

Commentary

CeNTech - Nanotechnological Research and Application

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Abstract: The Centre for Nanotechnology (CeNTech), Münster, Germany, represents one of the first dedicated nanotechnology centres in Germany providing space and infrastructure for application, research and development in the area of nanotechnology. It offers an optimised environment for entrepreneurs to further develop their research ideas into marketable products as well as excellent conditions for application oriented research and further education. Three years after the opening of the CeNTech building most of the expectations are fulfilled. The article describes the general aspects of the CeNTech concept and reviews its development in the first years.

Introduction

Nanotechnology is a rapidly growing interdisciplinary field. To foster the cooperation between science and industry nanotechnology centres were founded. The centre for nanotechnology (CeNTech) in Münster was created as one of Germany's first centres of its kind being collaboratively supported by the state of North Rhine-Westphalia, the University and the City of Münster. CeNTech is located in a state exhibiting the largest number of inhabitants in Germany and is integrated into the densest network of universities all over Europe. Three years after CeNTech opening synergetic effects become clearly visible.

Concept and Ideas

The basic and overall concept of CeNTech provides the environment to perform basic research with strong application perspectives and to direct selected ideas and results of nanoscience into technical applications. Short in-house ways and a creative mixture between different scientific disciplines provide a fruitful background. Central to this basic concept is the promotion of start-up companies that originate from university research as well as the settlement of existing companies with nanotechnology and nanobiotechnology background. Evidently, patent support and contacts providing financial support are essential for the expansion of companies in the field. Another aim of CeNTech is the promotion of education ranging from level of schools to advanced training of external scientists in the field of nanotechnology, resulting in the concept of *Integrated Nanotechnology* (Figure 1).

CeNTech consists of a unique structure that has a complementing character in terms of combining research work and infrastructural, marketing, project proposal, exploitation, PR, patent, educational, and organizational activities. It consists of two different parts – a corporation (GmbH) and a research and development (R&D) department. Researchers and companies are supported by legal entity - CeNTech GmbH, i.e. a

corporation providing an optimised infrastructure, support for preparation of patents, initiation and evaluation of projects, initiation and realization of know-how transfer towards industry, initiation and support of start-up founding processes, public relations, workshops, marketing and further education. By founding such an economically oriented structure research is transported much closer to the economic value creation chain. The gap between basic and applied research and industrial exploitation could be reduced significantly by implementing this system that actively seeks technological ideas, potential products, special know-how, and project ideas for third party funding. Researchers are interviewed in regular personal meetings where in a common approach the potential values shall be identified if not already clear. The researchers are well supported by the CeNTech GmbH and can therefore better focus on their main strengths and passion: research and development.

The R&D part of CeNTech is dealing with nanotechnology research preferentially in the areas of nanoanalytics and nanobiotechnology. Within these foci the projects in CeNTech include the optimization of scanning probe microscopy such as STM, AFM [1, 2] and advanced x-ray- and light microscopy techniques [3], the study of novel materials and nano-scaled template structures [4], the analysis of biophysical effects especially in intra- and intercellular processes, and the development of new approaches for the utilization of biological and biochemical processes in nanotechnology.

In these areas CeNTech researchers co-operate with groups in Germany, Europe and maintain close relations with research centres in the USA, Israel, China, and Japan, working together on nanoscience projects and exchanging visiting researchers. In particular CeNTech is engaged in the first German-Chinese Centre for Nanoscience (GCCN) which is based on a cooperation agreement between the State of North Rhine-Westphalia and the Chinese Academy of Science in the year 2000.

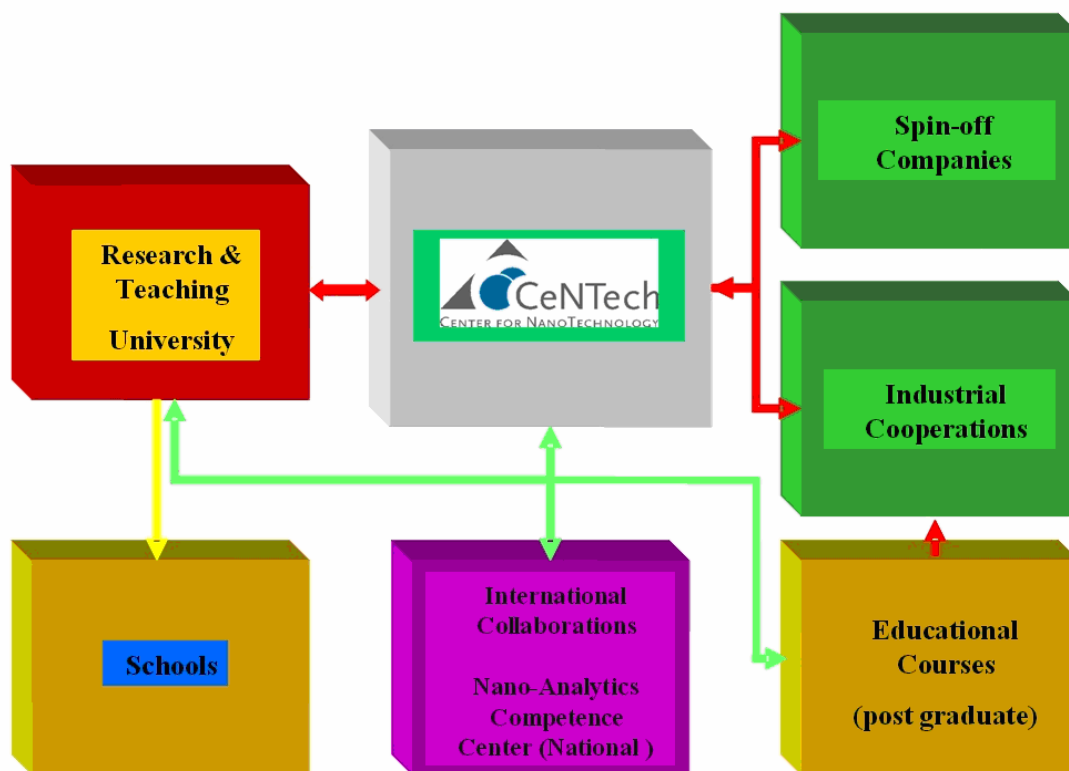


Figure 1: Integrated nanotechnology at CeNTech

The general research strategy follows a concept that formed the basis of a seminal scientific success in research laboratories of big US companies and which led to an unprecedented technological leadership over many decades. It consists, on the one hand of a fairly general topical framework or goal, which is sufficiently flexible to guarantee that new and completely unexpected technology leaps can occur, far beyond existing knowledge, linear product optimization strategies and the ostensible increase of market shares. On the other hand the general vision based on the product portfolio of the company had to be considered. Such a strategy has been leading, for example, to innovations such as the transistor, scanning probe microscopy, and high temperature superconductivity, to name a few. All these discoveries had a highly disruptive character making it virtually impossible to foresee their outcome just by evolutionary linear developments. The latter are extremely important and, in fact, indispensable in industrial product and

method development including road map and milestone concepts etc., but seem much less efficient for the exploration of really new frontiers.

In CeNTech R&D, the participating groups originating from physics, chemistry, biology, biophysics and medicine are dedicated to application aspects of nanoscience and the fields of nano-(bio) analytics, nanomaterials and nanobiotechnology. One third of the total lab space of the CeNTech building is dedicated to nanotechnology-related companies, while the other two thirds of the building are operated by research groups from the university. The formal barriers for a membership are fairly high. It is first based on a scientific/technological proposal describing the research approach of the applicant followed by a description of the potential applications. In the case of a successful application the groups have to bring their own personnel and instruments. In addition they have to pay overhead fees for general research related duties of the lab. This means that

the reach groups cannot participate, if they do not acquire external grants.

This concept resulted not only in over 100 high quality publications and more than 10 patent applications filed after three years but shows effects on the job market as well. More than 25 new positions were created within the last years and collaborating companies at CeNTech found new common customer markets that would otherwise have been inaccessible for the individual companies. Cooperation with SMEs and large companies from outside resulted in similar effects.

Nanotechnology at CeNTech

Nanotechnology is essentially based on physical and chemical effects that are characteristic for a certain small length scale, and which are not observed at larger length scales. As a consequence nanotechnology is rather an enabling technology than a specific technology field such as electronics, automotive or chemical industry. Thus, in contrast to existing technologies novel device and material properties arise, for example, by control of particle size (color, catalytic yield) tailoring electric trans-

port properties, and applying of molecular recognition. This approach has a high potential to lead to disruptive progress in all technology fields, certainly with high risks but eventually substantially bigger economic opportunities as compared to conventional development strategies [5].

Based on the fact that

- physical techniques reach functional structures (mainly in electronics) down to the nanometer scale and microscopy and spectroscopy methods are reaching molecular and atomic resolution,
- chemists can prepare complex cluster- and supramolecular systems, and
- functional biological systems (membranes, proteins, molecular motors) are nano-sized,

it becomes self evident that the traditionally well-separated disciplines of physics, chemistry and biology naturally meet on the nanometer scale and can form a platform for novel scientific and technological strategies reaching far beyond the individual disciplines (Figure 2).

For example, in molecular biology, nanosys-

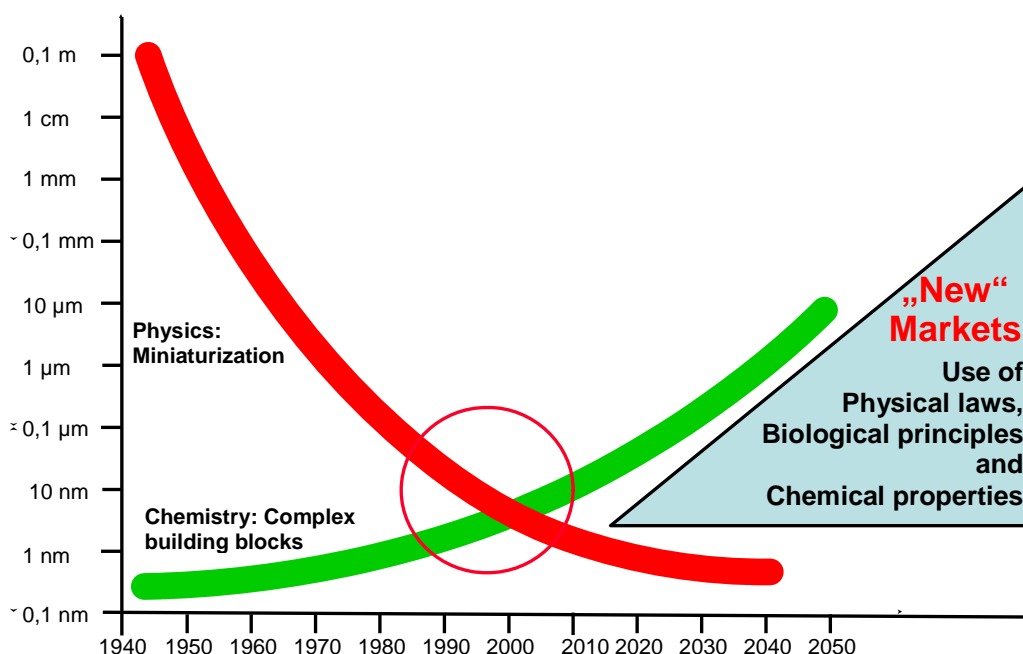


Figure 2: Nanotechnology - a transdisciplinary approach

tems - like proteosomes and molecular motors - are the fundamental machines that drive the cell and they are components of mitochondria, chloroplasts, ribosomes, and the replication and transcription complexes. In catalysis, nanostructures are ideal reaction centres as are the pores of zeolites.

Each of the disciplines has evolved to some extent its own separate view of nanoscience. The opportunities for integrating these views and for sharing tools and techniques developed separately by each field belong to the most attractive activities ongoing in science today. Some of the challenges for research and development at CeNTech are presented below.

Surface Matters - a Glance at Scientific Work at CeNTech

The development of novel techniques for scanning probe microscopy is the prerequisite for an increasingly deeper insight into the nano world. This method is based on a revolutionary microscopy concept by Gerd Binnig and Heinrich Rohrer from the IBM research laboratory in Zurich, Switzerland, who, in 1981, built the first scanning tunnelling microscope. They were awarded the Nobel Prize in physics in 1986. Their method resulted in the development of a whole family of complementary techniques and made an extremely strong impact for getting nanotechnology really started.

Novel methods for improved visualisation of

nano-scale structures and for even measuring the forces between individual atoms and molecules are developed at CeNTech. Questions such as the basic mechanics of friction and wear can be addressed on the atomic scale (Figures 3 and 4) [6]. It becomes particular evident in this field that the borders between basic research and application become fuzzy.

Another topic of CeNTech research is the preparation of self-organised molecular layers. Usually, molecules or atoms – i.e. the building blocks of all materials – are arranged in a more or less randomised fashion in existing products. Using self-organization techniques ubiquitous in biology molecular building blocks arrange themselves spontaneously and in a well defined position. They may eventually lead to novel and useful macroscopic systems based on cooperative effects which then are technologically relevant as, for example, nanostructured templates and scaffolds [7].

Materials produced in this way exhibit totally new electronic and optical properties and, in the extreme case, are only as thick as an atomic or molecular monolayer. This technique is highly demanded for a whole range of applications. In future it will be possible to build electronic chips with huge memory capacities, to house a whole bioanalytical laboratory on the size of a thumbnail, or to build organic light emitting diodes with tailored optical properties. According to the interdisciplinary character, the investigation of interaction between nanoparticles and nanostructured surfaces is another new research topic. Here the action of

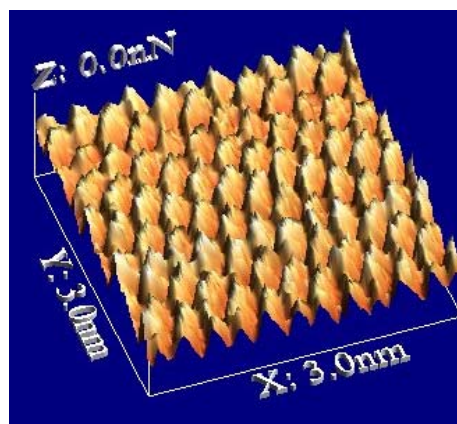


Figure 3: "Lateral Force Microscopy" on single carbon atoms on a graphite surface

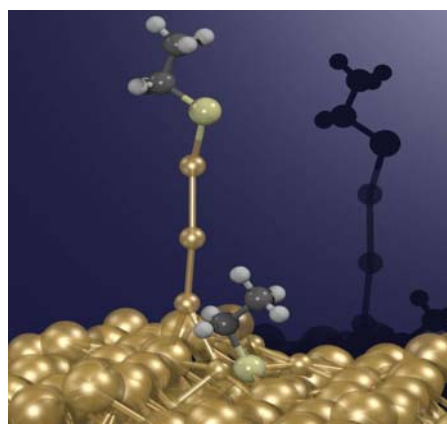


Figure 4: Molecular tweezers – Mechano - Chemistry

those structures on the immune system will be investigated to make a risk assessment and to find new applications for medical devices.

The research fields performed in CeNTech include

- Design of novel scanning-probe techniques [8, 9] and advanced optical and x-ray methods.
- Manufacturing and characterisation of supermolecular, self-organizing film-systems (Langmuir-Blodgett, self-assembly-techniques) [4, 7])
- Molecular Beam Epitaxy (MBE) for the construction of novel electronic systems based on organic molecules [4]
- Development of theoretical models related to scanning-probe techniques

Beyond Electron Microscopy (SEM), Photoelectron spectroscopy (XPS) and other surface analytical techniques a state of the art dual beam Focused Ion Beam (FIB) system is available at CeNTech. Important applications are nanoscale machining, the modification of the electrical routings on semiconductor devices, the preparation of probes for physico-chemical analysis, or the preparation of ultra precise sections for transmission electron microscopy (TEM), just to mention a few examples. In what dimension manipulation is possible is demonstrated in Figure 5.

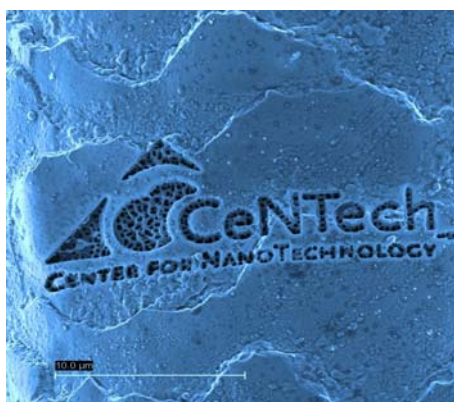


Figure 5: CeNTech logo written on a hair with a Focused Ion Beam (FIB) system,

In addition to the above mentioned research areas CeNTech offers several groups of young scientist the great opportunity to develop their own research fields in nanotechnology.

Biological Barriers - Cooperation and Development at CeNTech

Indicative for the interdisciplinary character of nanoscience at CeNTech is the cooperation between the groups. Within the framework of a special research area of the University of Münster, scientists work together on the deliberate modification of cellular membranes. Biological membranes are made of water-repellent, fat-like molecules with built-in protein molecules serving as transport slices. The whole exchange of matter within and between cells is being arranged and controlled by these slices. Biochemists work on the modification of definite bonds within the fatty acids of the membrane in order to make them less water-repellent, thus gaining novel surface-active properties. To achieve these aims, biochemists use the nanotechnological brick box of the partners [10, 11]. The final application area of this research cooperation is in medicine. The development of implants which take root particularly well in the body without causing unwanted immunological repulsions is only one possible end product of this nano project in Münster.

The presence of the biochemists at CeNTech was not only fruitful for scientific reasons. In cooperation with *nano.Analytics* - a company located in CeNTech - a new product was made ready for market: the so-called cellZscope® (Figure 6). With this new device the impedance, i.e. resistance and capacitance of biological barriers can be characterised as a measure for the correct contact between the cells of a cellular monolayer [12]. It is a tool that can be used e.g. as a substitute for animal testings to investigate drugs and the biocompatibility of nanoparticles.

These are a few examples which demonstrate the interaction between science and SMEs. Other companies and researchers like e.g. a group dealing with the optimization of nanostructures for protein and DNA synthesis are as well successful at CeNTech.

CeNTech fosters not only the interaction between science and industry but also that of SMEs

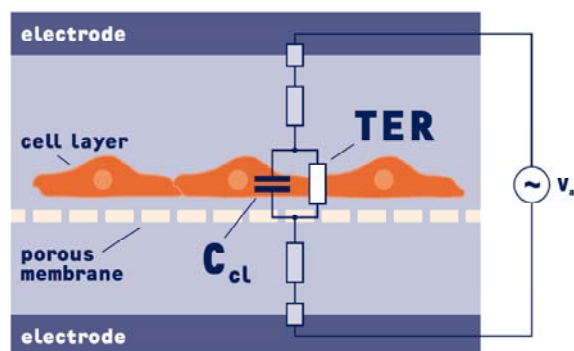


Figure 6: cellZscope® - photography and basic principle of the device

and big companies which leads to new additional market shares on both sides.

Another example for a company hosted by CeNTech is *arrows biomedical Deutschland GmbH*. It is an independent, international medical and scientific consultation and service firm, which advises and supports business, research institutions and hospitals in the area of molecular biomedical sciences. An intensive cooperation with NIKON Mikroskop GmbH enables them to work with advanced high-quality optical microscopes. All employees within the company are physicians and scientists, who continuously work on innovative methods of problem solving in molecular biology and medical science. Close collaboration with all disciplines open contacts and applications within nanoscience as well as in stem cell research. The expanding company appreciates the transdisciplinary environment as well as other companies like *Chembiotech*, *Tascon* or *nanoAnalytics* hosted by CeNTech.

Conclusion

After its first three years of operation CeNTech has formed a new regional platform in the field of nano(bio)technology which combined basic research and technology transfer in an efficient way. Researcher groups at CeNTech have acquired more than 12 Mio € during that time on a national and European basis beyond their individual funding in their mother institutions of the University of Münster. Clearly, some of the big instruments such

as advanced laser scanning microscopy, UHV- (ultra high vacuum-) surface inspection tools and the Focused Ion Beam system can be used much more efficiently at CeNTech than by an individual group in one of the discipline-separated scientific faculties. The mixing of optimised laboratories, common seminars and meeting rooms etc. generated a new creative atmosphere resulting in much new interdisciplinary collaboration including the in-house companies. CeNTech as a unit also provides strong support for companies and press presentation, education, and workshops. Several young researcher groups were established which are of particular interest for the initiation of new interdisciplinary educational and research approaches. One of the secrets of CeNTech's success is the freedom that established groups, and in particular young researchers have in performing their research. This freedom is due to the financial concept that is based on the individual external funding of peer reviewed projects that are harboured in CeNTech, rather than institutional contracts provided by the unit. The dynamics and freedom resulting from this concept as well as interdisciplinary science and development creates a great potential for innovation. The job generating effect of CeNTech is the strongest index for the quality of the strategy of this centre.

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