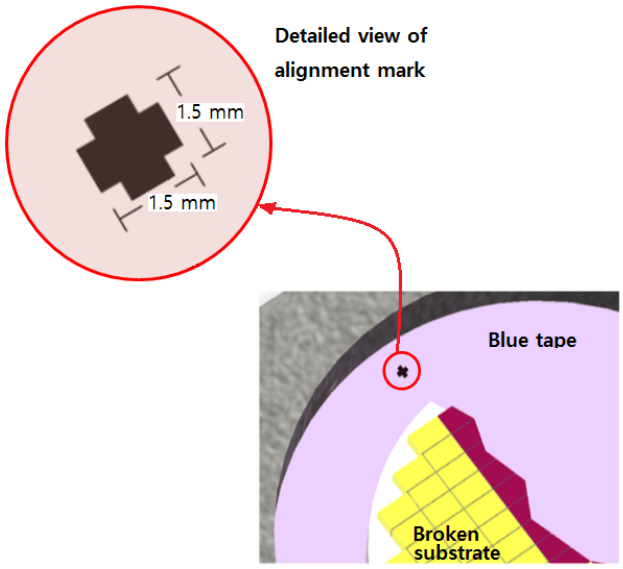

Fig. 2 Concept of auxiliary alignment marks on blue tape to save dies from broken LED substrates (The marks are exaggerated to show-up)

In this paper, a stamper module to pattern the alignment marks is proposed, designed and fabricated to make higher the usage of expensive sapphire substrate of LED. The module has two main components: The first is positioning mechanism and the second is stamping head. Their performances are also presented after motion control and image processing, respectively

2. Design of Stamper Module

The LCD industry requires that the stamper module has fast speed, high precision, and good reliability. The speed is from the stamping speed faster than 0.3 cycle/s. The precision is from the positioning finer than ±5.0 μm after image-processing to obtain the center of the patterned mark. The reliability is from the wear resistance which can endure more than 300 times of stamping.

For the requirements of wear resistance, the material of stamping head was selected as stainless mold steel which has good hardness and high toughness. It has also good corrosion resistance against the chemicals in process. The head was machined with a series of turning, milling, electro-discharging, heat treatment and grinding. These conventional machining is cheaper that the process used in semiconductor fabrication like electroplating, etching, lithography and etc.

At the tip of stamping head, the shape of "+" is engraved in relief. It has the width & height of 1.5 mm and the protrusion of 1.0 mm as in Fig. 3. The stamping head has a shank to be mounted on the stamper module as shown in Fig. 4.

The stamping head is to be transported along x-direction for positioning and to be moved along z-direction for stamping. Therefore, the stamper module has a linear servo motors in each direction as shown in Fig. 4(a). Y-directional motion is not presented because it is done by other servo system carrying the substrate. The x-directional mechanisms are with a servo motor, HF-KP13 from Mitsubishi and a single axis linear motion (LM) guide, LX3010C-B1-A3040-350 from Misumi. The z-directional mechanism is a servo motor, HF-KPO53B from Mitsubishi and a LM guide, LX2005C-B1-A2040-100 from Misumi.

The pattering and alignment marks are monitored using a CCD camera and an illumination. The CCM camera is MV-CV30U from Sony. The illumination is a ring type LED illumination (LED 36ea from ATS Global) which is mounted

around the stamping head.

The stamping process is as follows: The assembly with stamping head, CCD, and illumination is positioned on a specific site over the blue tape using the x-directional servo mechanism after the substrate is transported to a predetermined location. The stamping on the tape is performed using the z-directional servo mechanism. All the process is monitored with the CCD camera. The positioning, stamping, and monitoring are with controller and image-processor, and interface in Fig. 4(b).

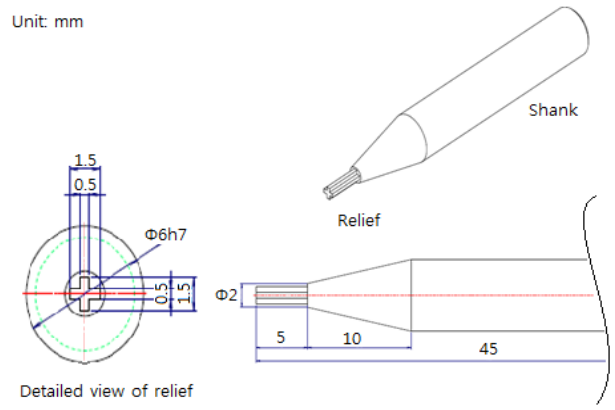

Fig. 3 Stamp for patterning alignment marks on blue tape

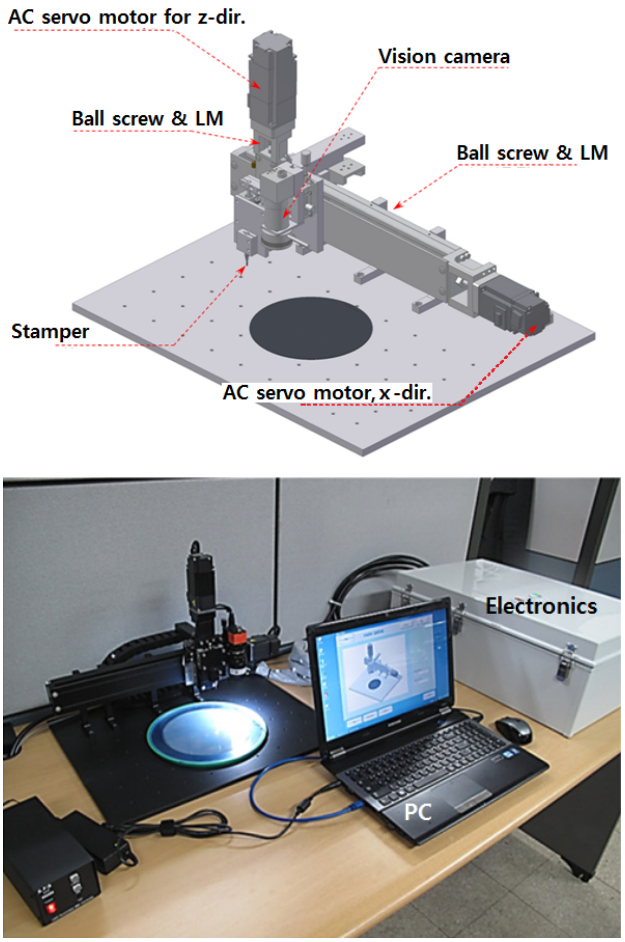

Fig. 4 Stamper module for patterning alignment marks on blue tape: (a) Mechanism with vision camera, (b) experimental setup

3. Results and Discussion

3.1 Reliability of stamp against wear

In order to evaluate the wear resistance of stamping head, the relief was investigated by using a scanning electron microscope (SEM) after 300 times of stamping as shown in Fig. 5(b). There was no significant wear on the relief when considering the initial image before stamping in Fig. 5(a)[4].

3.2 Positioning of stamper module motion

The horizontal positioning capability of the module is tested before the stamping experiment. The stamping head had 30 times of reciprocal motion between two desired locations along its direction with translation of 100 mm, repeatedly. The positioning was measured using Renishaw Laser Interferometer (RLE10 Laser Encoder). The positioning error data has a standard deviation (σ) of 0.21 μm. ±σ is considered as its

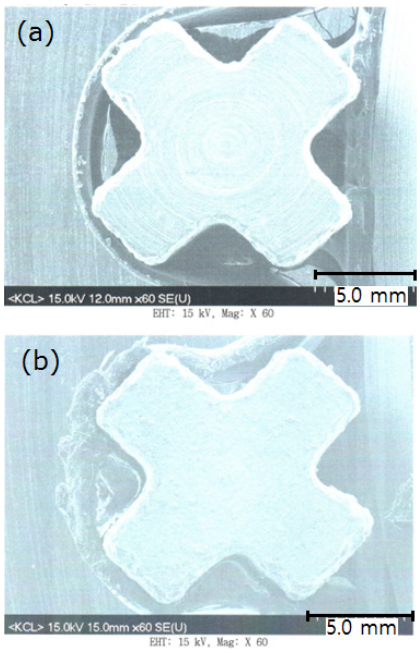

Fig. 5 Wear resistance of stamping head: (a) Electron microscope image before stamping, (b) the one after 300 times stamping

repeatability i.e. positioning capability. The positioning capability was ±0.21 μm as shown in Fig. 6[5]. This seems enough to guarantee the high precision of stamping. The z-directional performance was not evaluated because the stroke of motion is so short that it can be anticipated that the mechanism has good precision.

3.3 Patterning performance of stamper module

The module should have sufficient speed to pattern the auxiliary alignment marks for productivity of LED process. For whole stamping process the cycle speed is tested. The stamping head patterned the marks with speed is 0.5 cycle/s. This stamping speed can satisfy the requirements from industry.

In order to evaluate the stamper module, the positioning itself is not sufficient. After positioning, stamping and then patterning, it should be investigated the position error from the center of marks. In this experiments, 30 time of the whole stamping process were repeated on the blue tape. In stamping process, all the auxiliary alignment marks were captured in image grabber and then the center points of marks are calculated using a tool which can detect the edge and the center as shown in Fig. 7[5].

The statistics of the experiments are presented in Fig. 8 with the standard deviation, frequency number of the center position error from the desired location[5,6]. It shows the repeatability of ±5.23 μm, but it is somewhat insufficient considering the requirement of from the industry, ±5 μm.

When the stamping head is being mark on the blue tape, it was investigated that the z-directional linear motion has a tiny parasitic horizontal motion because of tilted mounting of the stamping head during the experiment. In the experiments, there were two times of mounting.

The performance of repeatability cannot meet the industry's

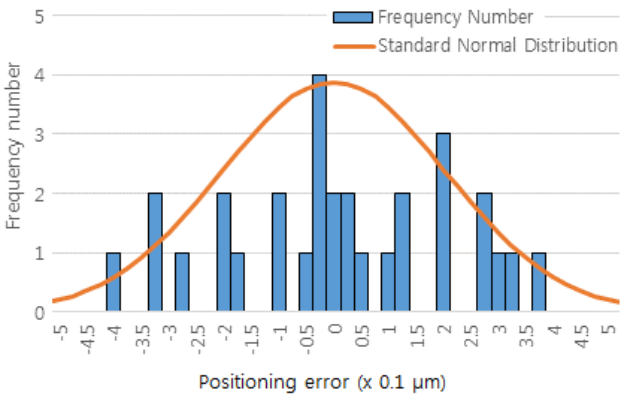

Fig. 6 Positioning performance of stamping module and its standard normal distribution

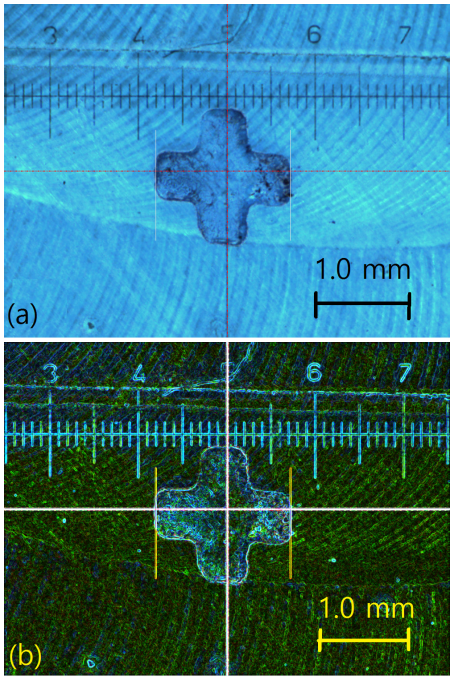

Fig. 7 An example of stamped alignment mark: (a) the one captured after stamping on blue tape, (b) the one captured image-processed to get a center of the mark

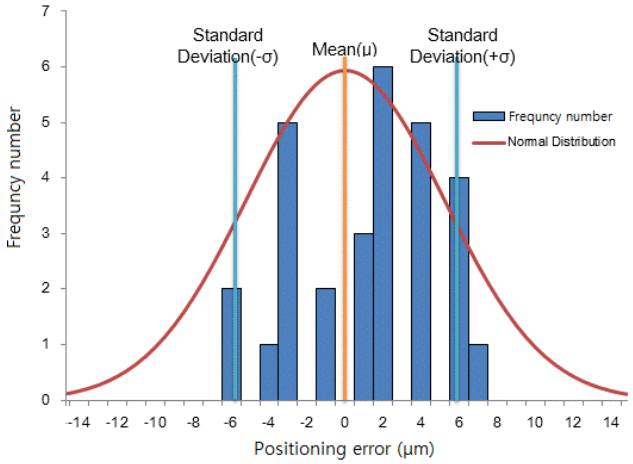

Fig. 8 Stamping performance of the module and its normal distribution

Table 1 Performance of stamping module

	Requirements	Results
Wear resistance	> 300 times	> 300 time
Speed	> 0.3 cycle/s	> 0.5 cycle/s
Repeatability	< ± 5.0 μm	< ± 5.23 μm

requirements. It is anticipated from the imperfect guide mechanism of z-directional motion of mechanism.

4. Conclusions

In this paper, a stamper module is proposed, designed, fabricated, and then verified. It has a stamping head with good reliability against wear and high speed mechanism with fast stamping speed. These characteristics can meet the requirements from LED industry. It has also positioning mechanism with precision motion control which provides fine precision of ±0.21 μm. However, the clamping mechanism of stamping head to be improved because it gives parasitic motion.

The stamper module patterns the auxiliary alignment marks clearly on the blue tape. This is because the ink, pressure and drying conditions of stamping process are selected well. From the patterned marks, the precision of center was ± 5.23 μm after image-processing. This should be enhanced by modifying the z-directional motion mechanism.

If the module is applied to prost-processing equipment, it can make smaller the waste of expensive LED substrate even after breakage. This can make lower the chip-making cost during the post-process such as handling, sorting, dicing and investigating in LED industry.

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