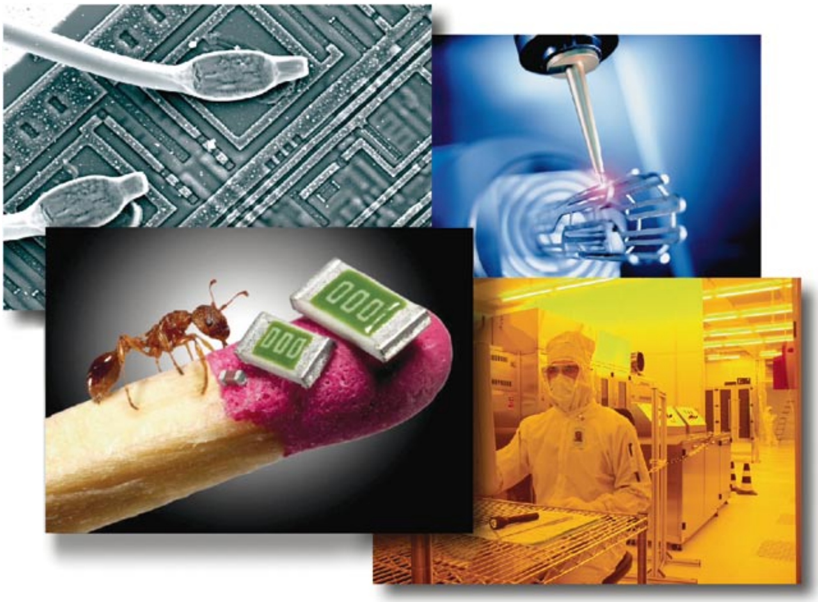
2 ELECTRONICS AND PHOTONICS



The diverse industries and lifestyles of society today would not be possible without the discovery and utilisation of electrons and photons. If we are able to exploit the technical potential of these two elementary particles, it is because modern science – in particular quantum mechanics – has done a great deal to explain their nature and their significance for solid-state physics.

In recent decades, electronics has contributed greatly to rapid technical progress in information and communication technologies, and will continue to be the enabler of many innovations and developments. World-wide sales in the electronics industry amount to about 800 billion euros, which makes it the leading manufacturing industry, even overtaking the automotive industry. *Semiconductor electronics*, which is largely based on silicon, has a market share of over 98.5 %. About 22 % of the industry's sales is reinvested in research and development, which is pursued intensely in this sector. Due to the favourable properties of silicon, the scalability of the electronics processing technology and advances in *photolithography*, there is still room for progress in reducing the size of components, as well as increasing the clock speed and number of components on *integrated circuits*. The greatest innovation potential is expected to be in highly integrated electronics and in energy-saving electronics. Research and development efforts are also going into introducing new materials, developing new component architectures, improving design, and developing new lithographic processes. The latter is closely related to the development of optical technologies.

The 20th century is often referred to as the century of electrons. The 21st century is expected to become the century of photons. Photons – light particles – can do far more than just illuminate rooms: the technical use of light – from lasers in the processing industry to scanners at check-out counters – has become part of our everyday life and is often connected with electronics. Light is a medium with unique properties and characteristics. It can be focused to a spot with a diameter of about one nanometre. *Lasers* can engrave words on a single hair. Of the many different laser types, there are high-power lasers capable of cutting steel, while in ophthalmology, lasers are used to cut thin flaps in the cornea of an eye. Photonics is the enabling technology for a number of industries and products, ranging from information and communication, biotechnology and medical technologies, to microelectronics, environmental technologies, industrial production and sensor systems.

► **The topics**. *Semiconductor* devices are the core of all modern electronic products. They consist mainly of integrated circuits (ICs), which combine the basic elements of electronic circuits – such as transistors, diodes, capacitors, resistors and inductors – on a semiconductor substrate, mainly silicon. Today's ICs already combine more than 100 million transistors on an area of just a few square centimetres. The two most important elements of silicon electronics are transistors and memory devices (such as flash RAM and DRAM). New memory concepts include ferroelectric memories (FRAM) over phase change memories (PC-RAM), conductive bridging random access memory (CB-RAM), and magnetic random access memories (MRAM). The latter is based on the tunnelling magneto-resistance (TRM) effect. Exploitation of this effect, and of the giant magneto-resistance (GMR) effect, gave rise to the new technological field of *magneto- electronics*. Its main areas of application are computer and automotive engineering. Computer hard discs have been fitted with GMR sensors, for example, which enable data to be saved on very small areas of magnetic hard discs, thus greatly increasing storage capacity. In automotive engineering, next-generation GMR sensors are used in passive and active safety systems such as ABS, EPS and airbags, to provide greater protection to drivers and passengers. They are also used to help optimise engine management and adaptation to ambient conditions, in support of lower fuel consumption and emissions.

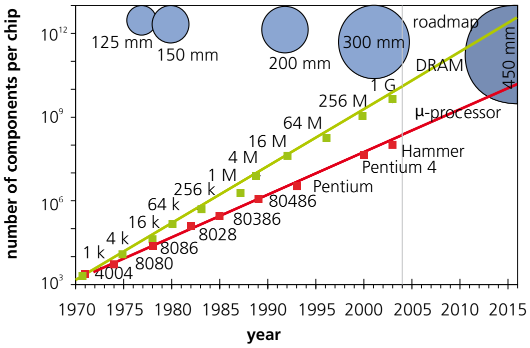
Among the promising alternative materials in electronics are polymers. As a new technology platform, *polymer electronics* is paving the way to thin, flexible, large-area electronic devices that can be produced in very high volumes at low cost thanks to printing. A number of devices and applications with huge potential have already been created, for example RFID, thin and flexible displays and smart objects.

Advances in both silicon electronics and compound semiconductors are also contributing to further developments in power electronics. This particular field is concerned with switching, controlling and conversion of electrical energy. The idea behind the application of electronic switches is to control the energy flow between source and load at low losses with great precision. *Power electronic components* are already deployed in a variety of areas, notably energy transmission lines, engine control systems (such as variable speed drive), hybrid electric drive trains, and even mobile phones. Advanced power electronics converters can generate energy savings of over 50 %. One trend in this field is to miniaturise and enhance the reliability of power electronics systems, essentially through system integration.

System integration is also an issue in *microsystems*. The main aim of microsystems is to integrate devices based on different technologies into miniaturised and reliable systems. Microsystems are already in evidence in automotive engineering, medical applications, mechanical engineering and information technology. The devices are made up of electronic and mechanical as well as fluid and optical components. One example from optical components: an array of microlenses that concentrate light in the front of solar cells.

The term "*optical technologies*" describes all technologies that are used to generate, transmit, amplify, manipulate, shape, measure and harness light. They affect all areas of our daily life. The most obvious technical use of light is lighting. Biophotonics and femtonics are the trend in this field. For most of these applications the enabling device is a laser. Laser light differs from other light sources by its very narrow spectral bandwidth, as well as its high temporal and spatial coherence and directionality. High-power laser systems are used in material processing such as welding, cutting or drilling. Other fields of application are medical technologies, measuring technology, as well as information and telecommunications. *Optics and information technology* deals with the processing and generation, transfer, visualisation and storage of information. Optical data storage systems include CDs, DVDs and Blu-Rays. Systems for the visualisation of information would comprise, for example, plasma or liquid crystal displays as well as projectors. Holographic projection systems are a trend in this particular field. The technological progress and growing use of lasers in material processing and information and communication, for example, has led to a reduction in size and cost of laser systems over the past few decades.

Measuring techniques have profited from this development. Laser spectroscopy, laser radar, and gas spectroscopy are examples of applied measuring technologies. These techniques are particularly suitable for use in industrial automation and contribute to quality assurance, safety and efficiency in industrial production and process control. The enabling devices for measuring techniques in general are *sensors,* which measure changes in physical properties, such as humidity and temperature, or which detect events such as movements. The measured variable is then converted into electrical signals that can be further processed. In cars, for example, sensors are indispensable to the reliability and safety of the systems employed. ■



Development of silicon electronics: The graph shows the number of components per chip in microprocessors and DRAMs since 1970 and the continuing increase forecast in the International Technology Roadmap for Semiconductors (ITRS). The progression in size of the silicon wafers used in production is also shown. Source: VDI Technologiezentrum GmbH