



Fabrication of Electronic Components in Plastic

This invention relates to the manufacture of electronic devices with components embossed in a plastic substrate instead of conventional printed circuit boards. In some aspects, the invention provides methods of forming an electronic device in plastic. In another aspect, the invention is an electronic device formed according to the invention.

Background to the invention

Electronic devices are traditionally made on a printed circuit board (PCB) where devices such as chips adhered to the substrate and are connected by metal tracks deposited onto the substrate.

For some applications there is a need to encase the electronic components in a protective package. Recent guidelines in Europe require use of lead free techniques in electronics assembly which means alternatives to solder are needed. Standards also require the use of recycled or recyclable plastics and biodegradable plastics.

Polycarbonate is a material used in electronics and microfluidic devices but a method for using it in packaging electronic components has not been developed. One possibility is to encase the components in the polycarbonate but most embossing machines are manually operated and pressure and temperature and other variables cannot be controlled uniformly. The brittle nature of the materials also adds to the difficulty of controlling the process.

Summary of the Invention

In a first aspect, the invention is a method of forming an electronic device in plastic, in which

- a) one or more electronic components are placed in one or more recesses in a thermoplastic substrate;
- b) electrical connections and circuitry are deposited over the one or more components on the thermoplastic substrate; and
- c) bonding a sheet of thermoplastic material over the circuitry, thereby sealing the one or more electronic components and the electrical connections and circuitry between the sheet and thermoplastic substrate.



In a second aspect, the invention is a method of forming an electronic device in plastic, in which

- a) one or more electronic components are placed in one or more recesses in a thermoplastic substrate;
- 5 b) electrical connections and circuitry are deposited on a thermoplastic sheet; and
- c) the thermoplastic substrate is bonded to the sheet to complete the electrical connections between the components and the circuitry and to seal the one or more electronic components and the electrical connections and circuitry between the sheet
- 10 and the thermoplastic substrate.

This process is applicable with most mouldable thermoplastics capable of being hot embossed. Preferably the plastics are biodegradable, recyclable and/or biocompatible. No chemical solvents or solders are used in the process and the circuit package is

15 sealed. Advantageously, electronic devices formed according to the method also conform with environmental guidelines.

The deposited circuitry may be flexible, such as flexible ink or flexible tape.

- 20 The electronic device may be an electronic product having the one or more electrical components and the electrical connections and circuitry isolated from surrounding environment.

The deposition of the circuitry may be by any one of the following:

- 25 i) screen printing of conductive inks
- ii) adhering conductive tapes
- iii) adhering a plastic film with the preprinted circuitry to the substrate.

More than one sheet may be used and printed with additional conductive tracks to

30 create a multilayer circuit board. One or more circuit components may be formed by printing different materials over the electrical connections to form active and passive circuit components.

The thermoplastic substrate may be heated and then embossed to form the one or more

35 recesses for the one or more components. The thermoplastic may be a Polycarbonate.

In one example, the equipment required for carrying out this process is:

- a) a hot embossing machine having a former shaped for each particular circuit to be assembled
- b) a pick and place machine with standard reel loading of components
- 5 c) and a screen printer for printing the conductive ink circuitry or a station for adhering conductive tape or preprinted film.

Instead of an embossing machine the recesses may be machined out of the plastics using any suitable technique including laser machining. The circuits produced by this
 10 invention are ideal for low power circuits. Although the circuits are difficult to repair their sealed modular form makes them relatively easy to replace.

In a third aspect, the invention is an electronic device formed according to the method of the first or second aspect.

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Detailed Description of the Invention

Non-limiting examples of the invention will now be described with reference to the accompanying drawings, in which:

Figure 1 illustrates a process flow chart according to an example of this
 20 invention;

Figure 2 is a schematic diagram of the process of an example of this invention.

Best Modes of the Invention

The hot embossing machine preferably uses a pneumatic press which is electrically
 25 regulated to control the applied pressure. The pressure plates incorporate embedded heating elements. A temperature controller controls the plate temperature with thermocouples and limits the activation of the system until the preset temperature settings are achieved.

30 The embossing is carried out in two stages

- 1) In stage I, a die and substrate are aligned, held together and placed on the bottom plate.
- 2) The top pressure plate contacts the die and substrate and preheats it to the set temperature.
- 35 3) Regulated pressure is then applied by the top plate to emboss pockets into the substrate.

4) The electronic components are then applied using a pick and place machine for correctly placing the components.

5) In stage 2, the components are embossed into the substrate using a thin cover sheet of the same plastic as the substrate.

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As shown in figure 1 polycarbonate sheet is cut to size and the edges are smoothed. Pockets are pressed into the sheet as described above to accommodate the components.

Following the placement of the components the contacts and circuitry is screen printed
10 onto the components and substrate using a flexible conductive ink. A laser cut steel shim is used as a mask for the conductive ink.

Alternatively the circuit is screen printed on a film and this is aligned with the contacts printed on the components in the substrate.

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The assembled device is then returned to the hot embossing machine to adhere a cover sheet over the circuitry.

The total process is schematically shown in figure 2 :

- 20
- (a) Recesses are embossed into the plastic substrate
 - (b) A pick-and-place robot places the components into the holes
 - (c) Conductive tracks are printed onto the substrate
 - (d) The cover sheet is pressed onto the substrate to seal the circuit.

25 Bare silicon die has been successfully embossed in plastic and the electrical connections to the pads on the die have been made using screen printing.

To reduce the cost of printing circuit tracks and assembly reel to reel printers may be used.

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Indicator lights can be enclosed in the plastic without the need to bring them to the surface as most plastics are translucent. Antennas can be printed and sealed as the material is highly insulating with very low loss (lower than standard fibreglass materials). EMC shielding can be incorporated using multiple layers of conductor
35 covered material in the embossing process.

External electrical contacts for batteries etc can be made by allowing insulated wires or connector pins to protrude from the edge of the sealed package or placing through holes in the plastic cover sheet which will allow the conductive paste to flow into the next layer/surface. Multilayer boards can be made using this hole technique. Standard PCB design software can be used as the layouts are the same. The transfer of existing circuits to the new technology is therefore simple.

The conductive paste or ink is preferably flexible when dry to allow movement (eg stretching) during the hot embossing process. Flexible ink or paste is also needed when flexible plastic materials are used to produce flexible circuits. Some circuit components such as resistors, capacitors and sensing elements can be printed during this stage of the process.

The circuits may be manufactured in any shape - 3D curved edge edges are possible using an external mould and custom designed jig during the embossing process.

The process of this invention reduces the volume of electronic goods by reducing the usual three layers of packaging (bare die, PCB, enclosure) to one in which bare die, encapsulated components and printed components can be included. The process can also be carried out in one facility.

The amount of waste generated in the process of this invention is much less than that produced in the standard solder reflow system and the wet/dry etch PCB technology.

This technique is applicable to small electronic devices that need to have the electronics isolated from the environment. They are particularly suitable for low power applications with low heat loss such as sensors used in watering systems, sports data loggers, internal medical monitoring devices and for microfluidic biological devices. The technology can be used for support electronics in microfluidics applications with the fluid channels being manufactured during the hot embossing and sealing process. The technology can be fully automated using reel-to-reel machines.

From the above, those skilled in the art will see that the present invention provides a low cost embossing and assembly process. Those skilled in the art will realize that this invention maybe implemented in embodiments other than those described without departing from the essential teachings of this invention.

CLAIMS

1. A method of forming an electronic device in plastic, in which
 - a) one or more electronic components are placed in one or more recesses in a
5 thermoplastic substrate;
 - b) electrical connections and circuitry are deposited over the one or more components on the thermoplastic substrate; and
 - c) bonding a sheet of thermoplastic material over the circuitry, thereby sealing the one or more electronic components and the electrical connections and
10 circuitry between the sheet and thermoplastic substrate.
2. A method of forming an electronic device in plastic, in which
 - a) one or more electronic components are placed in one or more recesses in a thermoplastic substrate;
 - 15 b) electrical connections and circuitry are deposited on a thermoplastic sheet; and
 - c) the thermoplastic substrate is bonded to the sheet to complete the electrical connections between the components and the circuitry and to seal the one or more electronic components and the electrical connections and circuitry between the sheet
20 and the thermoplastic substrate.
3. A method as claimed in claim 1 or 2 in which the deposited circuitry is flexible.
4. A method as claimed in claim 3 in which the deposited circuitry is flexible ink
25 or flexible tape.
5. A method as claimed in claim 1 or 2 in which the electronic device is an electronic product having the one or more electrical components and the electrical connections and circuitry isolated from surrounding environment.
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6. A method as claimed in claim 1 or 2 in which the deposition of the circuitry is by any one of the following:
 - i) screen printing of conductive inks
 - ii) adhering conductive tapes
 - 35 iii) adhering a plastic film with the preprinted circuitry to the substrate.

7. A method as claimed in claim 1 or 2 in which one or more circuit components are formed by printing different materials over the electrical connections to form active and passive circuit components.
- 5 8. A method as claimed in claim 1 or 2 in which the thermoplastic substrate is heated and then embossed to form the one or more recesses for the one or more components.
9. A method as claimed in claim 1 or 2 in which the thermoplastic is a
10 Polycarbonate.
10. A method as claimed in claim 1 or 2 in which the one or more recesses are formed by laser machining.
- 15 11. A method as claimed in any one of claim 1 or 2 in which more than one sheet is used and printed with additional conductive tracks to create a multilayer circuit board.
12. An electronic device formed according to the method as claimed in any one of the preceding claims.