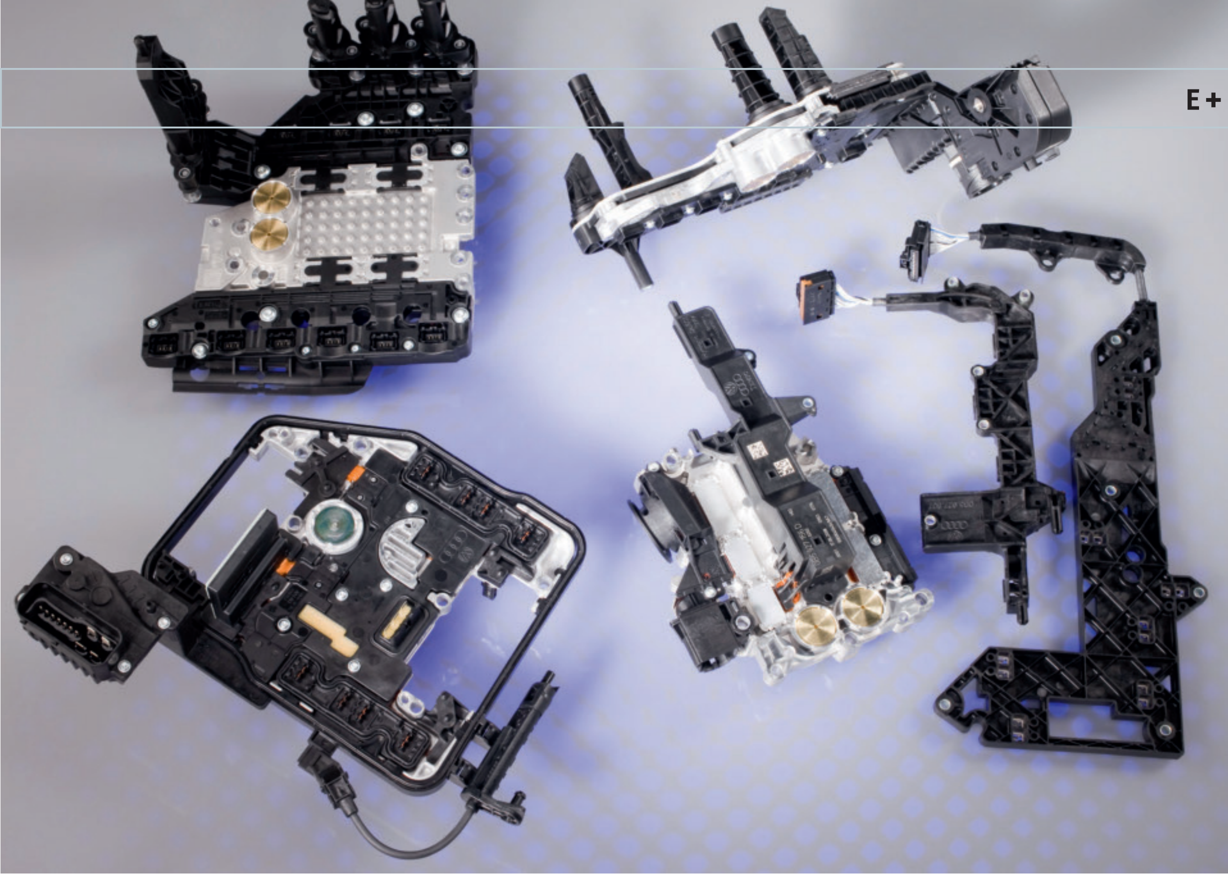

The dual-clutch gearbox controls from Continental are made out of a polyamide 66 that is particularly resistant to hot and aggressive gearbox oil

Ever More Electricity and Plastic

Current Trends. Interest in mechatronic components is growing in the automobile electrical and electronic sector. At the same time the installation space is shrinking further and component weights have to be as low as possible. This leads to demand for even thinner wall sections in connectors and sensors as well as growing requirements for particular material properties. It is principally engineering plastics, such as specially developed polyamides and polybutylene terephthalate, that are considered to be suitable in this context.

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Even though the growth curve for the automobile market as a whole has suffered a clear downturn due to the current crisis, it is expected that the quantity of electronics per car will continue to grow. According to a study by Mercer Management Consulting from 2006 the market for automobile electrical and electronic systems will grow by nearly 6 % per annum (Fig. 1). In 2007 Roland Berger in partnership with BASF came to similar conclusions. According to their investigation the electrical & electronic share of vehicle value will be around 30 % by 2015, with one third in electrical and two thirds in electronic systems. Electronic systems are also going to increase in the growing segment for small automobiles, particularly where they contribute to improved safety. Today the majority of innovations in vehicles are based on electronic control and the cable loom has now become almost the largest single component in a car. Alongside passenger safety and comfort, reductions in emissions and fuel consumption are naturally also a central issue. Here the reliability of components is of particular importance. In order to meet all of these requirements plastic as a material is becoming ever more significant. Its advantage lies in its low weight combined with excellent freedom of design and the ability to integrate different functions. For this reason the proportion of plastic components in electrical and electronic systems is growing more strongly than in other vehicle areas.

Whilst in the sixties a car had electrical systems, but practically no electronics, today a top of the range automobile can contain up to 70 electronic control systems. According to Bosch the use of

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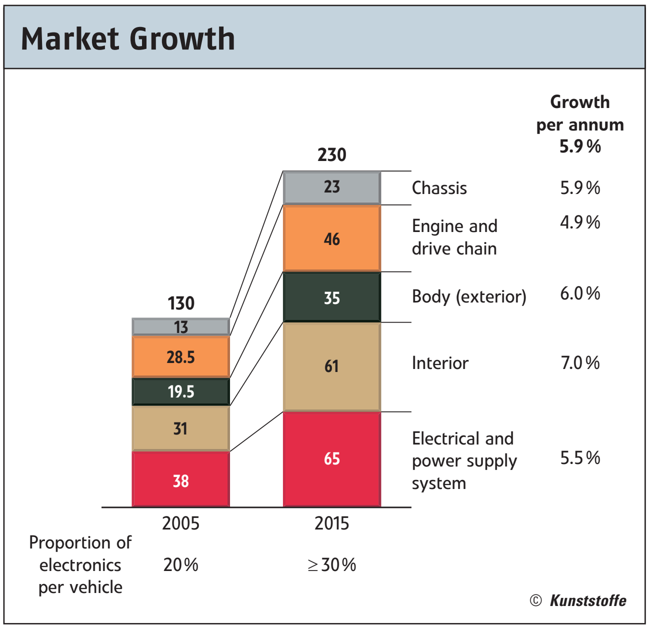

Fig. 1. The world market for automobile electrical and electronic systems is growing at almost 6 % (data in billion EUR) (source: Mercer Management Consulting, 2006)

ESC (Electronic Stability Control) for example has grown continuously over the past few years. The proportion of new vehicles with these active safety systems has grown particularly strongly in the NAFTA region and has now overtaken the proportion in Europe. Future growth rates are still going to be high since ESC is going to be mandatory in the USA for new cars from the model year 2012 onwards. Europe has also tightened up on the regulatory side and announced a mandatory requirement for new cars from 2015 and for new models as early as 2012. Strong growth for ESC is also predicted in Asia. Figure 2 shows many other devices and modules right across the range of vehicle electronics that cannot be produced without plastics. These components can be categorized into the areas of electronic controls and actuators (e.g. relays and motors), plug connectors, sensors as well as lighting technology.

The growing interest in mechatronic components is amongst the current trends in electrical/electronic systems in automobiles. At the same time the installation space is shrinking further and component weights have to be as low as possible. This leads to demand for even thinner wall sections in connectors and sensors as well as growing requirements for particular material properties. Hydrolytic stability and laser weldability of plastics are examples of these properties. On top of this there is the demand for materials that are resistant to calcium chloride and biofuels and can withstand a large number of thermal shock cycles. The most commonly found classes of material are therefore polyamide (PA) and polybutylene terephthalate (PBT).

In this article we will show which new products and applications from its Ultramid (PA) and Ultradur (PBT) product ranges BASF has selected to address these trends and challenges.

Mechatronics

Modern compact, integrated mechatronic components are different from conventional systems in that the functional groups of sensors, actuators and intelligent electronics are directly mounted on or very near to the mechanical part being controlled. It is only possible to construct such highly integrated parts through the use of high-performance engineering plastics. Only a freely formable material, a high degree of stiffness and strength, together with chemical and temperature resistance can protect the electronics and at the same time combine the actuators and sensors in very limited space within a single component. Wiring work, the number of cables and connectors can be drastically reduced, interfaces are no longer needed and the part is small, light and reliable. Even though the impetus for mechatronics originally came from the electronic and machinery industry, it is the automobile sector that is the driving force today.

Gearbox controls are typical mechatronic components that are under continuous development. Ultradur B4300 G6 is used in the dual-clutch gearbox control that was introduced by Volkswagen in 2006 and is still in production today. This special PBT is suitable for hot oil resistant component groups and is able to integrate nearly two dozen sensors and actuators as well as the necessary connection technology into a single part. However, in further developing the construction concept of the control systems for the next generation of dual-clutch gearboxes, the highly thermally stabilized Ultramid A3WG6 is being used (Title picture). Since gearbox oils are more aggressive and less standardized than motor oils and at times also very hot, the continuous operation of gearbox control systems represents a very demanding application. In the original as well as the newest control models the specific requirements for di-

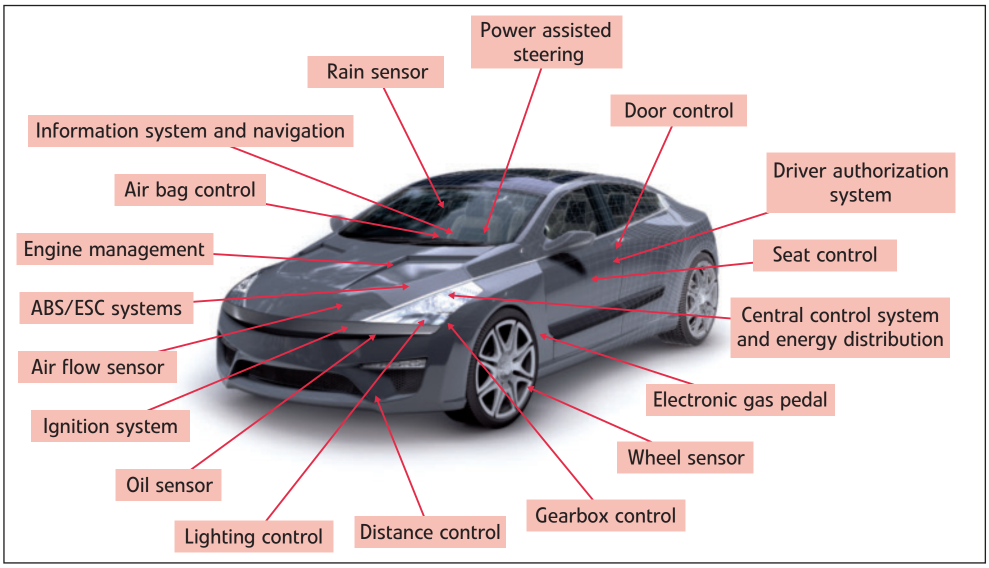

Fig. 2. Electronic devices in automobiles

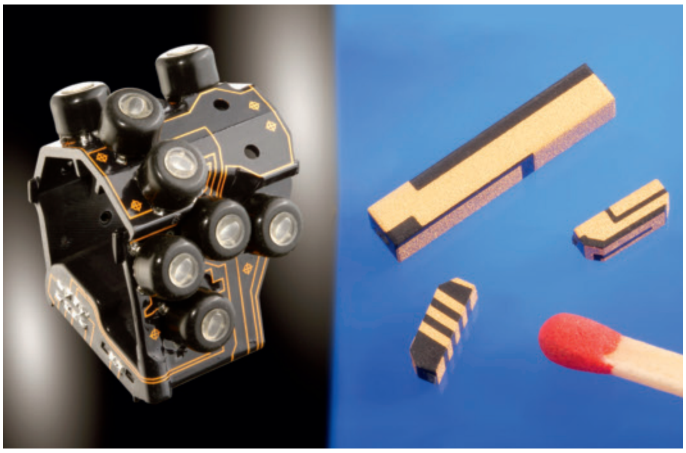

Fig. 3. Ultramid T 4381 LDS, a laser structurable polymer, is used in mechatronic parts (left) as well as in polymer aerial chips for cell phones (right)

Fig. 4. The filigree and thin walled polymer housing of the latest steering angle sensor from Bosch is made out of Ultradur B4300 G4 LS High Speed, a laser markable, 20 % glass-reinforced version of the very high flow PBT

mensional stability and chemical resistance could be safely met by the material types used.

Exceptional mechatronic components can be produced when laser activatable polymers such as Ultramid T 4381 LDS are used. This polymer contains laser sensitive additives. It can therefore be structured and activated with the help of a laser, so that in the steps that follow, metallic conducting tracks can be precisely applied to the three-dimensional surface of the plastic component using an electro-chemical process. Thus without PCBs and cabling the plastic component can be made into a carrier for electronic circuitry. Prominent examples of this are 3-D MIDs (Molded Interconnected Devices – injection molded circuit carriers), like the ones manufactured by German automobile or South Korean cell phone suppliers (Fig. 3). The polymer, which is from the Ultramid T LDS range, is a partly crystalline, partly aromatic reinforced PA 6/6T. The high temperature stability needed for lead free soldering (melting point 295 °C) and the high heat distortion temperature under load (265 °C at 0.45 MPa) are amongst the most important requirements for the material. 3-D MIDs are a very innovative example of the ability of the polymer for functional integration. In addition they have a very high potential for further miniaturization.

Laser Welding

A joining technique in automobile electronics that is finding growing interest is laser (transmission) welding since it can join plastic parts without contact, dust generation or mechanical loading. Thus it is not only cleaner than gluing, but also prevents potential damage to the electronics through vibrations, which occur in other techniques. On top of that components can be particularly reliably sealed by laser welding. During laser welding a laser transparent component is joined to a laser absorbing one, where the energy is transferred to the absorbing part, causing it to melt and form the joint. Whilst all black standard materials absorb laser light to a certain extent the challenge lies in developing laser transparent materials. Laser welding requires special materials that have good and in particular uniform laser transparency. Alongside the well known black laser transparent Ultramid A3WG6 LT (PA 66) BASF already offers a particularly suitable Ultradur grade that guarantees a very high level of process security. The portfolio of these laser transparent PBT special grades is being further expanded in order to meet future market requirements [1].

Thin Walls

Smaller and lighter – this trend is leading to ever thinner component walls in electronic parts. For example in order to produce dimensionally stable and correctly filled connectors during the injection molding process optimized high flow materials are necessary. The improved flow properties can however also be used for components with normal wall thicknesses to reduce manufacturing times and thus save costs. Following the success of the high flow, reinforced nano-additive Ultradur High Speed grades (Fig. 4) for the first time a new unreinforced version has been included in the range. The new material, Ultradur B4520 High Speed, ▶

Fig. 5. Quick release couplings for fuel lines from A Raymond made out of high performance Ultramid T KR (PA 6/6T)

Fig. 6. Ultramid T KR 4355 G7, a partly aromatic polyamide with 35 % glass fibers, meets the requirements of Bosch for their tank pressure sensors

that has recently been introduced into the market combines high flow, stiffness and good toughness in a completely new way.

In 2008 it was also possible to show that the concept can be extended to polyamides with the first Ultramid High Speed products. This first product family has thermal stabilization typical for applications in the engine compartment. In the next stage an additional Ultramid High Speed range is to be introduced shortly. The first product in this range is the new Ultramid A3EG7 High Speed, which like its predecessors is a PA66 and with its very good flow properties offers the typical High Speed feature. The benefit of this feature can be seen in reduced injection pressure and clamping force, reliable part filling and a low level of rejects, even with complex geometries. On top of this the material offers an additional advantage that is particularly useful for electronic components: A3EG grades have a light self-color and are therefore suitable for the widest possible range of colorations at customers.

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Hydrolytic and Thermal Shock Resistance

The requirements for hydrolytic resistance of materials for electrical and electronic components, e.g. housings for control systems, sensors and connectors, at OEMs worldwide are growing in step with the increasing significance of the USCar Test, an American set of regulations for the automobile industry, in other regions of the world. On the whole components made from polyamide do very well under the USCar Test. However, under the conditions of the USCar Test many PBT grades commonly found in the market that due to their good dimensional stability are popular in the electronics industry, suffer from hydrolytic attack.

During hydrolysis of PBT the polycondensation reaction that is used to produce it is reversed. The polymer breaks up into short polymer fragments and becomes brittle. In order to test the hydrolytic suitability of PBT materials cyclic testing between -40° and +150 °C under wet conditions are no longer uncommon. The tests are typically performed following long term conditioning at 85 °C and 85 % relative humidity or accelerated conditioning at 110 °C and 100 % rel. humidity. Under these conditions two of the new particularly hydrolytic resistant PBT grades from BASF, Ultradur B4300 G6 HR and Ultradur B4330 G6 HR, perform significantly better than standard grades. By using these two materials the service life of components under extreme hydrolytic conditions can be improved many times over. In addition Ultradur B4330 G6 HR in comparison to conventional products in the market offers improved resistance to alkaline environments. Recently a trend towards more stringent thermal shock rather than temperature change tests has been seen. These are cyclic tests where the part is taken rapidly backwards and forwards between temperature extremes, for example -40 and +140 °C. Since the hydrolytically stable Ultradur B4330 G6 HR is particularly tough it offers the required mechanical properties in order to reliably survive such thermal shocks, even in combination with metal. With the help of the new Ultradur HR grades the application spectrum of PBT under unusual conditions has been significantly widened.

Calcium Chloride and Biofuel Resistance

Biofuels bring new and challenging requirements for electronic housing materials in the fuel supply system. Materials that come into contact with modern fuels now have to be not only resistant to gasoline, but also resistant to methanol and ethanol. These substances are mainly found in the fuel tank due to the addition of alcohol to normal gasoline (biofuel). On top of this components of the underbody can come into contact with the zinc plated body work where under certain circumstances through the action of water spray the salt zinc chloride can be formed. Components such as quick release couplings for fuel lines (Fig. 5) or tank pressure sensors (Fig. 6) are therefore made out of Ultramid T, which has high temperature stability. However, the requirements for water spray resistance are also continuously rising. With the increasing use of calcium containing gritting salt in the USA and Japan the calcium chloride resistance of polymers has become a topic of discussion. Ultramid T grades are also stable in respect of this salt. Unlike polyamide PBT is generically calcium chloride resistant.

Metal-Polymer Composites

At the scale at which metal and polymer form a close composite in mechatronic

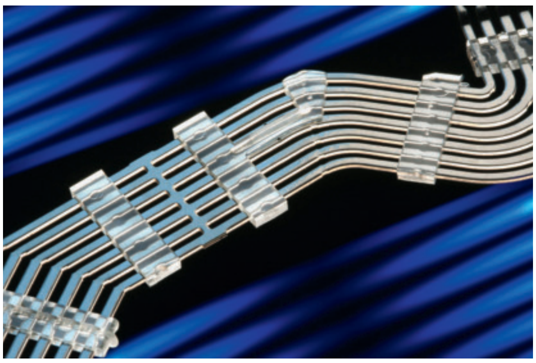

Fig. 7. Gas tight mechatronic composite parts made out of metal and polymer can be manufactured in two steps using Ultramid Seal-Fit in a simple injection molding process

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component parts the sealing of this composite has to be ensured. The risk of an incorrect function through contact with moisture or oil increases in parallel with the rising number of electronic components. BASF offers an elegant way to reduce this risk through the use of Ultramid Seal-Fit. This unreinforced transparent copolyamide is used to seal conductive tracks of electronic components by overmolding. It has good adhesion to metal as well as polyamides. Thus it represents an alternative to conventional concepts, which are very complex and use silicone adhesives, hot melts or impregnation/pre-coating. From a process technology standpoint it is helpful that Ultramid Seal-Fit, just like the classic housing material, can be injection molded. The premolding of the conductive tracks with Ultramid Seal-Fit can therefore be directly followed by overmolding with the housing material. Since the customer also uses premolding in the conventional process the housing material is simply substituted by the more effective sealing material and pre-treatments are no longer necessary (Fig. 7).

Conclusion

In automobiles the critical issues of fuel saving, environmental protection and safety are closely linked to the presence of high-performance electronics and modern electronics in their turn require solutions for the joining of polymers and metal. Decisive developments in the sensitive area of automobile electrical systems and electronics occur when an understanding of the function of the components is brought together with in-depth knowledge of material properties. This can only be the result of intensive cooperation between the component developer and a polymer specialist. The target for the experts in doing this is to combine intelligent mechanical design with the reliable transmission of electrical energy or electronic signals. This means that there is a great deal of development space for well established as well as innovative materials and concepts. ■

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1 Reference should be made to patent number EP-B 751 865 in respect of the manufacture of single color components

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