Method for producing microsystems

The invention relates to a method for producing microsystems having microelectronic components inserted, adjacent to and/or above one another, into cavities created during the layered construction of base bodies composed of photocurable material, which components are connected with one another so as to be electrically or thermally conductive.

Furthermore, the invention relates to a device for implementing the method.

The layered construction of microstructures and complex microsystems consisting of photocurable material is known, for example, from DE patent 44 20 996. In the case of the method described there, a photocurable liquid is held between two plane-parallel plates solely by means of the surface tension. One of the plates is permeable for electromagnetic waves.

The 3D model is stored in a PC, broken down into individual layers. By calling up the individual layers, the layer structure is transferred through the plane-parallel plate to the adjacent liquid layer by means of a source that emits electromagnetic

waves. Exposed areas cure, when this happens, while the non-exposed regions, which remain liquid, are removed. After production of this layer, the plates are moved apart by an additional layer thickness, causing liquid to flow in, and another exposure process can take place.

Using this technique, however, it is not possible to produce microstructures in great numbers, since only a limited number of microstructures can be generated in each device, in each instance.

Therefore the inventor has proposed, in the patent application 101 44 579.2, which was not published prior to this application, to provide a roller pair, which can be followed by additional roller pairs, in place of the plane-parallel plates.

With this device, the individual layers of the structure to be built up are generated between two rollers that stand opposite one another, forming the delimitation surfaces, in each instance, whereby the distance between the rollers of the roller pair, in each instance, is determined by the thickness of the layer to be formed and the thickness of the layers that already exist. In this connection, the first layer is applied to a substrate carrier film that passes through between the rollers, and the exposure of

the layer to be generated takes place by means of one of the rollers.

This roller contains the source that emits electromagnetic waves. Exposure of the photocurable liquid present between the rollers takes place by means of a mask that corresponds to the layer structure, in each instance, which can be applied to the surface of the exposure roller, in each instance, but can also be passed through between the rollers of the roller pair, as a separate film.

In such a device, the roller pairs are followed by rinsing devices in which the material that has not cured is rinsed out. Additional stations are provided in order to fill cavities that are present in the structure that has already been built up, with electronic components, for example. After insertion of the electronic component, in each instance, construction of the microstructure is then continued. Such a method is reminiscent of rotation printing, and has the advantage in common with the latter of producing large "editions" in a very short period of time.

Until now, however, it is difficult to connect the individual electronic components with one another so as to be electrically or

thermally conductive; this holds true both for electronic components in the same plane and for electronic components in different planes.

The invention is therefore based on the task of conducting a method of the type stated initially in such a manner that while the microstructure is being built up, at the same time, the electrically or thermally conductive connections between individual electronic components can take place.

The invention accomplishes this task according to the characterizing part of claim 1, in that after the insertion of the electronic component, layered construction of the base body is continued, but that a structure of electrically/thermally conductive material is built up, vertically rising, above the contacts (PADS) of the electronic component, whereby this conductive material produces a direct connection with another electronic component disposed above the electronic component, or by means of a horizontally running conductive track of conductive material rising from the pad to one (several) other electronic component(s) disposed at a lateral distance from the electronic component.

The present invention therefore makes it possible to generate the conductive connections both in the vertical and in the horizontal direction, without interruption of the structure construction of the microsystem, practically integrated into the method.

In the alternative according to claim 2, it is proposed that the conductive, vertically rising structure is generated in openings in consecutive layers that are left clear above the pads, by means of screen printing, in which connection the openings left in the layers of photocurable material, above the pads, are filled with the electrically conductive material, and finally the horizontally running conductive track is printed.

An electrically conductive adhesive has proven to be particularly suitable for this screen-printing method (claim 3). Because of the properties of the adhesive, a good electrical contact to the pad is obtained, for one thing, and of the layers to one another, during the construction of the conductive structure.

The horizontally running conductive tracks lead to a component disposed laterally relative to the first component. By continuing the method, the structure can then be built up further, whereby

now additional connections upward are produced from this laterally disposed component, according to the method from claim 2.

For faster curing of the conductive adhesive, a heat source is provided, which can consist, for example, of a pass-through oven.

In order to be able to achieve great packing densities in the case of the microsystems produced in this manner, it is desirable that the electronic components can be contacted not only from above, as just described, but that there is also a possibility of contacting from below. This means that a direct electrically conductive connection can be produced between electronic components (chips, for example).

This preferably takes place according to claim 4, in that the electrically conductive vertically rising structure consists of a small pile of soldering paste that is applied to the pad, in each instance, through the corresponding opening of a template, which small pile is formatted into a solder bead (bump) in the subsequent step, after removal of the template, by means of heating, and after further layered construction of the base body and production of a corresponding cavity, another electronic component is inserted into the latter, in such manner that the

bumps previously produced are connected with the pads of the second component by means of heating.

In this manner, a chip having the pads facing upwards is connected with a chip disposed above it, having the pads facing downwards.

A second heating of the bumps can take place in a subsequent roller stand, in which a roller is provided with a heating device.

Although the production of the corresponding bumps was presented using the method according to claim 4, in the present case, there is also the possibility of producing such a structure by means of the method that has been described in DE patent 44 20 996.

Of course the methods from claim 2 and claim 4 can be combined with one another, so that first of all, the work is performed using the screen-printing technique (conductive adhesive), and subsequently (if two electronic components are supposed to be connected with one another directly above one another), by means of the "bump technique."

Other embodiments and/or further developments of the invention are evident from the dependent claims 8 to 17.

The invention will be presented and explained in detail, using drawings.

These show:

Fig. 1 roller pair in the production of a first substrate layer

Fig. 2 roller pair according to Fig. 1 with mask film

Fig. 3 roller pair in the production of the second layer

Fig. 4 roller pair and feed device of components to be inserted

Fig. 5 roller pair with feed of a film

Fig. 6 construction of a structure of photocurable material with conductive tracks of conductive glue

Fig. 7a-e method steps for the production of a conductive connection between two electronic components, one on top of the other.

A roller pair is shown in Figures 1 to 5, in each instance, and provided, in general, with the reference symbol 1. For the device according to the invention, one must imagine n of these roller pairs switched in series with one another, whereby n is dependent on the structure height or on the properties that such a structure is supposed to have. Alternatively, however, a roller pair in which the distance between the rollers is increased by the layer thickness during each pass can also be provided.

In Figure 1, the first roller pair is shown within the device. It consists (as do the other roller pairs, as well, in principle) of an exposure roller 2 that is permeable for electromagnetic waves, and a counter-roller 3, which leave a roller nip 4 between them. A source 5 that emits electromagnetic waves (UV source, laser, etc.) is disposed in the exposure roller 2. A stationary exposure slot 6 is located in the roller 2, between the light source 5 and the roller nip 4. A substrate carrier film 7 is passed through the roller nip, and a photocuring liquid 8 is provided between the film and the exposure roller 2, held in place by adhesion forces. A mask (for example a chrome/glass mask) is applied to the surface of the exposure roller 2, which mask represents a negative of the layer topography of the first layer to be produced.

The liquid 8 is exposed using the light source 5, through the exposure slot 6. In those locations where the light can penetrate into the liquid (i.e. is not blocked by the mask), the liquid polymerizes and becomes solid. This results in the first layer 9 of the structure to be generated.

Figure 2 shows a device that is essentially the same. Here, however, the mask is not applied to the surface of the exposure roller 2, but rather it is passed through between the exposure slot and the surface of the liquid, in the form of an exposure film 10.

Figure 3 shows a roller pair 1' that follows the roller pair 1 shown in Figures 1 and 2, by means of which the second layer 9' is generated on top of the first layer 9, in the same manner as described with regard to Figures 1 and 2. In this connection, the substance for producing the second layer 9' can be the same as the substance of the first layer 9, but can also consist of a material having different properties.

Figure 4, in turn, shows a roller pair 1'', at which the structures 11 previously generated, already provided with a trough, arrive, and there are fitted with components 13 that are

supplied by a coil 112 (for example). The components 13 adhere to a film 14. After the components 13 have been laid into the troughs of the structure 11, they are peeled off the film 14 by means of a peeling blade 16. To attach the parts 13 in the trough, gluing techniques can be used, in which the work is also performed with photocurable substances, specifically in the manner as described above.

Finally, Figure 5 shows a final roller pair 1''', in which the finished structures 11 are covered with a cover film 15, for protection and transport. Here again, gluing of the film to the structures 11 can take place by means of the method described above.

Films that then form individual layers in the structure can also be supplied during the production, i.e. during the generation of the structures 11, as a function of chemical, physical, and biological properties, similar to what is shown in Fig. 5.

However, the invention is not limited to the embodiments shown in Figures 1 to 5.

Figure 6 shows a structure of a microsystem that is already far advanced, which is constructed on a film in layers. The constructed base body is provided with the reference symbol 20. During the construction of the base body 20, a cavity 21 is left in it, into which an electronic component 13 (in this case a microchip) has been inserted. During the further construction of the base body structure 20, openings are left in the individual layers, above the pads 22, which are filled, layer by layer, by means of a conductive adhesive, using the screen-printing method. Thus, a vertically rising structure 23 of a conductive material is formed, from which (as shown in the drawing) a conductive track 24 that runs horizontally is then applied to the currently last layer of the base body 20, also using the screen-printing method. This conductive track (or these conductive tracks) lead(s) to other electronic components or to lateral contacts, thereby implementing electronic functions.

Figure 7 shows how two electronic components (in this case two microchips) can be directly connected with one another in conductive manner, vertically above one another.

Figure 7a shows the status in which, similar to Figure 6, a base body 20 is constructed on the film 7, in which a microchip 13 has

already been inserted into a corresponding cavity. The electrical connections (pads) 22 point upward. Above these PADS 22, openings are left in the material of the base body 20, which correspond with openings in a template 25. Soldering paste is now applied above the openings of the template 25, which fills the space above the pads 22.

Figure 7b shows the status after removal of the template 25. Small piles 26 of soldering paste have been left behind above the pads 22.

In a subsequent station, the small piles 26 of soldering paste are heated up, so that the soldering paste becomes liquid and forms so-called bumps 27. This status is shown in Figure 7c.

In Figure 7d, the base body 20 has been built up further, whereby an additional cavity 28 has been formed, into which another microchip 13' is now placed, with the pads 22' facing downward. The pads 22' rest on the solder bumps 27, which have solidified again.

In a subsequent roller device, in which one of the rollers is provided with a heating device, the second microchip 13' is now

pressed into the cavity 28, whereby the solder bumps become liquid again, as a result of the heating, and produce an electrical contact with the pads 22'.

This status is shown in Figure 7e.

Accordingly, the further layered construction of the microstructure, i.e. of the microsystem can proceed as just described, whereby the alternatives from Figure 6 and Figure 7a to e can also be combined with one another.

Claims

1. Method for producing microsystems having microelectronic components inserted, adjacent to and/or above one another, into cavities created during the layered construction of base bodies composed of photocurable material, which components are connected with one another so as to be electrically or thermally conductive, characterized in that after the insertion of the electronic component (13), layered construction of the base body (29) is continued, but that a structure (23, 26) of electrically/thermally conductive material is built up, vertically rising, above the contacts (pads) (22, 22′) of the electronic component, whereby this conductive material produces a direct connection with another electronic component (13') disposed above the electronic component, or by means of a horizontally running conductive track (24) of conductive material rising from the pad (22) to one (several) other electronic component(s) disposed at a lateral distance from the electronic component.

2. Method according to claim 1, characterized in that the conductive, vertically rising structure is generated in openings in consecutive layers that are left clear above the

pads (22), by means of screen printing, in which connection the openings left in the layers of photocurable material, above the pads (22), are filled with the electrically conductive material, and finally the horizontally running conductive track (24) is printed.

3. Method according to claim 2, characterized in that the conductive material is an adhesive.

4. Method according to claim 1, characterized in that the electrically conductive vertically rising structure (26) consists of a small pile of soldering paste that is applied to the pad (22), in each instance, through the corresponding opening of a template (25), which small pile is formatted into a solder bead (bump) in the subsequent step, after removal of the template (25), by means of heating, and after further layered construction of the base body (20) and production of a corresponding cavity (28), another electronic component (13') is inserted into the latter, in such a manner that the bumps (27) previously produced are connected with the pads (22') of the second component (13') by means of heating.

5. Method according to one or more of claims 1 to 4, characterized by a combination of characteristics from claim 2 and 4.

6. Method according to one of claims 1 to 5, characterized in that the layered construction of the microsystem takes place between two plates, at least one of which is permeable for electromagnetic waves, whereby a liquid of photocurable material is present between the plates, which is exposed and cured in layers, in accordance with a 3D model of the structure to be generated, which has been stored in memory in layers.

7. Method according to one of claims 1 to 5, characterized in that the layered construction of the microsystem takes place between at least one pair of rollers, whereby the region between the rollers is filled with a photocurable liquid and the exposure of the liquid layer, in each instance, takes place by means of one of the rollers and through a mask that corresponds to the layer structure, in each instance.

8. Device for implementing the method according to claim 7, characterized by at least one roller pair (1, 1', 1'', 1'''), in which the distance between the rollers (2, 3) is changeable, whereby one roller (2) of the roller pair (1, 1', 1'', 1'''), in each instance (exposure roller) consists of a material that is permeable for electromagnetic waves, whereby a source (5) that emits electromagnetic waves (light source) is disposed in this roller (2), a mask (10) having regions that are permeable and non-permeable for electromagnetic waves, assigned to each exposure roller (2), as well as by a substrate carrier film (7) as the basis for the generated structures (11), passed through between the at least one roller pair (1, 1', 1'', 1''').

9. Device according to claim 8, characterized in that the mask is applied to the surface of the exposure roller (2).

10. Device according to claim 8, characterized in that a stationary exposure slot (6) is disposed in the exposure roller (2), between the light source (5) and the roller surface, and the mask is configured as a strip (10) of film that is passed along the surface of the exposure roller (2), below the slot (6).

11. Device according to one of claim 9 or 10, characterized in that several roller pairs are disposed in series behind one another.

12. Device according to one of claims 9 to 11, characterized in that flushing devices are disposed between individual roller pairs (1, 1', 1'', 1''').

13. Device according to one of claims 9 to 12, characterized in that film windings (112, 15) are disposed between the roller pairs (1, 1', 1'', 1'''), the films of which are configured as carriers for an adhesive layer and/or electrical and/or electronic and/or mechanical and/or optical and/or biological components (13).

14. Device according to one of claims 9 to 12, characterized in that film windings are disposed between the roller pairs (1, 1', 1'', 1'''), whereby the films demonstrate defined physical or chemical properties.

15. Device according to one of claims 9 to 14, characterized in that at least the exposure roller (2) is provided with an anti-adhesion coating.

16. Device according to one of claims 9 to 15, characterized in that at least one heating device follows the at least one roller pair (1, 1', 1'', 1''').

17. Device according to one of claims 9 to 16, characterized in that at least one screen-printing device follows the at least one roller pair (1, 1', 1'', 1''').