

Integration of micro-mechatronics in automotive applications

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Abstract Micro-Mechatronics and System Integration is a multidisciplinary field, which offers low cost system solutions based on the principle of homogenizing system components and consequent elimination of at least one material component or packaging level from the system. These system approaches show, compared to the existing solutions, a higher functionality, more intelligence and better reliability performance. The number of interconnects necessary to link a motor, or sensor, or an actuator to the digital bus decreases, as the smartness of the devices increases. The paper presents system solutions and manufacturing technology for mechatronic systems, developed at Fraunhofer IZM. To reduce package volume, advanced packaging technologies as Flip Chip and CSP are used, for increased reliability and additional mechanical functionality encapsulation processes as transfer-molding, a combination of transfer- and injection-molding or modular packaging toolkit based on LTCC are selected. The first system is a multi-chip-module for motor control used for automotive applications as window-lifts or sun-roofs. For the module at least three interconnection layers were eliminated using novel concepts as intelligent leadframes and integrated plugs. The package resists harsh environment as present in automotive applications. Another mechatronic package called TB-BGA or StackPac respectively, is a 3-D solution, containing a pressure sensor and the complete electronics necessary for control and data transfers. This package involves CSP-technologies on flex, with an increase of functionality per volume unit by direct CSP-to-CSP mounting, eliminating substrate layers and large signal distances of unamplified signals from sensor output. The mechatronic packages will be discussed in detail. Especially cost, reliability performance and according “Design for Reliability” show the potential of micro-mechatronic solutions in automotive and industrial applications.

1

Basic conditions for the development of mechatronics

The development of mechatronics is a vital key for the future of electronics. Ever more complex applications

require the processing of ever increasing data volumes: a corresponding increase in flexibility and functionality is the only possible response – leading to the development of micro-mechatronics [1].

Synergistic co-operation between individual disciplines concerned is also an indispensable condition. Electronic and mechanical simulation and designs must be compatible for a proper realization of the thermomechanical concept. The package fits to an optimum place within a macroscopic system of mechanical parts, which are especially designed to work with electronics as intelligent subsystem. It is of equal importance to generate a software map of all requirements and functions, as early as possible, preferably at the planning and development stage; this is the ideal way to shorten development times while optimizing the resulting system.

1.1

Target temperature range for automotive applications

Another important requirement is the question of an increase in the reliability of electronic and mechatronic components. Electronic components in the area of the car engine, for example, must be able to perform consistently at temperatures of up to 200 °C and at extreme temperature cycles.

The assemblies used in these areas must be cost-effective and yet at the same time able to perform for the entire technical life span of the automobile. They need to be assembled in a light and compact pattern. All this can be delivered by sub-modules as parts of subsidiary intelligence with interconnection levels which have been reduced to a bare minimum. Both, materials used and processes applied must be carefully attuned to each other in order to meet all requirements of and in particular to achieve the highest possible standards of reliability. This means that, beyond the quality of the individual component, it is the way the components are combined and put together which determines the functionality and quality of the integrated set-up.

1.2

Novel concepts for polymer materials

Focusing on micro-mechatronic applications there are a few additional demands to encapsulants commonly used for packaging. The encapsulants need a wide range of temperatures, a high resistance against harsh environment and the integration of moving and sensing elements without losing package functionality.

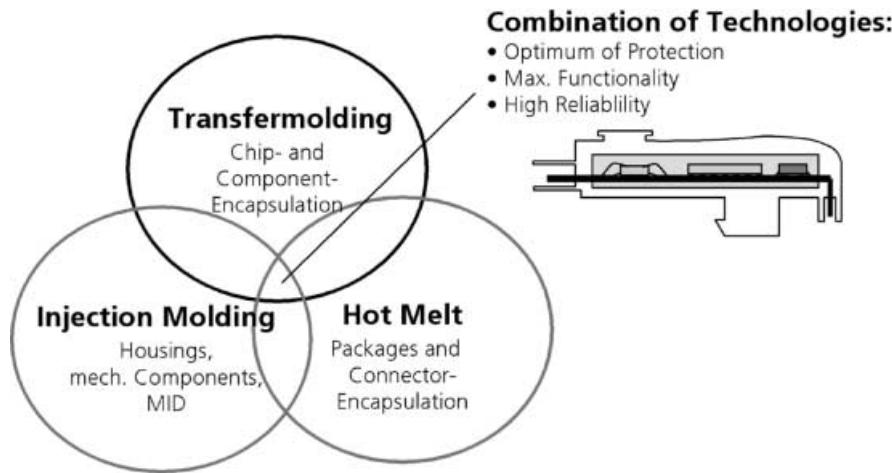


Fig. 1. Combination of packaging materials for optimized package functionality

Typical materials used for microelectronics encapsulation are epoxy resins, where the chemical basis is a multifunctional epoxy oligomer based on novolac. These materials do have T_g 's beyond 200 °C and so they have the potential for short term – high temperature application. The evaluation of encapsulants for optimized long-term stability is one of the topics the micro-mechatronics center is focusing on. Further potential for micro-mechatronics lies in the use of advanced thermoplastic materials. In the past they have been used rather for electronics housing than for the direct encapsulation of microelectronics. The suitability of thermoplastics for the process of direct encapsulation, meanwhile, is subject to a number of conditions. In order to preserve a multifunctional package, both technologies would have to be joined in the forming of two- or multi-component-packages (see Fig. 1).

The use of thermoplastic hotmelt materials for micro-mechatronic packaging allows a decrease of processing temperature, the use of cost effective low temperature materials. Research of Fraunhofer IZM is performed in the fields of direct encapsulation of microelectronics using thermoplastic polymers, thermoplastic circuit boards a.k.a. MID-devices for both, Flip Chip and SMD components and on the material compatibility of classic encapsulants and novel thermoplastic materials. Other areas of research important for the manufacturing of miniaturized mechatronic systems are wafer level encapsulation.

1.3

Process selection

For the purposes of material and process selection, many considerations are relevant, e.g., the processing in the course of standard operations, a homogeneous interconnection technology and procedures under conditions designed to minimize stress factors. It is fairly difficult, meanwhile, to make universally valid propositions about the suitability of certain technologies and materials for mechatronic products. Such statements can only have value if they refer to individual products and the clearly identified purposes they are supposed to serve [2].



Fig. 2. CavityPack: molding on flex approach to sensor packaging

2 Mechatronic applications

2.1

Modular construction systems for mechatronics

In the course of a project sponsored by the BMBF, the Fraunhofer Institute for Reliability and Microintegration (IZM) developed a modular construction system for subsystems. Spatially stackable single components include sensor elements, signal processing, actors and bus technology. The components are mounted taking into account the application they are supposed to serve. They produced standard components and can be mounted by soldering, leading to a minimized number of different interconnection technologies.

Based on molding-on-flex-technology the StackPac concept allows the insertion of individual ICs by contacting through either wire bonding or flip chip technology and integration of SMD-components. Multichip modules can be created using different contacting technologies.

Molding the package widens the range of possible package designs from simple patterns to additional func-

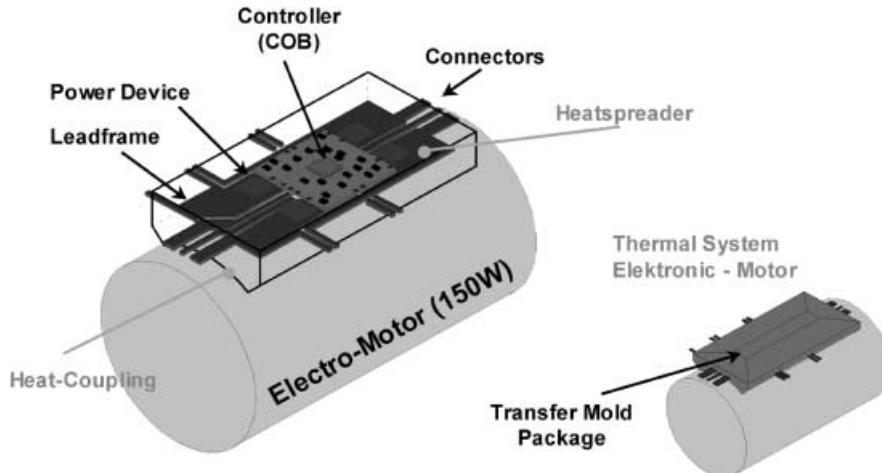


Fig. 3. H-Bridge motor control unit

tional geometries which are compatible with the modular construction system as depicted in Fig. 3. Connection to the actorics can be effected by a direct integration of the components.

The same technology can be used to design chip size packages (CSPs). The necessary combination with the sensorics can be created by using a CavityPack (see Fig. 2).

The systems have already been used successfully in engineering applications. StackPac's achieve excellent reliability scores, in particular for high-temperature applications, using the mentioned novel encapsulants. This allows a reduction of development and qualification costs by using standard modules, which makes the use of advanced technology in confined spaces economically viable.

2.2

Mechatronic solutions for the automobile

In the course of a project jointly run by BMW AG and the Fraunhofer-IZM, an H-bridge circuit with control logic, bus connection and sensor facility has been developed (Fig. 3). The use of power ICs required a concept for the heat dissipation of the package. The reduction in the number of interconnecting levels was another purpose of this mission. The power semiconductors have more advantages: in comparison with relays, they use substantially less space and are extremely well suited for the software selection process. This can turn out to be a particularly decisive advantage to conventional solutions, once the 42-V-on-board-network has been installed.

Thermal management functions are fulfilled perfectly by the heat sink comprising the inserted copper lead frame and the engine which has been mounted right at the bottom side of the package. The motor block has the effect of

an active cooling element. This integrated thermal concept allowed the substitution of the conventional trigger system by spatially optimized electronics. The high degree of integration resulted in a reduction of spatial requirements by about 50%.

3

Summary and outlook

Future fields of application for mechatronics will include robotics and industrial engineering, i.e. the construction of machinery and production plants. Intelligent robots who are programmed to learn on their own, to communicate with each other by means of wireless communication and to develop solutions to complex tasks autonomously can be used in either the exploration of space/other planets or more earth-bound functions such as repair/maintenance works in inaccessible machinery or the service labor in hospitals.

Medical technology can be regarded as one of the markets with the biggest potential for the use of micro-mechatronic technology. The increased use of such technology in the area of minimally invasive surgery has made a substantial contribution.

References

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