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## **Bosch poised for leap in e-mobility technology** Silicon carbide semiconductors make electric cars more efficient

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- ▶ Harald Kroeger: “Silicon carbide semiconductors bring more power to electric motors. For motorists, this means a 6 percent increase in range.”
- ▶ Only Bosch is equally at home in the automotive and the semiconductor industries.
- ▶ With its new semiconductor plant in Dresden, Bosch is strengthening its competitiveness.

Reutlingen and Dresden, Germany – Nowadays, all cars feature semiconductors. There are more than 50 of them in every vehicle that rolls off the production line. The new microchips made of silicon carbide (SiC) that Bosch has developed will now help electromobility make a great leap forward. In the future, the chips made of this extraordinary material will set the pace in the power electronics – the command center for electric and hybrid vehicles. Compared to the silicon chips used to date, SiC semiconductors have better electrical conductivity. This enables higher switching frequencies while also ensuring that much less energy is dissipated in the form of heat. “Silicon carbide semiconductors bring more power to electric motors. For motorists, this means a 6 percent increase in range,” says Harald Kroeger, member of the Bosch board of management. Bosch manufactures the new generation of semiconductor chips at its Reutlingen plant, 25 miles south of Stuttgart. At this plant, the company has been turning out several million microchips every day for decades.

### **SiC: a booster for e-mobility**

Semiconductors made of silicon carbide set new standards for switching speed, heat loss, and size. It all begins with additional carbon atoms, which are introduced into the crystalline structure of the ultra-pure silicon used to manufacture semiconductors. The chemical bond created in this way turns the semiconductor chips into real powerhouses. Especially for applications in electric

and hybrid vehicles, this means many advantages. In power electronics, they ensure that 50 percent less energy is lost in the form of heat. This saving translates into more efficient power electronics and more energy for the electric motor and therefore for the battery range. Motorists can drive 6 percent further on a single battery charge. In this way, Bosch is addressing one of the stumbling blocks for potential buyers of electric cars: nearly one in two consumers (42 percent) decide against buying an electric vehicle because they are afraid the battery will run out while they are on the road. In Germany, this anxiety is even more prevalent, affecting 69 percent of consumers (source: [Consors Finanz Automobile Barometer 2019](#)). Alternatively, car manufacturers can make the battery smaller for a given range. This reduces the cost of an electric car's most expensive component, which in turn reduces the vehicle's price. "Silicon carbide semiconductors will transform e-mobility," Kroeger says. The reason is that the new technology also offers further potential savings down the line: the much lower heat losses of the chips, combined with their ability to work at much higher operating temperatures, mean that manufacturers can cut back on the expensive cooling of the powertrain components. That has a positive impact on electric vehicles' weight and cost.

### **Bosch: at home in the automotive and semiconductor industries**

With this silicon carbide technology, Bosch is systematically expanding its semiconductor know-how. The company will be using the SiC semiconductors in its own power electronics in the future. For its customers, this brings together the best of both worlds, as Bosch is the only automotive supplier that also manufactures semiconductors. "Thanks to our deep understanding of systems in e-mobility, the benefits of silicon carbide technology flow directly into the development of components and systems," Kroeger says. As one of the leading manufacturers of automotive semiconductors, Bosch has been exploiting this globally unique advantage for almost 50 years. In addition to power semiconductors, these include microelectromechanical systems (MEMS) and application-specific integrated circuits (ASICs).

Whether in airbags, belt tensioners, cruise control systems, rain sensors, or powertrains, there is scarcely a domain in modern automotive technology that does not rely on microchips. In 2018, the value of the chips in an average car was around 370 dollars (337 euros) (source: ZVEI). While this amount is growing by 1 to 2 percent annually for applications not relating to infotainment, connectivity, automation, and electrification, on average an electric vehicle has additional semiconductor chips worth 450 dollars (410 euros) on board. Experts predict that this figure will increase again by around 1,000 dollars (910 euros) as a result of automated driving. This makes the automotive market one of the drivers of growth in the semiconductor sector. Furthermore, key applications of

the internet of things, such as artificial intelligence, cyber security, smart cities, edge computing, smart homes, and connected industry, will drive future growth in the domain. With its semiconductor factories in Reutlingen and Dresden, Bosch is well prepared for these developments: “Our semiconductor know-how helps us not only to develop new automotive functions and IoT applications but also to continuously improve the chips themselves,” Kroeger says.

### **Bosch is strengthening its competitiveness**

Turning the circular discs of silicon or silicon carbide – the wafers – into semiconductor chips involves an elaborate manufacturing process that can last up to 14 weeks. In several chemical and physical processes, the wafers acquire ultra-fine structures that will subsequently make up the tiny chips, each of which measures just a few millimeters. In June 2018, Bosch laid the cornerstone for its state-of-the-art semiconductor factory in Dresden. Its manufacturing operations will use wafers with a diameter of 300 millimeters. This means significantly more chips from a wafer, and correspondingly greater economies of scale than with semiconductors based on 150- and 200-millimeter technology. Bosch produces the latter in Reutlingen, where it will also manufacture the new SiC chips. The wafer fabs in Reutlingen and Dresden complement each other perfectly. This enables Bosch to further strengthen its competitiveness. “Semiconductors are a core component of all electrical systems. They are also turning data into a coveted raw material of the future. As they are becoming increasingly important in our fields of activity, we want to continuously expand our manufacturing operations,” Kroeger says. In its wafer fab in Dresden, Bosch is investing around a billion euros – the largest single investment in the company’s history. In the factory, facilities are currently being installed in the clean room areas. The first associates are due to start work in the spring of 2020. Bosch will operate the plant as a carbon-neutral site.

**Press photos:** #2780142, #2780143, #2780424, #2780425, #2780427, #2780428, #2780430, #2780512

### **Further information:**

Bosch compact: [Facts, figures, and amazing truths about semiconductors](#)

Bosch compact: [A brief guide to semiconductor technology](#)

Video: [Silicon carbide semiconductors in the Bosch wafer fab in Reutlingen](#)

Factsheet: [Semiconductor production at Bosch](#)

Factsheet: [Reutlingen wafer fab](#)

Factsheet: [Dresden wafer fab](#)

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*Mobility Solutions is the largest Bosch Group business sector. In 2018, its sales came to 47.6 billion euros, or 61 percent of total group sales. This makes the Bosch Group one of the leading automotive suppliers. The Mobility Solutions business sector pursues a vision of mobility that is accident-free, emissions-free, and fascinating, and combines the group's expertise in the domains of automation, electrification, and connectivity. For its customers, the outcome is integrated mobility solutions. The business sector's main areas of activity are injection technology and powertrain peripherals for internal-combustion engines, diverse solutions for powertrain electrification, vehicle safety systems, driver-assistance and automated functions, technology for user-friendly infotainment as well as vehicle-to-vehicle and vehicle-to-infrastructure communication, repair-shop concepts, and technology and services for the automotive aftermarket. Bosch is synonymous with important automotive innovations, such as electronic engine management, the ESP anti-skid system, and common-rail diesel technology.*

*The Bosch Group is a leading global supplier of technology and services. It employs roughly 410,000 associates worldwide (as of December 31, 2018). The company generated sales of 78.5 billion euros in 2018. Its operations are divided into four business sectors: Mobility Solutions, Industrial Technology, Consumer Goods, and Energy and Building Technology. As a leading IoT company, Bosch offers innovative solutions for smart homes, smart cities, connected mobility, and connected manufacturing. It uses its expertise in sensor technology, software, and services, as well as its own IoT cloud, to offer its customers connected, cross-domain solutions from a single source. The Bosch Group's strategic objective is to deliver innovations for a connected life. Bosch improves quality of life worldwide with products and services that are innovative and spark enthusiasm. In short, Bosch creates technology that is "Invented for life." The Bosch Group comprises Robert Bosch GmbH and its roughly 460 subsidiary and regional companies in over 60 countries. Including sales and service partners, Bosch's global manufacturing, engineering, and sales network covers nearly every country in the world. The basis for the company's future growth is its innovative strength. At nearly 130 locations across the globe, Bosch employs some 68,700 associates in research and development.*

*Additional information is available online at [www.bosch.com](http://www.bosch.com), [iot.bosch.com](http://iot.bosch.com), [www.bosch-press.com](http://www.bosch-press.com), [twitter.com/BoschPress](https://twitter.com/BoschPress)*



## Did you know...

Facts, figures, and amazing truths about semiconductors

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### The market

- In 2018, some 469 billion dollars (427 billion euros) worth of semiconductors were sold worldwide, an increase of around 15 percent over 2017 (source: World Semiconductor Trade Statistics). At 40 billion dollars (36 billion euros), memory chips make up the largest market share.
- The German semiconductor market grew by around 8 percent in 2018 and was worth 16 billion euros (source: ZVEI).
- While the semiconductor share in smartphones, tablet computers, PCs, and TVs will stagnate over the coming years, it will grow in vehicles as a result of increasing electrification, automation, and connectivity.
- Bosch today is one of the leading manufacturers of semiconductors for automotive applications and has been the leader in the manufacture of MEMS sensors since 2013.

### Production

- Semiconductor chips are manufactured on circular discs of silicon or silicon carbide, known as wafers. Up to 50,000 semiconductor chips fit on an eight-inch (200-mm) silicon wafer.
- Wafer production is carried out under cleanroom class 1 conditions. Every cubic foot (approx. 28 liters) of normal ambient air contains 100,000 particles. When manufacturing semiconductors, by contrast, there must be no more than one particle weighing half a microgram in every cubic foot of air. That is roughly the equivalent of having a single cherry pit in all of Lake Constance.
- In a complex production process lasting up to 14 weeks, the raw silicon wafers are made into semiconductor chips.
- In 1994, Bosch developed the “Bosch Process” for manufacturing MEMS sensors. For this work, the developers Jiri Marek, Michael Offenberg, and Frank Melzer received the German Future Prize.
- Bosch holds more than 1,500 patents and patent applications in the field of semiconductors, 1,000 of which are for MEMS technology.

## **The development of semiconductor technology at Bosch**

- Bosch has been manufacturing a wide range of semiconductor chips for nearly 50 years. These include application-specific integrated circuits (ASICs), power semiconductors, and microelectromechanical systems (MEMS).
- In the mid-1950s, Bosch research began to explore the development of particularly robust semiconductor components that are suitable for use on the road.
- In the 1960s, Bosch developed the first power semiconductor for cars. Back then, special generator diodes made generators more reliable and longer-lasting.
- At the end of the 1960s, Bosch built its first semiconductor factory in Reutlingen due to the growing demand for the components from within the Bosch Group.
- In 1970, Bosch launched the world's first mass-produced ASICs for cars. Specifically, they were power transistors for voltage regulators and integrated circuits.
- When Bosch began producing its Motronic – a digital engine control system (ignition and injection in one control unit) – in 1979, it had an eight-bit microprocessor on board. Together with the erasable memory used, this was effectively the world's first use of a computer in a car in a driving-relevant role.
- Bosch has been producing MEMS sensors for 25 years; the first model was a pressure sensor for the Bosch Motronic.
- In 2010, Bosch took its 200-millimeter semiconductor factory in Reutlingen into operation. With a total outlay of 600 million euros for the wafer fab, this was the biggest single investment ever made in the history of the Bosch Group.
- In June 2018, Bosch laid the foundation stone in Dresden for the construction of the Bosch Group's most advanced semiconductor factory. The company is investing around one billion euros in this facility. In the plant, the company will manufacture semiconductors based on 300-millimeter technology.

## **Use in vehicles**

- In 2018, every new vehicle featured semiconductors worth 370 dollars (337 euros) on average. By 2021, this figure is set to rise to around 406 dollars (369 euros) (source: ZVEI). Experts predict that the biggest growth will be in the compact and middle-class segments, as typical high-end functions gradually seep into the mass market.
- Today's vehicles feature around 50 MEMS sensors.

- Semiconductors account for some 75 percent of innovations in new vehicles. They can be found, for example, in the powertrain, in the cockpit, and in the infotainment and driver assistance and safety systems.
- In 2016, every car rolling off the production lines worldwide had on average more than nine Bosch chips on board, of which five were MEMS sensors.

### **Use in consumer and entertainment electronics**

- For more than ten years, Bosch MEMS sensors have also been used in consumer electronics. 2006 saw the market launch of the first MEMS sensor for consumer electronics. It enhanced the fun of games consoles.
- In 2018, more than 1.4 billion smartphones were sold (source: International Data Corporation (IDC)). In addition, wearables – the collective term for electronics that can be worn on the body, such as smart watches, fitness armbands, and data goggles – are growing in popularity. In 2018, sales of wearables were around 172 million units (source: IDC). All these devices contain sensors that evaluate a very wide range of information.
- On average, five MEMS sensors are built into every smartphone. They enable the mini-computers to recognize when the screen has been turned, and they stabilize photos and facilitate navigation.
- Every second smartphone has at least one Bosch semiconductor chip (MEMS sensor).

### **Amazing but true**

- When Bosch began the production of micromechanical sensors in 1995, the edge length of an acceleration sensor was 133 millimeters. The edge length of the smallest MEMS sensor currently in Bosch's portfolio is 1.56 millimeters. That is smaller than a pinhead and represents a miniaturization of the sensor size by a factor of 85 within about 25 years – while simultaneously featuring more functions. More than 80 of these microchips would fit on a thumbnail.
- To date, Bosch has manufactured well in excess of 10 billion MEMS sensors in Reutlingen, with several million more added to the tally every day.
- On average, Bosch semiconductors are two millimeters thick. If the 10 billion semiconductors already manufactured by Bosch were laid end to end, the row of chips would be about 20,000 kilometers long. That is roughly the distance from the North to the South Pole.
- In consumer electronics, MEMS sensors are less than one millimeter in height. Some components inside the sensors measure a mere four micrometers – 17 times thinner than a human hair.

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## 300 mm wafer fab in Dresden

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### General information

- ▶ Total investment approx. 1 billion euros
- ▶ Site approx. 100,000 m<sup>2</sup>  
(about 14 soccer fields)
- ▶ Total floor space approx. 72,000 m<sup>2</sup> of production area  
and office space
- ▶ Construction timeline Groundbreaking in spring 2018,  
installation of machinery mid-/end 2019,  
pilot production to start at end of 2021
- ▶ Associates in the completed plant Up to 700
- ▶ Qualified professionals needed Experts from the semiconductor industry,  
such as process, production, and  
maintenance engineers, mathematicians,  
software engineers, as well as  
professionals with degrees in physics,  
chemistry, and microsystems  
technologies
- ▶ Manufacturing technology Highly automated wafer production  
(300 mm silicon substrate wafers  
with structures up to 65 nm in width –  
1 nm equals one millionth of a millimeter)

- ▶ Connected manufacturing  
Every second, the machines will transmit one gigabit of production data. The volume of data produced is equivalent to more than 42 million written sheets of paper, weighing 22 metric tons.

## Details on the building

- ▶ Total building volume  
600,000 m<sup>3</sup>
- ▶ Concrete  
approx. 66,500 m<sup>3</sup>  
(about 8,300 concrete mixer trucks)
- ▶ Steel  
approx. 16,400 metric tons  
(about 30 A380 passenger jets)
- ▶ Earth moved/excavated  
approx. 90,000 m<sup>3</sup>  
(some 7,500 truckloads)
- ▶ Bored piles for the foundation  
approx. 860
- ▶ Floor slabs  
100 cm thick
- ▶ Length of piping and ductwork  
approx. 80 km
- ▶ Length of electrical cabling  
approx. 380 km  
(from Dresden to Berlin and back)

## Internet

- ▶ For job seekers  
[www.bosch-career.de/jobs](http://www.bosch-career.de/jobs)
- ▶ Site for the Dresden location  
<https://www.bosch.de/en/our-company/bosch-in-germany/dresden/>
- ▶ Bosch semiconductors  
[www.bosch-semiconductors.com/](http://www.bosch-semiconductors.com/)