Sensor Packaging using a Batch Packaging Process based on RMPD® and 3D-CSP

The integration of sensors and evaluation electronics into a housing suitable for the measuring location is one of the many tasks taken on by microsystems technology. Standard sensors at economical prices are available but with traditional technologies they can only be integrated with difficulty into small measuring areas. As a rule a cable is required for connection to the evaluation electronics. Short routes for most signals, which are analogue, for conversion into a bus-compatible digital signal have the advantage of low sensitivity to interference. Thus for instance parasitic capacity and induction that occur in cables can be reduced to a minimum.

Solutions have been developed based on the MID process in which the evaluation electronics convert the analogue signal into a bus-compatible digital signal directly at the location where the measurement is taken. The MID process is however a tool-based process that gives rise to very high tool costs, especially with small components.

Batch processing based RMPD® processes together with the 3D-CSP process offer an economical alternative here. It is only the batch size that determines whether the use of tools is worthwhile. Also the 4-stage production processes works without expensive tools, making RMPD® and 3D-CSP even more cost efficient and attractive.

With RMPD®-Mask as with microelectronics, the mask is the tool of production, individually tailored to the product. microTEC currently has machines for 5 inch, 9 inch and 14 inch formats available. The number of products produced in parallel in the batch process is determined by an appropriate choice of mask format in combination with the maximum component size. The smaller the system, the more of them can be produced in parallel. Unlike in injection moulding, the small size of a product is a cost advantage. Cost efficient production is not limited by quantities needed by the customer. The production time for a mask is a few days, which leads to faster innovation cycles. Future innovation cycles for a product can be done easily, there are no expensive tools which must be used to pay back for non reoccurring engineering costs.

Design and model phase

The following software tools are used in the design phase. Firstly there is a 3D-CAD program with which all mechanical components can be defined and designed. Here too a bare chip (die) becomes the mechanical construction element that must be defined in all its dimensions and tolerances.

Secondly, an EDA system is required, this being indispensable for the routing of complex electronics layouts. EDA systems also permit the calculation of the geometry of RF components such as baluns, antennae and coils. Design rules are available for EDA applications and they are constantly updated to the latest technological state of the art.

The layout can then be transferred to the 3D-CAD system and it defines all the metal structures in the total system. The connections can be followed right down to the pad of the sensor or the electronic component. The entire system is available as a three-dimensional system and it can be defined in accordance with the materials used with its parameters of relevance to the simulation. In the simulation electromagnetic compatibility, heat dissipation, flow characteristics and mechanical stresses can be optimised. The merger of 3D-CAD and EDA systems into an integrated design tool has now been called E-CAD by microTEC.

Available computer capacity is sometimes exceeded at this point, so simplification of the components relevant to the simulation sometimes has to be undertaken first.

The four production stages to the system

First stage: RMPD® processes, which were established 10 years ago, are used for the production of microsystems. Here the components grow in parallel on a substrate in the batch process by means of photopolymerisation. Layer thicknesses and component measurements down to the μm range are possible. Multimaterial (area-specific material properties in one component) has long been used and a variety of materials from soft to hard, from transparent to opaque or from hydrophilic to hydrophobic have applications in products.

Second stage: This is the integration of components. Here discrete components are inserted into the cavities produced with the RMPD® process, so that their top surface align with the top surface of the of the plastic parts. For insertion the substrate (generate in a parallel manner) is inserted into a pick-and-place machines, and all discretes are placed in the cavities. This is the only non-parallel step in which costs are determined by the speed of the automatic pick-and-place machines. With very large numbers of units, this sequential stage is the crucial cost factor.

Third stage: This is the metallisation of the batches, after they have been given a covering with the RMPD® process that contains openings to the lower levels only for vertical electrical or fluid connections. In metallisation, all components are covered at the same time with a metal layer that also form electrical contacts with the underlying components via the openings. All contacts are produced at the same time.

Fourth stage: This is the structuring of the metal coating. For this there are a number of processes available that are used depending on the precision required for the electrically conductive layer. The precision required for the circuit geometries and distances to the ground layer for high frequency purposes is achieved and confirmed in the context of the EC-funded project INOS (www.INOS-ist.org).

One can easily imagine that the repeating steps 1–4 various functions (microelectronics, microfluidics, integrated optics) can implemented in one single package.

Applications

Integration of a Surface Acoustic Wave (SAW) sensor for measurement of the flow rate of chemical and biological parameters:

A SAW sensor consists of a monocrystal material that is very sensitive to pressure. This leads for one thing to the fact that its pads cannot be bonded in the traditional way and for another thing that it must be protected from pressure resulting from temperature fluctuations when in it is embedded in a housing. These temperature fluctuations lead to tensions in the material that shift the resonance frequency and demonstrate sensitivity to interference. A further problem consists of the fact that the measurement substances (usually gases or liquids) must pass the sensor surface area. This combination of microfluidics and electronics can be integrated into a single component simply and economically with the 3D-CSP process. The sensor is placed into a cavity, carefully aligned with the RMPD® multimaterial. In the next step the channels are made, and also the paths to the pad are produced directly via the sensor surface. The next layer then contains the conductive tracks made of copper, which also provide the contact with the pad of the sensor by the metallisation stage. The contact surfaces needed for probing are thus remote from the pressure sensitive sensor and therefore no longer create any interference. In this way a sensor package is created featuring minimum volume and very short access times.

Another task associated with liquids is the integration of a pressure sensor. The membrane of a silicon pressure sensor comes into direct contact with the liquid. Many of these pressure sensors work are capacitive based, which means that long routes to evaluation electronics can lead to great sensitivity to interference. An ASIC located adjacent to the pressure sensor must convert the analogue signal into a bus-compatible digital signal. With the 3D-CSP process, the sensor and ASIC can be located right next to each other in a housing. The interconnection step works batch-orientated, i.e., the metallisation and microstructuring step work I parallel (no serial wire bonding process is needed). Here apertures in the housing directly interface the measurement medium at desired positions and also avoid cross sensitivity of the package in the event of temperature fluctuations.

Orientation-dependent sensors such as acceleration sensors, gyroscopes and magnetic field sensors must often be arranged in orthogonal way. With 3D-CSP, sensor chips can also be precisely orientated in all three spatial axes as "dies" and be integrated into a housing with the electronics for analogue/digital conversion, which is often necessary here too, with the shortest distances.

Prospects

The batch-orientated production process presented here provides a tool that can integrate all the characteristics required for sensor integration in a simple manner. With the high frequency design rules, inexpensive balun filters and antennae can be integrated in the RMPD® 3D-CSP system and directly connected with the transmission module with RF technology without the interference of bonding wires. An energy source may be integrated with the same technology so that the autonomous system can transmit the relevant sensor signals wirelessly via a ZigBee interface to the control unit or the actuator.

Author:
Dipl.-Ing. Reiner Götzen
microTEC Gesellschaft
für Mikrotechnologie mbH
Bismarckstraße 142b
47057 Duisburg - Germany
Tel.:+49(0)203/3062050
Fax: +49(0)203/3062069
www.microtec-d.com
or
microTEC Gesellschaft
für Mikrotechnologie mbH
67098 Bad Dürkheim - Germany
Tel.: +49(0)6322/650220
Fax: +49(0)6322/650221
www.microtec-d.com