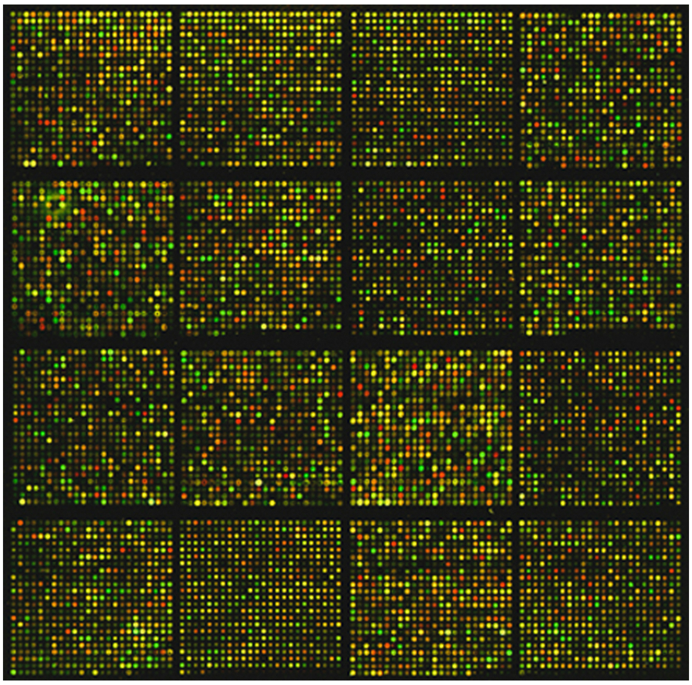
Biochips: microsystems technology for the life sciences

Nanoscale robots and intelligent measurement systems in arteries, fingernail-sized DNA chips that can be used to analyze thousands of genes in tiny samples, intelligent DNA microsensors – the trend in the life sciences is moving towards miniaturization in all areas including electronics, sensor systems and the handling of liquids. Over the last few years, a research area with growing potential has developed at the interface of physics, the engineering sciences, chemistry, biology and the computer sciences, and is now also going nano.

On 29th January 1886, Carl Friedrich Benz, who was born in a town near Karlsruhe, made history when he was granted a patent (DRP-37435) for a three-wheel vehicle with a four-stroke combustion engine from the Reichspatentamt (Imperial Patent Office). His great achievement was to combine two things: a horse carriage and the Otto engine. At the time, the Otto engine was already being used to drive different machines. However, it was at least as big as today's cars if not bigger. The inventor had to reduce it in size before the first engine versions of modern Mercedes Benz cars could go into production. More than a hundred years after Benz's invention, researchers and developers in Germany and elsewhere are faced with a similar problem in the field of life sciences and other areas.

Smaller and better



Biochips can be used to carry out hundreds of experiments simultaneously.

Mobile diagnostics, personalized micromedicine and intelligent implants are the keywords of the future in the life sciences. Whether it is the diagnosis of diseases or the high-throughput screening of the tiniest quantities of substances in drug development – medicine, pharmaceutics and biological research will all benefit from microsystems technology (MST). Estimates suggest that a one per cent increase in the expenditure for in vitro diagnostics – which is an important field of application for microsystems technology – could lead to cost reductions of five per cent in the healthcare sector, to cite just one example. In Germany, such cost reductions would account for more than 10 billion euros per year. The trend in technological development is clearly heading towards the miniaturization of devices and the simultaneous increase in performance of all components involved.

Biochips are an example of the technical optimization that has been made possible by microsystems technology. Biochips are miniaturized laboratories that can perform hundreds and thousands of simultaneous biochemical reactions. They are carriers made of glass or other materials on which a large number of biomolecules can be immobilized at high density in a defined order (microarray). Between one hundred and ten thousand spots containing synthetically produced biological probes (e.g. DNA or enzymes; sometimes even entire cells) can be immobilized on the surface of a chip. Each spot (radius: 100-300 µm) can selectively bind a specific molecule, gene or ion. When the test sample is labelled with fluorescent dyes, the biochip indicates the presence of the substance of interest when it is analyzed under a fluorescence microscope and can even provide information about the substance concentration.

The robot laboratory and microsystems technology that is an economic driver

Ten years ago, researchers still had to carry out molecular biology investigations manually. Nowadays, robots enable the high-throughput analysis of hundreds of samples that are placed on fingernail-sized plates where they react with cells, enzymes or DNA. Researchers use biochips to investigate entire genomes of organisms and compare them with each other. In the pharmaceutical industry, biochips help to rapidly analyze the effect of large quantities of unknown substances on biological material. In the food industry, biochips can be used for the identification of genetically modified food. The combination of microfluidic and microelectronic applications enables different series of autonomous reactions to be carried out one after another on a single chip. Biochips become mobile microlaboratories that enable the bedside analysis of patient samples or the analysis of soil samples in African wheat fields at the push of a button.

Microsystems technology has already become a driver of technological progress. And this also has economic implications. According to information from the German Federal Ministry of Education and Research (BMBF), microsystems technology had a sales volume of more than 82 billion euros in 2009. According to the BMBF, these numbers are increasing, with annual growth rates of around fifteen per cent between 2009 and 2011. The German government funds this key technology under its "High-tech Strategy for Germany" programme. In 2010, the BMBF provided around 80 million euros in funding for microsystems technology research through its "Information and Communication Technologies (ICT 2020)" funding programme. At present, around 490 application-oriented research projects are supported with funds totalling 184 million euros. The German government also funds a Baden-Württemberg cluster that won the second round of the German government's Leading-Edge Cluster Competition in 2010. The "MicroTEC Südwest" microsystems technology cluster has its headquarters in Freiburg and is specifically focused on the life sciences, amongst other things.

Even smaller in the future?

The fields of microsystems technology and nanobiotechnology are likely to amalgamate in the next few years. Researchers are already working on making the world of biological molecules accessible for engineers with the help of synthetic biology. In future, DNA or signalling protein kits in combination with microelectromechanical systems (MEMS, also called micromachines) will be able to provide even more efficient microsensor systems for chemical test procedures. In addition, the guidance of defined pulses of light through so-called DNA blocks on biochips might in future also replace the transfer of information with electrons in computer chips and make them considerably faster.

Pipetting station for the tiniest amounts of liquid.

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What problems can be expected to arise in the development of microscopically small systems such as biochips? In which areas of the biosciences and the biotech and pharmaceutical industry is there further potential? How do the life sciences already benefit from such tools? And how will they benefit in the future? This dossier provides insights into current and future developments.

Publication:

Wintermantel, E., & Ha, S.-W. (2008). *Medizintechnik: Life Science Engineering*. Springer-Verlag Berlin/Heidelberg

Dossier

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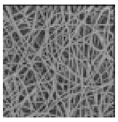

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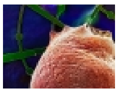

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