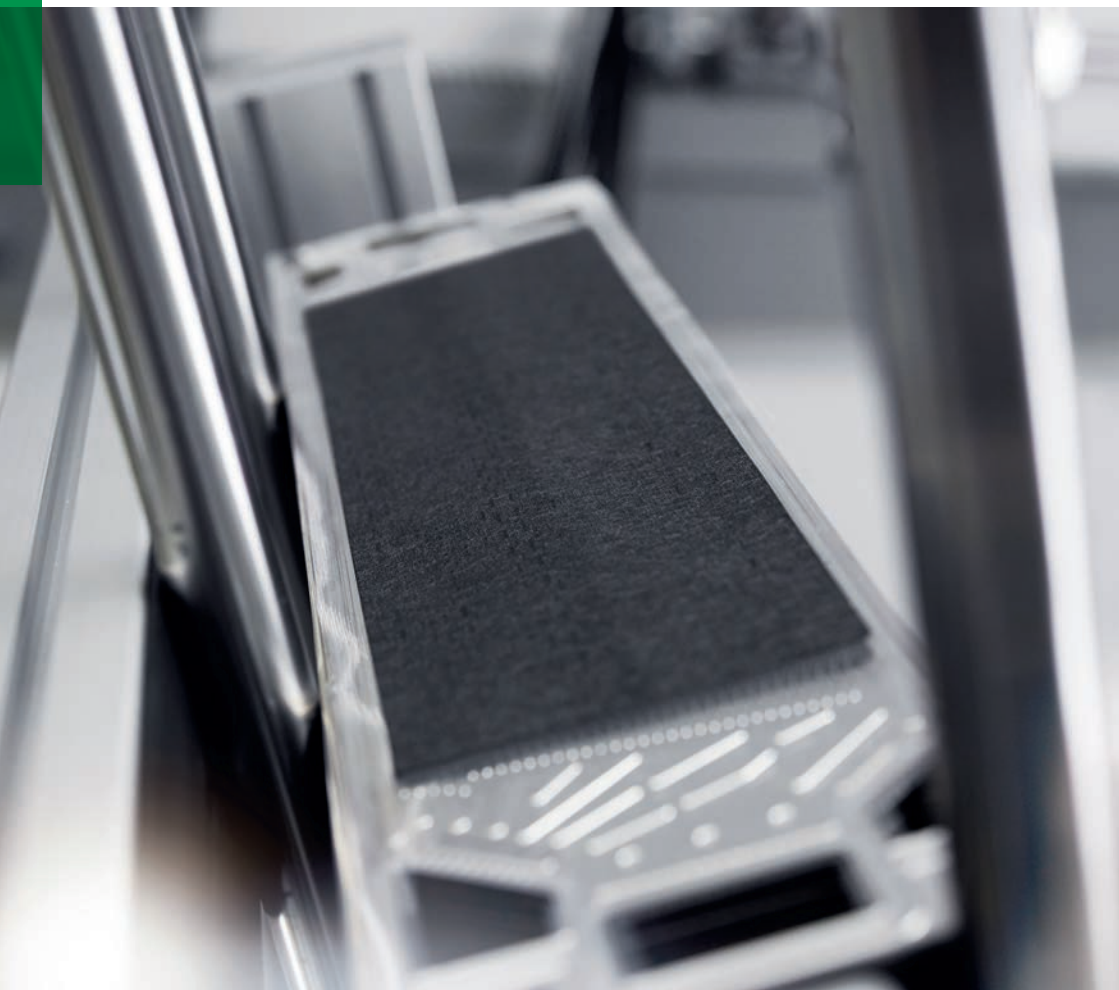
SCHAEFFLER

We pioneer motion

Surface Technology



We want to move the world – as pioneers, with innovation, superior quality, comprehensive system understanding, and the excellence in manufacturing that has set the Schaeffler Group apart for many decades.

Klaus Rosenfeld, CEO Schaeffler AG

Content

Functional Coatings for Automotive and Industrial Applications

Surface technology is one of the most important key technologies in industrialized countries, and it will become even more significant in the future – not only in mature industries but especially for new types of products. Examples include energy systems, wind energy and challenging new applications in the field of e-mobility. Furthermore, a future contribution to the digitalized networking of Schaeffler components and systems will be made possible by the surfaces of our parts as a result of their multifunctional characteristics. In particular, there will be an increased emphasis on tribological and sensor-related functions.

The selection of the appropriate coating system is critical and must take into account the surrounding system condition.
In addition, coating systems and coating technologies should always be individually matched to the operating condition and the component's geometry.

To ensure the optimal coating selection, Schaeffler has focused its knowledge and expertise within the Surface Technology department.

Consequently, precision components and systems from Schaeffler offer increased performance, extended maintenance intervals as well as a long service life.

By utilizing the appropriate coating systems, it is possible to fulfill higher requirements in terms of corrosion or wear protection as well as friction reduction. As a result, coating systems from Schaeffler contribute to the conservation of resources, since the resulting reduction in friction extends the components' operating life while at the same time reducing energy losses. Moreover, Schaeffler coatings can support electric conductivity and insulation properties.

Surface Technology Vision & Mission

Vision

Schaeffler is the worldwide market and technology leader for components and systems with added value through functional surfaces by coating technology.

Mission

We ensure added value with coatings in the external market:

- By providing innovative application- and customer-oriented system solutions from a single source for all divisions (Automotive Technologies, Automotive Aftermarket, Industrial)
- Through coating technology leadership, with efficient, environment- and resource-friendly coating processes
- By offering a superior cost-benefit advantage along with dedicated, passionate employees who gain the customer's confidence with Schaeffler's unmatched surface technology expertise

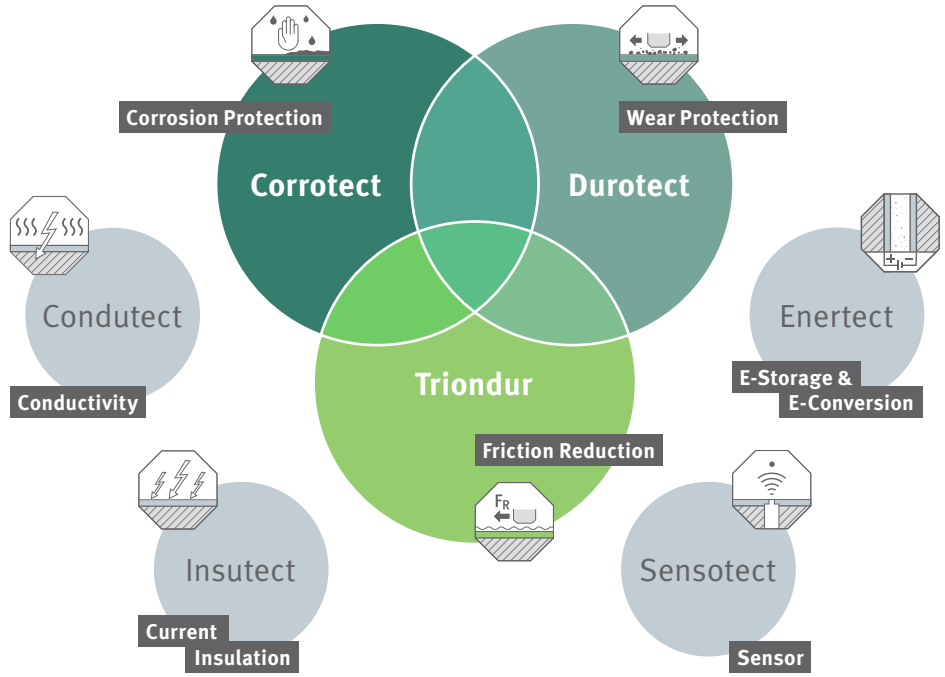
Accordingly, we are the first point of contact for all topics related to coatings.

The Schaeffler Coating Toolbox

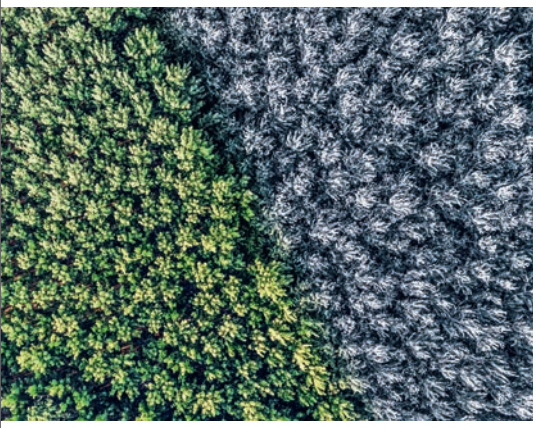
Customer – Specific Solutions
The Schaeffler Coating Toolbox offers our customers tailor-made coating solutions, which are applied using state-of-the-art coating technologies – Including electro-plating, thermal spraying, varnishing, PVD and PACVD.

The Schaeffler brand names and coating families Corrotect, Durotect, Triondur, Condutect, Enertect, Sensotect and Insutect offer over 30 different validated coating systems, which are used in automotive and industrial applications. Detailed information about all coating systems can be found in the Schaeffler Technical Product Information (TPI) 186.

Ensuring consistent quality is one of the main reasons why Schaeffler established its Coating Toolbox, which offers standardized coatings throughout the world along with individualized solutions for our customers.



- **Corrotect**
  Corrotect covers all coating systems that are used primarily to provide protection against corrosion (coating and base metal corrosion).
- **Durotect**
  These coating systems are mostly used in applications that require protection against wear, friction reduction, or both.
- **Triondur**
  Triondur coating systems offer the best combination of wear protection and friction reduction for components subjected to very high tribomechanical stress.
- **Condutect**
  Condutect systems improve the thermal and/or electrical conductivity of specific surfaces in a variety of applications.
- **Enertect**
  Enertect coating systems ensure efficient conversion and storage of chemical and electrical energy.
- **Sensotect**
  Sensotect is a sensory coating that expands the functionality of a variety of components. This is particularly relevant with respect to today's emphasis on Industry 4.0 solutions and digitalization.
- **Insutect**
  Insutect covers coating systems that are used primarily to provide insulation against electric current.

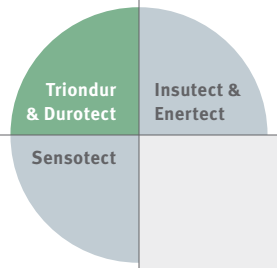


The fight for more sustainability and against climate change will require innovative technologies for the transition to renewable forms of energy and efficient options for energy storage and distribution. Consider our rail or wind power business, for example, where we are able to offer technologies such as friction-optimized bearings for maximum energy efficiency.

Sustainability & Climate Change

Key drivers include the rapid pace of regulatory and technological changes, increasing urbanization, and the growing social awareness of the negative environmental impacts of traditional mobility concepts. At the same time, we are seeing a growing preference for new electrified powertrain technologies as opposed to conventional combustion engines.

New Mobility & Electrified Powertrain



Data Economy & Digitalization

In an increasingly connected world, data is now a valuable asset for businesses. The generation, processing, and monetization of data is becoming an ever more important part of the economic ecosystem.

Coating Solutions for the Future Trends

We see addressing these trends not only as an obligation within the context of our corporate social responsibility, but also as a strategic opportunity for our future business success. Innovative coating solutions and coating technologies enable Schaeffler to meet these trends in the applications of today and tomorrow.

Additional future trends reflected in the Schaeffler Group's strategy: demographic changes, autonomous production

Triondur C & Durotect B – Climate Change

Influencing tribological systems with coatings has been a major task to optimize the energy efficiency in the wind power business. In recent years, the demands placed upon wind turbine gearboxes have increased enormously. Friction and, especially, wear must therefore be reduced to extend this essential component's service life and decrease maintenance costs.

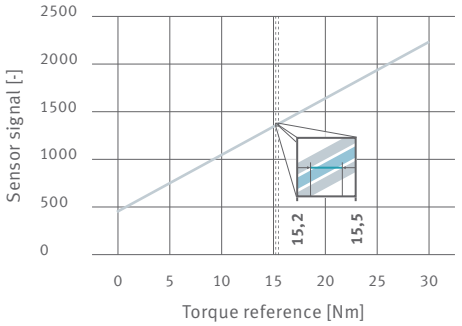
Triondur C, a carbon-based PVD coating, can reduce friction by up to 35 % in very harsh system environments. Triondur C protects not only the coated roller but also the counterparts from immanent wear.

Durotect B, Schaeffler's advanced black oxide coating, can also significantly extend the material's service life. This means Durotect B can reduce failures due to white etching cracks (WECs).

WECs are a well-known phenomenon in the wind energy sector. WECs, which are the result of structural changes in the material below the surface of bearing components, cause premature bearing failure.

The root causes of WECs are still not fully understood, but current research indicates a complex combination of different factors: base material, load collective, lubricant, hydrogen diffusion and electrostatic charges.

Sensotect – Data Economy



Continuous torque measurement on a shaft
(hysteresis deviation 0,25 % FS)

Generating data for processing and monetization purposes requires precise sensors that must be positioned as close as possible to the source of the data.

Sensotect is an innovative thin-film coating system with intelligent properties that can be applied to any three-dimensional surface. This allows data to be collected right at the source with a high linearity and low hysteresis (see graph).

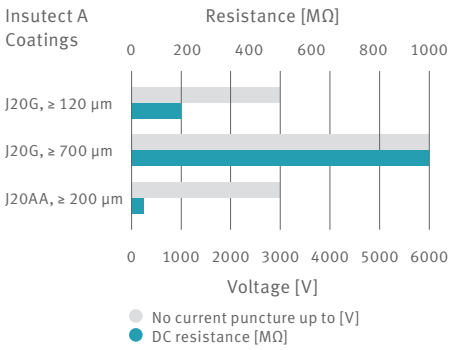
Sensotect can be used to monitor bearings in operation. Schaeffler has also developed a "load sense pin" (see below) that allows Sensotect to be used in extremely large bearings. To that end, Sensotect-coated metal pins are pressed into several positions on the bearing. Sensotect then detects the deformation of the pins' surface, which makes it possible to calculate the load that is applied to the bearing.

This innovative coating system can also be utilized to monitor and control the actions of robots, for example.

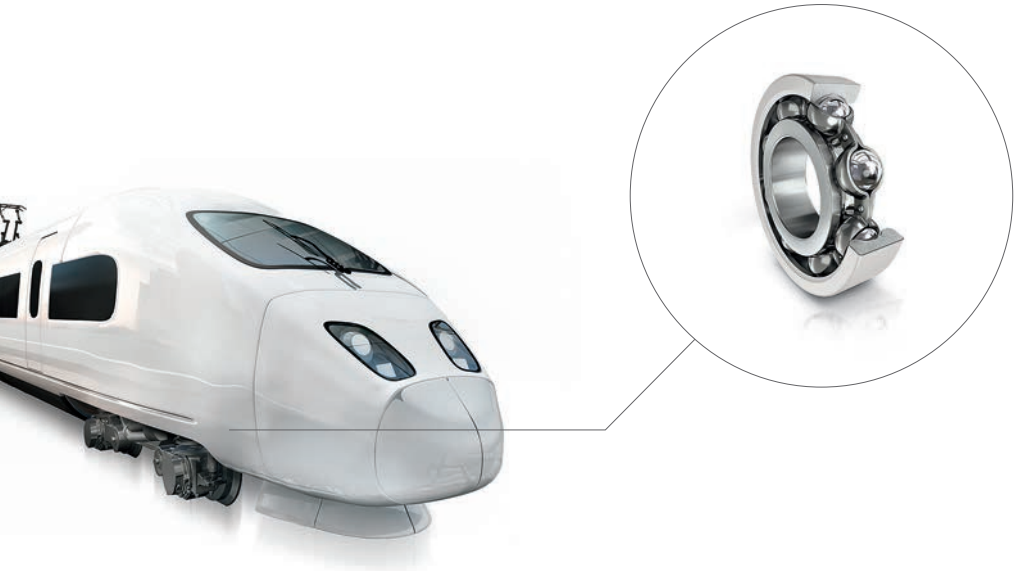
Insutect – New Mobility

With the increased need for new mobility solutions and the electrification of future vehicles, electric current is becoming a permanent companion in components. Current passage can cause severe wear in the bearing's raceway and significantly shorten the lifetime of the lubricant.

Insutect A is a coating that has been proven to prevent the passage of electric current – such as inside the powertrains of today's new mobility concepts, where the maximum breakthrough voltage is no longer limited to DC 3000 V. In response, Schaeffler developed a new coating system, Insutect A J20G, which was engineered to meet higher and more differentiated demands. Insutect A J20G's high resistance and breakthrough voltage (see diagram) are effective in both dry and wet conditions.



Cost-effective insulation coatings for low- and high-voltage applications are especially in demand within the latest automotive powertrains. Schaeffler is responding to this trend by developing completely new types of insulation coatings.

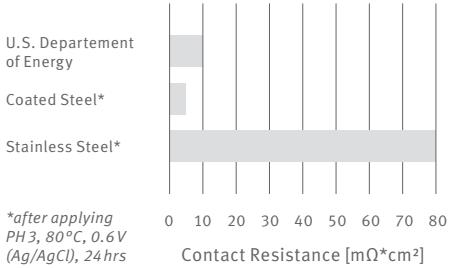


Enertect – New Mobility

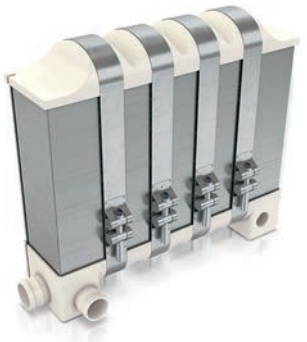
For years, Schaeffler Surface Technology has been developing coating systems for internal-combustion engines in order to meet constantly changing regulatory requirements. For instance, the friction torque of mechanical tappets had been decreased up to 50 %.

This relentless drive to innovate has continued in response to the technological changes mandated by electric mobility – in this case through the development of new coating systems. Years of research on coatings for bipolar plates for fuel cells resulted in customer-specific solutions such as our innovative Enertect coatings, which are able to easily meet governmental requirements.

The U.S. Department of Energy requires a maximum surface contact resistance of 10 mΩ*cm² after being exposed to a standardized electrolyte and applying a voltage (see diagram). Schaeffler's Enertect coatings exhibit a resistance of less than half of the reference value with a thickness of less than 1 µm.



The knowledge gained from innovations including Enertect is enabling Schaeffler to develop new coatings for applications such as stationary fuel cells and electrolyzers. These breakthroughs are helping to drive the transformation from traditional to new mobility concepts.



Closed-Loop Model

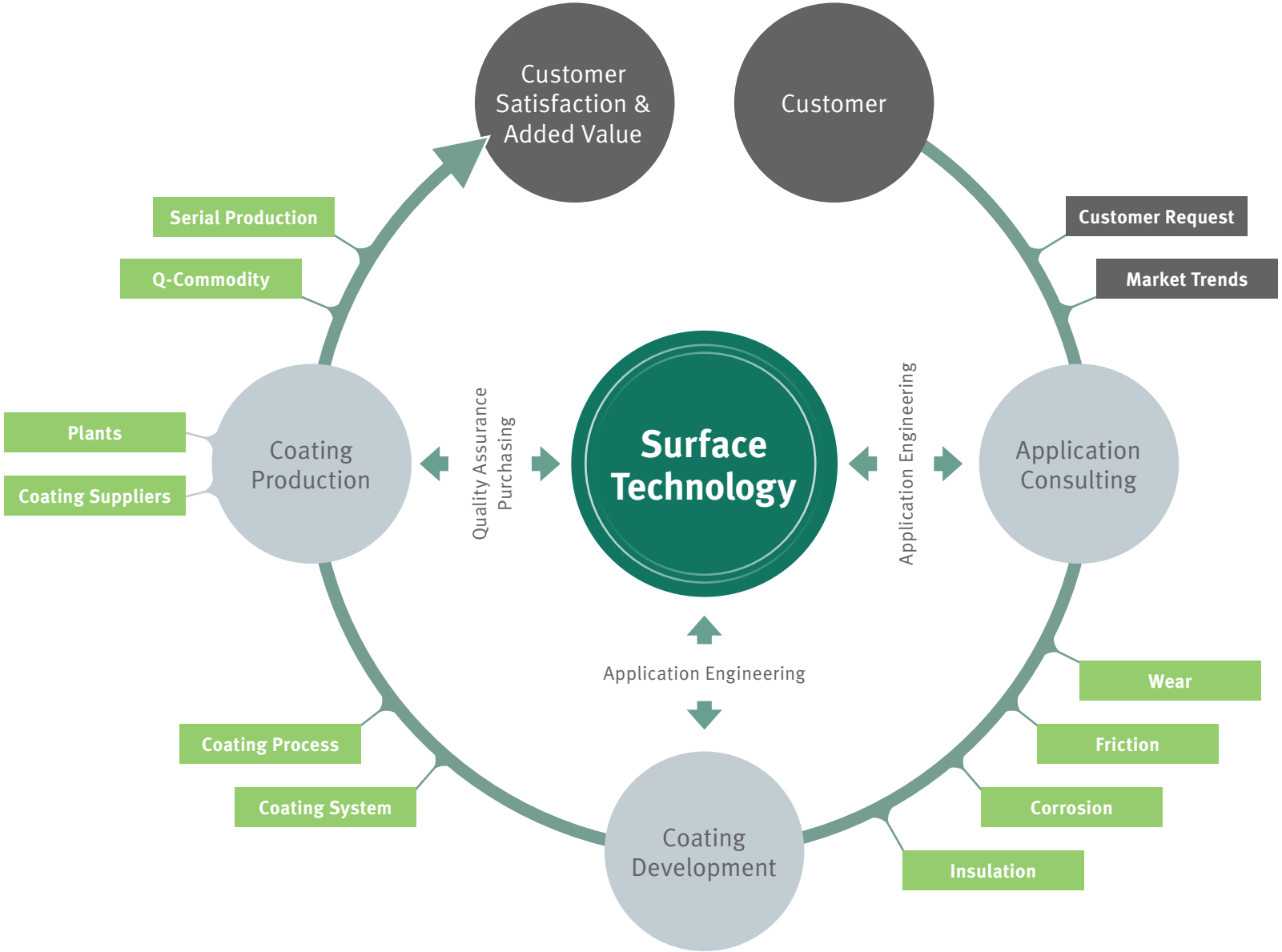
In response to requests from our application engineers and sales engineers who are in direct contact with the customer, Schaeffler Surface Technology has established a closed-loop model to ensure that our customer orientation is both highly efficient and highly effective.

The loop starts with the Application Consulting team receiving, collecting and checking the customer's requirements. Based on these specifications, the appropriate coating system is selected from the Schaeffler Coating Toolbox. The coating can then be applied right away in serial production.

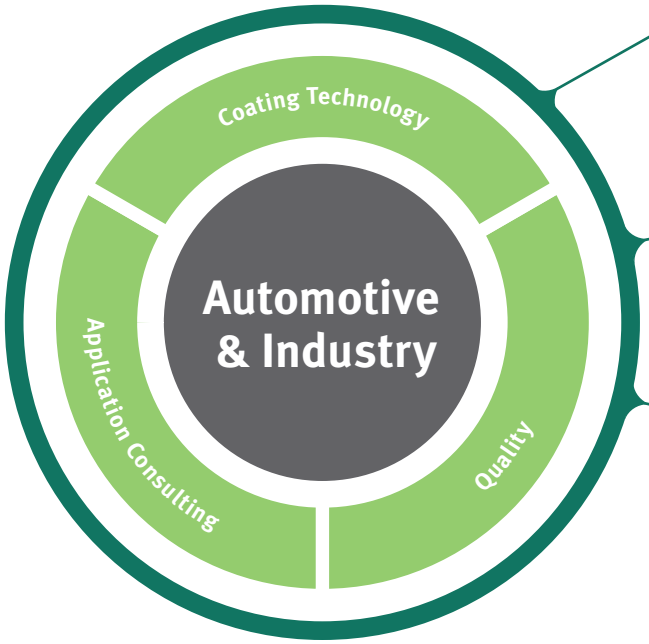
If, however, the existing solutions from our Coating Toolbox cannot meet all of the customer's requirements, a new, customized coating system will be developed. The new coating design is based on a detailed system analysis which includes e. g. tribological or corrosive system parameters. This development process not only involves validating the coating, but also the establishment of the serial production coating process, which must meet the quality requirements defined by internal standards.

Subsequent plant engineering and supplier management in the Q-commodity depend on whether the coating process will be realized internal or external.

This closed-loop model ensures that our customized coating systems, techniques and processes adhere to the same quality standards at all Schaeffler locations throughout the world.



Knowledge Transfer Between Divisions



Application Consulting

Representation of customers' interests within Schaeffler Surface Technology and consulting on coating systems.

- Technical consulting on coatings within Schaeffler
- Selection of a suitable coating system for technological and cost-effective solutions (Schaeffler Coating Toolbox)
- Business development
- Training courses

Coating Technology

Development of coating systems and processes. Ensuring a worldwide production of profitable coated products with consistently high quality.

- Management of R & D projects
- Development of coating systems and processes within Schaeffler
- Selection of suitable coating facilities and support in their investment process
- Support of coating facilities for serial production

Quality

Ensuring a global standardized coating quality for coated products and coating processes to achieve a high customer satisfaction.

- Generation, development and definition of quality concepts and standards for selected coatings, coated components, coating processes and coating analysis
- Communication of defined quality standards to Schaeffler plants and suppliers
- Supply chain management and supplier development

Schaeffler's profound understanding of applications, tribology, coating technologies and systems enables our Surface Technology team to transfer its knowledge between all divisions.
Working solutions are applied to similar applications throughout Schaeffler, ensuring that customers from different fields and industries benefit from our expertise.

All teams in Surface Technology work along this closed-loop process to ensure that only the most suitable coating solution is provided to the customer.

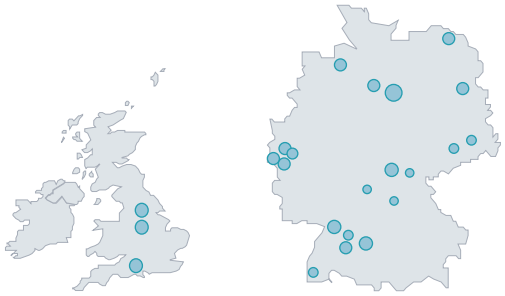
From R & D to Serial Production

Schaeffler Surface Technology coordinates R & D projects for coating solutions ensuring that our Automotive and Industrial customers benefit from the results. Transferring knowledge between the divisions is a key responsibility for our departments.

Moreover, Schaeffler's global research network enables us to develop award-winning coating systems of the highest quality. We develop customized solutions for your applications to maximize the benefit to our customers.

Our Strategic Research Partners

Universities & Institutes



Public Partners

Funded by the European Union

Federal Ministry for Economic Affairs and Energy

Federal Ministry of Education and Research

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Quality and Research Awards

Customer Awards

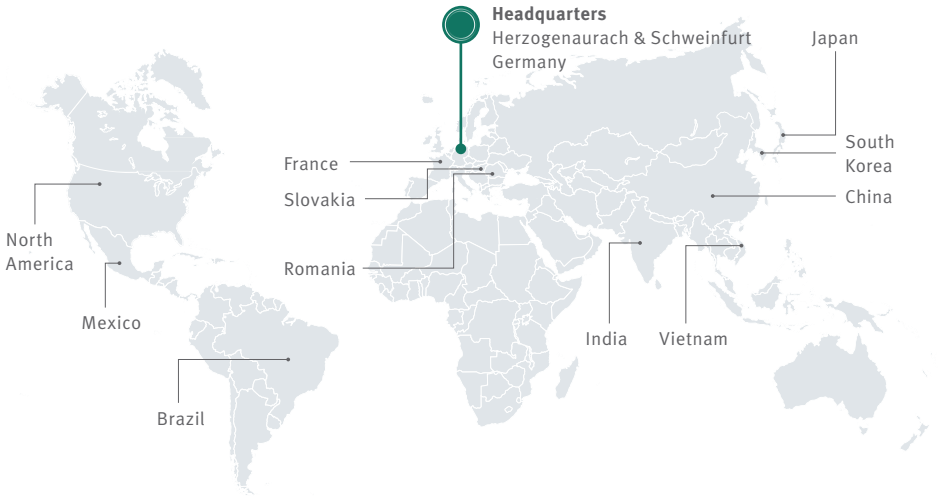
Public and social acceptance

Local & Global Presence

We use our experience to help you to communicate directly with Schaeffler's customers. Our highly experienced coating specialists and experts are available to you around the world. And, of course, technical information about Schaeffler coatings is always available in our brochures or in any one of our informative training courses.

- Customer Tech Days & Fairs
- Consulting & Support
- Product Information & Training

Schaeffler Surface Technology Network



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