

Study of ACF Bonding Technology in Flexible Display Module Packages

Yen-Huei Lai*, Wan-Tsang Wang*, Chia-Hsun Tu*, Keh-Long Hwu*, Hsueh-Hsing Lu,
Lee-Hsun Chang* and Yu-Hsin Lin*****

*Advanced System Technology Div., AU Optronics Corp., Hsinchu, Taiwan, R.O.C.

**Advanced Process Research Div., AU Optronics Corp., Hsinchu, Taiwan, R.O.C.

***Advanced Technology Platform Center, AU Optronics Corp., Hsinchu, Taiwan, R.O.C.

Abstract

Anisotropic conductive film (ACF) has been used for more than 30 years in flat panel display (FPD) module package. In this paper, the technical trends and development of ACF are described. Among all of them, ACF material design for flexible substrate bonding is critical for the development of flexible display. According to different process flow of flexible AMOLED, flexible substrate bonding technologies can be classified as “PI/Glass” and “Film type” substrate bonding. That is to say the flexible substrate bonding process can be implemented before and after PI substrate separation from the original carrier glass substrate. Based on the current results, soft conductive particles of ACF are developed and chosen in the PI/Glass substrate bonding. For the film type substrate bonding, especially in IC bonding, the design of ACF is very important in avoiding the insufficient conductive particle deformation issue induced by the sink of plastic substrate. Here, we present a feasible and simple flexible substrate bonding technology to package driver IC, FPC or COF for flexible AMOLED application.

Keywords: Flexible, Bonding process, ACF

1. Introduction

Anisotropic conductive film (ACF) has been widely used as interconnection material in flat panel display (FPD) module package, that is, to connect the drive IC, COF (chip on film) or FPC (flexible printed circuit) with the electrodes of FPD panel or PCB (printed circuit board) [1-2]. It is proven a more compact, robust and cost effective bonding method than other bonding technologies. However, this technology also faces great challenges due to the miniaturization of electronic devices, the demand of

higher resolution as well as the advent of flexible display. In order to achieve these requirements, intense efforts have been made to develop new ACF materials. According to the recent progress on ACF, the future development trends of ACF can be briefly classified into three major trends: low temperature bonding, fine pitch bonding and flexible substrate bonding. In this paper, these technical trends and development of ACF are discussed, with the particular emphasis on the flexible substrate bonding technology, including their issues, failure analyses and technical solutions.

2. Technical trends and development of ACF

In recent years, many studies or LCD module manufacturers both indicate that lowering bonding temperature of ACF is very important in avoiding the warpage issue and light leakage issue when driver IC is packaged in LCD modules. Especially, the overall trends are expected to be slimmer border and thinner panel and reducing the bonding temperature is one of important technical development in ACF bonding technology. In addition, for film type touch panel or flexible display applications, low bonding temperature of ACF is also prerequisite to reduce the thermal damage of plastic substrate.

In terms of fine pitch bonding, because of high resolution requirement, many innovative strategies have been developed to prevent the short circuit issue induced by the aggregation of conductive particles between bumps or leads, such as insulation surface treatment, two-layer ACF design and fixed array ACF design.

For flexible substrate bonding, it is another new technology evaluation for module bonding on plastic substrate of flexible display. Flexible displays have been discussed for years, and most

people are looking forward to getting the different applications from it. Among the many media technologies, AMOLED has been considered the most ideal media for flexible display applications because it is self-emissive and optical condition doesn't change when device structure is bent or twisted.

However, a flexible AMOLED includes a plastic substrate rather than a conventional glass substrate. So, it is required to apply different ACF materials, designs and bonding parameters for module bonding on plastic substrate. In the next section, our recent experimental results in flexible substrate bonding are described.

3. Flexible substrate bonding technologies

According to different process flow of flexible AMOLED, flexible substrate bonding technologies can be classified as PI/Glass and film type substrate bonding. That is to say the flexible substrate bonding process can be implemented before and after PI substrate separation from the original carrier glass substrate. Figure 1 shows the different between PI/Glass and film type substrate in respects to vertically-stacked structure.

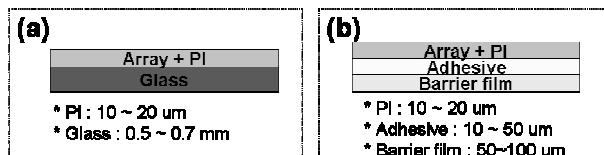


Figure 1. The structure of (a) PI/Glass and (b) film type bonding substrate.

3.1 Bonding on PI/Glass substrate

At the beginning stage of development, it is found that hard conductive particle of ACF or inappropriate bonding parameters will result in the thin film cracking which has a significant influence on display performance. To solve this problem, soft conductive particle of ACF are developed and used in the PI/Glass substrate bonding. Figure 2 presents a SEM cross section image of driver IC bonded on PI/Glass substrate using different hardness of conductive particle. It is indicated that soft conductive particle of ACF is preferred to use in PI/Glass substrate.

Furthermore, for mass production and improving yield rate on PI substrate lift-off process, flexible substrate bonding process after PI substrate lifted off are evaluated and developed.

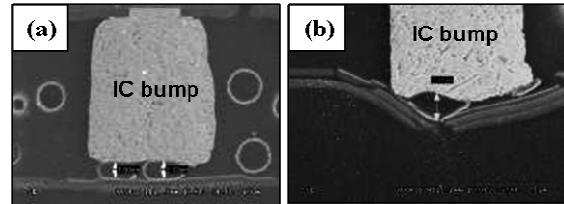


Figure 2. Driver IC bonding on PI/Glass substrate using (a) soft and (b) hard conductive particles.

3.2 Bonding on film type substrate

Bonding process after PI substrate lifted off has many potential advantages for manufacture of flexible AMOLED, such as easy to manage, large-scale and high yield rate of laser lift off or mechanical debonding process due to without interference of driver IC or FPC packaging on flexible substrate. However, module bonding process is becoming more and more difficult when film type substrate replaces PI/Glass substrate.

Figure 3 illustrates a cross section of the connected part after completion of film type substrate bonding for IC and FPC respectively. It is interesting to note that the adhesive of barrier film absorbs the most part of bonding pressure, which has a negative influence on the reliability of the interconnections, especially for IC bonding applications.

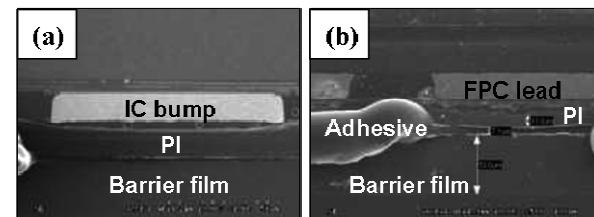


Figure 3. Module package on film type substrate: (a) IC and (b) FPC bonding applications.

In addition, the pliability of the film type substrate may cause some problems during the bonding process. The issues and corresponding solutions of film type substrate bonding technology will be discussed in detail in the subsequent section.

4. Film type bonding issues

To realize this film type bonding technology, it is required to overcome the following issues, such as plastic film warpage, Akkon weaken or array crack and plastic substrate sink.

4.1 Plastic film warpage

In terms of film type bonding, the first problem is the issue of plastic film warpage when free form film type substrate replaces the rigid PI/Glass substrate. Figure 4 shows the example of PI/Glass and film type substrate, respectively.

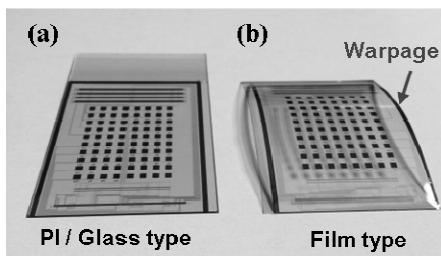


Figure 4. A example of (a) PI/Glass substrate and (b) film type substrate.

This warpage issue may result in the film sample handling difficult and fuzzy CCD alignment during bonding process. To ease this issue, bonding machine need to be modified and designed for film type bonding applications.

4.2 Akkon weaken or array crack

For FPC bonding applications, film type bonding would induce two major problems at the early of development. First, Akkon weaken often be observed in film type bonding and thereby lead to high contact resistance. Second, when high bonding pressure is used to solve high contact resistance issue, it may cause array crack. Examples of such Akkon weaken and array crack issues are presented in Figure 5.

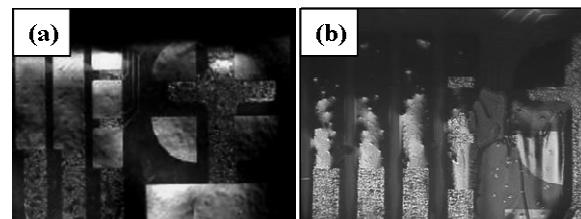


Figure 5. Microscope images presenting the (a) Akkon weaken and (b) array crack issues.

To get better bonding quality, special ACF designs and development are inevitable for film type substrate bonding. Finally, we can achieve the film type substrate bonding with good quality by using new ACF developed from ACF suppliers, as shown in Figure 6. The results indicate that the design of ACF is very important for good quality interconnections.

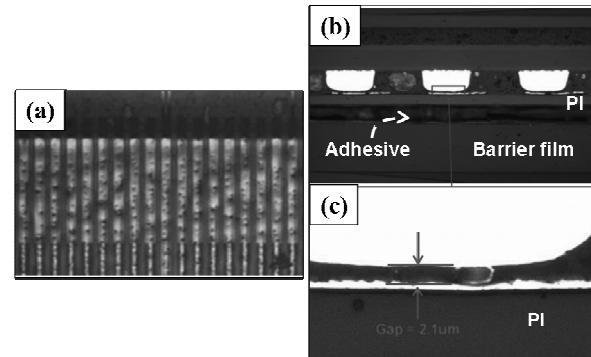


Figure 6. Microscope images for FPC bonding on the film type substrate: (a) clear Akkon, (b) smooth film type substrate and (c) typical deformation degree of conductive particle.

4.3 Plastic substrate sink

Next, for IC bonding applications, IC bonding on film type substrate has very poor interconnection characteristic at normal ACF bonding condition (180 °C / 30~100 MPa / 5~10 sec). By means of SEM cross section analysis, it is found that poor interconnection quality is resulted from insufficient conductive particle deformation, as shown in Figure 7.

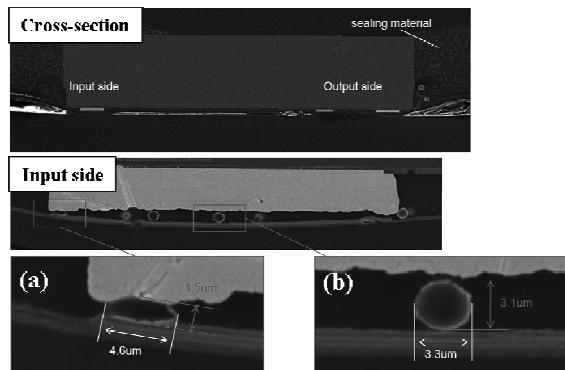


Figure 7. Micrographs presenting the cross section of IC package on the film type substrate: (a) normal conductive particle deformation and (b) no or less deformation at middle of input bump.

Moreover, further in-depth analysis, the insufficient conductive particle deformation may as a result of PI substrate sink induced from adhesive flowing.

Thus, the design of ACF is needed and developed in avoiding PI substrate sink. Figure 8 shows SEM micrographs of driver IC packaged on film type substrates with two different ACF, that is, using special developmental ACF and common ACF. As can be seen, no obvious adhesive flowing occurs by using special developmental ACF and thereby increases the quality of the interconnection. In contrast, the adhesive of barrier film flows away and absorbs the most part of bonding pressure when using common ACF. It is worth pointing out that conductive particle deformation of common ACF is not sufficient to achieve a good contact. The results indicate again that the design of ACF is very important for film type substrate bonding applications.

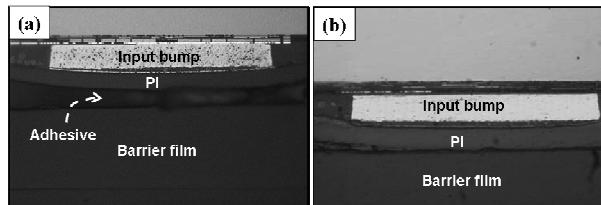


Figure 8. Driver IC bonding on film type substrate using (a) special developmental ACF and (b) common ACF.

5. Conclusion

In this paper, several OM and SEM analyses of ACF interconnections are described. Many of these have been critical to both understanding the failure model of flexible substrate bonding and also for the development of the novel ACF. For the PI/Glass substrate bonding, soft conductive particles of ACF are developed and chosen. For the film type substrate bonding, the design of ACF is very important in avoiding the insufficient conductive particle deformation issue induced by the sink of plastic substrate. In the future, we continue to develop new ACF, special hardness of conductive particles and film substrate handling methods in order to meet the requirement of flexible substrate bonding technologies.

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7. References

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