Polyurethane encapsulation for the protection of sensitive electronics

By Gerd Viertel and Daniel Lüthi

MANY DIFFERENT PLASTICS and processes are used to encapsulate and protect the sensitive inner workings of electronic devices. Thanks to a new technology, it is now possible to combine the encapsulation of the electronics and the production of the housing in a single step. Only one material is needed, namely polyurethane, as this product is ideally equipped to meet the many stringent specifications that relate, for example, to the mechanical and thermal properties.

In the production of IT equipment, in automotive and mechanical engineering, in process engineering and in many other branches of industry, the number of electrical and electronic components such as plugs, cables, contacts and circuits is increasing at a rapid rate. The functions of such parts are becoming increasingly complex and, due to the trend towards miniaturization, the parts themselves are becoming smaller and smaller.

In most cases, they also have complex geometries because their shape is governed by the available space. At the same time, the demands made on functional reliability are very high. For example, plug contacts have to be reliably protected from oxidation and moisture. The insulating layer of moving cables must be resistant to abrasion, and cable harnesses in the engine compartment, for example, have to be able to permanently withstand temperatures of up to 130 °C without any deterioration in their mechanical properties.

In order to successfully combine such properties as sealing characteristics, temperature and chemical resistance, shaping, dimensional stability, abrasion resistance and electrical insulation, electrical and electronic components have, until now, been "packaged" in a wide variety of different plastics designed to meet specific requirements. Examples include rubber and nitrile sleeves, PVC, polyester and polyamide sheathing, polypropylene, corrugated hose and hot-melt casting compounds. For the manufacturer, this means he must be familiar with the processing of the respective plastics and must invest in the relevant technologies. This can mean enormous logistical expense. At the same time, he is under heavy cost and time pressure.

Fig. 1: It is now possible to combine the encapsulation of the electronics and the production of the housing in a single step – with polyurethane.

Frequently, the electronic components are so small and delicate that it is virtually impossible to provide them with thermoplastic sleeves or sheathing accurately and cost-effectively.

One simple process technology

It would be significantly easier and less expensive if this wide variety of "packaging materials" could be replaced by a single plastic that complied with all the specifications and could be processed variably using one simple process technology. The Danish BaySystems polyurethane systems house of Bayer MaterialScience got together with a company called Isotherm based in the Swiss town of Uetendorf to tackle this challenge. The two partners opted for a universal material that has proved its worth over many years in the production of housings: polyurethane. Together, they developed an economical process that combines the encapsulation of the electronics with the manufacture of the housing in a single process step using polyurethane.

The process is a further development of the reaction injection molding (RIM) technology that has long been established in polyurethane processing. It is based on polyurethane systems from Bayer MaterialScience's Baydur E and Bayflex E ranges. In this cooperation, Isotherm concentrated mainly on the plant and mixing head technology, while Bayer MaterialScience focused on material optimization. The Leverkusen-based plastics manufacturer offers its customers individual, tailor-made formulations of Baydur EUR and Bayflex E for the new technology all over the world. This service is provided via the global BaySystems systems house network.

Polyurethane systems have the fundamental advantage that their properties, in contrast to other materials that are already

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in a polymeric state, can be adapted precisely to the particular demands made on the part simply by varying the liquid, low-viscosity raw materials. It is just as easy to produce rigid and impact-resistant grades as it is to produce flexible, foamed or solid types. Flexible PU formulations, which are often chosen because of their warm and pleasant tactile properties, do not, by the way, need any plasticizer. Gradual embrittlement of the surface due to evaporation of the plasticizer is therefore not a problem.

Production of complex geometries

In the new process, solid elastomer systems or semi-rigid integral skin foams are normally used to manufacture the housing and simultaneously encase the components. To manufacture, for example, a compact power supply unit, a cable harness or battery pack, the electronic components are first positioned in the mold.

The liquid polyurethane raw materials are then homogenized and filled into the mold at a low pressure of up to 6 bar. Because of the low viscosity of the mixture (max. 2,500 Mpa.s), hardly any shear forces are generated that might exert stress on the components. The polyurethane system cures quickly and with minimum shrinkage. As a rule, the part can be removed from the mold after less than two minutes.

The temperature during the chemical reaction reaches a maximum of 120 °C, which also eliminates any stress on the often heat-sensitive electronics. Large variations in wall thickness are no problem. This can have design benefits, enabling for example ventilation slits, reinforcing ribs and snap-fit joints to be molded into the housing shell. It also has a favorable effect on production costs in that assembly aids made of other materials such as clips, couplings, guides and screw threads can be inserted into the mold and thus integrated into the part.

Made-to-measure technology

With the new process, barely accessible cavities and the tiniest of gaps can be reliably filled with foam even via very narrow flow paths of varying lengths. To do this, polyurethane machines with a very low output of less than 10 ccm/s must be used to enable, among other things, void-free venting from the mold. The process engineering specialist Isotherm has accordingly modified the RIM technology and offers special filler-resistant piston-type metering devices and special mixing heads with ceramic nozzles designed for ultra-small outputs.

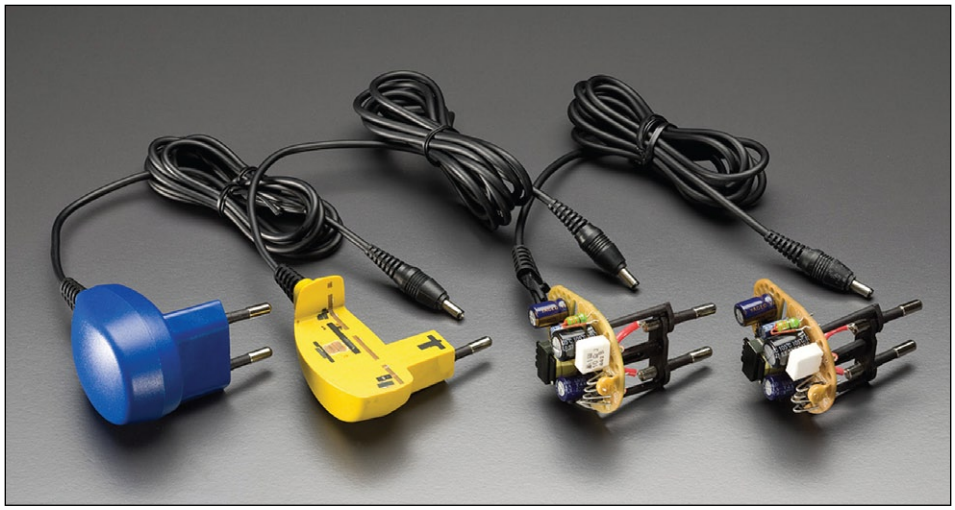

Fig. 2: Thanks to polyurethane plug contacts can be reliably protected from oxidation and moisture.

With precise metering, they allow turbulence-free filling of the mold and ensure excellent mixing quality even with filler contents of up to 60 percent. Such high filler contents are needed, for example, for effective flame retardance or for high heat dissipation with parts subjected to high thermal loads.

For housings and for the encapsulation of very small electronic modules, Isotherm has developed high-pressure piston-type metering units that use proportional valve technology for extremely accurate metering of the polyurethane mixture. Ultra-small shot sizes of only 2 cc with outputs of 10 cc/s are no problem for these metering units.

Lower mold costs

The processor derives a number of economic benefits from the improved RIM process and the use of only one family of materials to satisfy many different requirements. It saves costs, for example, through reduced logistical outlay, lower processing temperatures, and simplified assembly due to the integration of functions in the part.

It also benefits from short cycle times. Investments in equipment are minimal, because the low cavity pressures that are typical of RIM technology with polyurethanes enable inexpensive synthetic resin and aluminum molds to be used instead of expensive steel ones. Compared with the processing of thermoplastics, this is an important advantage, and also means greater flexibility, for example with small and medium production runs.

The new process has already proved its practical worth, for example in the production of wire strand bundles that lead from the engine compartment of a car through the bulkhead to the instrument panel in the passenger compartment. Encapsulation of this wire bundle with polyurethane ensures that the crossover from the engine compartment to the interior is air and water-tight and that contact plates do not become corroded through condensation.

The new technology is also well suited for protecting compression-molded or screwed plug contacts against oxidation. For such applications, polyurethane is an economical alternative to hot-melt casting compounds because the material costs are very much lower.

Automotive cable sets which when encapsulated with polyurethane foam, permanently assume the given shape, are an outstanding example of the advantages of the new process – see figure 1. At the same time all plug contacts are sealed off and plastic and metal fixing elements are molded in.

Completely encased

Equally attractive is the manufacture of power supply units for mobile phones, shavers and laptops – see figure 2. Instead of encapsulating the electronic workings inside the power supply units by welding together two thermoplastic half-shells, they can be completely encased with polyurethane. The result is a solid housing in which the sensitive internal parts can no longer work loose and are effectively protected against impacts. Thanks to the good thermal conductivity of the flame-retardant polyurethane, these power supply units are 20-30 percent smaller than their thermoplastic counterparts. ■