Anisotropic Conductive Adhesive Bonding

Comprehensive Manufacturer of Metalworking Machinery

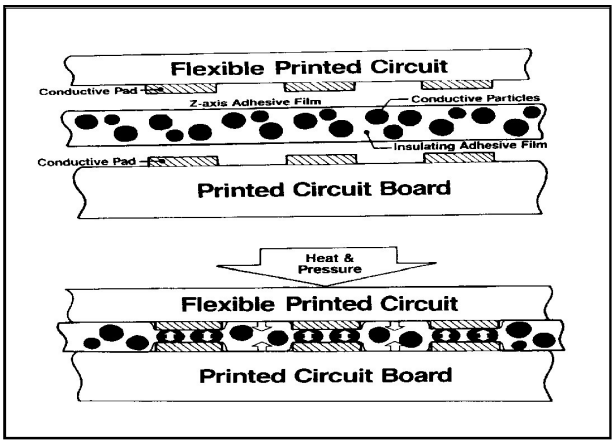
A high-quality Interconnection Technique

AMADA MIYACHI EUROPE

Anisotropic Conductive Adhesive Bonding is an interconnection technique mostly used for connecting displays to pcb's using anisotropic conductive adhesive and flex foils. For successful implementation there are a few basic constraints. If these are followed, display connection is a simple and reliable process, giving top quality connections. Heat-Sealing can be done in any factory and can be introduced in a few months, from start of design to mass productions.

WORKING PRINCIPLE

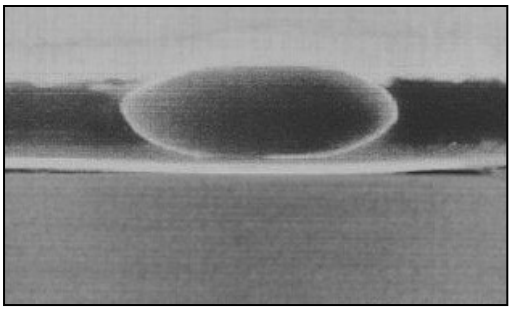
An often-used definition for ACA is "Adhesive with conductive particles for electrical contact in Z-direction only". The working principle is shown in the picture below.



Before connection, an insulating adhesive film separates the conductive particles. When a heating element (normally called thermode) is pressing the top- and bottom circuit board together, with the glue in between, the adhesive will flow, and conductive particles will be trapped, resulting in an electrical connection.

As the compression is only in the Z-axis direction, an electrical connection will be made in this direction only. Because of the low filler content (1-5%) short-circuiting between adjoining tracks cannot take place.

Next picture shows a scanning electron microscope picture, with one hollow conductive particle squashed in between two conductive tracks. Actual particle size is about 5 mm. Only one particle can be seen, normally there are between 100 to 1000 particles involved in one connection.



The adhesive normally consists of a mixture of thermoplastic and thermohardening (also known as thermoset- or duroplast-) glues, to get the best of both properties

The conductive particles can be:

- massive conductive particles
- massive plastic particles coated with conductive material
- hollow plastic particles coated with conductive material.

Most used are massive graphite particles, gold particles and gold plated plastic particles. Graphite particles are sharp, which can be a benefit if one of the materials that must be connected has a thin isolating oxide layer. The disadvantages are that the particles are not elastic, causing higher resistance. Graphite particles are also hygroscopic. Moisture that is attracted can influence the glue matrix and cause corrosion in between the contacts.

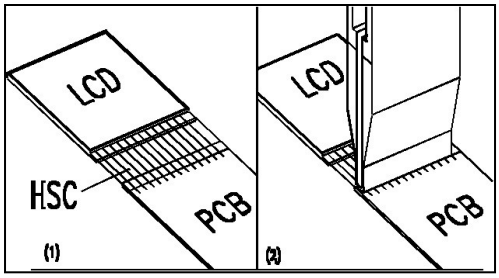
Because gold is not hygroscopic, it is sometimes preferred above graphite. Contact resistance is also lower compared to graphite particles. However, gold can be more expensive then carbon. Gold plated plastic particles are compressible, giving two big advantages. Contact resistance is lower, because a bigger surface is in contact with the upper- and lower track. The particle also works as a spring: a small relaxation of stress in the glue is compensated by an extension of the particle, resulting in an extra safe connection.

Particle size is dependent on pitch; most common size is 3-10 mm. To prevent short-circuits in the XY direction, particle size must decrease if pitch is decreased. About 100 - 1000 particles per square mm are present.

The thickness of the adhesive is also dependent on the pitch. Thickness varies from 35 to as low as 18 mm for fine pitches. The reason for this is that fine pitches normally have lower trace heights: a trace height of 10 to 20 mm is considered ideal. When tracks are to high in relation with the pitch and the thickness of the glue, voids can occur in between the tracks. These voids can attract moisture and decrease the mechanical strength.

PROCESS HEAT SEAL CONNECTOR

A difference must be made between HSC and ACF. For HSC, only one process step is needed, making the process relatively fast. This process step is, because of the thermoplastic nature of the glue relatively fast: the glue only has to be heated to a certain temperature; there is no need for curing time at elevated temperature.



PROCESS ANISOTROPIC CONDUCTIVE FILM

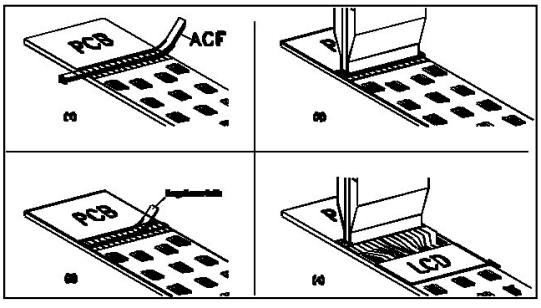
ACF has three process steps. If the ACF has three layers (the glue and two protective layers) one layer is peeled off before the first process step.

Positioning the glue and protective layer on the connection area, with the protective layer facing the thermode.

The material is presealed: it is heated to 80 °C for a few seconds to tack it to the display or PCB.

The last protective layer is removed.

The flexconnector is placed on the ACF and aligned



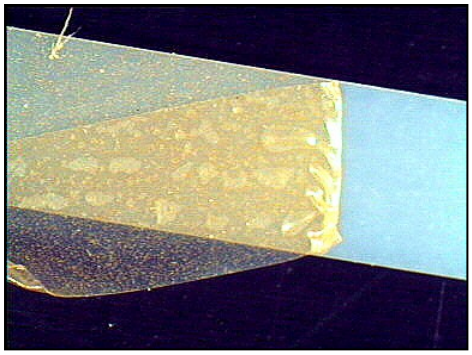
The endsealing is made, with a temperature of 150-180°C in the glue for 10-30 seconds.

Because of the multiple process steps, this process is slower then using HSC. Often one machine is used for the presealed and one for the endsealing. ACF can be presealed on the flexfoil or the display / PCB. Normally it is presealed on the display / PCB for ease of handling.

ACF Tape

The picture shows ACF tape peeled from the carrier tape. The conductive particles can be seen as small dots. Tape width is ~2 mm in this picture.

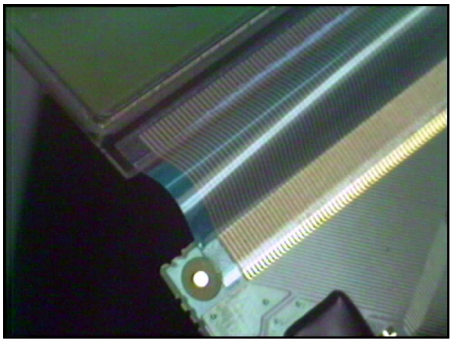
ANISOTROPIC CONDUCTIVE PASTE



Anisotropic Conductive Paste (ACP) is not used a lot, despite the benefits that are to be gained from the lower cost price and the more flexible production process. A consistent particle distribution is very difficult to obtain, resulting in either bad electrical connections or short-circuits.

HEATSEAL FLEX CONNECTOR DESIGN

Most heatseal connectors are made from a polyester foil, 20 to 50 mm thick. Below 25mm thickness the strength of the base material will not be sufficient, while a thickness above 50 mm will increase the heat barrier of the foil to



such a level, that not enough heat can be passed to the glue. Above 50mm the flex would become much more rigid, resulting in higher shear stresses in the glue when the flex is folded. Tracks are made from either carbon- or silver-/carbon. ACG is screenprinted on the connection area. The picture shows an LCD - PCB assembly made with a heatseal connector.

ACF FLEX CONNECTOR DESIGN

Most ACF glues are thermo-hardening. These glues need a higher temperature and a longer curing time then thermoplastic glues. Because of this a foil with a higher melt temperature is needed: most used is polyamide foil, also known under the trade name Kapton®. Kapton is a very good heat isolator, special care should be taken to prevent heat

Tracks on the flex connector are normally made from copper, 12.5 or 25 mm thick. Plain copper can be used for the connection, but no oxidation must have taken place. It is better to use passivated copper. Gold plated contacts are the most reliable, but also more expensive. Solder or tin coatings are also seen; reliability can be good if the appropriate adhesive is used. Tin layers should be thin to prevent height differences within the connection area (because of the convex nature of the tin).

Most flexes have three layers, on the bottom side of the flex a protective Kapton layer. This layer is best held thin, to keep the flex flexible and stresses on the connection as low as possible.

ACHIEVABLE PITCHES AND LENGTHS

The general trend is towards finer pitches and more connections. Pitches vary from 1000 mm to as low as 50 mm. In mass production pitches up to 200 mm are used, the finer pitches are reserved for laboratory products. Pitches ranging from 500 - 1000 micron are mostly used without active alignment (accuracy is obtained by the parts themselves, through reference holes, etc.), whereas pitches below 500 mm use alignment by either manual or automatic adjustment, after the parts are put in a fixture.

The problems that limit the use of very fine pitches, in the 50 -100 mm ranges, do not occur from the glue or the equipment, but from thermal expansion. Both materials that must be connected (the connector and the LCD) are heated by a thermode to about 150 to 200°C. The LCD has a lower thermal extension coefficient then the connector, and will elongate less then the connector. The glue is fixating the parts at elevated temperature, in the extended state. Mismatches of one full pitch are observed with connection lengths of 100 mm. This effect is mainly dependent on temperature, thermal expansion coefficient of the connector and length of the connection. It is possible to compensate for this by making the pitch on the connector slightly smaller. Alignment should be done in the middle of the product, or on both ends.

The length of the connection may vary from 5 mm to 130 mm. Lengths between 25 and 50 mm are most common.

CONNECTION PROPERTIES

Heatseal connections have a relatively high resistance and a low maximum current density.

Electrical resistance is in the range of 2-10 Ω for PCB connections and 10-100 Ω for LCD connections.

Insulating resistance is in the 10^9 to 10^{10} Ω range. There is no difference between suppliers and types. Mechanical properties are different between HSC and ACF. A 90° peel strength averages from 5 N/cm for HSC to 7 N/cm for ACF. Pull strength gives the same image, ACF is stronger then HSC. The effective temperature range is better for ACF then for HSC.

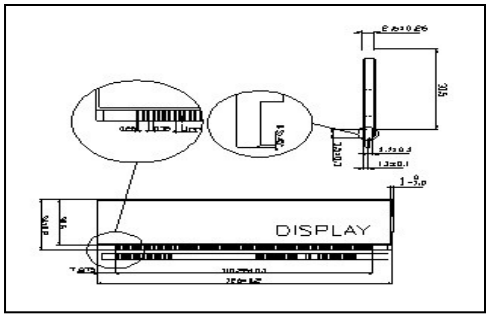
A range of -40 to +60 °C is save for most HSC, ACF can withstand temperatures up to +80 to -+120 °C. Humidity can pose a threat for this type of connection, causing swelling of the glue and corrosion (also corrosion of the ITO tracks).

DISPLAY DESIGN

Generally the display areas on the displays are as large as possible in comparison to the outer dimensions of the display. This means contact areas should be kept as small as possible. In areas where this is a must (for example cellular telephones) some manufacturers even moved away from COG (Chip On Glass) because of this reason.

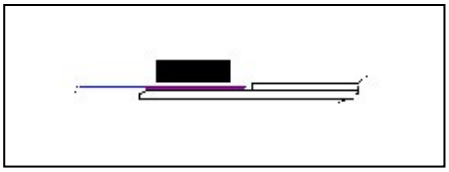
Most of the time an area over the total length of the display is available for making connections. The width of the connection may vary. Normally this width is 3 or 3.5 mm.

In the picture a possible design is shown. The connection width is 3.5 mm. The top glass layer has a dimensional tolerance, and a position tolerance because of the glueing (0.3mm in XY directions is often specified).
To prevent the ACF touching the top glass

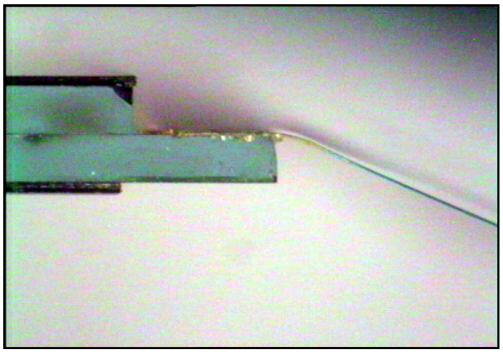


layer, about 0.5 mm tolerance should be between the ACF and the top glass. ACF width is best-chosen 2.5 mm, this leaves 0.5mm to both sides for this tolerance.

The flex is best positioned on the full width of the ACF, to prevent the ACF polluting the thermode when it is pressed out of the connection. A small bevel (0.3mm) should be present to prevent the edge of the glass acting as a knife and cutting though the traces. Especially when using HSC this is important, as the carbon traces are much easier to damage then the copper traces of an ACF connector. The next picture shows a good design and positioning.



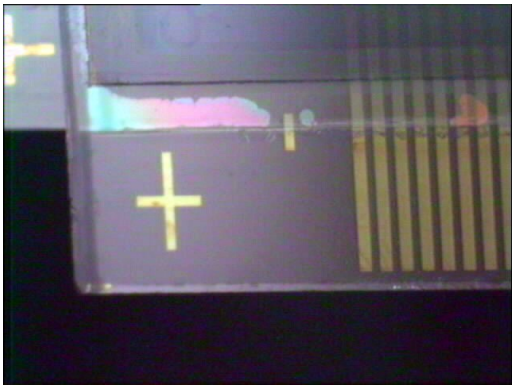
The next picture shows an example of how a HSC should not look like: there is no bevel and the foil bends downwards directly after the connection. The (matrix) glue that is pressed out should form a kind of meniscus and bend the HSC upwards. In this case the problem is caused by using a thermode that is too wide, or positioned too much near the edge.



ALIGNMENT

As said before, alignment of the parts can be done passive or active. For the PCB, passive alignment is best done with reference holes. Most of the times two holes are added, one round hole (Æ1 to 1.5mm) and one slotted hole, with the elongated side parallel to the display. It is important to position the holes as close as possible to the display (PCB) to get maximum accuracy.

When active positioning is used, a camera system is needed for the necessary enlargement. ITO tracks are difficult to see, so a special lightning source is needed to get a good contrast. The next picture shows a good example of how this looks like.



Alignment can be done on the tracks themselves, on special markers (like crosses, thick tracks, round, etc.) on the piece of track that can be seen in between the glass plates, or on special ink markers (see pictures)

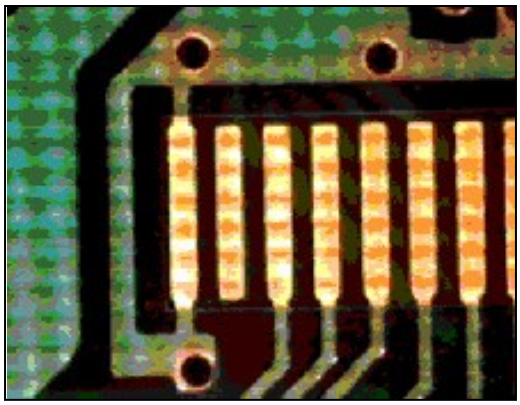
Looking through the flexconnector can be done only when a HSC is used. Another possibility is to use a “frame-freeze” option, where half of the

image of the monitor is a frozen ITO image, taken before the flex was placed, and half the actual image, showing the flexconnector on top of the ITO.

PCB DESIGN

A lot of the design rules for LCD's are also true for PCB's. However, there are some extra rules for PCB's.

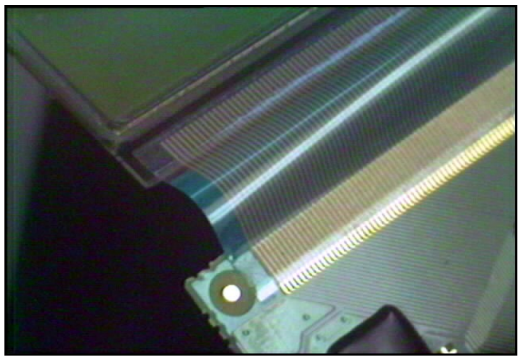
Flatness of the PCB should be guaranteed. This means that the thickness should be constant: traces or components on the backside are not allowed in the heatseal area. On the backside of the PCB, in the heatseal area, a 100 % mechanical support should be present from the fixture.



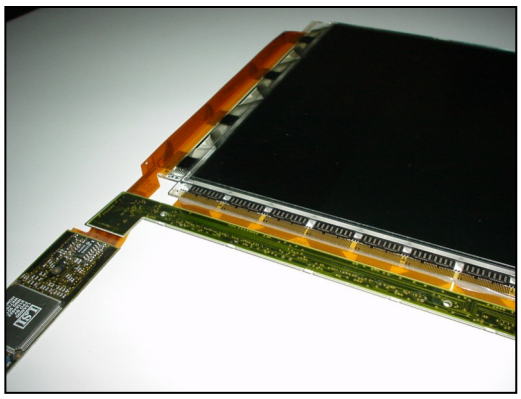
Thermal balance in the connecting area is very important. This is a big difference compared to conventional oven soldering. In a conventional reflow-soldering oven the whole PCB heats up, when using thermode soldering only the area beneath the thermode is heated. A lot of heat diffuses in all directions, in the XY plane and in the Z-axis. Figure 13 shows an example of PCB design. There are three flaws in this design: the double connection of the most left track, via's close to the last track, and the solder mask close to the last track. The first two flaws will decrease temperature locally because of the higher heat sink, In order to get a good connection the temperature of the thermode has to be increased, causing possible thermal damage and a smaller process window. When the thermode hits the solder mask it takes away the necessary pressure for the heat seal connection, thus compromising joint reliability.

EXAMPLES OF TYPICAL APPLICATIONS

Cellular telephones use a relative high I/O count on a connection length of about 30-40 mm. Weight and building size is extremely important for this type of product. This display has a PCB with the driver IC on there. After sealing the driver is folded below the display. Building height is bigger then when a Chip On Glass method is use, but the keypad can be moved up to 5 mm closer to the display, making the phone easier to use.
The next picture shows a heatseal connector for a typical cellphone application.

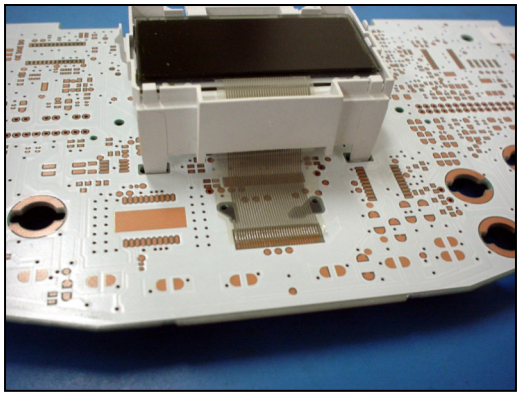


Laptop displays are a good example of ACF Bonding usage. A Chip On Foil technique is used here, one side of the foil is Hot Bar Reflow Soldered to a PCB and the other side is connected using ACF. When using the right production equipment, a extremely reliable joint can be made. Repair is possible, using new foils or using old foil from another display. This type of production is normally done on in-line production equipment.



Automotive dashboards use more and more complex displays. This one is connected with Heat-Seal Bonding. Because of the large size, and the single connection, this type of applica-

tion is normally done on a medium- to large-scale rotary table. The extreme environmental tests in the automotive industry do not form a problem any more with the newest Anisotropic Conductive Adhesives.



PROCESS EQUIPMENT

Using the right equipment gives the highest possible yield and product quality. Equipment can vary from simple manual stations (suited for small series production and laboratory environments, see picture) to fully automated inline systems, for the highest production rates, up to one million products a year.

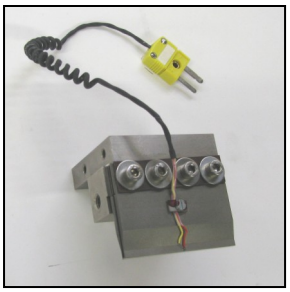
POWER SUPPLY

The power supply generates a precisely controlled electrical current that is passed through the thermode. The thermode is manufactured from a resistive metal and therefore generates heat. The cross sectional area of the thermode should be as small as possible in order to achieve a fast temperature rise and also to allow rapid cooling. A thermocouple attached to the thermode provides the power supply with temperature feedback. Pulse heating refers to the rapid update of the energy output to the thermode based on the temperature feedback loop. In this way the power supply can precisely control the temperature profile of the thermode and therefore the thermal transfer to the parts.

THERMODE

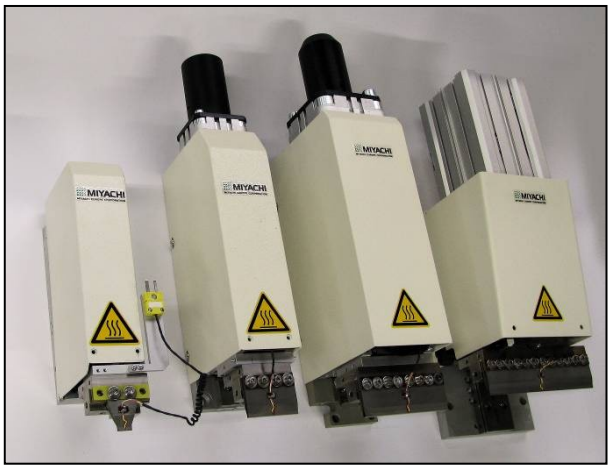
The thermode is shaped in the form of a “U”. The current flows in a parallel direction to the conductors and as a consequence there is practically no discernable voltage drop between two neighbouring conductors. The pulse heating method allows the thermode to heat and cool quickly.

Fast cooling is beneficial as it allows pressure to be maintained at the end of the heating cycle, which means that conductive particles are held stable in the compressed position during curing.



BONDING HEAD

The bonding head provides a repeatable force to guarantee the thermal transfer of heat to the parts and provides the actuation method for the thermode.



CONCLUSION INTERCONNECTION TECHNIQUES

In conclusion can be said that HeatSeal Bonding and Anisotropic Conductive Adhesive Bonding are the interconnection technologies with the highest connection quality. New developments in production equipment, being Vision supported Automatic Alignment and Fully Automated Anisotropic Conductive Foil modules have recently opened up the path for widespread usage of this technique, by significantly lowering interconnection costs.

A shift is taking place towards these interconnection techniques, supported by the market pull for higher i/o counts, further miniaturization and weight reduction of the interconnection.
This combined with the evident explosive increase of usage of displays will grow the total market for interconnections. Because Bonding techniques are more and more widespread, a bright future shines for these technologies.