

19.1: Invited Paper: Driver IC Packaging Technologies using Anisotropic Conductive Films in Flat Panel Display

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Abstract

Anisotropic conductive films (ACFs) are adhesive films with anisotropic conductivity induced by dispersing conducting particles such as metal coated plastic balls and metal particles into polymer matrices such as thermoplastics and thermosetting resins. ACFs have been widely used for driver IC packaging technologies in FPDs (Flat panel displays) such as LCDs (Liquid crystal displays) for last two decades. So far various packaging technologies such as TCP (Tape carrier package) on LCD panel or PWB (Printed wiring board), COF (Chip on flex) on LCD panel or PWB, and COG (Chip on Glass) using ACFs have been realized to meet the requirement of fine pitch capability and make the flat panel displays smaller, lighter and thinner. In this paper, the history of ACF and driver IC packaging are described. In addition, it is mentioned that how important driver IC packaging is in implementing the miniaturization, high resolution, low cost and high display quality. ACF material design for COF which is advantageous in fine pitch interconnection is described. It is indicated that low temperature curable ACF is very useful in improving productivity of LCD modules and reducing the thermal stress at the interface in large LCD modules. We also indicate that the warpage of LCD panel after COG interconnection induces the light linkage issue in LCD modules. Lowering bonding temperature of ACF is also very important in reducing the warpage issue and avoiding the light linkage issue when COG is applied for driver IC packaging in large LCD modules.

1. Introduction

ACFs are thermosetting based adhesive films in which the three to five μm size of conducting particles such as Ni particles and metal coated plastic spheres are dispersed. The ACF can mechanically and electrically bond several thousand electrodes with 30-200 μm pitches by applying heat and pressure for around 10-15 sec. The connection mechanism of ACF is shown in figure 1. The ACF has been widely used as an interconnect material for driver IC packaging in FPD such as LCD, plasma display and organic EL display for last 20 decades. Driver IC packaging technologies using ACFs have played an important role in the development of LCD technologies which require high resolution, light weight, thin package and low consumption power [1]-[4]. Especially, driver IC packaging using ACF has contributed toward high resolution of LCD and making LCD modules thinner, lighter and smaller. Generally, ACF interconnection between TCP or COF on which driver IC was attached, and LCD panel, ACF interconnection between TCP or COF on which driver IC was attached, and PWB, and COG using ACF are used as driver IC packaging in LCD shown in figure 2. In this paper, the history of ACF and driver IC packaging are described. In addition, it is mentioned that how important driver IC packaging is in implementing the miniaturization, high resolution, low cost and high display quality.

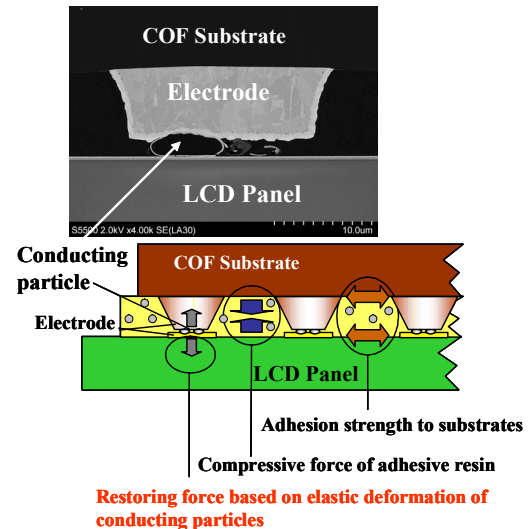


Figure 1 Connection mechanism of ACF

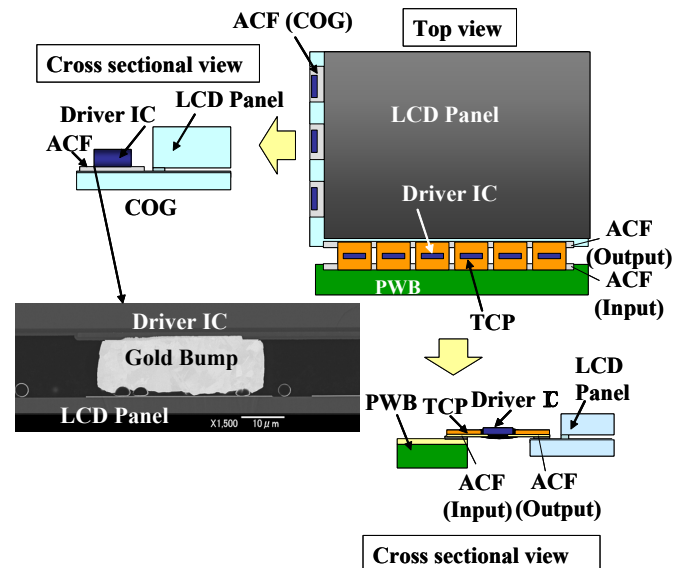


Figure 2 Example of driver IC packaging using ACF in LCD

2. History of ACF and driver IC packaging technologies

In late 1970s, we had tried to render a dicing tape electrically conductive to avoid the influence of static electricity during dicing of wafer. To render the dicing tape electrically conductive, we had simply filled the conductive fillers into pressure-sensitive adhesives. However, when we fill at least 40 % volume fractions of conductive fillers such as carbon black to make the adhesives electrically conductive, we have to sacrifice the pressure-sensitive properties and are able to apply to the dicing tape no more. Therefore, we thought how we can render the adhesive electrically conductive without any degradation of pressure-sensitive properties and focused on the adhesive with low volume fractions of conductive fillers. During the investigation, we had accidentally found out the anisotropic conductive phenomenon which the high electric conductivity is obtained only in perpendicular to the film plane in the polymer-conductive fillers composite films filled with low volume fractions of fillers [2].

In the late 1970s-the early 1980s, LCD technologies had been mainly used for the electronic calculator. Since ITO based electrodes are formed onto a LCD panel, solder joint technologies which are widely used for electronics application can not be used for driver IC packaging. In those days, mainly zebra-strip-type rubber had been used for driver IC packaging in LCD modules for electronic calculators. In addition, an anisotropic conductive sheet filled with carbon fiber was also used for the same purpose. However, these anisotropic conductive materials can be applicable to only more than 500 μ m pitches of interconnection, and alignment processibility is very poor because of their opaqueness. When the LCD technologies were tried to apply to electronic games and note PCs which require the fine pitch interconnection in the early 1980s, new interconnect materials which have fine pitch capability smaller than 200 μ m pitches had been required for the applications. In almost same time, we had found out the anisotropic conductive phenomena [5] as described before and succeeded in commercializing Ni particle-filled ACF which is almost same structure of current ACF for the first time in the world in the early 1980s.

The driver IC packaging technologies using ACF has contributed to the implementation of high resolution of LCD. Fine pitch capability of ACF has been significantly improved by using metal plated plastic spheres in the late 1980s[6]. Now the fine pitch capability of ACF as small as 25-30 μ m has been realized in COG by using double-layer structure of ACF[7] and surface treated metal plated plastic sphere technology. Also the performance of adhesives of ACF has been improved a lot by developing latent thermosetting resin systems with low temperature curability and base resin system with strong adhesion properties. At the beginning of ACF material technology development in the early 1980s, thermoplastics were used as adhesives in ACFs because of their processibility and solubility in organic solvents. However, since the thermoplastics have relatively low Tg and do not have interchain crosslinks, ACFs fabricated with thermoplastics do not have enough reliability in electronic products. The thermosetting based ACF was released into the market by developing the latent thermosetting resin system which has fast curability and long pot life at room temperature in the early 1990s. The developed thermosetting based ACF was used for note PCs in 1992. In addition, the performance of the thermosetting based adhesive of ACF was

improved for bare chip interconnection such as COG. The ACF was applied to COG interconnection for medium size of LCD such as electronic games and audiovisual products in 1994.

LCD module manufactures have been interested in reducing interconnection pitch and lowering bonding temperature to avoid thermal damage of bonding substrates, and to improve the productivity of LCD modules since around 2000. In the next section, the recent technological trend of driver IC packaging in LCD modules is described.

3. Driver IC packaging technologies for TCP(COF)-LCD Panel Interconnection

So far most of LCD modules larger than 10 inches have been assembled by TCP interconnection technologies using ACFs. The fine pitch capability smaller than 50 μ m is required in outer lead interconnection of TCP using ACF, as LCD resolution increases. It is said that the limitation of outer lead of TCP is 50 μ m pitch. In order to improve the fine pitch capability, COF technologies have been introduced in driver IC packaging of large LCD modules since 2002. The COF technologies would overcome the limitation of the fine pitch capability in TCP by using thin Cu foils and low CTE base film materials. Therefore, outer lead interconnection of COF using ACF has been of much interest because it provides the fine pitch capability smaller than 50 μ m pitch. In addition, COF is much thinner than TCP, and it provides excellent bending properties. Now COF-LCD interconnection as small as 40 μ m has been realized by using ACF filled with 3 μ m metal coated plastic spheres.

For ACF in COF technologies, strong adhesion strength against COF substrates and short time bonding are required. Since the surface of COF is very smooth, and consists of inert polyimide, it is said that the adhesion strength of ACF in COF interconnection is generally weaker than that in TCP. We have developed ACF with strong adhesion strength against COF by introducing the functional group into base resin of ACF and reducing the internal stress as shown in figure 3.

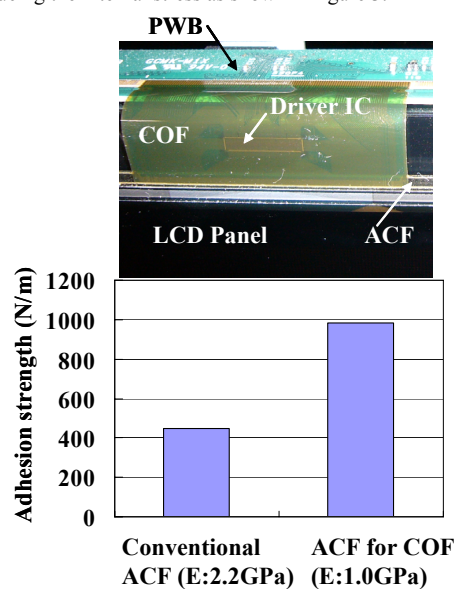


Figure 3 Adhesion strength between COF and LCD panel

Conventionally epoxy based ACF was used for LCD panel-TCP(COF) interconnection, and the bonding time was normally 10-15 sec.. Now the production volume of LCD module has significantly increased and the reduction of bonding time(ex: shorter than 10 sec.) is needed to increase the productivity of LCD modules. In order to meet the requirements, we have developed new ACF with high reactivity by utilizing new curing system.

Figure 4 shows the connection reliability test results of low temperature curable ACF. The low temperature curable ACF deforms metal coated plastic spheres sufficiently, and the joints are retained even after exposed to a high temperature humidity test because the ACF is fully cured. On the other hand, conventional epoxy based ACF provides insufficient particle deformation in joints at even higher temperature bonding because the ACF was not fully cured yet. Therefore, the contact resistance increases after exposed to a high temperature humidity test as shown in fig.4. Driver IC packaging using the low temperature curable has used for COF-LCD interconnection in large LCD modules for note PCs, monitors and TVs, etc. and contributed to the improvement of productivity of the LCD modules.

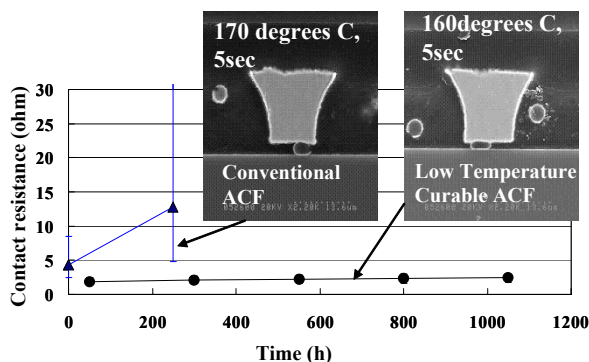


Figure 4. Connection reliability of low temperature curable ACF

4. Driver IC packaging for TCP(COF)-PWB Interconnection

Conventionally, TCP/PWB interconnection in LCD modules is performed using an ACF which can connect at 180-190 degrees C (10-15sec.). However, when the bonding temperature exceeds over the T_g (160-170 degrees C) of PWB, the increase of the thermal stress at the ACF joints and the warpage of PWB are induced. Therefore, lowering bonding temperature (below 160 degrees C, bonding time: <10 sec.) of ACF in TCP/PWB interconnection is very effective in solving these problems. As shown in figure 5, three-dimensional finite element model (3-D FE model) has been conducted. Since the TCP-PWB interconnection is conducted after bonding TCP onto LCD panel, PWB is restrained mechanically during the bonding, and PWB shrinks more than LCD panel after the bonding. Therefore, the thermal stress is induced at bonding area of the edge of PWB. It is known that the stress at the interface between ACF and PWB decreases with lowering the bonding temperature from the simulation analysis. This simulation analysis also indicates that the low temperature curable ACF is effective in improving the connection reliability.

Since low temperature curability of ACF is determined by the reactivity of curing agents in the ACF, we explored various curing agents, and adhesive resin including reactive resin, and additives. In order to satisfy both low temperature curability and the long pot life at room temperature, we designed the adhesive formulation including a new curing agent. The low temperature curable ACF shows the curing degree higher than 80% at around 40 degrees C lower temperature than the conventional ACF as shown in figure 6. In addition, we confirmed that the ACF shows the pot life longer than 30 days at 23 degrees C as well as the conventional ACF. The reliable ACF joint with strong adhesion strength is accomplished by the cross-linking of polymer matrix of ACF and the reaction rate should exceed 80%. The low temperature curable ACF shows the strong adhesion strength as high as 1000N/m which compares with 300N/m in the case of using the conventional ACF at low temperature bonding (140 degrees C). The developed low temperature curable ACF shows no increase in contact resistance even when the interconnection was performed at 40 degrees C lower than the conventional ACF. Therefore, the developed ACF is expected to apply for the large volume of LCD module manufacturing process and the bonding substrate with low heat resistance. The low temperature curable ACF has been widely used for TCP-PWB interconnection in large size of LCD modules such as note PCs, monitors and TVs. In addition, we can expect to replace solder joint and board-to-board connectors with these ACFs for environmentally friendly and high density interconnection in portable electronic products such as cellular phones.

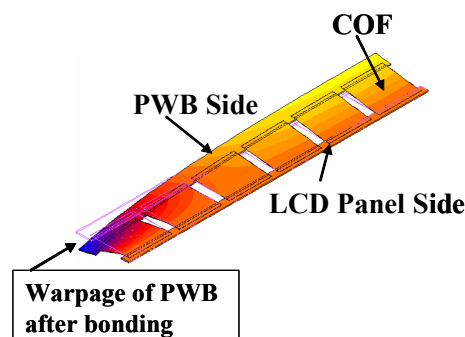


Figure 5 Simulation analysis of PWB-COF interconnection using ACF

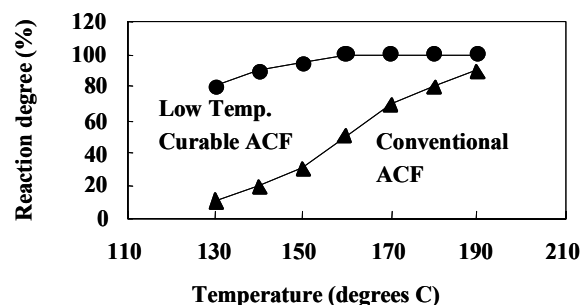


Figure 6 Reaction degree of ACF as a function of bonding temperature in PWB-COF interconnection

5. Driver IC packaging technologies for COG Interconnection

COG technology using ACF is typically conducted by flip-chip and widely used for relatively small size of LCD modules for cellular phones and audiovisual products. COG is advantageous in reducing cost and making the LCD module smaller and lighter, because there is no tape and inner lead bonding unlike TCP and COF. However, when COG using ACF has been used for relatively large size of LCD modules such as note PCs and monitors, it should be considered that the CTE mismatch between a driver IC and a LCD panel causes the thermal stress at the interface, resulting in warpage behavior after COG bonding. The warpage behavior of COG induces the light leakage issue on the panel around driver IC attached by COG as shown in figure 7. In order to understand the warpage behavior of COG using ACF, we have done the elastic simulation analysis. The simulation analysis indicated that the warpage issue of LCD panel is due to the temperature difference between driver IC and LCD panel during bonding. In other words, the temperature difference between the driver IC chip and the LCD panel is more dominant and promotes the extension of the IC regardless of its low CTE. The driver IC attached LCD panel by COG bends concavely since actual temperature of the LCD panel is much lower than that of IC chip, and the IC chip shrinks more than the LCD panel after COG bonding. In addition, the technological trend toward thin LCD panel makes the warpage issue more seriously as shown in figure 8.

Light leakage issue

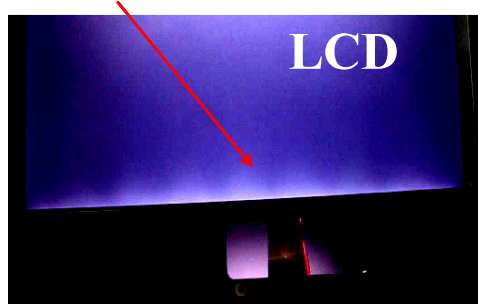


Figure 7 Photograph of light leakage issue induced by warpage of LCD panel fabricated with COG.

The figure 8 indicates that lowering bonding temperature is very important in reducing the warpage of LCD panel after COG. Therefore we have developed a low temperature curable ACF which can be cured below 160 degrees C. The developed ACF reduces the warpage of LCD panel by around 50% compared to conventional ACF in COG interconnection and reduces the light leakage issue of LCD. The ACF has been widely used for COG in driver IC packaging of LCD panels such as note PCs and monitors. From now on, trends toward narrower frame size of LCD panels and thinner LCD panels continue and reducing the warpage of LCD panel is one of important technical challenges in driver IC packaging. We continue to develop new adhesive resin, functional conducting particles, and the novel film structure in order to overcome the challenges.

6. Conclusions

This paper described history of ACF, and recent advances of driver IC packaging technologies using ACF in flat panel display applications. As the trend toward higher resolution continues, fine pitch capability smaller than 40 μm pitches in outer lead interconnection of COF and 20 μm pitches in COG has been required. In order to meet the fine pitch capability, conducting particle material technologies such as surface treatment technologies have been developed. ACF material design for COF which is advantageous in fine pitch interconnection was described. It was indicated that low temperature curable ACF is very effective in improving productivity of LCD modules and lowering the thermal stress at the interface in large LCD modules. In addition, it was mentioned that lowering bonding temperature of ACF is very important in avoiding the light linkage issue induced by the warpage of LCD panel and improving the display quality when COG is applied for driver IC packaging in large LCD modules. We continue to develop new adhesive resin, functional conducting particles, and the novel film structure in order to meet the requirements of fine pitch interconnection, low temperature curability and fast curability in ACF interconnection technologies.

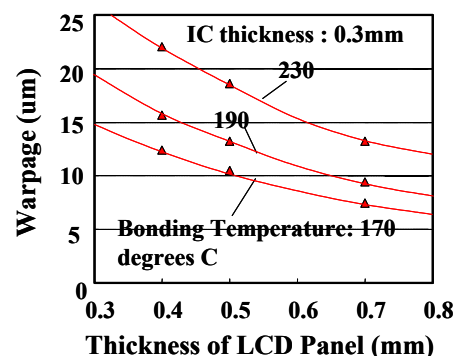


Figure 8. Simulation analysis for warpage behavior of LCD panel fabricated with COG

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