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Optimization of Anisotropic Conductive Film Bonding for Improving the Quality of the Image in Vision Inspection

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Abstract

In this paper, we investigate the compression shapes in the process of pressing the anisotropic conductive film to improve the recognition accuracy of the indentation image obtained by automatic optical inspection. In order to increase inspection efficiency, we find the optimal bonding conditions. For the test, the bonding press was self-manufactured, and the temperature, compression time, and pressure were varied to find the optimal bonding condition. Test results show that the radius and thickness of the indentations calculated using the pixel values for each pressure, are linearly related to the change in pressure. In addition, the optimal conditions were 160°C of temperature, 1 bar of pressure, and 15s of time.

Keywords: COG, AOI, ACF, Indentation marks,

INTRODUCTION

Recently, the liquid crystal display (LCD) industry has invested a lot of research and development into production and inspection in order to downsize the product, lower the price and increase the performance. For acquiring these goals in LCD modules, it is essential to miniaturize the lead pitch of the driver ICs. Therefore, the bonding process of bonding between the bump of driver ICs and the LCD panel is becoming more important [1, 2]. In the bonding process, selection of the optimal inspection method for checking the bonding results is the only way to secure the quality and reliability of the LCD panel. For maximizing the inspection efficiency, it is required to do final inspections in the production lines as many as possible. In order to satisfy these conditions, a vision inspection method using line scan cameras is the most widely adapted in the related factories. Understandably, auto focusing is essential to secure a clear scan image for ensuring the reliability of inspection. Such a system referred to as an automatic optical inspection (AOI) system. In this study, to increase the accuracy of indentation recognition of indentation images acquired by AOI equipment, we investigate optimal bonding conditions using three parameters - temperature, compression time and pressure - with a self-manufactured bonding press.

AOI SYSTEM FOR LCD PANEL INSPECTION

The auto-focusing ability also plays an important role in obtaining clear images with the performance of the lens. In order to understand these devices, it is necessary to have prior knowledge of the kinematic relationship between the optical system including the objective lens and the line scan camera and the inspection panel in the LCD panel inspection.

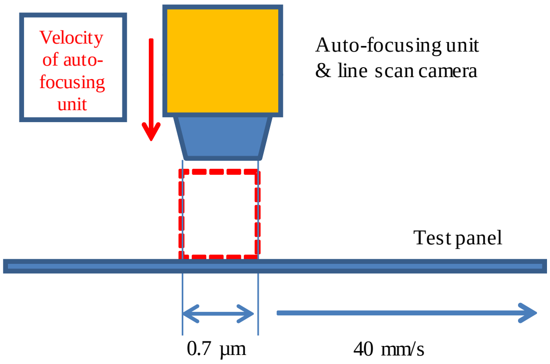


Figure 1: Line scan camera in AOI system

As shown in Fig. 1, the time taken to move one pixel when the test panel moves at 40 mm/s (0.7 µm based on the Dalsa line scan camera for using LCD panel inspection) is calculated as follows;

Moving time = moving distance / speed
= (0.7 m / 1000) / 40 mm/s
= 0.0000175 s
= 0.0175 ms = 17.5 µs

Therefore, the exposure and shutting time required for the line scan camera to take one pixel size may be 17.5 µs or less. The width of 0.7 µs is called object pixel resolution, which is determined by the magnification of the lens to be photographed. That is to say, when a lens having a magnification of 10 times is used, the camera pixel size is divided by the lens magnification. Exposure and shutting time of the line scan camera used in the actual process can be taken even in a range much shorter than the above calculated value.

As shown in the previous figure, the sharpest image can be obtained only if the feed rate of the auto-focusing unit accurately follows the exposure and shutting speed of the line scan camera.

In fact, since the transferring distance of the auto-focusing unit is determined by the surface condition of the inspection panel, it is a key factor to reduce the difference in surface irregularities for obtaining a clear image. The actual transferring distance of the auto-focusing unit is determined by the exact focus range inputted in the initial setting. Within the range of the focal depth of the objective lens(the area where the focus is maintained), the auto-focusing unit need not to move intentionally to take a picture.

Therefore, in order to obtain a clear image, it is important to keep the surface irregularities of the inspection panel within the depth range of the mounted objective lens. Also, if the feed rate for auto-focusing of the auto-focusing unit is slower than the feed rate of the inspection panel, the focus is lost and blur appears.

ANISOTROPIC CONDUCTIVE FILM(ACF)

ACF is an adhesive film in which conductive particles are dispersed uniformly in a thermosetting resin such as an epoxy resin or an acrylic resin [3, 4]. Through the thermo-compression bonding process, the ACF has electrically conductibility in direction of the thickness (up and down) while it does not have electrically conductibility in direction of the width (left and right). Therefore, it is called as ACF [5]. ACFs are used for connecting tape-automated- bonding (TAB) or chip-on-film(COF) to indium-tin-oxide(ITO) electrodes or printed circuit boards (PCB) on LCD panels shown as Fig. 2. As the bump of driver ICs is getting smaller and fine-pitched, the capability of fine-pitched ACF interconnection is much more desired for chip on glass(COG) and even out-lead-bonding(OLB) assemblies [6].

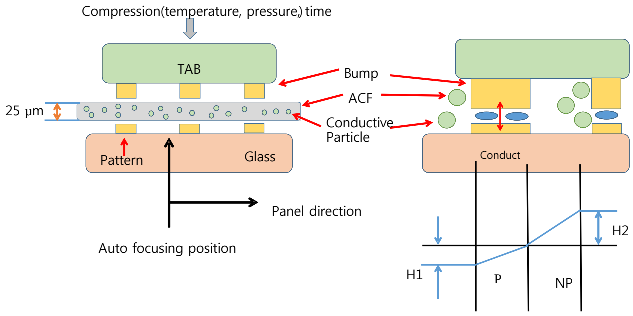


Figure 2: Bonding driver IC in LCD panel

As shown in Fig. 2, the structure of the LCD panel consists of a patterned portion and a non-patterned portion on the upper surface of the glass, and ACFs disposed for bonding the glass and the tab between both. In the above bonding process, the conductive particles inside the ACF are broken by the compression method at a high temperature around 160°C to 180°C, and the electrode pattern on the glass and the TAB bump are bonded.

Looking into the bonding structure, the P region having the electrode pattern is formed by compressed the conductive particles in the ACF, and after they were partially protruded, the space between the both electrodes is reduced due to the compressing. So that a clear image can be obtained. However, in the NP region without the electrode pattern, unbroken conductive particles exist between the glass and the TAB, and they are not uniformly distributed. As a result, the distance between the TAB and the glass is not uniform. It may cause out-range of the focal depth of the mounted lens. In that case, a blurred image can be taken or the image quality is deteriorated.

SELF-MANUFACTURING A BONDING PRESS

The bonding process was performed using a self-manufactured bonding press. As shown in Fig. 3, the bonding press was manufactured by using a manual hydraulic press machine, an electric heater, and a pressure gauge. Samples used for the experiment were ITO glass (20 x 20 mm), flat flexible connectors (6pin, 7mm (Parlex, USA)), and. ACF(TSC5030HN produced by Nanotech, Korea).

Initial bonding conditions are shown as in Table 1.

Table 1: Bonding conditions

		Temperature (°C)	Bonding Time(s)	Pressure (Mpa)	Remark
Pre-bonding	Standard Condition	40-70	1-2	1-2	
Main bonding	Standard Condition	140-200	≥5	1-3	
	Recommended Condition	160	15	3	NANO Tech.

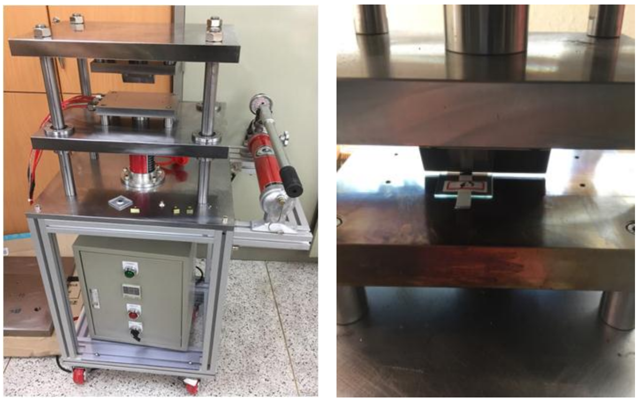


Figure 3: The ACF bonding press

EXPERIMENT

PRESSURE

A pressure test was performed using an ACF (TSC5030HN-35) suitable for the 6pin FFC used in the experiment. First, the change of the conductive particles according to the pressure was observed. At a pressure of 1 bar, we observed that the adhesive matrix around the conductive particles was not fully adhered to the electrode pads and some parts were partly floated. From 1.5 bar to 3 bar, the adhesive matrix was fully compressed on the pad(see Fig. 4). Also, as the pressure was increased, the diameter of the indentation mark was increased. At 4 bar, the adhesive matrix was observed to be cracked. Based on test results, a pressure of about 2 bar seemed to be optimal.

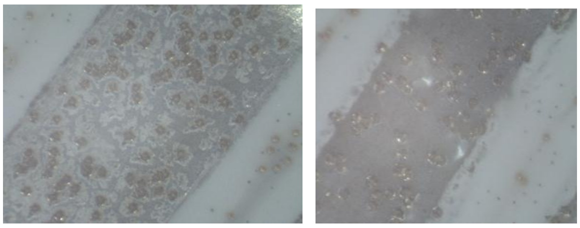

(a) 1 bar (b) 2 bar

Figure 4: Some test results of changing press

COMPRESSION TIME

Next, the change of the conductive particles according to time was observed. At 160℃, the pressure was fixed at 1.5 bar and the compression time was changed. In the case of the compression time of 10s, the adhesive matrix was floating on the electrode pad in the place where there was no conductive particles, and in the case of 15 s and 18 s, the conductive particles and the adhesive matrix were stably bonded and adhered on the electrode pad respectively. In the case of 20 s, the adhesive matrix showed a very thin thickness. Therefore, it was judged that the optimal compressing time was about 15 s as shown as Fig 5.

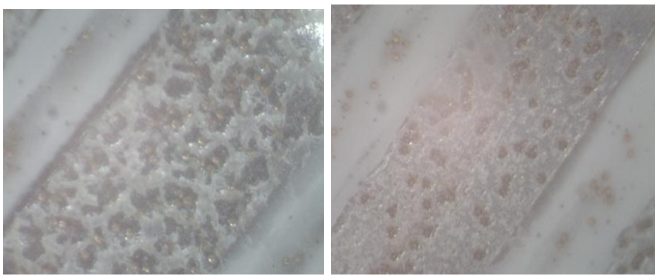

(a) 10 s (b) 15 s

Figure 5: Some test results of changing compression time

COMPRESSION TEMPERATURE

Finally, we observed the change with the temperature. The pressure was fixed at 1.5 bar, the compression time was 15 s, and the temperature was changed. At 120℃ and 140℃, there were regions where the adhesive matrix was not completely adhered onto the electrode pads, and at 160°C and 180°C, the adhesive matrix was completely bonded and adhered. From 180℃, it found that the adhesive matrix deteriorated and turned red due to heat. In the case of 200℃, even though the bonding state was good, the adhesive matrix deteriorated severely and it was observed that the adhesive matrix hardened. We noticed that the adhesive matrix loses its elasticity and lowers the adhesive strength, when it hardens too much. Therefore, it is considered that 160℃ of the bonding temperature is optimal condition (see Fig. 6).

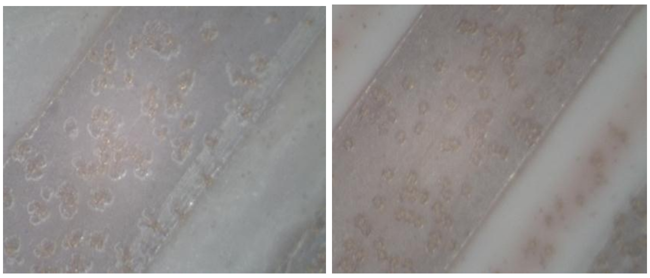

(a) 120℃ (b) 160℃

Figure 6: Some test results of changing temperature

CONTACT RESISTANCE ANALYSIS BY BONDING CONDITION

The contact resistance was measured for each sample in order to examine the availability of them.

Contact resistance by pressure

The contact resistance measured for each pin of the samples in order to compare for each pressure. The results are shown in Fig. 7.

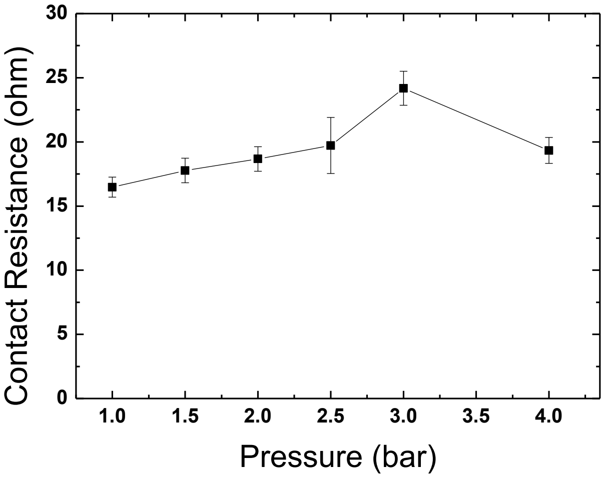


Figure 7: Contact resistance as a function of pressure

As shown in the graph, the lowest contact resistance shows at one bar and the contact resistance of each pin at 1bar shows the smallest in the range of change. We observe that the contact resistance increases with increasing pressure. Because the contact resistance is similar at a pressure range between one and two bar, it expects to have almost the same effect on bonding performance even under certain pressure conditions in the above pressure range.

Contact resistance by compressing time

The contact resistances measured for the pins of the samples made to compare by compression time are shown in Fig. 8.

In the case of 10 s, the adhesive matrix is not completely adhered to the electrode pad, so that some of the conductive particles are bond to the electrode pad incompletely. Because of that, the contact resistance shows high. As shown the graph, 15 s of the contact time shows the lowest contact resistance and the standard deviation between the pins shows the lowest.

As the compressing time becomes longer, the contact resistance tends to increase. It is thought that this is because the adhesive tape is completely cured in about 20 seconds, and therefore the elasticity is reduced and the contact area is reduced[7, 8].

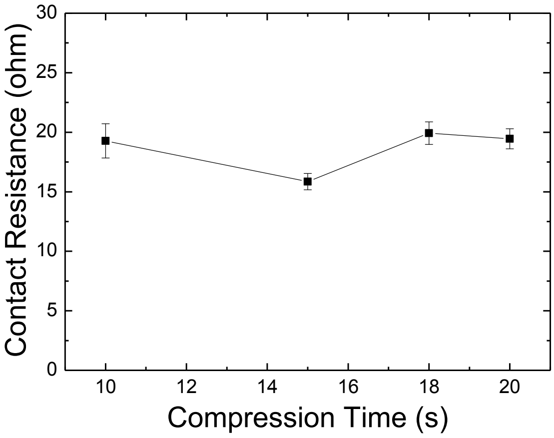


Figure 8: Contact resistance as a function of compression time

Contact resistance by compression temperature

In order to compare the contact resistance by the compression temperature, the contact resistances measured for the pins of samples are shown in Fig. 9.

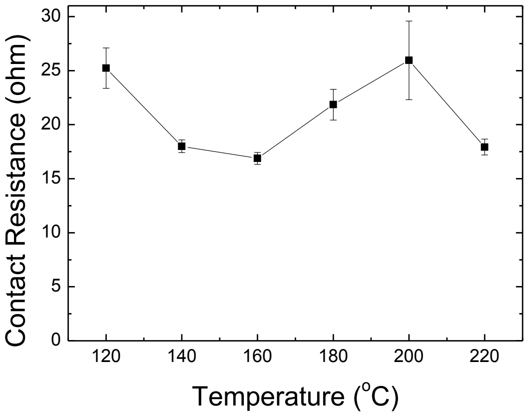


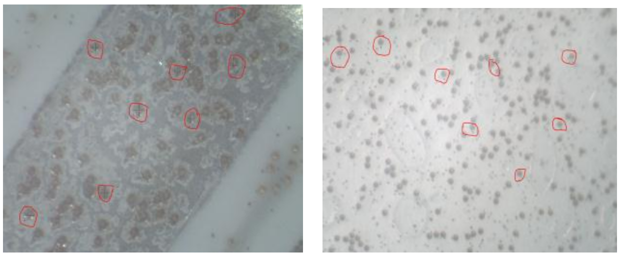
Figure 9: Contact resistance as function of temperature

In the case of 120°C, the adhesion matrix is not fully adhered to the electrode pad, so that the contact area of the broken conductive particles is small and the contact resistance is generally high. At 160°C, the average contact resistance is the lowest and the standard deviation is small too. It means that the entire pin has a similar contact area. From the pictures of Fig.6, we identify that the sample of 160°C has the perfect connection. These trends show that when the temperature is low, the adhesion is not perfect and the contact resistance is high. On the contrary, at 160°C or more, complete adhesion achieved and the contact resistance becomes low. In case that the temperature is too high, the hardening of the adhesive matrix becomes severe and the elasticity is lost, and the contact resistance tends to increase again.

RELATION BETWEEN PRESSURE AND INDENTATION RADIUS

The changes in the radius and thickness of the indentations by pressure were investigated with respect to the compression pressure which had the most effect on the size of the irregularities on the surface of the inspection panel. 8 indentations were selected for each pressure data from the previously obtained images as shown in Fig. 10, and compared with the conductive particles of 0 bar in the unpressurized state (the width was calculated using the number of pixels occupied).

The radii and thicknesses of the indentations by pressure calculated by the number of pixels are shown in Fig. 11. A significant trend line except for 2 bar can be acquired. In other words, the indentation radius tends to increase with increasing pressure, and indentation thickness gradually decreases.



(a) 0 bar (b) 1 bar

Figure 10: Some indentations for measuring size by pixel

Figure 11: The thickness of the Indentation by pressure.

* The value of 0 bar was obtained by calculating the sphere volume with the radius of the measured conductive particles, and then changing the value to the cylinder volume.

DISCUSSION

Comparing the image data of the samples with the contact resistances of the three factors (pressure, compression time, temperature) affecting the ACF bonding, we found that 1 to 2 bar in pressure can be the optimal bonding condition because the contact resistance is small. Also, it was found that the radius and thickness of the indentation calculated using the pixel value for each pressure were linear with the change in pressure.

These results demonstrate that the bonding condition which the bonding thickness between electric pad of driver ICs and LCD panel falls within the depth range of the mounted objective lenses can be found using the combination of pressure, compression time, and temperature. Therefore, in order to obtain a clear image, it is important to restrict the excessive transfer of the auto-focusing unit by restricting the surface change of the test panel within the depth of the objective lens during COG bonding process.

From the results of the this test, it seems that the bonding conditions of 160°C, 1 bar and 15 s are optimal conditions for the self-manufactured bonding press and the used materials.

However, although it has not been reviewed here, it seems to be more realistic to find the bonding conditions considering the long-term storage stability factor, and this factor should also be considered [9, 10].

CONSLUSION

In this study, the optimum bonding condition of ACF was experimented to increase the accuracy of indentation recognition in COG process. Test results show that the bonding condition of 160°C, 1 bar and 15 s is most advisable for acquiring better resolution indentation images.

Using the linear relation between indentation thickness and pressure, the image that has highly recognized indentation marks easily acquired.

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