

Film Technologies for Semiconductor & Electronic Components

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Hitachi Chemical's film materials are widely used for small & thin electronic equipment, primary examples of which are anisotropic conductive film (ACF), used to connect displays from the late 1980's and die attach film (DAF) used for memory packages from the late 1990's. These materials using Hitachi Chemical's film technologies have become established global standards and have contributed to a dramatic increase in flat panel display and various other electronic equipment for over 20 years. We will establish low-temperature fine-pitch connection technologies and high heat-radiation, film thickness control technologies to apply to various displays and package structures, on a continuous basis. Furthermore, these materials are also expected to spread to new fields such as three-dimensional packages.

1 Technical Trends and Future Development of Anisotropic Conductive Film

1.1 Introduction

Anisotropic conductive film (ACF) is a film adhesive with uniformly dispersed conductive particles several micrometers in diameter in thermosetting resin. Metal-plated plastic particles, or nickel and other metal particles are used for conductive particles¹. ACF is capable of interconnecting micro electrodes electrically and mechanically within 10 seconds by simultaneously heating and pressurizing². As shown in **Figure 1**, it is used for connecting electrodes of the COF (Chip On Film) package containing a driver IC with the display panel, COF with PWB (Printed Wiring Board) in the assembly of the FPD (Flat Panel Display) such as LCD (Liquid Crystal Display) or OLED (Organic Light-emitting Diodes), and connecting the bare chip of the driver IC on the display panel during the COG (Chip On Glass) process.

LCDs are used for cell phones, laptop PCs, monitors and television, and have recently attracted increasing attention for their contribution to rapid improvements in the performance and production of mobile information terminals, such as smart phones and tablet PCs, featuring excellent operability with high-resolution and high quality displays, slim lightweight bodies and touch control systems. At the same time, ACF has been improved to meet changing needs.

1.2 ACF Products

ACF is a 10–50 μm thick, 1–3 wide and 50–300 m long tape product with conductive particles dispersed on a support film (e.g. PET). As the frames of smart phones and tablet PCs are getting thinner to enlarge the display area, an ACF of 0.8 mm or less in width is discussed.

As shown in **Figure 2**, the ACF is placed on the electrodes, and the upper and lower electrodes are aligned with the ACF inserted in-between, and simultaneously heated to between 150 and 180 °C and pressurized at 2 to 3 MPa. For narrow ACF, its adhesion to the support film must be sufficient to facilitate the separation of ACF from the reel. Excessive adhesion, however, may cause ACF to be drawn by the support film, resulting in failure to attach to the electrodes. Careful adjustment is required to ensure suitable adhesion.

The need for fine pitch interconnection may be met using an anisotropic conductive adhesive (ACA), a printable connecting material that can be easily attached to a micro region using a general-purpose dispenser, but the liquid form of uncured area and unsuitability for fine pitch interconnection restrict its application³.

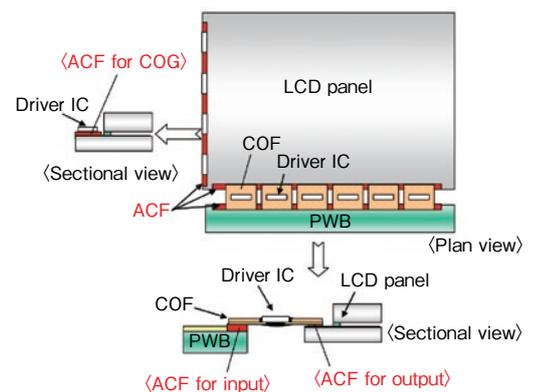


Figure 1 Illustration of Mounting Technology using ACF

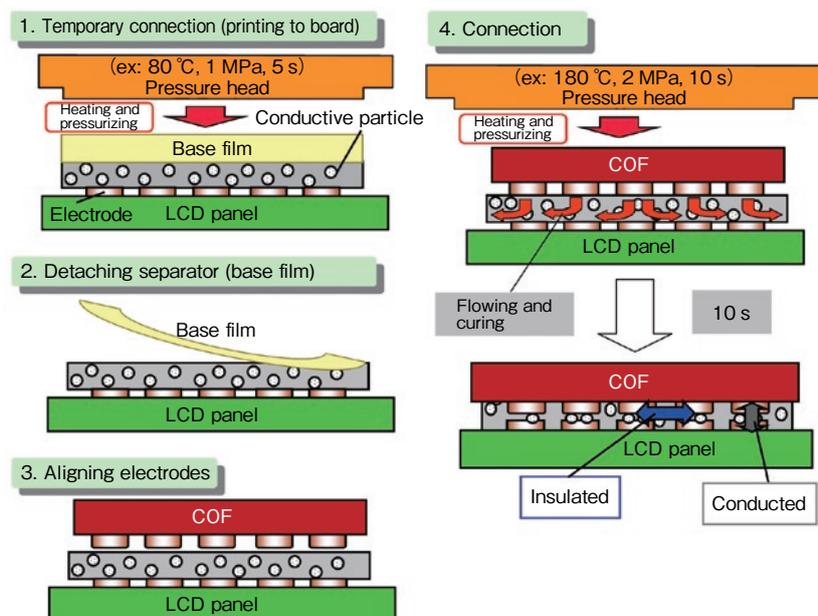


Figure 2 ACF Bonding Process

1.3 Low-temperature Interconnection with ACF

The interconnection using ACF, as shown in **Figure 2**, starts by attaching ACF to the electrodes, whereupon the upper and lower electrodes are aligned with ACF inserted in-between, and heated and pressurized simultaneously to between 150 and 180 °C and 2 to 3 MPa respectively.

The COG packaging is used for mounting devices on small- and medium-sized display panels for smart phones, tablet PCs and other mobile information terminals. COG interconnects the IC chip and glass substrate, both of which are highly elastic, with the ACF, potentially resulting in deformation of the connection area due to the heat-induced stress. Consequently, the brightness of LCD areas near the connection may become uneven, which is known as “uneven display.”

The stress on the connection area is caused by the difference in thermal expansion between the IC chip and glass substrate, due to a temperature gradient arising when the ACF is heated from the IC chip side which the pressure head touches, and the IC chip becomes hotter than the glass substrate. The thermal contraction of the IC chip exceeds that of the glass substrate when they cool to room temperature after being interconnected, causing the glass substrate³⁾ to warp. **Figure 3** shows the relationship between the warpage and the thickness of the IC chip and glass substrate. The IC chip and glass substrate for smart phones and tablet PCs become increasingly thinner, and the thin glass substrate increases the warp. It has been suggested that a low-temperature connection may be effective in preventing the warp.

We have developed and are currently commercializing a product usable for connection at low temperatures, namely 150 °C and 5 s, which is 30 °C lower than the conventional bonding temperature. This product, which has successfully reduced the warp by about 50%, can also effectively reduce any unevenness of LCD displays, hence its widespread use in tablets and thin laptop PCs at present. There is, however, an urgent need to lower the connection temperature more drastically to meet the demand for thinner LCDs, and our new product development is focused on achieving connections at 100 °C and 5 s using a curing method other than hot curing.

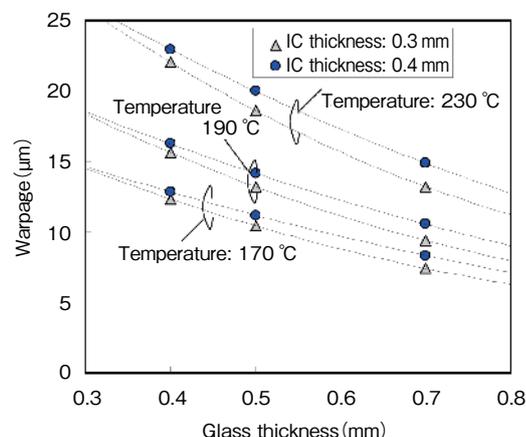


Figure 3 Relationship between Warpage and Thickness of IC (glass)

1.4 Double-layer ACF

In COG interconnection, bare chips are mounted on a glass substrate by connecting the bump on the bare chip with the glass substrate, meaning an electrode area of about 2,000 μm² or less, smaller than the COF connection area, is typical in the COG process. The recent demand for higher resolution panels and shrinking chips requires a bump pitch of less than 15 μm, and a connection area including an allowance for displacement of less than 1,000 μm².

To meet this demand, we have developed and commercialized double-layer ACF that separates functions for bonding and

insulation and conduction respectively, to effectively capture more conductive particles on the electrode⁴). The double-layer ACF consists of an adhesive layer containing dispersed conductive particles (conductive particle layer) and a layer containing only adhesive (adhesive layer). The adhesive layer contains inter-circuit bonding and an insulating function, while the conductive particle layer contains a conduction function. Its application for narrow pitch connections is enabled with more connecting particles captured on the electrode than single-layer film by arranging a layer of thin conductive particles of 10 μm or less on the side of the glass substrate, meaning good performance of the tape, despite the number of particles remaining unchanged.

Uneven distribution of conductive particles on a particular layer, which allows finer pitch connection, is a feature of ACF and paves the way for a new function to control fluidity and adhesion on individual layers. As shown in **Figure 4**, flow reductions on the conductive particle layer exceed the adhesive layer flow during the connection of adhesive, enabling the connecting particle capture rate on the electrode to improve⁵. We are focusing on interconnecting smaller areas, such as 500 μm², by developing these technologies in future.

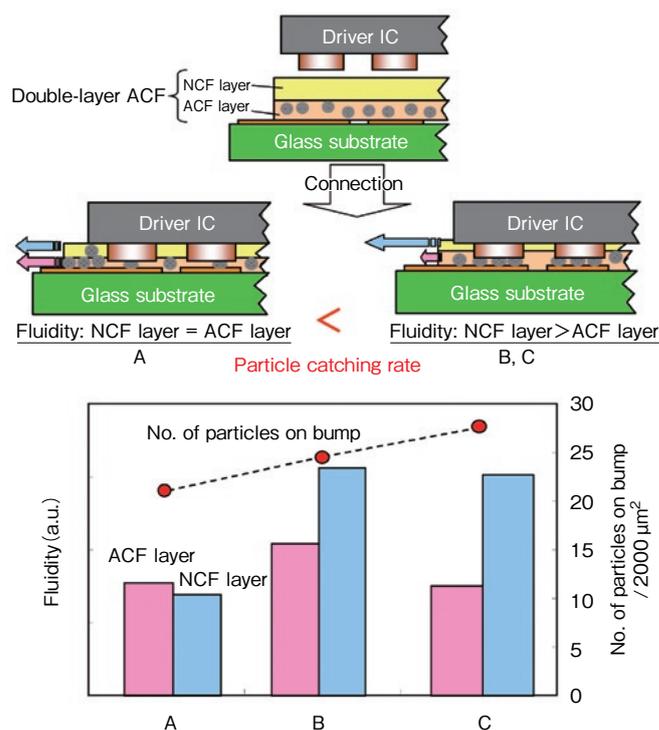


Figure 4 Relationship between Particle Catching Rate and Fluidity

1.5 Conclusion

As mentioned above, ACF for interconnecting FPD devices, typically LCD modules, has evolved based on the advantages of a film adhesive. To meet the needs for thinner substrates in recent mobile information terminals, we are currently developing materials specifically made for low-temperature, finer pitch connections, while considering the importance of developing general-purpose products for more wide-ranging applications in future.

2 Technical Trends and Future Development of Die Attach Film (DAF)

2.1 Technical Trends

As electronic equipment, typically cell phones, becomes faster, more sophisticated and more compact, organic substrate-based area array type packages BGA (Ball Grid Array) and MCP (Multi Chip Packages) are increasingly used as smaller and thinner semiconductor packages enabling high-density mounting⁶). Die bonding films are crucial for these semiconductor packages, which must meet various functions.

Compared with packages using a lead frame, the wire bonding terminal of BGA and MCP packages is significantly closer to the chip, hence the problem of the wire bonding terminal being prone to contamination due to extrusions and bleeds of the conventional die bonding paste. Another problem arising in the latest MCP, which tends to have thinner chips due to the limitation of the package thickness, is the fact that the extra paste may emerge on the surface of the chip. Film-type materials have a definite advantage in this case, and are also advantageous in terms of insulation reliability, void freeness and uniform thickness to prevent chip inclination. To solve the aforementioned problems, we developed the world's first die attach film (DAF) in 1995^{7, 8}).

Figure 5 shows the structure of typical BGA and MCP packages connected with wire bonding. The wire bonding approach is beneficial for reducing costs because its connection method is the same as packages using a lead frame, and conventional equipment can be used. Almost all semiconductor assembling manufacturers introduced this system.

Today, DAFs with various characteristics are demanded according to the types of semiconductor packages shown in **Figure 6**. For example:

- 1) Chip-substrate bonding film (step filling type)
- 2) Chip-chip bonding film (uniform film thickness, thinner film)
- 3) Film allowing wire bonding of complicated layered structures (Spacer film: thicker film, gold bonding wire supply film: fluidity)
- 4) Small chip film (high elasticity)

Hitachi Chemical has met these requirements through our studies on

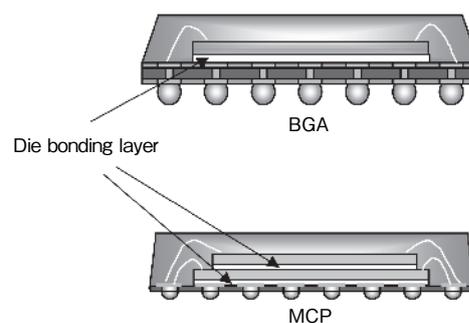


Figure 5 Structures of BGA/CSP and MCP

various base polymers⁹⁾, research into thermosetting materials, and the use of reaction-induced phase separation structures and other technologies^{10), 11)}, as well as various products.

As the number of layers in the chip increases, the need to solve new issues, such as ensuring wafer conveyance, has arisen. In the process of selecting a chip with DAF and die bonding it to the substrate or lower stage chip, two laminating processes for DAF and dicing tape are ineffective in that the number of processes is increased and potential damage (cracks, omission) to the wafers is possible during the conveyance of wafers between processes.

To solve these problems, an integrated tape combining dicing and die bonding (“DC-DB”) becomes a critical factor. With this tape, two processes for attaching DAF and dicing tape to wafers are integrated into a single process, simplifying the work. Once laminated, the wafer and tape are fixed to the wafer ring to facilitate the wafer conveyance. This also reduces potential damage to wafers in the laminating process.

Hitachi Chemical developed Dicing/Die-bonding (DC-DB) Double Functioning Tapes, “High Attach FH/HR Series” and “DC-DB Integrated High Attach DF Series” (Figure 7). These films boost the adhesion of the dicing tape and DAF, and prevent chips from scattering during dicing. They are also designed for picking up chips with DAF. DC-DB double functioning tapes suitable for process compatibility and reliability have been widely used¹²⁾.

2.2 Future Development

More diversified DAF characteristics and technologies may be required according to changes in package structures and the growing demand for diversification in future:

- 1) Thick film (>50 μm) and thin film (<10 μm) production technology
- 2) Die bonding and dicing tape technology suitable for dicing processes
- 3) High heat dissipation (high thermal conductance) technology

The development of new fields includes:

- 1) Packages of new structures (e.g. TSV)
- 2) New bonding films for sensors, etc.

In addition to existing technologies, the development of new technologies for photosensitivity, etc. is required for achieving new fields. The development of various mounting materials, including adhesives for sensors, is also important.

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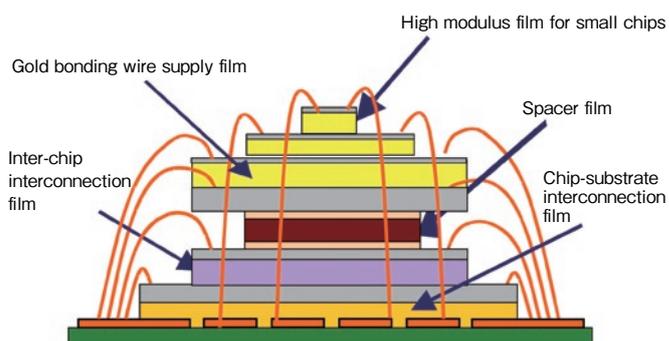


Figure 6 Application of Die-bonding Film in the Semiconductor Package

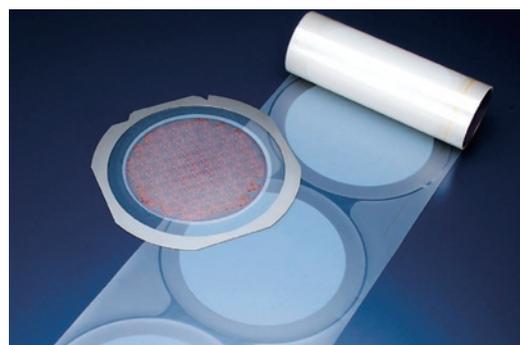


Figure 7 Appearance of Dicing/Die-bonding Double Functioning Tape