Description

Method for producing electrically conductive cross connections between two wiring layers on a substrate

The number of connections on integrated circuits is becoming ever greater, while said integrated circuits are at the same time becoming miniaturized to an ever greater extent. The difficulties expected in the course of this increase in miniaturization in the application of solder paste and component mounting are intended to be overcome by new housing forms, where emphasis may be given here in particular to single-chip, few-chip or multi-chip modules in a ball grid array package (DE-Z productronic 5, 1994, pages 54, 55). These modules are based on a plated-through substrate, on which contact is made with the chips for example via contact-mating wires or by means of flip-chip mounting. The ball grid array (BGA) is situated on the underside of the substrate, and is often also referred to as a solder grid array, land grid array or solder bump array. The ball grid array comprises solder studs arranged over the area on the underside of the substrate, which allow surface mounting on the printed circuit boards or assemblies. The arrangement of the solder studs over an area allows large numbers of connections to be realized, in a coarse grid of 1.27 mm, for example.

In the case of so-called MID technology (MID = Molded Interconnection Devices), injection-molded parts with integrated conductor runs are used instead of conventional printed circuits. High-quality thermoplastics suitable for the injection molding of three-dimensional substrates form the basis of this technology. By comparison with conventional substrate materials for printed circuits, such thermoplastics are distinguished by better mechanical, chemical, electrical and environmental properties. In the case of one specific direction of MID technology, the so-called

SIL technology (SIL = Spitzgießteile mit integrierten Leiterzügen [injection-molded parts with integrated conductor runs]), a metal layer applied to the injection-molded parts is structured without using the mask technique that is otherwise customary,

by means of a special laser structuring method. In this case, a plurality of mechanical and electrical functions can be integrated in the three-dimensional injection-molded parts with structured metalization layer. The housing support function is simultaneously undertaken by guides and snap-connections while the metalization layer, in addition to the wiring and connection function, also serves as electromagnetic shielding and provides for good heat dissipation. In order to produce electrically conductive cross connections between two wiring installations on each of the opposite surfaces of the injection-molded parts, corresponding plated-through holes are produced as early as during the injection-molding process. The inner walls of these plated-through holes are then likewise coated with a metal layer during the metalization of the injection-molded parts. Further details relating to the production of three-dimensional injection-molded parts with integrated conductor runs are revealed for example in DE-A-37 32 249 or DE-A-0 361 192.

According to a variant of MID technology which is disclosed in EP-A-0 645 953, a substrate is produced by injection molding and provided with a well and then a first conductor plane, a dielectric layer and a second conductor plane are successively produced on said substrate, whereupon an electronic component is incorporated in the well, the connections of the component are electrically conductively connected to assigned connection areas on the substrate, preferably by bonding, and then an encapsulation is formed for the component by the well being filled with plastic. A compact, thin structure with a high wiring density is produced. The recessed mounting and encapsulation of components in wells of the injection-molded substrate not only results in a thickness reduction but also attains optimum protection of the component and the connection wiring thereof.

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WO-A-96 096 46 has disclosed a so-called polymer stud grid array (PSGA), which combines the advantages of a ball

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grid array (BGA) with the advantages of MID technology. The new design was called a polymer stud grid array (PSGA) on the basis of the ball grid array (BGA), the term "polymer stud" being intended to refer to polymer studs which are concomitantly formed during the injection molding of the substrate. The new design is suitable for single-chip, few-chip or multi-chip modules and comprises

- an injection-molded three-dimensional substrate made of an electrically insulating polymer,
- polymer studs which are arranged over the area on the underside of the substrate and are concomitantly formed during the injection-molding process,
- external connections which are formed on the polymer studs by solderable end surface,
- conductor runs which are formed at least on the underside of the substrate and connect the external connections to internal connections, and
- at least one chip which is arranged on the substrate and whose connections are electrically conductively connected to the internal connections.

In addition to the simple and cost-effective production of the polymer studs during the injection molding of the substrate, the production of the external connections on the polymer studs can also be carried out with minimal effort together with the production of the conductor runs, which is normal for MID technology and SIL technology. The fine laser structuring which is preferred in SIL technology enables the external connections to be realized on the polymer studs with a large number of connections in a very fine grid. It should be emphasized, furthermore, that the thermal expansion of the polymer studs corresponds to the thermal expansion of the substrate and to that of the printed circuit board accommodating the module. Should any mechanical stresses occur, then the elastic properties of the polymer studs allow at least partial compensation. The dimensional stability of the external connections formed on the polymer studs

also allows the reliability for repair and replacement to be considerably enhanced by comparison with ball grid arrays,

whose external connections are formed by solder studs. In the case of the polymer stud grid array, the polymer studs and the chip or the chips are usually arranged on the same side of the substrate. In the case of a substrate provided with plated-through holes, the polymer studs and the chip or the chips may perfectly well be arranged on different sides of the substrate as well. Such an arrangement of polymer studs and chips on opposite sides of the substrate is of interest particularly for large chips, which require a multiplicity of assigned external connections.

WO-A-89 00346 discloses single-chip modules which are suitable for surface mounting and are based on an injection-molded three-dimensional substrate with plated-through holes. In addition to these plated-through holes, during the injection-molding process, the substrate acquires a well, arranged centrally on the top side, and a multiplicity of polymer studs arranged in one or else in two peripheral rows on the underside. The chip arranged in the well on the top side is connected to assigned conductor tracks, which lead to the outside in the form of strips, via fine contact-making wires. These conductor tracks are then electrically conductively connected to the assigned, surface-metalized polymer studs over plated-through holes arranged in the outer region. If the edge regions of the substrate are then separated with cutting lines which pass centrally through the plated-through holes, then electrically conductive cross connections with a semicircular cross section are produced, which electrically conductively connect the outer ends of the conductor tracks arranged on the surface of the substrate to the assigned polymer studs arranged on the underside of the substrate.

The invention specified in claim 1 is based on the problem, in the context of MID technology, of simplifying the production of electrically conductive cross connections between two wiring layers on the top side and underside

of an injection-molded substrate. In this case, the cross connections are intended to be suitable, in particular, also for the polymer stud grid arrays explained above.

The particular advantages attained by means of the invention are that, by comparison with conventional through-plating technology with metalized holes, it is possible to realize substantially finer structures with higher reliability of the cross connections. The outwardly open toothing of the substrates can be metalized with a very good layer thickness distribution, in contrast to the inner walls of narrow plated-through holes. In this case, the structuring of the metalization layer to form the individual cross connections by at least partly removing the metalization layer in the region of the teeth requires only little effort.

Advantageous refinements of the method according to the invention are specified in claims 2 to 9. A particularly advantageous application of the method is specified in claim 10.

The development according to claim 2 enables the teeth to be structured particularly finely during the injection-molding process.

The refinement according to claim 3 allows the application of the cross connections according to the invention in polymer stud grid arrays. In this case, it should be emphasized that the teeth and the polymer studs are produced in the same work operation during the injection-molding process.

The refinement according to claim 4 has the advantage that, for the application of the metalization layer, it is possible to resort to technologies which have long proven their worth in the production of printed circuits.

Although the method according to the invention can, in principle, also be carried out using the semiadditive technique, the subtractive

technique according to claim 5 affords quite a few advantages. In addition to the simple and economical production of the desired conductor patterns, emphasis may be given here in particular to the possibility of fine laser structuring which, making no use of costly, conventional photolithography, enables extremely fine structures to be produced even with three-dimensional substrates. According to claim 6, the etching resist layer can in this case be applied in a simple manner by the electrodeposition of tin or tin-lead and subsequently be structured by processing with the laser beam.

The development according to claim 7 enables particularly simple and reliable mechanical structuring of the metalization layer for the purpose of producing the cross connections. In particular, this mechanical structuring in the region of the ends of the substrates can be carried out in a particularly rapid and simple manner by the teeth being ground down, in accordance with claim 8, or cut off, in accordance with claim 9.

In accordance with claim 10, the method according to the invention is suitable in particular for the production of a polymer stud grid array with a chip arranged on the top side of the substrate. The arrangement of the chip on the top side and the arrangement of the studs or polymer studs on the underside of the substrate in this case results in ideal preconditions for realizing so-called chip scale packages, in the case of which the dimensions of the array essentially correspond to the dimensions of the chip.

An exemplary embodiment of the invention is illustrated in the drawing and is described in more detail below.

In the figures

Figure 1 shows a partial plan view of a substrate with integrally formed teeth in the outer end region,

Figure 2 shows a three-dimensional illustration of the teeth in accordance with Figure 1,

Figure 3 shows a partial plan view of a substrate with integrally formed teeth in the region of a cutout in the substrate,

Figure 4 shows the partial plan view of the substrate in accordance with Figure 1 after the application of a metalization layer and of an etching resist,

Figure 5 shows the partial plan view of a substrate in accordance with Figure 4 after laser structuring,

Figure 6 shows a partial plan view of the substrate in accordance with Figure 4 after the teeth have been ground down in order to form cross connections, and

Figure 7 shows a side view of the substrate formed as polymer stud grid arrays.

In accordance with Figure 1, the starting point is a substrate S having a multiplicity of teeth Z in the outer end region, said teeth being arranged at a uniform distance from one another. The substrate including the teeth Z and the studs H, which will be explained later with reference to Figure 7, is produced by injection molding, suitable substrate materials being thermoplastics which are resistant to high temperatures, such as polyetherimide, polyether sulfone or polyamide. The three-dimensional illustration in accordance with Figure 2 shows that the teeth Z are designed in the form of a wave profile with a planar base area and extend between the top side O and the underside U of the substrate S. In the exemplary embodiment illustrated, the top side O and underside U are designed to be parallel to one another, that is to say all of the teeth Z, which can, of course, also be integrally formed on the other three ends of the substrate S, have the same length. Figure 3 shows that in the region of a cutout A in the substrate S, too, the teeth Z can, in principle, be integrally formed on the end faces of the cutout A. In addition to the rectangular cutout A illustrated here, other shapes,

such as e.g. circular shapes or slot-like shapes, may also be suitable.

The substrate S produced by injection molding is firstly subjected to a series of customary pretreatments, in particular pickling, cleaning, seeding and activation of the seeding. Afterwards, in accordance with Figure 4, a metalization layer M is applied to the substrate S over the whole area by means of the chemical deposition of copper without external current and the subsequent electrodeposition of copper. An etching resist AR is then applied to the metalization layer M by electroless- or by electrodeposition of tin. Since Figure 4 illustrates in the end region of the substrate with teeth Z that is of interest here, it must be pointed out that both the metalization layer M and the etching resist AR cover the entire substrate S over the whole area.

After application of the etching resist AR, the metalization layer M is structured, in accordance with Figure 5, on the top side O and the underside U (cf. Figure 2) of the substrate S. In the exemplary embodiment illustrated here, the etching resist AR is removed again by means of laser radiation in all of the regions which do not correspond to the desired conductor pattern of the wiring layers to be formed. Further details of such laser structuring are revealed for example in DE-A-37 32 249. The unprotected regions of the metalization layer M are subsequently removed by being etched down to the surface of the substrate S. It is evident from Figure 5 that conductor tracks L are produced on both sides of the substrate S by this structuring process, said conductor tracks each extending in the region between two teeth Z toward the edge of the substrate S. The separating line T illustrated in Figure 5 serves only to distinguish the surface metalization layer M with the conductor tracks L and the metalization layer M at the end. In actual fact, however, the metalization layer M extends across the substrate S without any separation.

After the wiring layers have been formed in the manner outlined on the top side O and underside U

(cf. Figure 2) of the substrate S, the teeth Z are removed by grinding

or by cutting. In accordance with Figure 6, cross connections Q which are electrically insulated from one another are produced as a result of this in the end region of the former gaps between teeth.

Figure 7 shows a side view of the substrate S with conductor tracks L, cross connections Q and with the already mentioned studs H arranged over the area on the underside U. A chip C is applied to the top side O of the substrate S, contact being made with said chip either using the wire-bonding technology with bonding wires B as illustrated on the left or using the flip-chip technology with connections A as illustrated on the right. In the case of wire-bonding technology, the chip C is joined to the top side O of the substrate S by means of an adhesive layer K.

Figure 7 clearly shows that the individual connections of the chip C are electrically conductively connected to assigned studs H via conductor tracks L on the top side O, via cross connections Q at the ends and via conductor tracks L on the underside U. A solderable end surface E is applied to the underside of the metalized studs H, said end surface being formed for example by a layer sequence of nickel and gold.

The structure illustrated in Figure 7 is a polymer stud grid array, which is designated altogether by PSGA. Further details of such polymer stud grid arrays are revealed in WO-A-96 09646 for example.

In the case of the polymer stud grid arrays PSGA illustrated in Figure 7, the external dimensions of the chip C and substrate S are approximately the same size. Consequently, a form of housing is involved which is usually referred to as a chip scale package. It can also clearly be discerned that the cross connections Q at the ends, being structured extremely finely, enable the entire polymer stud grid array PSGA to be configured extremely compactly, and thus make a crucial contribution to the realization of the chip scale package.

Patent Claims

1. A method for producing electrically conductive cross connections (Q) between two wiring layers on the top side (O) and the underside (U) of a substrate (S), having the following steps:

a) production of the substrate (S) from an electrically insulating plastic by injection molding, a plurality of integral teeth (Z) being concomitantly formed during the injection-molding process in the outer end region of the substrate (S) and/or in the region of a cutout (A) in the substrate (S), said teeth being arranged at a distance from one another and extending between the top side (O) and the underside (U);

b) application of a metalization layer (M) to the substrate (S);

c) removal of the metalization layer (M) at least in the regions adjoining the desired conductor pattern and in the end region of the teeth (Z) in such a way as to produce cross connections (Q) which are electrically insulated from one another between the teeth (Z).

2. The method as claimed in claim 1, characterized in that, in step a), teeth (Z) are formed after the manner of a wave profile during the injection molding of the substrate (S).

3. The method as claimed in claim 1 or 2, characterized in that in step a), polymer studs (H) which are arranged over the area on the underside (U) of the substrate (S) are concomitantly formed during the injection molding of said substrate, and in that, after the application of the metalization layer (M), a solderable end surface (E) is applied to the polymer studs (H).

4. The method as claimed in one of the preceding claims, characterized in that the metalization layer (M) is applied to the substrate (S) by electroless- and electrodeposition of copper.

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5. The method as claimed in one of the preceding claims, characterized in that, after step b) an etching resist (AR) is applied to the metalization layer, in that the etching resist (AR) is removed again by means of laser radiation at least in the regions adjoining the desired conductor pattern, and in that the uncovered regions of the metalization layer (M) is etched away down to the surface of the substrate (S).

6. The method as claimed in claim 5, characterized in that the etching resist (AR) is applied by the electrodeposition of tin or tin-lead.

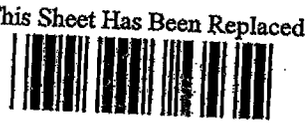
7. The method as claimed in one of the preceding claims, characterized in that the metalization layer (M) is removed mechanically in the end region of the teeth (Z).

8. The method as claimed in claim 7, characterized in that the metalization layer (M) is removed in the end region of the teeth (Z) by the teeth (Z) being ground down.

9. The method as claimed in claim 7, characterized in that the metalization layer (M) is removed in the end region of the teeth (Z) by the teeth (Z) being cut off.

10. An application of the method as claimed in one of claims 3 to 9, in the production of a polymer stud grid array (PSGA) with a chip arranged on the top side of the substrate (S) using wire bonding technology or using flip-chip technology.

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