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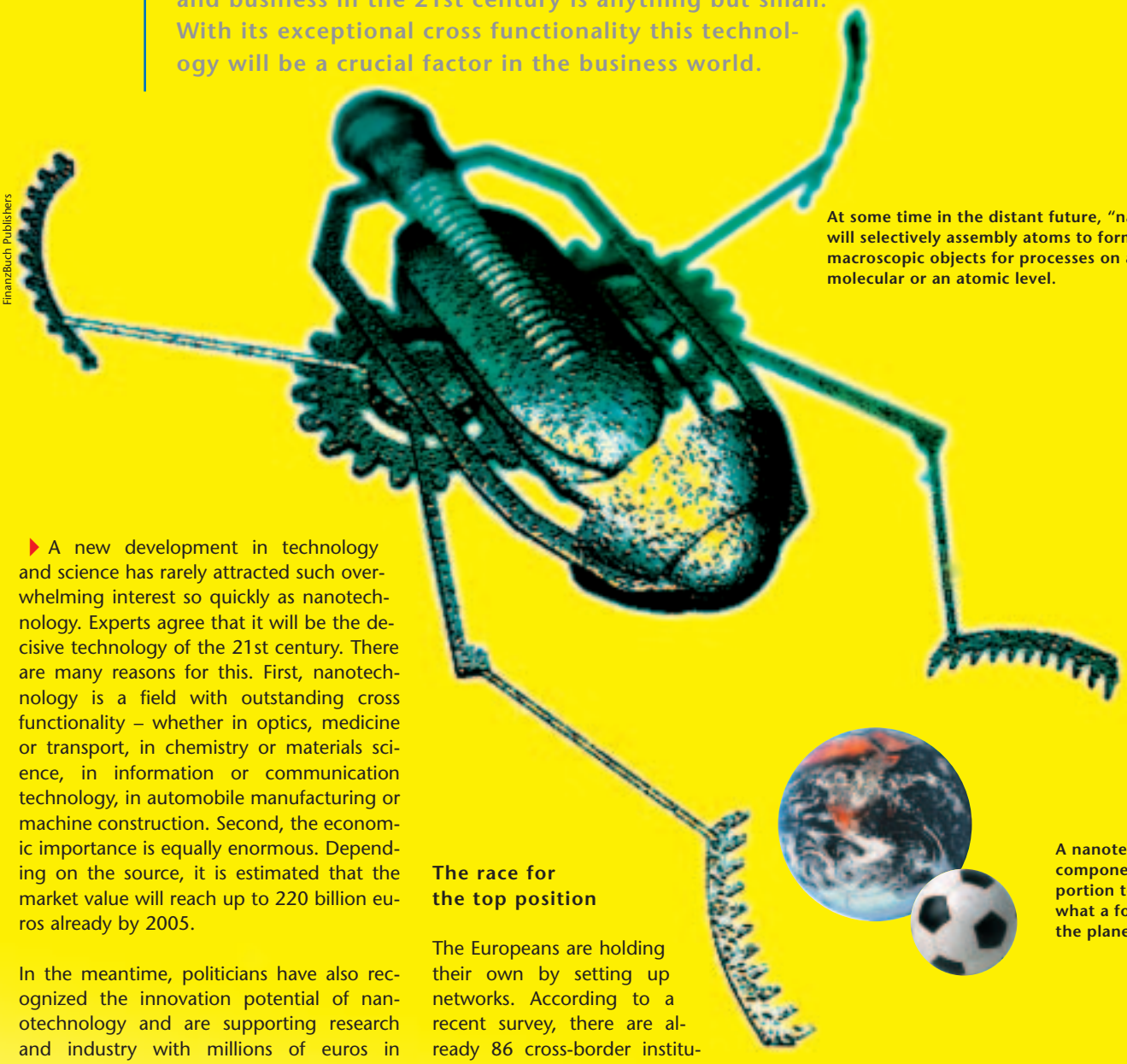
A Big Future for the **Tiniest of Particles**

The Greek nanos, as in **nanotechnology,** means dwarf, but the expected impact of this tiny realm on science and business in the 21st century is anything but small. With its exceptional cross functionality this technology will be a crucial factor in the business world.



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At some time in the distant future, "nanobots" will selectively assembly atoms to form macroscopic objects for processes on a molecular or an atomic level.

A new development in technology and science has rarely attracted such overwhelming interest so quickly as nanotechnology. Experts agree that it will be the decisive technology of the 21st century. There are many reasons for this. First, nanotechnology is a field with outstanding cross functionality – whether in optics, medicine or transport, in chemistry or materials science, in information or communication technology, in automobile manufacturing or machine construction. Second, the economic importance is equally enormous. Depending on the source, it is estimated that the market value will reach up to 220 billion euros already by 2005.

In the meantime, politicians have also recognized the innovation potential of nanotechnology and are supporting research and industry with millions of euros in grants. "The market for nanotechnology and nanomaterials is growing at a breakneck speed. There is fierce competition between the U.S., Japan and Europe in this field. Everyone is working hard to keep up with the rapid developments in nanotechnology," confirms Gerd Bachmann, one of the leading German experts in nanotechnology at the VDI Technology Center in Düsseldorf, Germany.

A nanotechnological component is in proportion to a football what a football is to the planet Earth.

The race for the top position

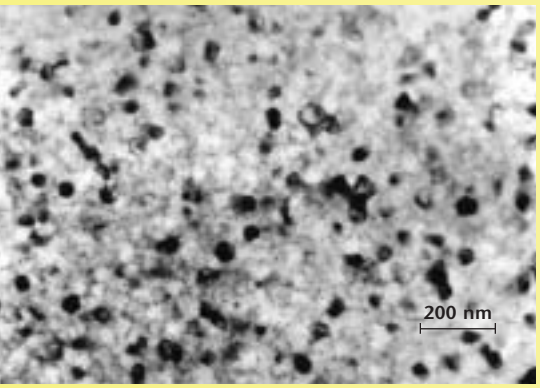
The Europeans are holding their own by setting up networks. According to a recent survey, there are already 86 cross-border institutions of this type in the field of nanotechnology in which some 2,000 organizations are involved. They have nearly 200 million euros of public grants at their disposal per year – plus a further 100 million euros in private funding.

Many products in the nanometer range (one nanometer is the equivalent of one billionth of a meter) are already on the market. Nevertheless, experts generally agree that nanotechnology is still at the beginning of its development. "This leads to the situation that on the one hand, the physical fundamentals still have to be investigated, while on the other hand, the first product groups have already penetrated the world markets. All this speaks for the high tempo of innovation in this field," explains Bachmann. It is thus no surprise that as a technology com-

pany SCHOTT also has some common ground with this innovative field.

"Old" and "new" nanotechnology

In the meantime, the widely accepted definition of nanotechnology is the production and research of structures less than 100 nanometers in size. This condition has to be met in at least one direction in space. "In fact, we have been involved in nanotechnology for decades, although we called it by a different name. All glass ceramics – from 'Zerodur' to 'Ceran' – contain crystals that measure only 30 to 80 nanometers in size, and they are responsible for the outstanding properties," says Professor Wolfram Beier, a scientist at SCHOTT's R&D Center. These glass ceramics, which in the meantime have become such successful brand names, are indeed fascinating materials that combine the main advantages of glass with those of ceramics. The company has attained many successes with its extremely temperature-stable "Ceran" cooktops. In fact, the 50 millionth "Ceran" unit was produced in 2002. In addition, the advances in astronomy, which have provided the world with breathtaking insights into the history of the universe's creation, would not have been possible without "Zerodur." This material has played a role in almost all the major achievements in space research and also in many advances in satellite observation in recent years.



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Glass ceramics like "Zerodur" also have nanostructures; they are responsible for giving the product its special properties, for example zero thermal expansion.

One could say that glass ceramics fall into the category of "old" nanotechnology, while the trendsetting biochips for which SCHOTT has developed coated substrates most certainly belong to the "new" kind of nanotechnology. With these chips it is possible to produce microarrays that allow a reliable analysis of DNA activity.

Such arrays are used in pharmaceutical research to identify disease-relevant genes. The specially coated substrate made of glass is printed with gene material – a process that was adapted from semiconductor technology. The substrate facilitates the evaluation of the experiments conducted by drug discovery researchers, improves the assessment and allows for reproducible test conditions and results. The innovative part is the extremely thin multiamino silane coating in the nanometer range on a special borosilicate glass. Compared with conventional products, these coatings have a much larger number of bonding points for the DNA probes. SCHOTT's coating know-how and the favorable material properties of the glass contribute to faster and more cost effective drug research.

Nanolayers for VCSELs and OLEDs

These ultrathin coatings, which are considered a key element of the nanotechnology, also play an important role in the production of vertical cavity surface emitting lasers (VCSELs), which have special properties as light emitters. With their help electrically stored information can be converted into optical signals. This makes it possible to transmit via glass fibers large quantities of data in the form of light – effectively and quickly. "The data are channeled into the glass fibers by turning a laser on and off. We produce these "light bulbs," says Dr. Burghard Schneider, Managing Director of ULM photonics GmbH in Ulm, Germany, in which SCHOTT has a majority holding.

ULM photonics is developing and producing the newest generation of VCSELs. These surface-emitting laser diodes have major advantages compared with the strip lasers that have dominated the market until now and emit their light laterally over the edges. For instance, surface-emitting laser diodes are easier to test and assemble. They also have better optical properties for coupling the light in the conductor. With the molecular beam epitaxy process, an ingenious structure of many ultrathin layers is applied to the substrate made from gallium arsenide. The layers consist of only a few atoms and thus measure only some nanometers in size. Most of these layers serve as reflectors, but some also actively amplify the light. An incredible number of some 90,000 diodes, which, after the epitaxy process, undergo several classic lithographic steps before they are finished, fits on a wafer measuring just eight centimeters in diameter. With data transmissions of 10 gigabits per canal, ULM

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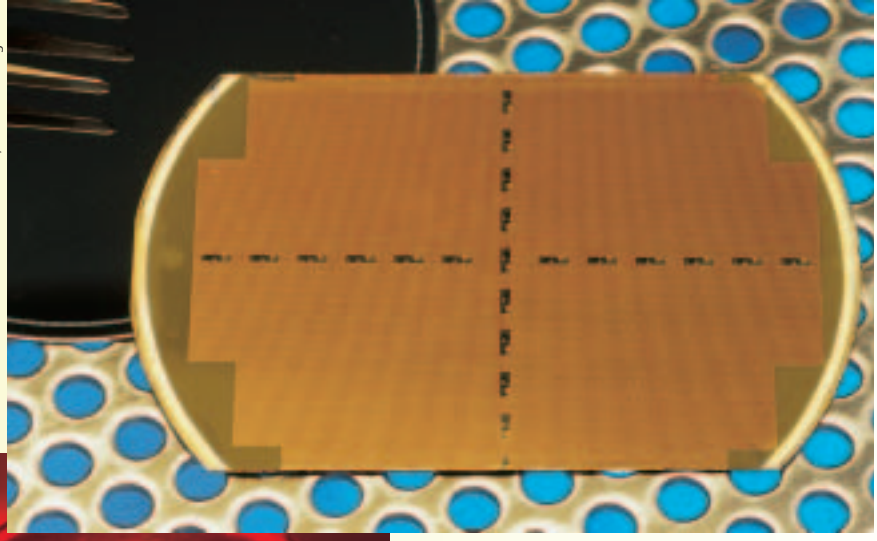
Microarrays, which are used to analyze DNA activity in the field of biotechnology, have a multiamino silane coating in the nanometer range covering a special borosilicate glass.



SCHOTT/Thomas Emsting

Using the molecular epithaxy process, many layers are crystallized onto substrates made from gallium arsenide. These act as reflectors on laser diodes or as active amplifiers of light.

SCHOTT/ Carsten Costard

Organic nanolayers are deposited on large surfaces of the substrates in the production of organic light diodes for lighting purposes. By applying an electric current, the components are caused to illuminate.

photonics is among the top producers of these components worldwide. The term "canal" implicates that the transmission capacity could also be increased by the coupling and decoupling of several lightbeams (VCSEL arrays for parallel transceiver).

Since the high expectations for data transmission have not yet materialized because there is still no major demand for greater bandwidths, the experts in Ulm are currently performing in alternative areas of application. "Among other things, we see possibilities in printing technology or in sensor technology, for example, to determine the oxygen content in furnaces," says Dr. Schneider.

Coating processes play a key role

Organic light emitting diodes, better known as OLEDs, which have caused quite a sensation mainly in novel display applications, are one of today's most exciting international research topics. OLEDs are not only superthin and light, but also flexible, bright and energy-saving. They are also an alternative to conventional light bulbs and fluorescent tubes for high-quality lighting components. SCHOTT was one of the first technology companies in the world to recognize and exploit the potential of this research field. "OLEDs for lighting purposes are an important innovation project for us," confirms Member of the Board of Management Dr. Udo Ungeheuer.

For the production of these lighting elements, organic coatings with a thickness in the nanometer range must be applied to the substrates over large surfaces. Coating processes thus play a key role, which is why extensive knowledge of substrates, their structure and cleaning are necessary. In addition, processes for the encapsulation of the surfaces, for analyses and for testing are required. SCHOTT has a good starting position because many technologies are already well established in the company, such as dipping methods, spin coating processes and screen printing techniques as well as various PVD (physical vapor deposition) and CVD (chemical vapor deposition) solutions.

These examples show that "nanos" are often at work behind the scenes. In many cases, their share in new technologies is not immediately recognizable. But the examples presented also prove that nanotechnology plays a role in many new developments and products, which is evidence of its important cross functionality. It is therefore also clear for SCHOTT that many further paths will lead into the realm of these tiny particles. ◂