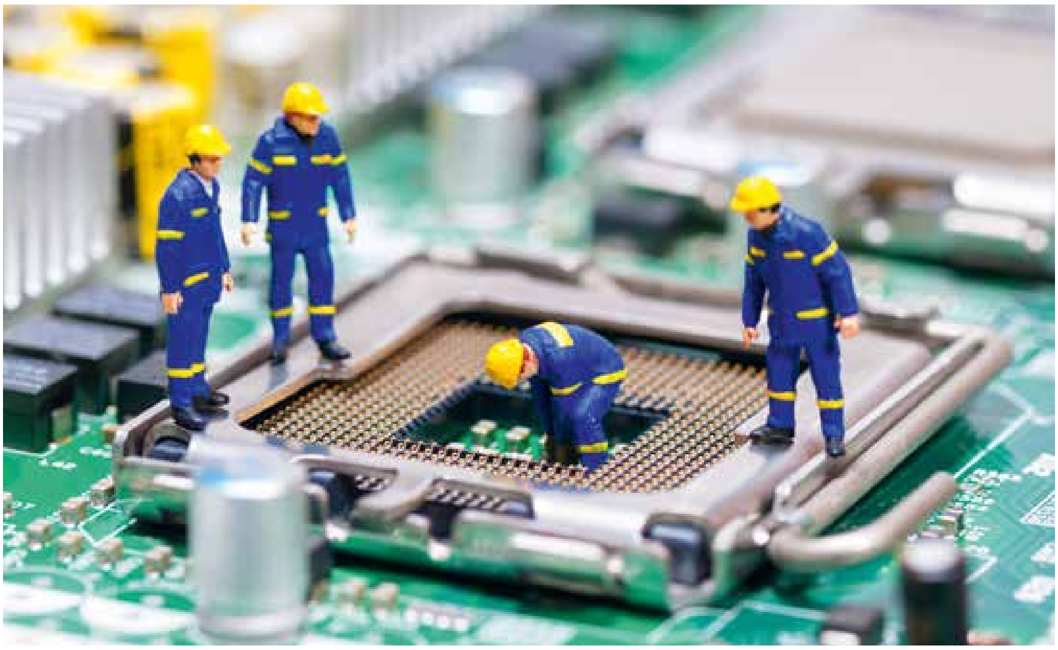
# Preventing Galvanic Corrosion Reliably

## *New Electrically Neutral Compounds Prevent Malfunctions*

Increasingly smaller sizes of complex electrical modules result in higher energy densities and rising temperatures. Occasionally, this leads to damage through galvanic corrosion and the failure of important functions. As this corrosion can also be influenced by plastics, its prevention is one of the major tasks automakers and their suppliers face.



Miniaturization also occurs in the electrical & electronics field (figures: Akro-Plastic)

The growing use of electronics has simplified and enriched many areas of our lives. Not only in smart phones and tablets do electronic components find everyday and meanwhile unquestioned application. More and more integrated circuits (ICs) can also be found in the automotive field. These miniature computers work untiringly in the control of many electrical functions: seat adjustment, positioning of side mirrors, window lifters, and windshield wipers. All of these motor-operated components in modern vehicles are controlled by small computers (**Title figure**).

Microelectronics not only increase passenger convenience – essential functions such as engine management would be impossible without computer power. Also the safety systems in vehicles have been upgraded electronically: airbag control, tire pressure monitoring, anti-lock brake system (ABS), electronic traction- and stability control are just a few of the better-known examples. All of these systems rely on the faultless analysis of physical values, and thereby the control of the associated operations. For example, rotation sensors on every vehicle wheel measure the present speed. The ABS system uses this information to reduce the braking force immediately, if there is a risk of the wheel locking during an emergency stop. Stability control circuits carry out this function individually for every wheel, regardless of the other wheels.

Other sensors determine engine oil level – sometimes even the lubricant's quality and humidity content – vehicle speed, the distance to the front and rear vehicles, or whether there are problems with the engine. What's more, even the driver's condition (e.g. tiredness) can be determined. By means of the collected information, measures such as emergency stops can be initiated even before the driver is able to react himself. This helps to mitigate accidents or even prevent them entirely.

Today, the use of sensors and computers in control circuits makes automobile driving safer and more convenient than ever before (**Fig. 1**). Consequently, reliably functioning electronics are an important safety feature for the operation of a vehicle. They must be designed, built, and installed in an utmost failsafe manner. ICs are at the heart of this technology. During the past years, they have be- »

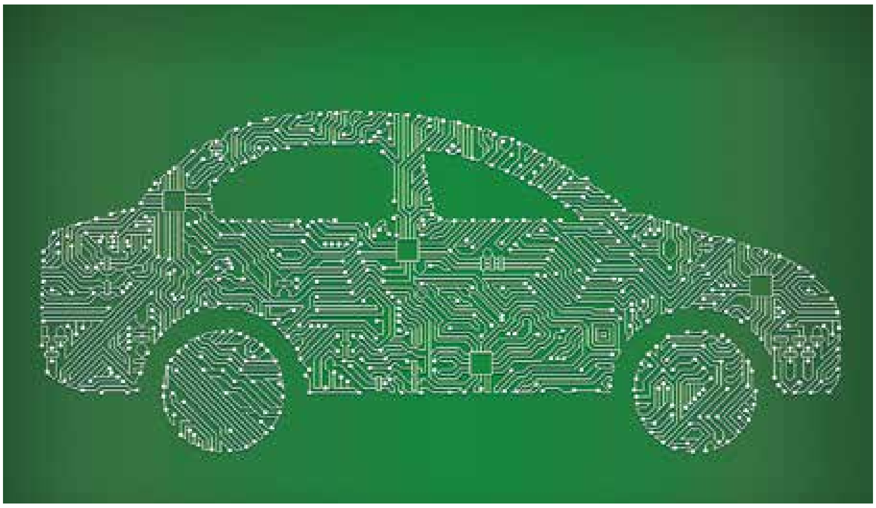


**Fig. 1.** Integrated circuits are widely used in the automotive industry

come increasingly lighter and smaller, which has enabled them to be installed in such an enormous range of applications. However, connecting and wiring the individual elements of these miniaturized modules has become a technical challenge. Dozens of electrical connections must be made in an extremely limited space.

Conventional soldering technology is no longer possible. Frequently, connections are made with hair-thin wires using the ultrasonic welding method. Moreover, many ICs are manufactured with gold-plated contacts. This ensures that the contact surface does not oxidize easily. Oxidized contacts would impair the required electrical quality. However, gold wires are not used in these cases. Instead, copper, copper alloys, and aluminum are the usual choice, with the result that so-called intermetallic phases are formed at the welded joints.

## *Temperature Accelerates Wear*

The modules used in automobiles are often exposed to high operating temperatures. In the engine compartment, these are caused by the heat from the engine, the exhaust train, and the cooling water pipes. In the vehicle's interior, they are caused by solar radiation on the body and through the glazing. The wide range of functions in modern vehicles means that the components must be installed ever more closely packed. This in turn leads to a further temperature rise, as it is not easy to dissipate the heat from the modules. For many electronic components, operating temperatures above 80 °C are the rule rather than the exception. Frequently, it has been observed that the service life of the installed elements and modules is reduced at elevated temperatures. In the worst case, the parts fail before the vehicle is ready to be scrapped.

Analysis of prematurely failed modules shows that a major cause for the failure is corrosion of the IC contacts. Contact corrosion occurs when two substances – in particular metals with different electrochemical potentials – are galvanically connected by means of an electrolyte (e.g. water or moist air). Hereby, the less noble metal forms the anode, and the more noble metal the cathode. This polarization results in an accelerated dissolution of the anode. Zinc "sacrificial anodes" to protect steel structures (e.g. for oil tanks in the ground, and for ocean-going ships) are a well-known and widely used application of this knowledge (**Fig. 2**).

## *Halogens Promote Galvanic Corrosion*

In the automotive industry, the housings and components of control systems and their connectors are usually made of polyamide. Polyamides are used, because they exhibit the best combination of long life, toughness, and strength, as well as temperature and media resistance. Traditionally, polyamides are stabilized against heat ageing. Hereby, systems with copper or potassium iodide have been used successfully for many years. However, the use of halogenated stabilizers comes with a decisive disadvantage. Halogens, particularly iodine and bromine, have been recognized as being harmful for intermetallic phases. In recent times, also organic stabilizers have been introduced. They reliably prevent degradation of the polyamides due to thermal oxidation at temperatures up to 150 °C.

The greater part of damage occurring with electrical components in the automotive field and industry in general, is due to galvanic corrosion. Hereby, a reaction occurs, in which the iodine or bromine ions undergo a complex interaction with the intermetallic phases. These ions originate from the stabilization packages in the plastic, and electrical fields guide them directly to the locations where they can develop their destructive effects. The copper content of inorganic stabilizers can lead to contact corrosion and attacks components made of magnesium and zinc. If such a reaction occurs between plastic and metal, the corresponding vehicle function is likely to fail.

Apart from copper-halogen compounds, metal soaps are also frequently used as stabilizers in electronics. Also these compounds can decompose into ions, which are then conveyed to the respective poles in the electrical field, where corresponding deposits can be observed (**Fig. 3**).

## *Development of Electrically Neutral Compounds*

The reliable prevention of such failures is one of the great challenges facing automakers and their suppliers. Due to the increasing number of electronic compo-

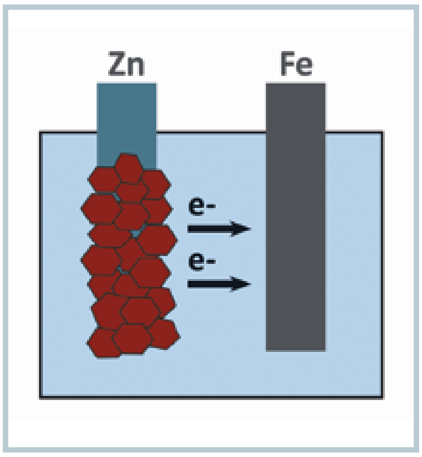



**Fig. 2.** Schematic representation of galvanic corrosion


**Fig. 3.** Metal soap deposits (left), and a detailed image of the deposits (right)

nents used in vehicles as well as the parallel development of low-cost electric motors, greater attention will be focused on this problem in the coming years. Akro-Plastic GmbH in Niederzissen, Germany, has already tackled this issue, and has developed a new product range of electrochemically neutral polyamide compounds with thermal stabilizers and lubricants, but without halogens and metal soaps. This product range has been given the suffix "EN" for electrically neutral.

Different grades with glass fiber reinforcement up to 50% have been developed already. Customer-specific grades will extend the portfolio. Apart from recipe development, a decisive question in this project is the proof of absence of iodine and bromine. For this purpose, a high-resolution analytic method was developed, which enables a bromine or iodine content of less than 1ppm to be confirmed. The documented results for every batch of material produced can be made available to the customer.

Akro-Plastic specifies a bromine and iodine content of less than 1ppm on every acceptance test certificate of the "EN" product range. Currently, this is probably the highest resolution analysis in daily operation. Standard methods for elemental analysis usually have a resolution of only >10ppm. Akro-Plastic applies the new method continuously during production. During the development of the method it was observed that some additives and polymers contain halogens, where it would not be expected. The company has to select halogen-free raw materials. To make the production and quality stable, certain raw materials are subjected to incoming goods testing applying the new analytical method.

In addition to developments in materials and measurement methods, the manufacture of such highly specialized products also represents a potential source for errors, because undesirable contents in the compound can result in cross-contamination during processing.

The cooling water for the extruded strands can be a possible source of contamination. Akro-Plastic discovered that cooling water containing copper iodide or potassium iodide can contaminate an intentionally electrically neutral product, thereby making it useless. This source of error can be eliminated reliably, if every line in the plant has its own closed cooling water circuit – an approach that was rigorously implemented in Niederzissen. Another possible source of contamination by iodine or bromine ions arises if the products are manufactured with machines, on which other products, not designed as electrically neutral, had been made previously. Even after intensive cleaning followed by 3 hours production (with a throughput of many hundred kg/h) of the electrically neutral compound, a halogen content above the 1ppm limit was observed. Therefore, series production with electrically neutral compounds at Akro-Plastic is done exclusively on selected machines and auxiliary equipment. As a result it can be guaranteed today that production is absolutely clean, and that analysis of the product always shows the required iodine or bromine content below 1ppm.

*Summary*

In future automotive applications, verifiably halogen-free polyamides will become increasingly significant. Plastics manufacturers and compounders must adapt their machines and analytical equipment to meet future demands for electrically neutral compounds, so that customers can benefit from technically mature products. It is not enough to abstain from using critical substances in the recipes. Advanced analytical techniques and good manufacturing practice can ensure that these substances do not find their way into production. ■

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