This invention provides a method of manufacturing an electronic assembly comprising the steps of: fixing a first electronic component 16 to a substrate 18 by means of an anisotropic conductive film 19, applying thermal compression to this first electronic component whereby electrical contacts formed on the component are brought into electrical contact with corresponding contacts formed on said substrate, applying solder 26 to the substrate at contact locations on the substrate where a second electronic component 24 is to be electrically connected on said substrate, and providing a thermal protective cover (10, Fig 1) over the first electronic component and performing a solder reflow process to electrically connect the second electronic component at the contact locations.

The substrate may be flexible, the first component may be active (a chip) and the second passive. An LCD display may be attached by means of an anisotropic film subsequent to the second component.
FIG. 11

(1) Load substrate

(2) Pre-bonding

(3) Peel off separator

(4) Alignment

(5) Bonding of IC on substrate

(6) Completion

Pattern
- IC pump and substrate connection parts are contacted
- The border is cut and the substrate is peeled off

Time: 3-5 seconds
Pressure: 0.2-0.394MPa
Temperature: 90°C

Time: 10-20 seconds
Pressure: 1250-60000Pa
Temperature: 245-355°C

Final bonding

Substrate is vacuum held in set

Pre-bonding

Substrate is vacuum held in set
PROCESS FOR THE ASSEMBLY OF ELECTRONIC DEVICES

FIELD OF THE INVENTION

The present invention relates to a process for the assembly of electronic devices, and in particular to the assembly of electronic devices, for example portable display modules, on flexible substrates.

BACKGROUND OF THE INVENTION

The trend in the requirements for portable electronic products such as mobile phones, personal digital assistants and the like, is towards smaller size, lighter weight, higher performance and higher component density. This leads to a number of issues with regard to the technologies that are used for the mounting of the various components, including in particular the display module and associated driver circuits. A number of known technologies have been developed in this area, including in particular chip-on-glass (COG) and tape automatic bonding (TAB).

In COG the display resolution is increased but not the width of the portable device. The dead area of the display module (e.g. a LCD) is greatly increased because the single driver chip connects to one glass edge and the common signals route through indium tin oxide (ITO) on the LCD. The poor conduction reliability of COG is another concern because of the residual stress arising from the expansion of the IC driver under the action of the heat during the thermal-compression bonding. The package thickness is at least 1.4mm and the mounting space needs to be sufficiently large and rigid.

In TAB a thicker base material of a flexible substrate is formed which is constructed with
3-layers of polyimide (75–125μm), adhesive (19μm) and copper (18–35μm). However, the passive components or the surface mount devices cannot be mounted onto the flexible substrate directly. The temperature sustainability of TAB is relatively low (~200°C) and so it cannot withstand the high temperature solder reflow process. The flexibility of TAB is also lower because the spring back forces are quite large.

PRIOR ART

Chip-on-flex (COF) technology has many advantages over COG and TAB techniques and is particularly suitable for portable display applications because it can provide lighter weight, thinner devices, more flexibility for bending, smaller but higher density devices and higher connection reliability of electronic packaging.

COF technology uses soft, light and flexible materials that are capable of bending through 180° when required so that design flexibility would be higher. The package thickness can be reduced to only 0.7mm with only 0.02mm thickness of the substrate so it is very thin and lightweight to suit mobile applications. COF can also be treated as a flex cable for outer-lead bonding to the main board so that a thinner LCD can then be used with only 0.4mm thickness. COF needs only a very small mounting space on the display and hence gives rise to larger display capacity. There are only two layers forming the flex substrate used in COF which is constructed of polyamide (eg approx. 20μm) and copper (8–12μm). The passive components or the surface mount devices can be directly mounted onto the flexible substrate and hence the number of inputs pins may be reduced.

COF technology uses an anisotropic conductive adhesive film (ACF). However, this means
that owing to the limitations of ACF, COF bonding should be performed before the surface mounting of passive components. Furthermore, during the reflow soldering process the temperature profile reaches the range of 200°C to 290°C in order to activate the solder formation. The flexible substrate has to be heated by exposure to a high temperature for a few minutes and then cooled. However, in this conventional process it is necessary to complete the reflow soldering of the passive components before performing any bonding of the integrated circuit on the flexible substrate due to the poor heat resistance of the adhesive resin that can damage the IC chip.

SUMMARY OF THE INVENTION

According to the present invention there is provided a method of manufacturing an electronic assembly comprising the steps of:

(a) fixing a first electronic component to a substrate by means of an anisotropic conductive film,

(b) applying thermal compression to said first electronic component whereby electrical contacts formed on said first electronic component are brought into electrical contact with corresponding contacts formed on said substrate,

(c) applying solder to said substrate at contact locations on said substrate where at least one second electronic component is to be electrically connected on said substrate,

(d) providing a thermal protective cover over said first electronic component, and

(e) performing a solder reflow process to electrically connect said at least one second electronic component at said contact locations.
Preferably the first electronic component is an active component and the at least one second electronic component is a passive component.

In a preferred embodiment in step (c) said substrate is supported on a rigid board and a stencil is provided over said substrate, said stencil being formed with openings corresponding to said contact locations, and wherein said solder is applied to said contact locations by means of a screen-printing process.

Preferably in step (d) said thermal protective cover is formed of a material of low thermal conductivity, such as aluminium. The solder reflow process may be carried out at between 200°C and 290°C.

Preferably after step (e) a third electronic component is fixed to said substrate by means of an anisotropic conductive film, and by applying thermal compression to said third electronic component whereby electrical contacts formed on said third electronic component are brought into electrical contact with corresponding contacts formed on said substrate. For example the first electronic component may be an integrated circuit chip, the at least one second electronic component may be a passive component, and the third electronic component may be a liquid crystal display module.

Viewed from another broad aspect the invention also provides a method of assembling a liquid crystal display comprising the steps of:

(a) fixing a driver integrated circuit chip to a flexible substrate by means of an anisotropic conductive film,
(b) applying thermal compression to said driver integrated circuit chip whereby electrical contacts formed on said chip are brought into electrical contact with corresponding contacts formed on said substrate,

(c) applying solder to said substrate at contact locations on said substrate where a plurality of passive electronic components are to be electrically connected on said substrate,

(d) providing a thermal protective cover over said driver chip,

(e) performing a solder reflow process to electrically connect said passive electronic components at said contact locations, and

(f) fixing a liquid crystal display unit to an edge of said flexible substrate by means of an anisotropic conductive film, and by applying thermal compression whereby electrical contacts formed on said liquid crystal display unit brought into electrical contact with corresponding contacts formed on said substrate.

BRIEF DESCRIPTION OF THE DRAWINGS

Some embodiments of the invention will now be described by way of example and with reference to the accompanying drawings, in which:

FIG. 1 is a schematic view of an embodiment of the assembly structure according to the present invention;

FIG. 2 is the top view of an embodiment of the assembly structure according to the present invention;

FIG. 3 is a cross-sectional view of an embodiment of the assembly structure according to the present invention;

FIG. 4 shows the design of the pallet board used in the SMT process according to an
embodiment of the present invention;

FIG. 5 shows the design of the stencil used in the SMT process according to an embodiment of the present invention;

FIG. 6 shows the design of the squeegee used in the SMT process according to an embodiment of the present invention;

FIG. 7 shows the design of the screen-printing method in the SMT process according to an embodiment of the present invention;

FIG. 8 is a schematic view of the aluminum protective cover used in the reflow soldering process according to an embodiment of the present invention;

FIG. 9 shows a schematic view of the outer lead bonding for flex substrate to LCD according to an embodiment of the present invention;

FIG. 10 shows the process flow of the assembly and manufacturing process according to an embodiment of the present invention;

FIG. 11 shows the ACF bonding of mount the IC chip to flex substrate according to the manufacturing process of an embodiment of the present invention; and

FIG. 12 shows a completed assembly module.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

In general terms, at least in preferred embodiments, the present invention provides a method for manufacturing a portable display module characterized by the following steps: directly attach the IC driver to the flex substrate with the use of ACF and thermal compression methods for interconnection, fix the COF module on a rigid board for solder screen printing, place the passive components on the flex substrate, add an aluminum protective cover to protect the said IC, and pass through the reflow oven for soldering.
For the above manufacturing procedures, COF bonding is performed before doing SMT mounting because of the effect of thermal expansion and contraction or shrinkage of the flex substrate. Thus, the warpage of the flex substrate can then be prevented and then any non-flatness of the flex substrate for COF bonding can also be avoided.

Another object of preferred embodiments of the present invention relates to the characteristics of the ACF. The ACF is a key factor affecting the reliability of COF bonding, which is highly dependent on the bonding parameters - temperature, pressure and time, so it is important to try to bond some samples in the range of +/-30 (°C for temperature/N for pressure) and +/-8 (s for time) of the recommended data. Then, test the samples by performing an open-short test or functional test and further by cross-section to verify the bonding performance in order to find out the optimal bonding condition.

As will be described below, in screen-printing stage, a rigid supporting pallet board is used to hold the flex substrate, and a stencil and squeegee used in order to enhance the performance of the manufacturing process.

An important aspect of the present invention is that a protective cover, which is made of aluminum is added on top of the IC bonded to flex substrate area before passing the assembly through the solder reflow oven. This can prevent the bonded IC chip on the flex substrate being over-heated or damaged during passage through the very high temperature furnace. Although COF can be applied to LCD manufacturing, there can be problems because the assembly module still has to pass through the reflow soldering at a high temperature. Thus, by
providing a protective cover on the IC to preventing any failure such as cracks, ACF can provide a reliable and stable condition.

FIG. 1 illustrates the assembly structure of an embodiment of the present invention that comprises Chip-on-Flex (COF) bonding using Anisotropic Conductive Film (ACF) for interconnection; surface mounting the passive components 24 by reflow soldering technique; and Flex-to-LCD bonding by use of ACF for interconnection.

The bonding structure shown in FIG. 3 is formed of a flex substrate 18 with an interconnection pattern 23 formed and an integrated circuit (IC) chip 16 bonded on the flex substrate 18 using Anisotropic Conductive Film (ACF) 19. Firstly, the ACF 19 is attached properly on the flex substrate 18. Secondly, the bumping pattern 17 of the IC 16 is aligned with the interconnection pattern 23 of the flex substrate 18 and then bonded together with the ACF 19 by thermal compression. The conductive particles 20 are trapped between the bumps 17 of the IC 16 and the corresponding terminals 22 of the interconnection pattern 23 of the flex substrate 18 and then form the interconnection, and finally the IC 16 is electrically connected with the flex substrate 18. The IC 16 is firmly attached onto the flex substrate 18 by means of the curing of the adhesive resin 21 of the ACF 19 through the application of heat and pressure during the thermal compression process.

The flex substrate 18 is made of a flexible and thin base material such as polyimide with 25μm thickness. The 12μm thickness of the interconnection pattern 23 is formed directly and laminated on the base substrate 18 without any layer of adhesive. Normally, copper (Cu) or Cu alloy is used as the interconnection pattern. Then, a very thin (few microns) layer of
nickel (Ni) and gold (Au) are electroplated on the Cu trace of the interconnection pattern 23. One end of the Cu trace is provided with an inner-lead 22, which is for bonding with bump 17 of IC 16, while the other end of the Cu trace is provided with an output terminal or an input terminal of a passive component to be mounted by surface mount technology (SMT) to be described further below.

The IC chip 16 is formed as an IC for driving a liquid crystal in a Liquid Crystal Device (LCD) 27 and includes a plurality of bumps 17 on an active surface on the IC chip 16 serving as an input electrode terminal or an output electrode terminal of the internal circuit. The IC chip comprises aluminum electrodes formed at appropriate areas of a surface of a chip body with passivation film provided on the surface of the chip in such manner that the aluminum electrodes are opened. Then, 17 μm height gold (Au) bumps 17 are formed on the aluminum electrodes. Moreover, the bumps 17 of the IC chip 16 are arranged along the two edges of the IC chip 16.

ACF 19 serves as a key component in the bonding structure of IC chip 16 and flex substrate 18. ACF 19 comprises an adhesive resin 21 and a plurality of conductive particles 20. The adhesive resin 21 is cured via the thermal compression process (relatively high temperature and pressure) so that the IC chip 16 can firmly connect to the flex substrate 18. The conductive particles 20 are formed with an outermost layer coated with a very thin gold layer and resin in the core, an insulated layer may additionally be coated on top of the Au layer in order to prevent any short-circuits from arising between the bumps of the IC chip 16 and flex substrate 18 via the interconnection layer. The conductive particles 20 are trapped and deformed under pressure between the Au bumps 17 of the IC chip 16 and the electrode
terminals 22 of the Cu trace 23. Then, the conductive particles 20 serve to electrically connect the respective bumps 17 of the IC chip 16 to the corresponding electrode terminals 22 of the flex substrate 18.

The ACF 19 is a key factor affecting the reliability of the completed module shown in FIG. 3 and the reliability depends to a large extent on the bonding parameters including temperature, pressure and time, so it is important to find the optimal bonding conditions before performing any ACF and COF bonding. Normally, there is a set of recommended bonding parameters provided by the ACF supplier, but it is necessary to try to bond some samples in the range of +/-30°C (C for temperature/N for pressure) and +/-8 (s for time). Then, test the samples by performing open-short tests or functional tests and further by cross-section to verify the bonding performance. After finding out the optimal bonding condition, COF bonding can be performed.

There are electrode terminals 25 on both ends of the passive components 24. The passive components including resistors, capacitors and transistors are electrically and mechanically mounted to the particular parts of the flex substrate via solder 26. The passive components 24 are mounted on the flex substrate 18 by using a Surface Mount Technology (SMT) assembly process, which consists of screen printing, chip mounting and reflow soldering. The IC chip 16 is bonded by ACF 19 before the passive components, which makes the screen-printing process difficult and this is helped by means of a custom design of stencil 37 and squeegee 38.

FIG. 4 illustrates the design of the pallet board 34 used in the screen-printing process. The
flex substrate 18 is too thin and flexible to hold on the stage of the screen printer, and so a rigid pallet board 34 is used to support the flex substrate. When the flex substrate 18 is placed on the board 34, this is done such that a horizontal edge of the substrate should tilt at 15 degrees to the edge of the board 34, and this positioning is achieved by adjusting the flex substrate 18 by mark A 32 and mark B 33 on the flex substrate 18. This is to prevent the squeegee colliding with the cover 35 during the printing process and tilting by 15 degrees is the optimum choice for this purpose and in the meantime being able to make sure that the entire open windows 36 are located in the printing area. The flex substrate 18 is held by vacuum when loaded on pallet board 34, and is held firmly on the pallet board 34 with high temperature adhesive tape on the four corners of the flex substrate 18.

FIG. 5 illustrates the design of the stencil 37 used in the screen-printing process. Stainless steel is normally used as the material of the stencil 37. The stencil 37 thickness is 0.15mm and the aperture ratio is 0.8-0.9. The stencil 37 is provided with a plurality of open windows 36 where solder paste 26 can be distributed on the corresponding areas of the electrode terminals 6, and is formed with a cover 35 in order to prevent the solder paste 26 from contaminating the chip 16.

FIG. 6 illustrates the design of the squeegee used in screen-printing process. A 0.3mm thickness stainless steel squeegee 38 is taken and designed for special printing requirement.

FIG. 7 illustrates the screen-printing process. The gap between line 1 and line 2 is 0.5mm in order to make sure the moving squeegee will not collide onto the cover 35. The gap between line 1 and line 3 is less than 1.0 mm; the gap between line 2 and line 1 is set to be 0.5mm in
order to avoid the squeegee 38 crashing onto the cover 35. Consider the taper at the edge of
the squeegee 38, line 2 straightness of 0.1mm is imposed for the same reason and in the
meantime is still able to cover all open windows 36. After loading the pallet board and flex
substrate 18 in advance, the squeegee 38 is moved from one end to an opposite direction and
finally the solder pattern forms on the corresponding pattern of the flex substrate 18.

The passive components 24 shown in FIGS. 1 & 3 are then placed on the solder, and the flex
substrate 18. Before starting a reflow soldering process, a protective cover 10 (FIG.1)
should be placed on the IC chip 16 to prevent any potential over heating of the chip. Without
the protective cover 10, the contact resistance of ACF joints increases significantly after the
reflow process due to the decrease in contact area of conducting particles 20 between mating
I/O pads 23. During the reflow process, the entrapped adhesive matrix 21 between the chips
16 and the substrate 18 expands much more than the Au bump 17 and bond pads 23 because
of the higher coefficient of thermal expansion. The linear thermal expansion coefficient (CTE)
of ACF 19 of 133 ppm/°C is one order higher than the linear CTE of metal which ranges
within 13 to 18 ppm/°C. The induced thermal stress will try to lift the bump 17 from the pad
23 and decrease the contact area of the conductive path and eventually result in a completely
separate joint. In addition, the glassy transition temperature, Tg of commercial ACF 19 is
about 130°C thus it will degrade when exposed to the reflow profile which includes a
relatively high peak temperature of about 290°C. This will result in degradation of the
reliability of the joints.

Therefore an aluminum (Al) protective cover 10 is used to protect the ACF joints 19 from
thermal degradation caused by the reflow process. Al has lower heat consumption and acts as
a heat resist to the IC chip 16, flex substrate 18 and ACF materials 19 without any major modification to the SMT equipment, process and materials. Fig.8 illustrates the design of this Al protective cover 10 which consists of a square cavity 41 to expose the solder joints to heat and a rectangular hollow 42 fit to the bonded chip 16 to protect it from the elevated temperature.

The flex substrate 18 with the Al protective cover 10 are exposed in a high temperature ambient up to 290°C in the very high temperature oven, the solder 26 then melts and finally soldering is formed. By adding a protective cover 10 on top of the IC 16 bonded to the flex substrate 18 area before passing through the reflow oven, and with the protective cover 10 being custom-designed to fit the part and made with aluminum materials because of lower heat consumption, it is possible to protect the IC 16 from heat thus minimizing the danger of damage to the IC 16, flex substrate 2 and ACF 19 materials, without changing any manufacturing process, equipments or materials. There is no need to change to special ACF materials or to any special adhesive resin and since it is very simple to make the protective cover its cost is very low, the final manufacturing process can still be kept as simple as before and the cost can still be maintained close to the conventional one.

The Liquid Crystal Display (LCD) 27 is the final device to be mounted to the flex substrate 18. The method of connecting the LCD 27 to flex substrate 18 is similar to that of IC chip 16 to flex substrate 18. ACF 29 is used as the interconnection media but with different chemical composition of adhesive resin and conductive particles, which is known as a type of outer-lead bonding ACF 29. The connecting pads 28 on the LCD are Indium Tin Oxide (ITO) pads that are aligned with the electrode terminals of the interconnection pattern 30 of
the flex substrate 18, then covered by an ACF 29, and then heat and pressure are applied and finally electrically connection is established between the electrode terminals of the interconnection pattern 30 and the ITO 28 of the LCD 27, whereas the cured ACF 29 serve the mechanical connection between the LCD 27 and flex substrate 18.

FIG. 9 illustrates schematically the LCD bonding structure. The LCD 27 with ITO pads 28 is aligned with the electrode terminals 30 of the flex substrate 18, and then attached by the ACF 29 to the flex substrate 46. The pulse heater 47 provides the heat and pressure to bond firmly the LCD 27 to the flex substrate 18 and thus the electrical connection formed between the ITO pads 28 of LCD 27 and electrode terminals 30 of flex substrate 18.

The assembly module of present invention with mounting IC chip 16, passive components 24 and LCD 27 to the flex substrate 18 can be applied to a portable phone, preferably a cellular or mobile phone.
CLAIMS

1. A method of manufacturing an electronic assembly comprising the steps of:
   
   (a) fixing a first electronic component to a substrate by means of an anisotropic conductive film,
   
   (b) applying thermal compression to said first electronic component whereby electrical contacts formed on said first electronic component are brought into electrical contact with corresponding contacts formed on said substrate,
   
   (c) applying solder to said substrate at contact locations on said substrate where at least one second electronic component is to be electrically connected on said substrate,
   
   (d) providing a thermal protective cover over said first electronic component, and
   
   (e) performing a solder reflow process to electrically connect said at least one second electronic component at said contact locations.

2. A method as claimed in claim 1 wherein said first electronic component is an active component and said at least one second electronic component is a passive component.

3. A method as claimed in claim 1 wherein in step (c) said substrate is supported on a rigid board and a stencil is provided over said substrate, said stencil being formed with openings corresponding to said contact locations, and wherein said solder is applied to said contact locations by means of a screen-printing process.

4. A method as claimed in claim 1 wherein in step (d) said thermal protective cover is formed of a material of low thermal conductivity.
5. A method as claimed in claim 4 wherein said material is aluminium.

6. A method as claimed in claim 1 wherein said solder reflow process is carried out at between 200°C and 290°C.

7. A method as claimed in claim 1 wherein after step (c) a third electronic component is fixed to said substrate by means of an anisotropic conductive film, and by applying thermal compression to said third electronic component whereby electrical contacts formed on said third electronic component are brought into electrical contact with corresponding contacts formed on said substrate.

8. A method as claimed in claim 7 wherein said first electronic component is an integrated circuit chip, said at least one second electronic component is a passive component, and said third electronic component is a liquid crystal display module.

9. A method of assembling a liquid crystal display comprising the steps of:
   (a) fixing a driver integrated circuit chip to a flexible substrate by means of an anisotropic conductive film,
   (b) applying thermal compression to said driver integrated circuit chip whereby electrical contacts formed on said chip are brought into electrical contact with corresponding contacts formed on said substrate,
   (c) applying solder to said substrate at contact locations on said substrate where a plurality of passive electronic components are to be electrically connected on
said substrate,

(d) providing a thermal protective cover over said driver chip,

(e) performing a solder reflow process to electrically connect said passive electronic components at said contact locations, and

(f) fixing a liquid crystal display unit to an edge of said flexible substrate by means of an anisotropic conductive film, and by applying thermal compression whereby electrical contacts formed on said liquid crystal display unit brought into electrical contact with corresponding contacts formed on said substrate.
**Application No:** GB0407635.2  
**Examiner:** Alex Littlejohn  
**Claims searched:** 1-9  
**Date of search:** 21 July 2005

**Patents Act 1977: Search Report under Section 17**

**Documents considered to be relevant:**

<table>
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<th>Identity of document and passage or figure of particular relevance</th>
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<td>1-4,6</td>
<td>WO 02/074028 A (DaimlerChrysler) see use of heat shield 9 during soldering</td>
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<td>Y</td>
<td>1-6</td>
<td>JP 2002299809 A (Matsushita) see WPI abstract 2003-251109 with component 4 attached by anisotropic film, component 7 by solder</td>
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<tr>
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<td>JP 01093102 A (Alps Electric) see use of heat shield 10 while soldering</td>
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<tr>
<td>Y</td>
<td>1-6</td>
<td>US 2002/0023342 A (Nakamura) see e.g. paragraphs [0072]-[0091], components 10,12,14 attached by anisotropic film and components 17,18,19 by solder</td>
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**Field of Search:**

- Search of GB, EP, WO & US patent documents classified in the following areas of the UKC<sup>X</sup>:
  - H1R

- Worldwide search of patent documents classified in the following areas of the IPC<sup>07</sup>:
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- The following online and other databases have been used in the preparation of this search report:
  - EPODOC, WPI