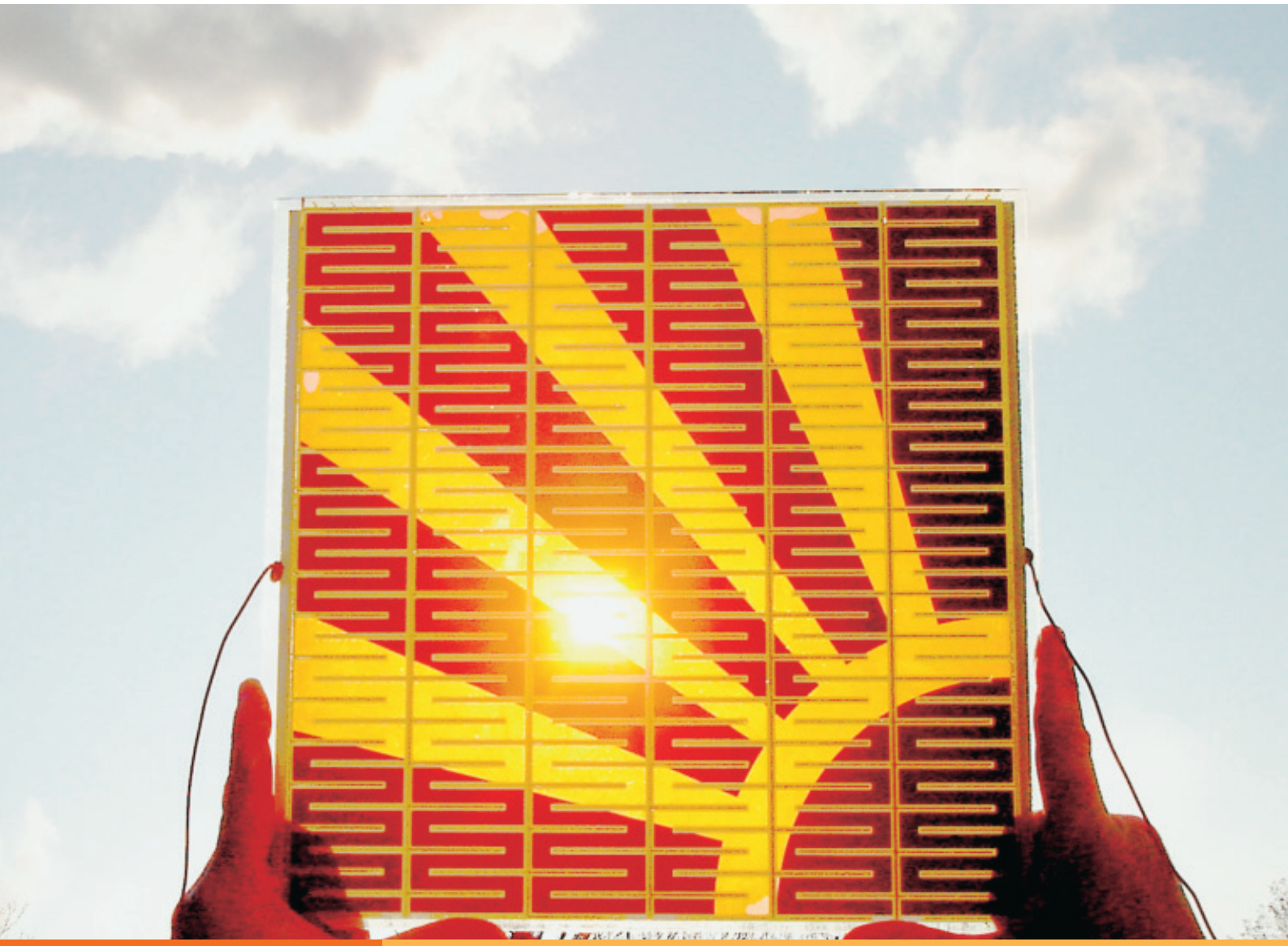
Federal Ministry
of Education
and Research

Nano-Initiative – Action Plan 2010



HIGH-TECH STRATEGY

Igniting ideas!

Imprint

Published by
Bundesministerium für Bildung und Forschung/
Federal Ministry of Education and Research (BMBF)
Public Relations Division
11055 Berlin
Germany

Orders
In writing to the publisher:
P.O. Box 30 02 35
53182 Bonn
Germany
Or by
Telephone: +49 (0) 1805 – 262 302
Fax: +49 (0) 1805 – 262 303
(0.14 €/min from the German fixed network)
E-mail: books@bmbf.bund.de
Internet: http://www.bmbf.de

Editorial office
VDI Technologiezentrum GmbH

Layout and photo setting
Baumann & Mäurer Fotosatz GmbH, Düsseldorf

Printing
WAZ Druck, Duisburg

Bonn, Berlin 2007

Photo credits
Cover picture: FhG-ISE
Prof. Fromherz/MPI-Biochemie Martinsried (page 28), Prof. Heckl/LMU München (6),
Prof. Wiesendanger and Prof. Heinze/CC-HanseNanoTec Hamburg (19), BASF (12),
BAuA (25), Bosch (24), INM Leibniz-Institut für Neue Materialien gGmbH (25),
Degussa (15, 18), Deutsche Börse AG (23), FhG-IPMS (12), FhG-ISE (12), Flad&Flad (30),
IBM (12), IKU GmbH (27), Infineon (19), LINOS Photonics (24), Nano-X GmbH (22),
OSRAM Opto Semiconductors GmbH (10), Philips (28), Siemens (12, 18), Singulus (17),
VDI TZ GmbH, ZAE Bayern (18)

Federal Ministry
of Education
and Research

Nano-Initiative – Action Plan 2010

HIGH-TECH STRATEGY

Igniting ideas!

Foreword

Key technologies are "tickets" to the future. New fields of technology and innovative service markets are particularly significant for the creation of jobs. Moreover, the development and production of high-tech products is closely linked to regional expertise. To survive as a strong economy, Germany has no choice but to concentrate on a strategy of permanent innovation. The availability of nanotechnology – one of the most promising interdisciplinary fields of technology in the world – determines the performance and international competitiveness of the German economy.

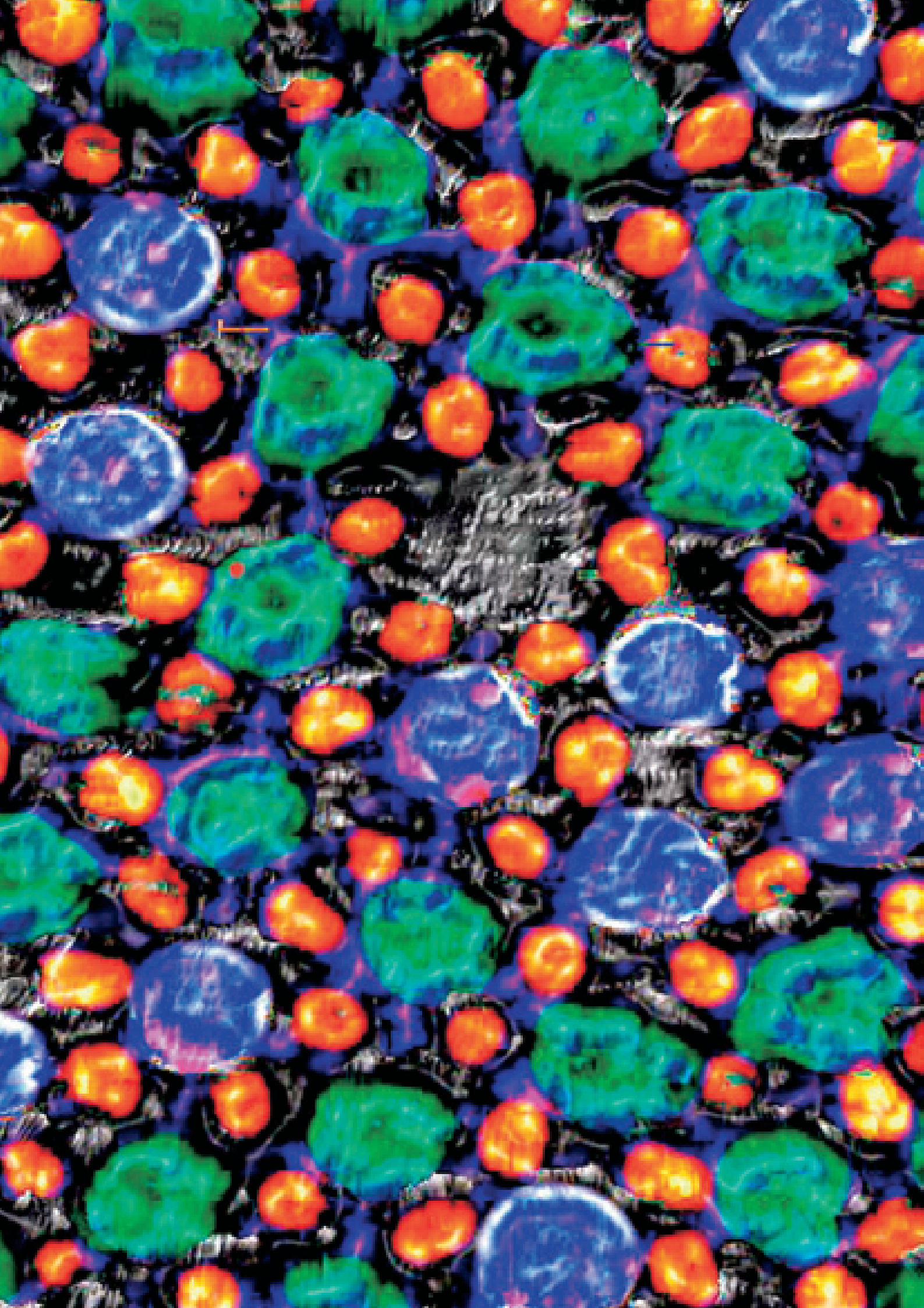
Advances in nanotechnology can both improve existing products and open up entirely new markets. For example, nanotechnology is helping manufacturers to make electronic components faster and lighting elements more efficient. However, nanotechnology does not only benefit high-tech markets – it also has applications in sports and leisure, textiles, and in the construction industry. Many possibilities are becoming apparent in relation to the environment, including applications for protecting resources and treating water more efficiently.

In the field of medicine, nanotechnology offers the possibility of better diagnostics and improved therapies. Since certain nanoparticles are not recognised by the human immune system as foreign bodies and – due to their small size – can permeate the blood-brain barrier, they open up extremely interesting possibilities for medical applications. Naturally, any possible side effects must be considered and researched first. Instead of making arbitrary promises or thoroughly rejecting nanotechnology, we need to conduct a rational, scientifically ethical debate. The topic is still fresh enough for us to enable this.

I am extremely pleased that the Nano-Initiative – Action Plan 2010 has emerged as an important part of the high-tech strategy of the German Government and has been developed as a cross-departmental initiative. The seven federal ministries taking part in the project have each nominated their own nanotechnology representative to follow and further the development of the initiative at regular workshops – a trendsetting job for the people involved.

Dr. Annette Schavan, MP
Federal Minister of Education and Research

Contents



Why is there a need for a Government Nano-Initiative?

Federal Ministry
of Labour and Social Affairs

Federal Ministry of Labour and Social Affairs

In the opinion of the Federal Ministry of Labour and Social Affairs (BMAS) and the Federal Institute for Occupational Safety and Health (BAuA), nanotechnology is an important technology of the future, and therefore has the potential to positively influence economic development in Germany in the long term. Nanoparticles, which have special characteristics thanks to their size, are an important component of nanotechnological developments. These nanoparticles, like ultra-fine particles, already constitute one of the most important new topics in occupational health and safety.

Current legislation on the protection of health in the framework of occupational health and safety makes no special provision for nanoparticles. The Chemicals Act and the EC Existing Chemicals Regulation do not address the fraction of nanoparticles. This means that there is, as yet, no legal obligation to investigate nanoparticles for possible harmful effects. The BMAS and BAuA intend to campaign for nanoparticles to be considered separately in the future Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) law.

The activities of the BMAS and BAuA intend to support the generation of information to enable the evaluation of risks relating to nanoparticles in accordance with international standards and to permit the development of appropriate recommendations for the safe handling of these substances. They also aim at ensuring that publicly funded research projects make allowances for regulatory occupational health and safety issues (such as threshold values and classifications). These objectives are being addressed by means of the participation of the BAuA in various national, European, and international bodies (DIN, EU, and OECD). At the suggestion of the BAuA, the BAuA, the Federal Environment Agency (UBA), and the Federal Institute for Risk Assessment (BfR) have developed a common research strategy for nanotechnology. This strategy is coordinated by the BAuA. The BAuA is also carrying out a survey of manufacturers in order to gain more information on the type of nanoparticles being produced.
A Nano-Initiative that is supported by the Government enables cross-departmental interests to be combined and an agreement to be reached on the sensible use of resources, including resources in the context of occupational health and safety.

– MinR Dr. Helmut Klein –
Nanotechnology representative for the BMAS

Federal Ministry for the
Environment, Nature Conservation
and Nuclear Safety

Federal Ministry for the Environment, Nature Conservation and Nuclear Safety

The Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) anticipates numerous economic developments as a result of nanotechnology, and wishes to actively encourage such innovations. In this way, the BMU can help nanotechnological developments to effect a significant increase in resource efficiency and a noticeable improvement in the results of environmental protection efforts. Innovative approaches to environmental protection should be recognised and promoted by the Government.

Despite the rapid pace of development in the field of nanotechnology, very little is known about the effects of exposure to nanoparticles on humans and the environment. Because of the novel properties of nanoparticles, the BMU has set itself the precautionary objective of following the technical development of nanomaterials and initiating an active debate on safety issues. Most importantly of all, there is a need to develop suitable measuring and testing methods.

As part of the Nano Dialogue 2006 – 2008, the BMU will be discussing this issue with interested parties from the fields of science and the economy and with NGOs (Non Governmental Organisations). Together, they shall formulate aims and steps to be taken in order to ensure the sustainable development of nanotechnology.

– MinR Prof. Dr. Ulrich Schlottmann –
Nanotechnology representative for the BMU

Coronene in the scanning tunneling microscope

Federal Ministry
of Food, Agriculture and
Consumer Protection

Federal Ministry of Food, Agriculture and Consumer Protection

The Federal Ministry of Food, Agriculture and Consumer Protection (BMELV) supports the exploitation of nanotechnology for the agricultural and food industries and for end consumers and emphasises that consumers should be protected from any risks that might arise in relation to the use of nanotechnology. The early identification of the potential risks of using nanomaterials in foodstuffs, packaging for foodstuffs, cosmetics, and other necessary commodities is particularly worthy of attention. The BMELV's risk communication policy and the corresponding policies of industry-specific bodies – in particular of the Federal Institute for Risk Assessment (BfR) – clarify the risks for consumers and channel discussions about potential risks.

Risk assessment and communication is based on sound knowledge pertaining to intentional and unintentional exposure and the effects/side effects of nanoproducts on consumers. In order to obtain the required data for this, relevant testing methods need to be developed or existing methods need to be adapted. The BMELV is especially concerned with ensuring that animal protection issues are taken into account right from the start and that alternative and complementary methods are used in place of animal testing wherever possible.

One of the challenges of working with nanotechnology is to ensure that the public's perception is balanced between an understanding of the benefits of nanotechnology and a fair and timely appreciation of any associated risks. The active and comprehensive approach to nanotechnology embraced by the Government's Nano-Initiative can contribute to meeting this challenge. In this way, we can enable the potentially positive health, ecological, and economical benefits of nanotechnology to be exploited to the full.

– MinR Dr. Gerhard Rech –
Nanotechnology representative for the BMELV

Federal Ministry
of Defence

Federal Ministry of Defence

One of the important features of nanotechnology is its exceptionally wide range of application. Innovative approaches are particularly prevalent in the established fields of technology of chemical substances, electronics, sensor technology, and biotechnology. The multifunctional nature of many nanotechnological innovations in the short and medium terms should increase the performance of future military systems even though they are unlikely to produce spectacular new weapons or defence systems – at least not at first.

The research activities of the Federal Ministry of Defence (BMVg) are primarily based on civilian research activities (in accordance with the add-on principle). Only in cases where the civilian market fails to deliver satisfactory results departmental projects are triggered. Since we use technology as a means of delivering capabilities to support the Federal Armed Forces, we are also investigating the potential capability of nanotechnological applications for equipping combat troops. However, the current focus is on protection technologies.

In the face of the challenges raised by a pivotal multifunctional technology such as nanotechnology, which will influence practically every sphere of life, the BMVg – as part of its duty as an end consumer of technology – has an obligation to contribute to continued development. The Government's Nano-Initiative joins together all departments affected by nanotechnology to create a platform for proceeding with development in this field in a coordinated manner.

– MinR Hartmut Wolff –
Nanotechnology representative for the BMVg

Federal Ministry of Health

Federal Ministry of Health

Widespread diseases such as cardiovascular disease, cancer, and diabetes, the increasing number of degenerative illnesses in an ageing population, and outbreaks of existing and new infectious diseases all demonstrate the increasing need for innovative diagnostics, therapeutics, and substances in modern medicine. We have high hopes for nanotechnology. However, in order to achieve our expectations, we require structured networks at all levels of organisation. On a political level, this includes the Government's Nano-Initiative.

The use of nanotechnology in medicine is still in its early stages. However, it is felt that "nanomedicine" has a huge potential – particular in pharmaceuticals and medicine products. It is hoped that nanotechnology can help to make earlier and more reliable diagnoses, prevent diseases, and improve prevention measures and treatment methods by making them more effective and specific. In addition, medical procedures could be made more pleasant for patients and the cost-value ratio could be improved.

As well as pointing out the potential benefits of nanotechnology, it is important to highlight any related health risks. This is why pharmaceuticals and medical products must only be brought into use following a comprehensive evaluation of risks and benefits. Risk assessment is another area where it is important for different disciplines to work together. For this very reason, the institutions that come under the authority of the Federal Ministry of Health (BMG) – the Federal Institute for Pharmaceuticals and Medical Products, the Paul Ehrlich Institute, and the Robert Koch Institute – will be working together on this issue.

– MinR Michael Meier –
Nanotechnology representative for the BMG

Federal Ministry of Economics and Technology

Federal Ministry of Economics and Technology

The implementation of the results of nanotechnological research in Germany's production locations for formative, export-oriented industries will be a decisive factor in the future international competitiveness of our industries. The approximately 600 nanotechnology-inspired companies in Germany – mostly small enterprises – constitute the start of this process but also demonstrate the extent of the challenge of implementing a widely effective, small-and-medium sized enterprises-based implementation of the results of research and development in this area. The quick diffusion of results in traditional industries and specific start-up promotion following successful application-oriented research in lead projects and technology trials are particularly important.

The implementation of nanotechnological products has a huge potential for cost saving with regards to the consumption of raw materials and energy and will also promote environmentally friendly economic circuits.

In order for nanotechnology to be used in an economically effective manner, research, economic, and technological policy must be interwoven. It is also necessary to ensure that federal innovation policy works well alongside private entrepreneurship. This is the only way to successfully make the small but important step of turning the technical potential of a nanotechnological product or procedure into an economically sound reality. The Government's Nano-Initiative promotes this aim.

– MinR Dr. Klaus-Juergen Exner –
Nanotechnology representative for the BMWi

I. The potential benefits of nanotechnology

Definition of nanotechnology

Nanotechnology is the investigation, application, and production of structures, molecular mate rials, and systems with a dimension or produc tion tolerance of less than 100 nanometres. The minute scale of the system components alone enables the realisation of new functionalities and properties for improving existing products and applications or developing new ones.

Nanotechnology enables tiny matter structures – a million times smaller than a pinhead – to be handled and used in a targeted manner. Nanotechnological knowledge exploits exceptional material properties and functions in order to realise the potential for product innovation in practically all fields of technology and economic branches. Germany's future competitiveness in industries such as automotives, chemicals, pharmaceuticals, medicine technology, information and communication technology, and optics, and in traditional industries such as engineering, textiles, and construction, will largely depend on the realisation of nanotechnological innovations.

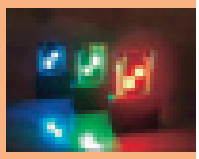
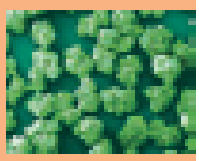
As an "enabling technology", nanotechnology is applied early on in the value-added chain, being used to realise smaller, quicker, more powerful, or more "intelligent" system components for products with significantly improved or even completely new functions. Nanoparticles that can attack tumours with the highest degree of precision, tiny data storage units that can store the content of an entire DVD on a surface no bigger than a one cent piece, self-cleaning surfaces, and mechanically enhanced sporting equipment – these are just a few examples of the possibilities offered by nanotechnology. It is estimated that the market potential of products based on nanotechnology will be in the region of one trillion euros by 2015. In Germany's quest to retain a strong economy and secure future jobs, nanotechnology – a key and cross-cutting technology – is of enormous importance.

On the scale of the dwarfs' world: A nanometre is as small in relation to a metre as the diameter of a one cent piece in relation to the diameter of the Earth.

However, the potential for innovations offered by nanotechnology stretches even further into the future. It is anticipated that the use of nanotechnological expertise will contribute significantly to solving pivotal global issues in the future, including how to meet energy demands, how to conserve natural resources, and how to provide comprehensive and preventative medical care.

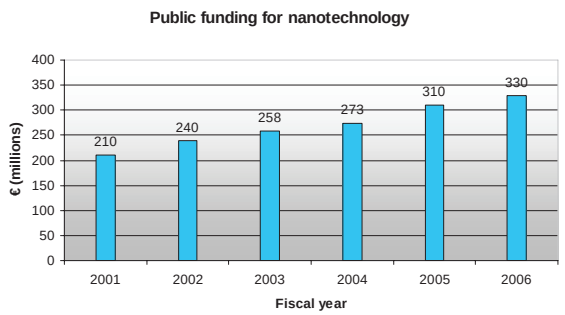
OLED illumination components

Application and product possibilities for nanotechnology

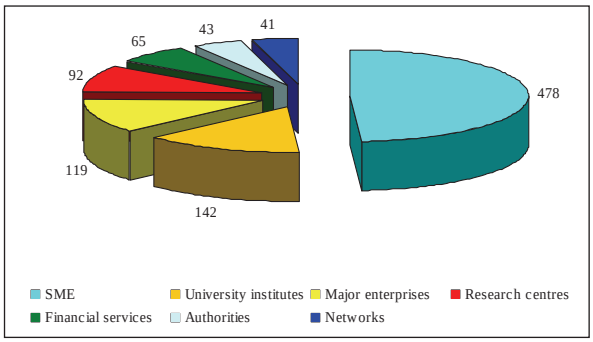
Medicine	• Less invasive, highly-selective cancer treatment • Long-life, slow-release treatments for diabetes and neurodermatitis • Specific-effect pharmaceuticals with fewer side effects • Preventative diagnosis systems for home use	
Optics	• Energy-saving lighting systems with adjustable colour selection • Tap-proof data exchange systems • Powerful components for consumer electronics	
Energy technology	• Economically priced solar cells and performance-enhancing photovoltaic components • Efficient accumulators with any required level of ductility • Super-insulation systems for windows and building components • Thermoelectrics for energy retrieval • Hydrogen storage units and fuel cells for new forms of propulsion	
Environ mental technology	• Corrosion-resistant components for everyday products • Energy-efficient treatment systems for drinking water • Stable, lightweight construction elements for buildings, machines, cars, and planes • The replacement of toxic substances with nanomaterials	
Consumer products	• Self-cleaning surfaces for kitchen equipment and home furnishings • Multifunctional textiles (dirt-repellent, scent-releasing, varied designs) • Foodstuff packaging with sensors to display the freshness of the product • Highly effective sun protection and other cosmetic articles	
Information and com munication technology	• Miniaturised data storage units with the capacity of the German National Library • Laptops as powerful as today's computer centres • Large, rollable flat display screens using organic LEDs	

II. Analysis of the strengths and weaknesses of nanotechnology

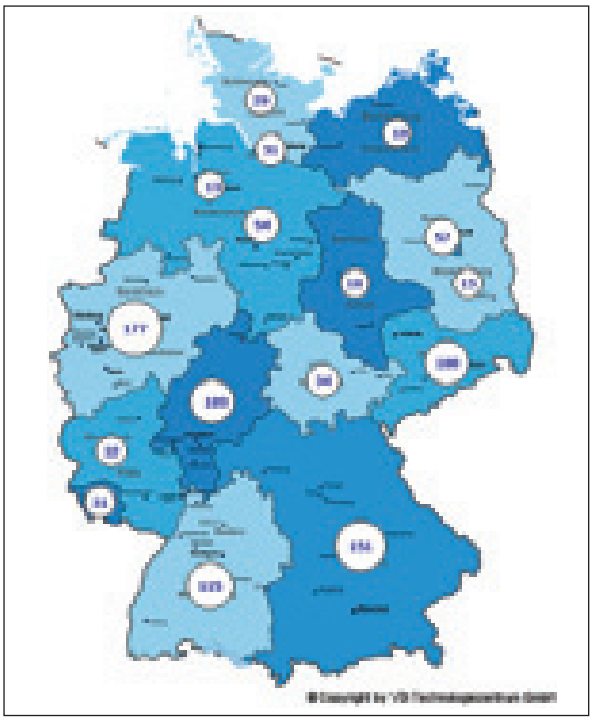
In comparison to other countries, Germany meets the prerequisites for exploiting the potential of nanotechnology very well. Germany's public R&D expenditure amounted to 310 million euros in 2005 – the third largest amount worldwide, behind only the USA and Japan. Germany is also amongst the top countries in patent applications for nanotechnology. In recent years, Germany also occupied third place for nanotechnology-related publications, although China recently pushed us into position four.



Germany's strengths include a well structured R&D infrastructure and a high level of research in the various subfields of nanotechnology. The industrial base for utilising the results of this research is also in place. Around 600 companies are currently involved in the development, application, and sales and marketing of nanotechnological products. 120 of these are large companies, and 480 are small or medium-sized enterprises. Around 60 financial service providers operate in investment matters related to nanotechnology. At the moment, approximately 50,000 industry jobs can be directly or indirectly attributed to this field. An increase in jobs can be anticipated in relation to start-ups and small and medium-sized enterprises in particular.



Distribution of German actors in nanotechnology (as of Sept. 2006)



Number of nanotechnology participants in the German states (www.nano-map.de)

The increasing industrial use of nanotechnology gives rise to a need for appropriately trained personnel. There is a growing demand for new training courses and study programs. Furthermore, the BMBF is enabling young scientist who are already qualified to set up their own research groups as part of the NanoFutur initiative. According to studies, another positive aspect is the open-mindedness of the German population as a whole towards nanotechnology.

But despite having good foundations for the use of nanotechnology, Germany must face up to increasingly demanding technological and economical challenges in the future: In comparison with the USA and South East Asia, Germany takes more time to turn the results of R&D into products. The distribution of nanotechnological approaches in various industry branches, the dynamics of start-ups, and the resulting diversity of products are too weak. This means that there are challenges to be faced with regard to the intensification of efforts to utilise the results of research as well as a need to realistically estimate benefits and risks, public relations and consumer advice requirements, and any necessary regulatory and standardisation procedures.

SWOT analysis for nanotechnology

Strengths	Opportunities
• **Strong basic research:** But pushed out of third place after the USA and Japan for worldwide publications by China	• **Diverse, more efficient materials:** New properties and functions for traditional materials
• **Elaborate research landscape:** Strong involvement by HGF, MPG, WGL, DFG, FhG, universities, departmental and industry researchers	• **New diversity of application:** Materials with tailored properties, particularly as a result of self-organisation processes
• **Positive prevailing mood:** German population is open-minded towards nanotechnological innovations	• **Competitive advantages:** Nanotechnological innovations are possible in all sectors
• **Interest from the new generation:** Increasing demand for new training courses and study programmes on nanotechnology	• **Good climate for innovation:** The community is involved in discussions on opportunities and risks
• **Good industrial base:** Around 600 companies (of which 480 are small or medium-sized enterprises) active in the nanotechnology field	• **Potential for investor interest:** High potential for nanotechnology
Weaknesses	**Challenges**
• **Utilisation shortfall:** Despite its leading position in Europe, the number of patent applications and participating companies in Germany significantly lags behind the USA and South Asia	• **Ensuring the quick conversion of the results of research into products** that can also be manufactured in Germany
• **Difficulties for start-ups:** Insufficient provision of risk capital, bureaucratic obstacles	• **Scientific risk assessment:** The possible toxic effects of nanoparticles have not been sufficiently investigated
• **Information deficits in commerce:** Potential investors currently lack a clear picture of the opportunities offered by nanotechnology	• **Safe, responsible handling of nanotechnology:** Consumer advice, consumer protection, occupational health and safety
	• **Risk communication:** The establishment of a dialogue process that includes all groups of society
	• **Standardisation and test strategy:** Germany must play a more active role

The Government aims at achieving the following with its "Nano-Initiative – Action Plan 2010":

- Speed up the implementation of the results of nanotechnological research in the form of diverse innovations
- Introduce nanotechnology to more sectors and companies
- Eliminate obstacles to innovation by means of early consultation in all policy areas
- Enable an intensive dialogue with the public about the opportunities offered by nanotechnology but also taking possible risks into account

III. Nano-Initiative – Action Plan 2010

The Government's Action Plan 2010 constitutes a list of measures for meeting the challenges that arise when attempting to successfully exploit the benefits of nanotechnology.

1. Opening up future markets – introducing new sectors

There is a real need to bring nanotechnology out of the lab and into companies. Many sectors have not yet recognised the opportunities offered by nanotechnology. This is particularly true of medium-sized enterprises. The combined activities of the participating federal departments intend to turn the economic potential of nanotechnology into growth and jobs.

The production of ceramic tape with a coating containing nanomaterials

Branch-level industrial dialogues

Branch-level industrial dialogues serve to explain and clarify the opportunities offered by nanotechnology and the usage possibilities that relate to the particular industrial sector. The BMBF and BMWi shall initiate the dialogue process with branches that have previously had little access to the results of nanotechnology research. In a second step, they shall aim to trigger cooperation in the development of innovative products and procedures. It is particularly important to introduce small and medium-sized enterprises to the opportunities offered by nanotechnology.
The first branch-level industrial dialogues are planned to take place in the plant engineering and construction, textile, and building industries. It is intended that unions and chambers of commerce and industry (IHK) shall take part in addition to companies. The dialogues will highlight sector research needs for nanotechnology, describe application scenarios, and designate participants for the construction of complete value-added chains. This can lead to the creation of branch-oriented promotion programmes.

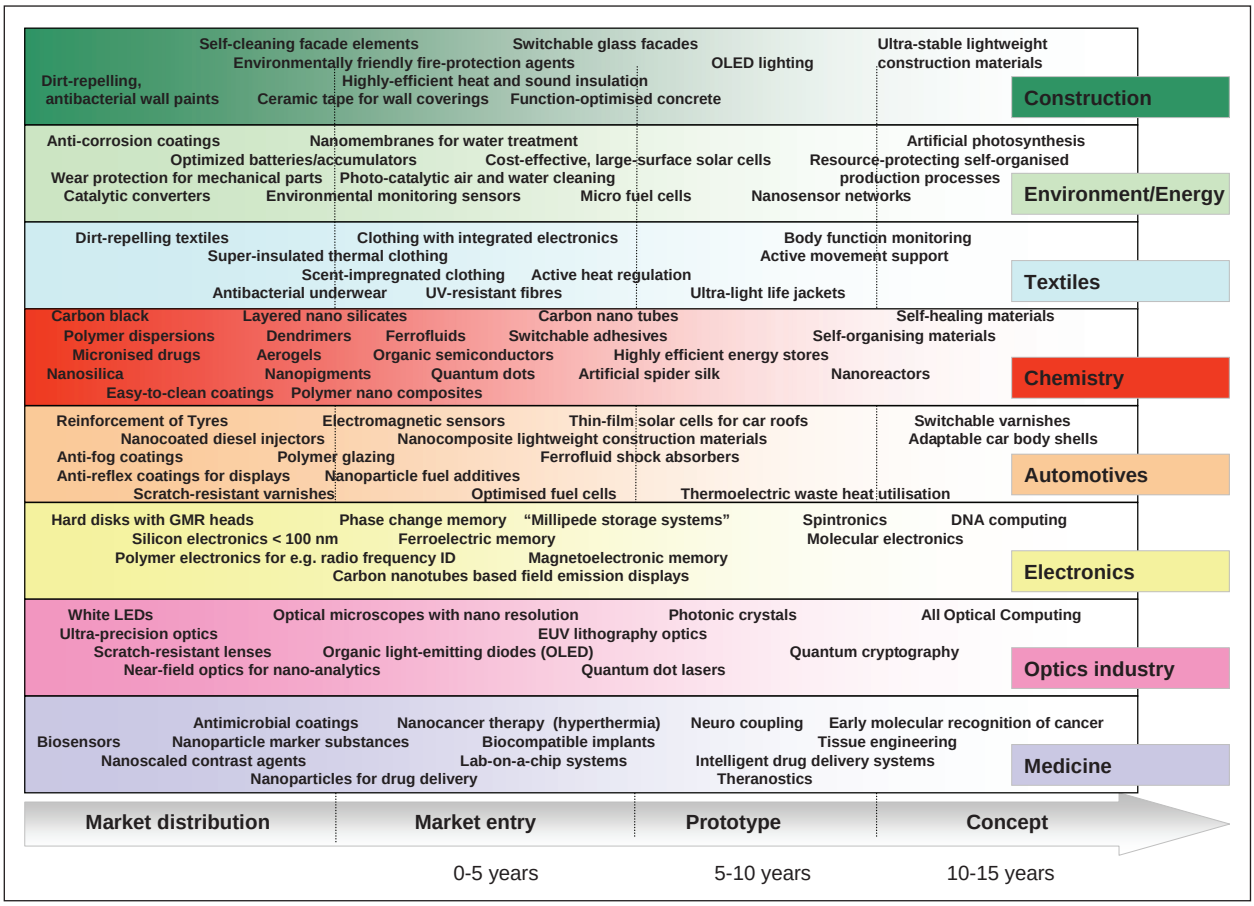
Example of a branch-level industrial dialogue: Plant engineering and construction

- **The "NanoWorlds" ("Nanowelten") impetus circle initiated the continuation of the dialogue with the German Engineering Association (VDMA) on nanotechnology products and processes.**
- **VDMA's Micro Technology industrial union took up the topic – the aim is to create a separate market platform for the technologies the group represents, ranging from light engineering and ultra precision technologies to microtechnology and nanotechnology.**
- **They developed a concept for an international fair/conference on "Microtechnology, Nanotechnology and Related Sciences". The event aims to act as an interface between technologies and the market and will take place for the first time in 2007.**

The Government will carry out additional branch-level industrial dialogues in the following areas:

- Automotives
- Construction
- Textiles
- IT
- Life sciences
- Optics
- Chemistry
- Energy
- Environment

The branch-level industrial dialogues address the competitive implementation of the results of research and development in the form of products relevant for specific sites. However, as a result of nanotechnology R&D that has already taken place, the various branches have extremely varied degrees of dependence upon the results already gained, and there is a corresponding disparity in their maturity. The scope of applications ranges from broad, preliminary design work to products that have already entered the market. The timelines for nanotechnological applications entering the market are accordingly diverse.



Examples of application opportunities and degree of maturity of nanotechnological developments in different sectors (VDI TZ GmbH)

Lead innovations

Lead innovations take the form of strategically created research cooperations that are expected to trigger the optimum leverage effect for growth and employment along the value-added chain. They attempt to secure and expand existing markets at the same time as opening up new areas for growth. Lead innovations are characterised by the cooperation of all sector participants necessary to realise a market development, from basic researchers to suppliers and customers.

Funded lead innovations:

- **Electronics:** Next generation production proce dures in nanoelectronics ("NanoFab" lead innova tion, launched 2001, 323 million euros in funding).
- **Automotive Engineering:** Ultra-light nanomate rials, nanosensors, and scratch-resistant varnish revolutionise automotives, improve driver safety, and save materials and energy ("NanoMobile" lead innovation, launched 2005, 37 million euros in funding).
- **Chemistry:** The chemicals industry joins with energy process technology and microprocess technology to develop nanocoatings and mate rials and to investigate safety-relevant issues ("NanoMikroChem" lead innovation, launched 2005, 31 million euros in funding).
- **Medicine:** Nanoparticles can help to enable the early diagnosis of cancer, destroy cancerous tissue in a gentle manner, and support an ageing popula tion by means of effective therapies ("NanoforLife lead innovation, launched 2005, 24 million euros in funding).
- **Light Engineering:** A NanoLux and OLED initiative: NanoLux aims at using energy-efficient light-emit-ting diodes from compound semiconductors in car and general lighting. The "OLED lead initia tive" aims at creating the technological basis for the production of organic light-emitting diodes (OLEDs) in Germany. OLEDs are good value for money, energy-efficient, and allow flat lighting ("lighting wallpaper").
("NanoLux" lead innovation, launched 2004, 10.6 million euros in funding. OLED initiative, launched 2005, 56 million euros in funding so far, planned funding of 100 million euros).
- **Energy:** Development of position-independent micro fuel cell systems and the follow-on produc tion thereof (launch 2005, 20 million euros in funding).

The Government will promote new lead innovations:

- **Production technology –** Nanotechnology enters into production

  Research for production gives rise to innovative produc-tion and service systems that contribute to the strong competitiveness of many producers in Germany. The BMBF launched "Nanotechnology enters into produc-tion" in April 2006. This research initiative is targeted at promoting the quick conversion of basic research results pertaining to nanotechnology from lab data into indus-trial practice. Above all, it aims to make procedures and equipment available which are appropriate for industry and which can be used to produce high-performing products safely and economically. The BMBF has allo-cated 15 million euros for projects related to this topic. Research projects are expected to start during 2007.

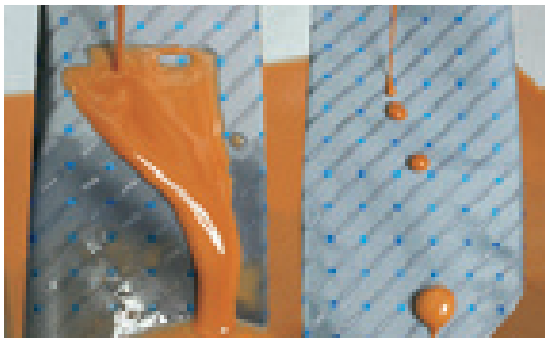
MRAM coating plant

- **Production technology –** Volume Optics

  The "Volume Optics" funding activity is the BMBF's way of promoting nanotechnology in the production of optics. The programme aims at encouraging the production of large numbers of optical components for medicine, automotives, and multi-media applications. This should consolidate the strong position that the German optics industry already enjoys in the field of special machinery so that the country also excels at mass production. Mass production is an economic option for Germany, too.

- **Textile industry –** NanoTex

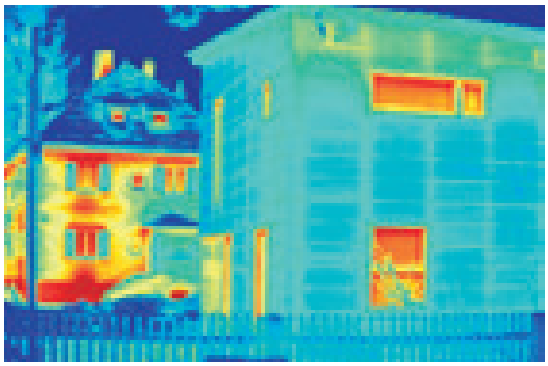
  New, high-tech textiles have an attractive market potential for use in textile lifestyle products and technical textiles in automotive, environmental, and medicine technology applications. Nanotechnology enables the production of extremely efficient insulating garment and self-cleaning textile surfaces that are capable of repelling even stubborn substances such as ketchup, honey, coffee, and red wine. "Smart clothes" can be produced by combining textile structures with miniaturised electronic components. These clothes can register and react to environmental influences or allow their wearers to access electronic communication and entertainment devices whenever they want.



Nanotechnology enables the production of dirt-repelling textiles

- **Building industry –** NanoTecture

  In the building industry, the use of nanotechnology is triggering innovations for energy-efficient building and facade design. Nanocoated glazing and novel insulating materials can achieve considerable savings in energy. One important potential benefit is the possibility of replacing environmentally harmful substances used, for example, in fire control applications. Another possibility is improving conventional building materials such as concrete, thereby enabling the use of completely innovative construction methods.



The potential benefits of nano-based insulation materials

- **Medicine/Health –** NanoforLife

  The continuing promotion of nanotechnological innovations in health care aims at realising the potential benefits of individual, preventative medical care. Nanotechnology will enable the wide-ranging and targeted use of medication, eliminate side effects, improve the quality of implants, and develop a means of making more efficient, earlier diagnoses. The biophotonics field exploits the optical properties of nanotechnology-based molecules in order to watch living cells at work. Light can be used to enable people to watch cells without touching or damaging them. Individual molecules can be tracked in living cells, thereby allowing the effects of medication and the development of diseases to be monitored. This "molecular imagery" will provide considerable support for preventing and fighting illnesses. The BMBF is already funding biophotonics to the amount of 33.5 million euros. It intends to allocate a further 25 million euros in an additional funding phase from 2007.

The use of nanotechnology in medical technology

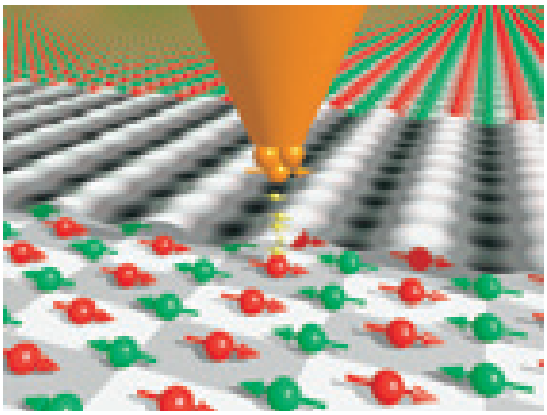
- **Medicine/Health –** Biomicrosystem technology

  When using nanotechnological applications for health, one of the greatest challenges is the bonding of nanomaterials into biological components and processes. This enables nanotechnology and microsystem technology to combine biology with technology. In this way, visionary medical applications such as neurointerfaces can be realised simply by using nanotechnology and highly developed integration techniques. Sub-areas of this field of activity are currently being addressed in the projects of the BioMST call in order to enable long-term, reliable, cost-effective, and easy-to-use systems.

Micro/nano integration in medicine

- **Measurement technology**

  Measurement and sensor technology is another area that will benefit considerably from nanotechnology. Nano-analytical measurement processes are extremely important to industrial quality control and form the basis for comprehending technological procedures at atom level. Miniaturised, highly-selective sensors offer new opportunities in process monitoring and control in numerous industrial fields of application.



Spin-polarised scanning tunnelling microscopy

- **Plant engineering and construction**

  In the field of plant engineering and construction, nanotechnology offers potential innovation benefits as a result of improved lightweight construction materials, novel joining technology based on switchable adhesives, and better lubricants. Nanotechnological surface coatings can improve the properties of machines and tools including wear resistance, corrosion prevention, and temperature resistance.

- **Micro/nano integration**

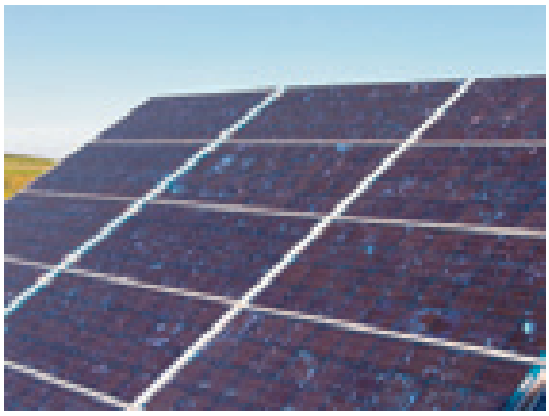
  Many nanotechnological developments cannot be used – or can only be used with limitations – without interfaces to micro and macro systems. The nanotechnological developments used in the smallest structures can often only be realised by means of microsystem interfaces that allow them to be used in a wide range of products. However, nanotechnology also offers opportunities for optimising integrated microsystems. For example, nanomaterials can be used for the highly efficient production and storage of energy for self-sufficient micro systems or completely innovative, highly sensitive sensor systems based on nanostructures.

- **Environment**

  The potential benefits of nanotechnology for protecting the environment and saving resources need to be realised on a large scale. Novel filter systems for wastewater treatment and drinking water extraction, the replacement of toxic substances with nanomaterials, and saving on raw materials by using miniaturised technical components are all good places to start.

- **Energy**

  In the energy field, the potential benefits of nanotechnology lie in the efficient, sustainable production of energy and in highly efficient energy stores for mobile electronic devices. Application possibilities include performance-optimised solar and fuel cells, hydrogen storage units, and accumulators or thermoelectrics for powering laptops, mobiles, and MP3 players.



Promoting networking

Successful technology transfer and the associated high level of innovation require that all participants in the value-added chain work together. For this reason, the Government is focussing more and more on interdisciplinary, multi-institutional networking by participants from the fields of commerce and science. This type of networking is particularly important for multifunctional technologies such as nanotechnology.

National cooperations

Since 1998, the BMBF has been promoting regional and nationwide networks of competence for nanotechnology. Since then, the participating centres of competence have established active, cross-topic networks throughout Germany. Nine networks for various sub-fields of nanotechnology have been awarded the "Kompetenznetz Deutschland" (German Network of Competence) seal of quality. They unite key commerce and science experts working in the fields of innovation that are relevant for each particular sub-field. In addition, numerous other active networks have been founded independently of these networks of competence in recent years – most of them on a regional level. The organised exchange of information is a particularly important way for small businesses to gain access to current developments. This also applies to measures for ensuring the responsible use of nanotechnology, an issue handled by the "Responsible Production and Use of Nanomaterials" working group of DECHEMA/VCI.

CCN exhibition stand

The Government intends to push for further networking at national level:

Networks should comprise of actors from basic research, application-oriented research and development, industrial marketing, financing, and technology transfer fields. The aims of networking are to:

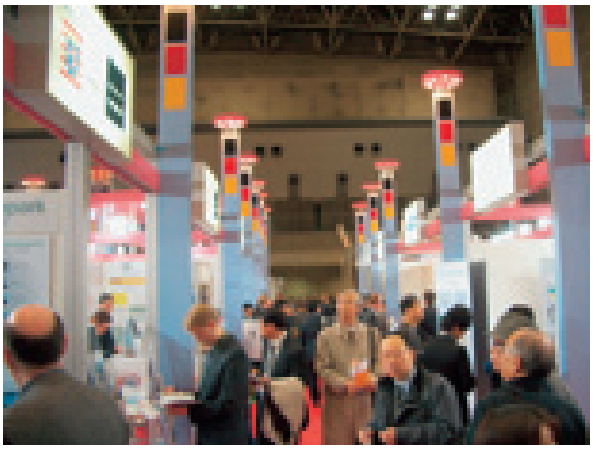
- Accelerate the conversion of the results of R&D into marketable products
- Enable the early recognition of obstacles to innovation, socioeconomic implications, and potential health risks
- Develop strategic visions for future developments in the field of application of each network
- Avoid the fragmentation or duplication of R&D activities
- Mobilise private and public investment
- Support spin-offs and start-ups

The following are important elements in the realisation of value-chain-oriented networking:

- Virtual networking using an Internet platform
- The identification of R&D priorities by means of technical road mapping
- Regular talks on strategy and the drafting of policy papers on R&D requirements, general conditions, etc.
- Coordination of activities to facilitate the development of nanotechnological products at state, national, and EU level
- Integration of interdisciplinary topics such as standardisation (DIN), measuring technology (PTB, BAM), risk assessment, and the potential for innovation in view of occupational health and safety, consumer protection, and environmental protection concerns (BAuA, UBA, BfR)

International relations

The increasing use of nanotechnology will have wide-ranging social and economic consequences throughout the world. Intensive international cooperation is absolutely essential in order to ensure that potential benefits and risks pertaining to nanotechnology and issues related to standardisation are identified and assessed in a timely manner.



The German Pavilion in Tokyo

The Government will intensify international cooperation on nanotechnology for the following topics:

- **Potential benefits and risks of nanotechnology**
  - German participation in the "OECD's Steering Group for Manufactured Nanomaterials", which assesses risks and manages the use of nanomaterials as well as estimating the commercial potential of nanotechnology on a global scale.
  - Contributing to the implementation of the European Commission's action plan for nanotechnology, in particular with regard to the establishment of economy-friendly, integrated, and responsible handling of nanotechnology in R&D.
  - Commitment to the "international dialogue on responsible research and development of nanotechnology" by international cooperations in relation to ecological aspects, benefits, risks to health and safety, socioeconomic and ethical aspects, and the use of nanotechnology in developing countries.
  - Cooperation with the International Risk Governance Council (IRGC), which is running an initiative on understanding and managing the potential risks of nanotechnology with respect to health, safety, the environment, the economy, and society.
  - Working with European and international bodies on regulatory issues for occupational health and safety, health, consumer, and environmental protection.

- **Standardisation in order to simplify product development and marketing**
  - Increased German participation in the recently initiated standardisation activities of the ISO in order to improve the competitivity of German companies in the long term.

- **Increased participation in the 7th Framework Programme for Research and Technological Development – consolidation of Germany's position as a European leader**
  - Intensification of work by the national focal point for nanotechnology in order to encourage the strong involvement of Germany in EU research promotion.
  - Consideration of the interests of other federal departments.

Supporting small and medium-sized enterprises

One of the main objectives of the Government is to facilitate the access of small and medium-sized enterprises to the results of R&D and to encourage an increase in the participation of small and medium-sized enterprises in national and European research programmes. This should involve introducing small and medium-sized enterprises to nanotechnology in a more intensified manner as well as supporting the establishment of a nanotechnology start-up scene in Germany. Funding measures for small and medium-sized enterprises in this field should be made transparent by means of centralised contact points and optimised consultation and made more attractive by means of the simplification of procedures and a reduction in bureaucracy for small and medium-sized enterprises when they file applications. Funding programmes that specifically target small and medium-sized enterprises and support for start-ups should encourage nanotechnological innovations in industry.

Anti-fog coating

The Government will focus on supporting small and medium-sized enterprises

- **Funding measures aimed specifically at small and medium-sized enterprises**

  – **NanoChance**

  The development of the "NanoChance" activity intends to support small and medium-sized enterprises that strive for extending their business area and their use of nanotechnology in order to strengthen their market position. In addition to fostering nanotechnology start-ups, support will be given to stabilise and encourage the growth of innovative small and medium-sized enterprises in order to make room for nanotechnological developments and realise the potential for networking activities and new applications. Initial funding of 20 million euros has been allocated to NanoChance.

  – **PRO INNO II**

  The "Programme for Promoting an Increase in the Innovation Skills of Medium-Sized Enterprises (PRO INNO II)" supports small and medium-sized enterprises that collaborate with other companies and research institutes in R&D activities. Nanotechnology is an important field of technology for this program, and has been allocated around 15 million euros.

  – **INNO-WATT**

  The "Innovative Growth Leaders programme (INNO-WATT)" supports industrial research activities by growth leaders (small and medium-sized enterprises and external industry research institutes) in the newly formed German states and in Berlin. The main objective is to successfully convert the results of R&D into market products. Since 2004, funding to the amount of 1.8 million euros has been granted for nanotechnology research projects. This triggered an R&D volume of around 3.5 million euros in the new German states and Berlin.

  – **IGF/ZUTECH programme**

  Since 1995, projects relating to nanotechnology have been promoted within the framework of the IGF programme and its sub-programme on future technologies (ZUTECH). The number of projects that can be clearly identified from their titles as having a relation to nanotechnology has grown continuously to a current level of around 3% (3 million euros) of the total annual funding (100 million euros in 2005).

- **Advice from the BAuA**

  The BAuA offers advice on issues relating to health protection and the measurement of nanoparticles in the air (www.baua.de/nanotechnologie). This information and advice is particularly useful for small and medium-sized enterprises, since they often lack the required technical infrastructure and personnel. The BAuA also highlights nanoparticle exposure in start-up companies, contributing to a description of the risks for small and medium-sized enterprises.

- **Support for new technology companies**

  – **EXIST-SEED**

  The "Business Start-Up from Science (EXIST)" programme promotes ambitious projects that aim at a permanent improvement of the culture of entrepreneurship at universities and research institutes throughout Germany. Technologically innovative start-up projects with the potential to succeed economically are supported by the EXIST programme from the early phase of the start-up to the maturation of the business idea in the form of a business plan. Around 10% of the some 400 funded projects since the year 2000 have related to nanotechnology.

– **High-Tech Gründerfonds (including ERP start-up funds/ERP/EIF umbrella funds)**

High-Tech Gründerfonds gives newly founded technology companies private equity of up to 500,000 euros in first round financing. The fund, which was established by the BMWi, partners from commerce, and the KfW Bank Group, amounts to a total of 262 million euros and hopes to give new impetus to company start-ups in Germany. From August 2005 to June 2006, 48 requests for funding were granted to newly founded technology companies, including high-tech nanotechnology start-ups in fields such as medicine technology and chemistry. High-Tech Gründerfonds has been supplemented by ERP start-up funds (volume of 250 million euros) and ERP/EIF umbrella funds (volume of 500 million euros). These funds contribute significantly to the mobilisation of private venture capital investment.

– **Power to female founders**

In 2005, the BMBF declaration "Power for female founders" ("Power für Gründerinnen") was published. It targets at improving the motivation of women to found companies and at increasing their capability to do so. One focal point of the scheme is the development of concepts for promoting the founding of companies by women in technology, and another is to support spin-offs by women from universities and research institutes. The BMBF plans to develop targeted, gender-specific "Nano Entrepreneurship Academies" to provide advice and qualifications so that female scientists (including the next generation) studying nanotechnology and related subjects can enjoy a concrete introduction to the theory and practice of starting up businesses.

2. Improving general conditions

Nanotechnology should be utilised in a manner that benefits the economy. This requires that a number of prerequisites be met, i.e. qualified employees, a positive attitude towards technology, an active commercial base, and established standards and testing strategies.

The Government will fulfil these conditions:

- **The coordination of federal departments and their policies**

The requirements of environmental, health and transport policy and of occupational health and safety and consumer protection policy need to be taken into account in the early stages of technological development in order to facilitate and accelerate nanotechnological innovations, to improve their quality, and to transparently describe and assess potential risks. The Government will combine multifaceted activities from different departments. For example, the BMU's steering group for assessing the potential benefits and risks of nanomaterials will also benefit from the participation of other departments and interested parties. This steering group aims at creating a consensus on the handling of open issues and risks relating to nanomaterials and at formulating a common position on nanotechnological innovations and benefits in relation to the protection of the environment and of resources.

The funding advice sections of the various departments should be harmonised and in tune with each other. In the future, a common funding policy will provide an overview of funding opportunities offered by different departments, thereby increasing transparency for applicants.

- **Nanotechnology future forum**

  The Government is planning to establish "Zukunftsforum Nanotechnologie" – a future forum on nanotechnology – to focus on further economic development and to discuss the relationship between commerce, science, technology, and the public as regards nanotechnology. The forum should provide an opportunity for potential benefits and risks to be considered and discussed as part of an interdisciplinary dialogue between natural scientists, humanists, politicians, managers, and journalists. The nanotechnology future forum should also aim at formulating recommendations for future promotion strategies.

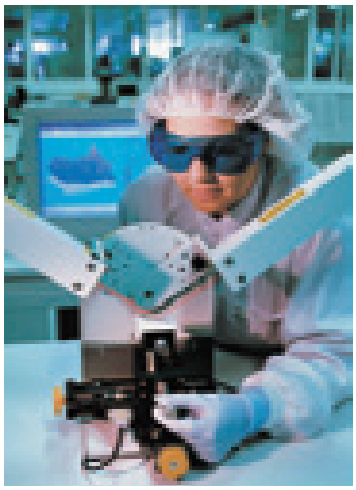
- **Support for qualified young scientists – Extending the NanoFutur scheme**

  As an innovative, interdisciplinary technology field, nanotechnology brings new challenges to education, further education, the development of skills, and the promotion of young scientists. The Government's innovation policies for nanotechnology focus, among other things, on competitions intending to encourage the new generation of scientists. Specific youth-oriented approaches, an increasing focus on new, promising opportunities in the jobs market, and the adaptation of learning opportunities in line with company requirements and the specific demands of nanotechnology remain the main focal points of the scheme.

The successful NanoFutur competition, which was launched internationally in 2003 as part of the "Materials Innovations for Industry and Society" programme, constitutes an important part of the drive to promote the new generation of scientists, and there are plans to extend the scheme. Young scientists in nanotechnological fields are given the change to carry out work relating to nanotechnology in research groups with a large amount of autonomy over a period of five years. Young natural scientists and engineers on industrial or academic career paths may take part. Since 2003, 17 groups of young scientist have been established during the first BMBF funding round. The BMBF has allocated around 20 million euros for further competitions starting from 2006.

- **Quality assurance, standardisation, and normalisation**

  Norms and standards are not only a key for accessing markets – they are also an important tool for accelerating the transfer of technology between science and industry. In order to strengthen the role of normalisation for research and innovation in nanotechnology, the Government is sponsoring the "Innovation with Norms and Standards" project of the German Institute for Standardization (DIN). In this way, the Government is lending support to the opportunity for Germany to exert a strong influence over international normalisation and standardisation processes. The project involves the DIN's national shadow committee and the German Commission for Electrical, Electronic & Information Technologies (DKE). These two bodies agree on national positions and delegate experts to European and international norms committees. As part of the European research project NANO STRAND (Standardisation related to Research and Development for Nanotechnologies), the DIN is playing a major role in the formulation of a road map for future normalisation and standardisation activities relating to nanotechnology in Europe and for the corresponding research.



Ellipsometer use in industry

In addition to this, there will be a multi-departmental push to pay more consideration to standardisation issues in nanotechnology research programmes and the evaluation of results. National norms committees

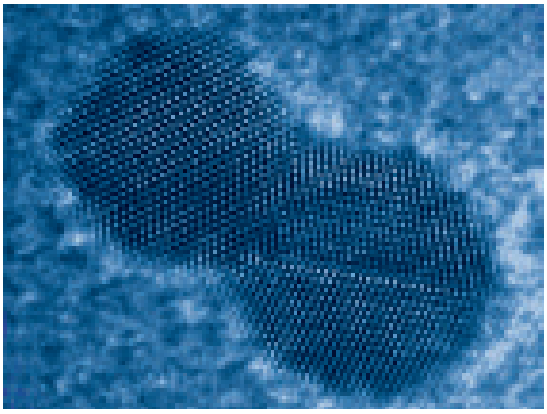
should be used to ensure that they are included in processes early on. Federal institutes such as the Federal Institute for Material Research and Testing (BAM) and the Physikalisch Technische Bundesanstalt (PTB) make an important contribution here thanks to their active work in normalisation. Another important aspect is the development of standardised measuring methods for determining the potential risks of nanotechnology in relation to health and the environment. The Federal Institute for Occupational Safety and Health (BAuA) and the Federal Institute for Risk Assessment (BfR) are involved in both national and international panels on this issue.

3. Behaving in a responsible manner

The Government will evaluate the effects of nanomaterials as part of a comprehensive strategy:

- **Investigating the effects on health and the environment**

  It is imperative that we extend our knowledge on the consequences of releasing nanoparticles for the environment and health so that we can better evaluate the potential for harm. For this reason, the BMBF has initiated the NanoCare project group (NanoCare, INOS, and TRACER projects). These projects involve participants from commerce and industry working together to investigate the potential risks of handling new nanoscaled or nanostructured materials at an early stage of the development process and to communicate the results to interested commercial groups and to the public (funding up to 2009 amounts to around 8 million euros).



Atomic structure of nanoparticles

The Government has initiated a nanotechnology dialogue on the benefits and risks of nanomaterials, to be led by the BMU. The dialogue will run between 2006 and 2008. Two ministry-led working groups – coordinated by a steering group – will consider issues relating to the "safety and responsibilities of research" and the "promotion of innovation and opportunities for environmental protection". In addition to these groups, the VCI and Econsense are willing to organise and run a further working group on a "Code of Good Practice and Innovation Spaces". All working groups are open to representatives from industry, science, authorities, and other groups (environmental, health-related, labour unions, churches, etc.)

The BMAS is committed to investigating issues relating to safety and health when working with nanoparticles and has carried out a company survey on the manufacturing and use of synthetic nanoparticles in workplaces in collaboration with the VCI. The aim is the identification of nanoparticles that are highly prevalent and to give those particles priority when evaluating risks. Another goal is to formulate a sound code of practice for working with synthetic nanoparticles in order to limit risks.

Measuring unit for determining exposure to nanoparticles in the workplace

The BMELV has contacted affected business communities in order to clarify in which products and in what manner nanotechnology is already being used in foodstuffs, cosmetics, and commodities and to determine whether or not nanoscaled products are being used in products with which consumers have direct contact. Since March 2006, the BfR has been conducting a Delphi survey on the potential risks of nanotechnological applications in foodstuffs, cosmetics, and commodities. The information gained as a result of these initiatives should help to identify the potential risks of nanotechnology in consumer-relevant fields at an early stage and to develop strategies for avoiding or minimising these risks.

The Federal Ministry of Health is extensively evaluating the potential risks and benefits of nanotechnological applications in pharmaceuticals and medicine products, clinical tests, and licensing. The cost-value ratio is extremely important in this field. Issues pertaining to patient and data protection are considered in the light of potential improvements in diagnostics.

- **Establishing an interdepartmental research strategy**

  On the initiative and under the coordination of the federal bodies BAuA, UBA, and BfR, the Government is developing a common research strategy that focuses in particular on the health and environmental risks of insoluble nanoparticles. The BMBF will take part in discussions on research issues. This research strategy, which is to be discussed and debated by participants from science, commerce, and NGOs as part of the Nano Dialogue in November 2006, focuses on the following:

  – Structuring the research demand

  – Developing standardised measuring procedures for nanoparticles

  – Gathering information on exposure and on toxicological and ecotoxicological effects

  – Formulating a risk-related test and evaluation strategy

  – Using substance property data for regulatory issues (threshold values, classifications, working recommendations)

  – Communicating potential risks

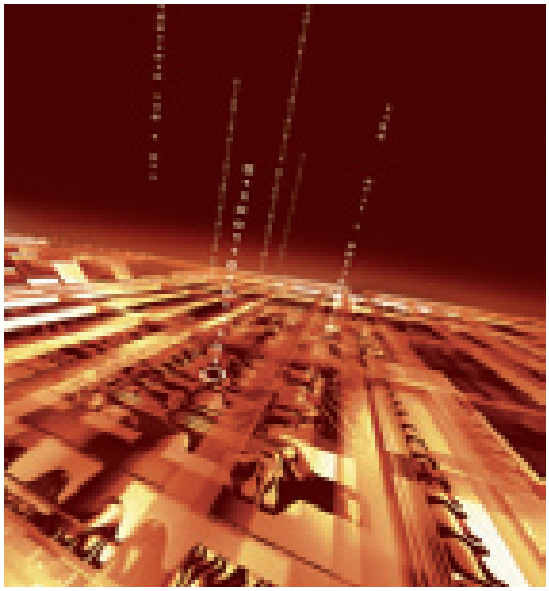
  The aim of the scheme is an active prevention of damage to health and the environment.

4. Informing the public

The Government wants to discuss both potential benefits and risks with the public:

- **Information initiative and social dialogue**

  Government-supported conferences, newsletters, Internet portals, analyses, and press articles already contribute continuously towards the distribution of the results of new research. They inform people about current knowledge, attempt to outline future developments, and highlight the current debate on potential risks. Information leaflets and pamphlets act as a point of entry into nanotechnology for interested parties, provide the new generation of natural scientists with support in choosing their course of study, and inform the public about the complex interactions of the world of nanotechnology in a way that is easy to understand. This should not only lead to a stronger general interest in this future field of technology but also, and more importantly, to the creation of a knowledge base for further social debate on the topic.



A journey to the nanocosmos

- **nanoTruck – a mobile information campaign**

  nanoTruck – marketed as “a journey to the nanocosmos – a world of minute proportions” – is an important component of the information initiative. It moves around Germany to spread the word to multiple locations. Each year, around 100,000 visitors enjoy the exhibition.

It mostly visits schools but also concentrates on locations that are open to the general public and numerous special events. It will continue its journey around the country during the next few years as a continuing part of the nanotechnology information initiative.

BMBF nanoTruck

- **Information leaflets and flyers on nanotechnology**

  The BMBF leaflet "Nanotechnologie – Innovationen für die Welt von morgen" ("Nanotechnology – Innovations for Tomorrow's World") is a standard work that has been translated by the EU into all official languages and into Chinese, Russian, and Arabic. It contains scientific information and application possibilities that are clarified by the use of striking examples. A new edition of the leaflet is due to be published in order to integrate the diverse activities of federal departments, further current new developments, and refresh the public debate on the benefits and risks of nanotechnology.

  The range of nanotechnology-related activities being pursued at state and national level and in research organisations is extremely diverse. A flyer is being produced to give an overview of publicly funded measures. It will provide information on contact partners and addresses, research opportunities, and Internet addresses.

- **Development and design of a nano portal**

  Both institution-based nanotechnology activities and those of the federal states and Government are usually presented on entity-specific Internet sites. It is now planned to publish all departmental and interdepartmental initiatives on the "Government's own nano portal".

- **Events for debating the potential benefits and risks of nanotechnology**

  The public needs to be actively involved in the dialogue process on the potential benefits and risks of nanotechnology in order to fill in the gaps in general knowledge about the field. New information on the benefits and risks of nanotechnology, such as the information collected as part of the BMU's "Nano Dialogue 2006 – 2008" and the BMBF's NanoCare project group should be distributed actively by means of public events. This gives members of the public the opportunity to inform themselves about the benefits and risks of nanotechnology and to discuss any reservations with experts. Publicly accessible databases are needed to provide a transparent information base (www.nanopartikel.info, www.nanotox.de, www.dialog-nanopartikel.de).

Dialogue processes to include the public in discussions on nanotechnology

In November 2006, the BMELV commissioned the Federal Institute for Risk Assessment to organise a public consumers' conference on the perception of nanotechnology in foodstuffs, cosmetics, and commodities. The aim is the development of an accurate idea of the opinions of consumers on nanotechnological applications in the aforementioned areas and to allow consumers to directly participate in public and political discussions on this socially-relevant topic.

5. Identifying the future demand for research

Extremely high-quality research is an essential prerequisite for successful commercial development – especially in high-tech fields. The results and findings of today's research form the basis of tomorrow's commercial product portfolio. The challenge lies in recognising the potential of basic research projects whilst making sure that research into relevant application-oriented issues also takes place.

The Government will talk with scientists and business persons in order to specify future research fields:

- **The future demand for research**

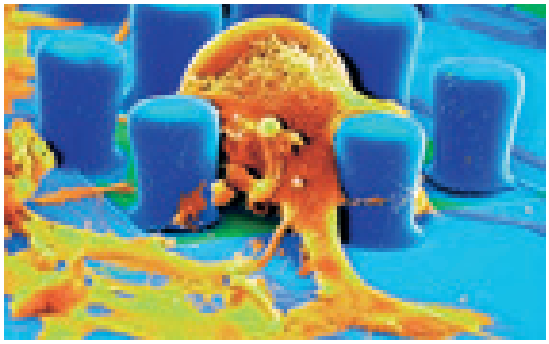
  The timely identification and evaluation of the future need for research is a constant challenge that needs to be addressed in collaboration with experts from the fields of science and commerce. Nanotechnology-related topics to be investigated include:

  - New technology approaches for data processing, storage, and transfer for communication and information technology
  - New therapeutic procedures, in vivo and in vitro diagnostics, and particularly imagery, implants and biomaterials in medicine technology
  - Revolutionary production techniques on the basis of self-organising processes
  - Preservation of resources and more efficient environmental protection and energy supplies
  - Basic research on the effects of nanomaterials on humans and the environment in adherence to the regulatory issues for occupational health and safety and consumer and environmental protection
  - Characterisation methods and verification procedures for estimating the potential risks of using nanomaterials
  - Improved technology for the comprehensive defence of homeland security

- **Converging technologies**

  The nanotechnology, biotechnology, information technology, and cognitive science research fields and technologies will converge increasingly in the future. Expectations of the results that might be achieved by means of implementing converging technologies range from healing paraplegics to developing new therapies and artificial organs and significantly extending life expectancy whilst retaining an equal or better quality of life. In the long term, more and more functions of the human body might be taken on by products and procedures resulting from converging technologies. One day, we might even be in a position to improve the mental and sensory capabilities of mankind. Fundamental ethical issues arise in conjunction with these kinds of development, since they have a bearing on human self-perception.

  The European Commission has therefore called for an initiative called "Knowledge for Mankind" with the aim of triggering an integrated approach to understanding the phenomena of converging technologies and their social, cultural, and political implications. Its goal is to promote desirable developments whilst preventing undesirable consequences. This requires a wide-ranging, public discussion on ethical concepts and the possibilities for regulating converging technologies by means of dedicated innovation and research policy. The Government wishes to actively contribute to the shaping of this process with the help of all groups of society.



Coupling cells to PCB tracks

Glossary

BAM	Federal Institute for Material Research and Testing (Bundesanstalt für Materialforschung und -prüfung)
BAuA	Federal Institute for Occupational Safety and Health (Bundesanstalt für Arbeitsschutz und Arbeitsmedizin)
BfR	Federal Institute for Risk Assessment (Bundesinstitut für Risikobewertung)
BMAS	Federal Ministry of Labour and Social Affairs (Bundesministerium für Arbeit und Soziales)
BMBF	Federal Ministry of Education and Research (Bundesministerium für Bildung und Forschung)
BMELV	Federal Ministry of Food, Agriculture and Consumer Protection (Bundesministerium für Ernährung, Landwirtschaft und Verbraucherschutz)
BMG	Federal Ministry of Health (Bundesministerium für Gesundheit)
BMU	Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit)
BMVg	Federal Ministry of Defence (Bundesministerium der Verteidigung)
BMWi	Federal Ministry of Economics and Technology (Bundesministerium für Wirtschaft und Technologie)
DFG	German Research Foundation (Deutsche Forschungsgemeinschaft)
DIN	German Institute for Standardization (Deutsches Institut für Normung)
DKE	German Commission for Electrical, Electronic & Information Technologies (Deutsche Kommission Elektrotechnik Elektronik Informationstechnik)
EIF	European Investment Fund
ERP	European Recovery Programme
FhG	Fraunhofer Gesellschaft
HGF	Helmholtz Association of German Research Centres (Helmholtz-Gemeinschaft Deutscher Forschungszentren)
IHK	Chamber of Commerce and Industry (Industrie- und Handelskammer)
ISO	International Organization for Standardization
MPG	Max Planck Society (Max-Planck-Gesellschaft)
NGO	Non-Governmental Organisation
OECD	Organisation for Economic Co-operation and Development
OLED	Organic light-emitting diode
PTB	Physikalisch Technische Bundesanstalt
UBA	Federal Environment Agency (Umweltbundesamt)
VCI	German Chemical Industry Association (Verband der Chemischen Industrie)
VDI	Association of German Engineers (Verein Deutscher Ingenieure)
VDMA	German Engineering Federation (Verband Deutscher Maschinen- und Anlagenbau)
WGL	Leibniz Association (Wissenschaftsgemeinschaft Gottfried Wilhelm Leibniz)


SCHOTT
FIOLAX

Further information

On the Internet

Nanotechnology-related activities of federal departments:

- www.bmbf.de/en/nanotechnologie
- www.baua.de
- www.bfr.bund.de/nanotechnologie
- www.bmu.de

Other Internet portals

- *High-Tech Strategy for Germany*
  www.ideen-zuenden.de
- *Nanotechnology portal of VDI TZ GmbH*
  www.nanonet.de
- *Mapping of German nanotechnology actors*
  www.nano-map.de
- *Science communications on nanotechnology*
  www.nanotruck.de, www.nanoreisen.de
- *Risk research and communication*
  www.nanopartikel.info, www.nanotox.de, www.dialog-nanopartikel.de
- *High-Tech Gründerfonds*
  www.high-tech-gruenderfonds.de
- *Networks of competence in Germany*
  www.kompetenznetze.de
- *European nanotechnology gateway*
  www.nanoforum.org
- *Nanotechnology homepage of the European Commission*
  www.cordis.lu/nanotechnology

Leaflets (in German)

- Hochschulangebote im Bereich Nanotechnologie (Higher Education Courses in Nanotechnology), VDI TZ GmbH 2006
- Kommerzialisierung der Nanotechnologie (The Commercialisation of Nanotechnology), VDI TZ GmbH 2006
- Duale Ausbildung in innovativen Technologiefeldern (Multi-Subject Qualifications in Innovative Technology Fields), BMBF 2005
- Nanotechnologie – Innovationen für die Welt von morgen (Nanotechnology – Innovations for Tomorrow's World), BMBF 2006
- Nanotechnologie erobert Märkte (Nanotechnology Conquers Markets), BMBF 2004
- Vom Sand zum Superchip (From Sand to the Superchip), BMBF 2004
- Nanotechnologie als wirtschaftlicher Wachstumsmarkt (Growth Market Nanotechnology), VDI TZ GmbH 2004

Fluorescent quantum dots

Notes

Federal Ministry
of Education
and Research