

**Innovationsallianz CNT –
Carbon nanomaterials conquer
markets**



Inno.CNT
INNOVATIONSALLIANZ
CARBON NANOTUBES

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“The declared aim of the German government is to put our country at the forefront of one of the world’s key future markets.”



With its “High-tech Strategy for Germany”, the German government has signaled its intention to promote the country’s innovative capabilities on a lasting basis. Across all the areas of politics, a national strategy has been submitted that sets out to put our country at the forefront of the world’s key future markets. The high-tech strategy is focused on pooling the forces of science and industry and, with the aid of public funds, on mobilizing several times the amount of private investment in research and development. Science and industry must work closely together to turn the results of the research into marketable products, processes and services. Of particular

importance here are innovations in the fields of environmental protection and energy technology, which can help to solve the pressing problems of the future.

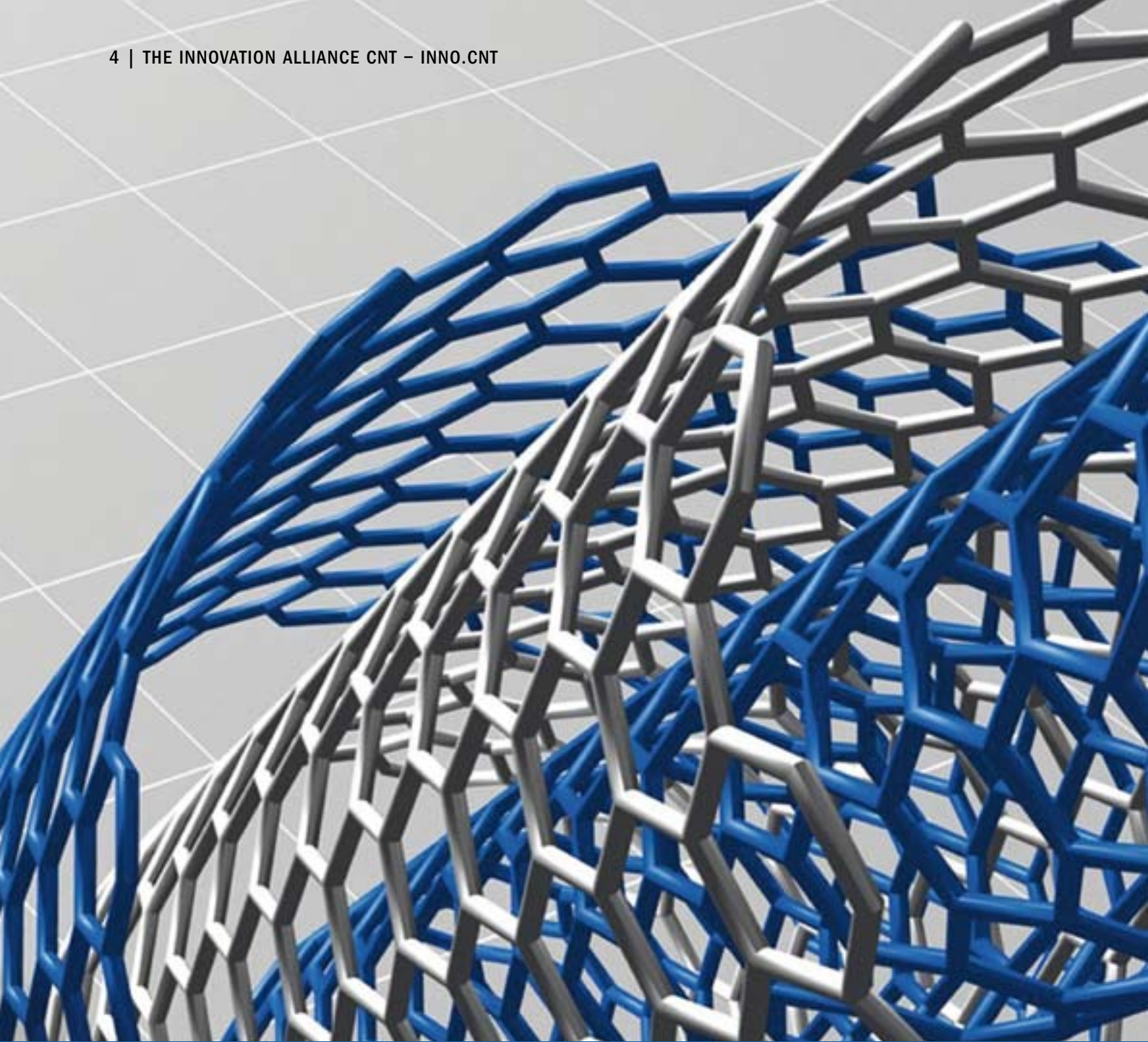
In its WING program (which is an acronym in German for “Materials Innovations for Industry and Society”), the Federal Ministry of Education and Research (BMBWF) is therefore specifically sponsoring the field of materials research. The innovation alliance called “Carbon Nanomaterials Conquer Markets – CNT” is very closely aligned to the aim of the government’s high-tech strategy to pool industry initiatives and establish lead markets for new technologies. Expert partners from science and industry have joined together in this alliance to pursue a common goal: to help a highly promising technology make a breakthrough and thereby secure prosperity and jobs in Germany. Furthermore, this initiative aims to exert a positive influence on developments in other areas and branches of industry. To secure success in the long term, the “Innovationsallianz CNT” particularly wants to motivate young people to join this attractive field of work with its excellent career prospects. The support being given to the

innovation alliance CNT reflects a special commitment to stronger economic growth in our country and is a worthwhile investment in a knowledge-based society and thus essential for safeguarding our future.

Dr. Annette Schavan, MdB
Federal Minister for Education
and Research



Federal Ministry
of Education
and Research



The innovation alliance CNT – Inno.CNT: A unique alliance between science and industry in Germany



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Carbon nanotubes (CNTs) represent a global mega-trend in materials technology. They have fascinating prospects. The innovation alliance CNT is a closely linked research alliance with over 70 distinguished partners from science, small and medium businesses and large-scale enterprises that has been formed in Germany with the aim of developing the basis for a lead market for this material. The alliance forges a link between pioneering technology and practicable applications. In 18 different projects, it will not only establish the technological foundations, but also develop innovative applications in the fields of energy and the environment, mobility and lightweight construction. It is sponsored by the Federal Ministry for Education and Research (BMBF).

Carbon nanotubes can help to fundamentally improve the mechanical, electronic and thermal properties of materials.

CNTs have the potential to create completely new materials and products with properties and property combinations that were impossible to achieve with previous technologies. Inno.CNT has set itself the task of exploiting the enormous range of applications for CNTs, and of developing a leading international position for Germany in this key technology. To leverage the market potential for carbon nanotubes quickly and effectively, the alliance will focus on areas of high global economic and social relevance. For example, the innovation alliance CNT aims to make a significant contribution to solving urgent problems in environmentally friendly, climate-compatible mobility and in energy supply. The alliance forms part of the German government's high-tech strategy, and, as such, is being sponsored by the Federal Ministry for Education and Research as part of its WING program (Materials Innovations for Industry and Society) over a period of four years.

Inno.CNT stands for joint solutions with numerous synergy effects.

In all, the alliance comprises 18 coordinated projects. Three of these are concerned with evolving solutions for the production, functionalization and dispersion of carbon nanotubes. 14 projects deal with applications in the fields of energy and the environment, lightweight construction, and mobility, while the other project is devoted to the cross-sectional subject of health, safety and quality. The particular strength of the innovation alliance CNT is the intensive networking of all 18 projects, which means that the partners' know-how can be utilized to optimum effect, and powerful synergies can be generated. In particular, the interplay between the cross-sectional technologies and the specific projects in the three areas of application offers major opportunities. Through their clear link to practical applications and the real market, the research results can be converted directly into commercially promising concepts.



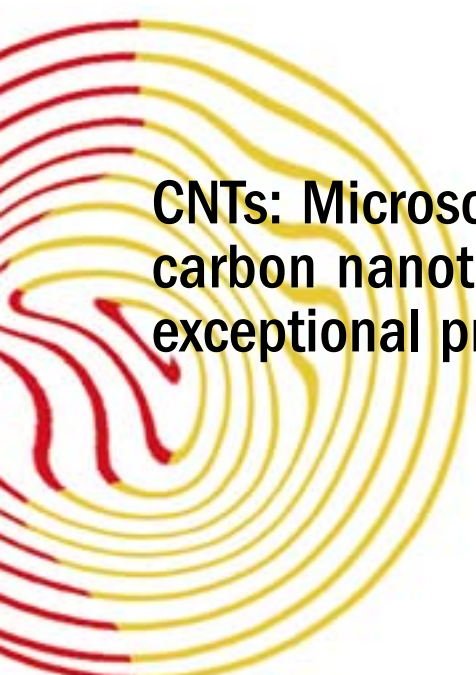
Intensive cooperation between the project partners will ensure practicable solutions.

The high technological potential of carbon nanotubes can speed up economic growth in many other areas along the value chain.

Experts calculate that products and applications based on carbon nanotubes represent a potential global market of up to hundreds of billion euros, and could create around 100,000 new jobs. Virtually all areas of industry will benefit. Two examples: The automotive industry – by far Germany's most important branch of industry – is responsible for 19 percent of total industrial sales, with two thirds of its turnover of 236 billion euros being exported. Machinery manufacture, which employs a good 950,000 people and has a production volume of 190 billion euros (2008), is the country's largest industrial employer. Both areas of industry are constantly working on innovations based on new materials that will enable them to maintain their leading international positions. Carbon nanotubes will open up exceptional prospects.



Research and development is one of the cornerstones of Inno.CNT



CNTs: Microscopic carbon nanotubes with exceptional properties

With their many outstanding properties, carbon nanotubes are among the most spectacular materials of the 21st century. They are capable of opening up entirely new dimensions in many areas of materials technology and thus of generating innovative products and applications. Over the last few years, the development of carbon nanotubes and their applications has advanced at a tremendous rate.

Outstanding mechanical and electronic properties.

Carbon nanotubes are microscopically small structures in the form of rolled-up graphite layers. They come in either single-wall (SWCNT) or multi-wall (MWCNT) form. As a special field of nanotechnology, the incorporation of CNTs can create completely new properties in all kinds of differ-



Ultra-pure carbon nanotubes are needed for many applications.



Much enlarged agglomerates of carbon nanotubes

ent materials and products. The tiny tubes help to fundamentally improve the mechanical and electronic characteristics of the materials. The mechanical properties of carbon nanotubes are particularly impressive. In terms of their weight, their specific strength is 400 times higher than that of steel or aluminum, and they are 20 times stronger than carbon fibers. That is why, through the incorporation of carbon nanotubes, it will be possible to manufacture exceptionally tough, ultra-light materials that are impossible to produce at present.

Apart from that, CNTs have exceedingly high conductivity for both electrical current and heat. According to estimates, the current-carrying capacity of carbon nanotubes is about 1,000 times higher than that of copper wires. Their thermal conductivity is about twice as high as that of diamonds – the best naturally occurring heat conductor known to man. If the outstanding thermal and electrical conductivity of certain carbon nanotubes are combined, transistors can be manufactured that withstand higher voltages and temperatures – and thus higher clock frequencies – than silicon transistors. The first experimental functioning CNT-based transistors have already been produced in the laboratory.

Who discovered carbon nanotubes and how are they manufactured?

Around the middle of the last century, various scientific findings were published by a number of authors describing carbon nanotubes or similar structures in different forms. However, it was not until the highly respected journal “Nature” published work by the Japanese scientist Sumio Iijima in 1991 that this new class of materials really attracted the attention of the scientific world. It was followed by a flood of publications, patent registrations and commercialization attempts for CNTs around the world. At present, there are basically three main processes for manufacturing carbon nanotubes: synthesis by arc discharge, production by laser ablation and a catalytically induced chemical reaction. In Germany, scientists were particularly quick to research the production processes for carbon nanotubes and analyze their properties and possible applications, which is why German research holds such a strong position today. It is important that this position be maintained and expanded in the face of intensive international competition. That is the aim of Inno.CNT.

Future visions in medical technology

Throughout the world, research teams are working on ever more effective medical tools, appliances and instruments. Carbon nanotubes could in future make a decisive contribution towards realizing this vision – for example, for components in electro-reactive elastic materials such as tiny, highly resistant mini-actuators that can be operated with a minimum of energy. If a very low voltage is applied to these mini-actuators, they change their shape like a muscle and, as a result, can perform mechanical tasks in the guise of a small tool. Apart from medical technology, carbon nanotubes have numerous other potential applications: the aerospace industry, precision engineering, robotics, automation and the automotive industry are just a few examples.

“Carbon nanotubes are the basis for a large number of key technologies, and will send out a signal effect to many branches of industry.”

In this interview, Dr. Péter Krüger, head of the Inno.CNT project cluster, talks about the aims and opportunities of the initiative. He also explains what applications and products are planned for carbon nanotubes in the near future and what visionary solutions would be conceivable.

Where are the strengths of the innovation alliance CNT and what are its aims?

Dr. Péter Krüger: *To begin with, Inno.CNT is made up of an exceptionally large number of well-known industrial companies, leading scientific institutions and universities. In all, the alliance is supported in 18 projects by over 70 partners, all of whom have their own acknowledged expertise. Other decisive strengths of the alliance are the combination of science and industry and the inter-project links between the partners. This means on the one hand that basic technologies can be driven forward to make carbon nanotubes usable for all kinds of different applications and, on the other, that we can simultaneously devote ourselves to current problems in industry and thus create the conditions for the rapid economic exploitation of the results for this still young generation of materials.*

Which fields of application will Inno.CNT focus on?

Dr. Péter Krüger: *Alongside the basic technologies for the production, functionalization and dispersion of the CNTs, the alliance will focus on special applications in the fields of energy and the environment, mobility and lightweight construction. This is where the major challenges lie, both social and economic. They range from climate protection and the careful handling of natural resources to questions of modern, energy-efficient mobility. We must ensure that the new approaches that are developed can always be safely implemented, with respect to both human health and the environment. Reliable answers can only be found if science and industry work together – through intensive, inter-project networking of the partners involved. This would not function if the projects were carried out separately from one another. I am confident that other areas of industry will subsequently be able to profit from the results of the innovation alliance CNT – with its many positive effects for Germany as a location for production.*

What new fields of application can be opened up by carbon nanotubes?

Dr. Péter Krüger: *The full potential of carbon nanotubes for industrial applications is not yet really known. What is certain is that a whole range of new materials with significantly improved properties can be developed on the basis of carbon nanotubes for existing and new applications. This means that CNTs will provide the basis for key technologies that will in future influence many other areas of industry and be a major value-adding factor. The new solutions conceivable with carbon nanotubes are exceedingly diverse. They could impact an enormous number of product areas, ranging from energy supply and medical technology to information technology. There is also the futuristic vision of exceptionally load-resistant CNT-based cables that could be used to support bridges or a space elevator.*

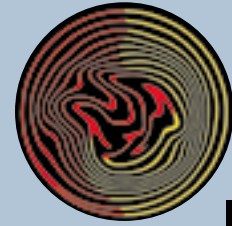


Inno.CNT Cluster Manager Dr. Péter Krüger

Carbon nanotubes: New opportunities for environmental and climate protection

The enormous potential of nanotechnology for solving urgent environmental problems is undisputed. In May 2007, for example, the British Environment Ministry submitted an initial estimate of the potential of nanotechnology for climate protection. It found that “through higher fuel efficiency, improved insulating materials and innovations in photovoltaics, energy storage and hydrogen technology, the United Kingdom’s greenhouse gas emissions could be reduced by up to 2 percent in the short term, and by up to 20 percent by 2050, bringing a similar reduction in air pollution.” Carbon nanotubes will play a major role here.

Energy and the environment: Innovations for the sustainable utilization of resources



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The Inno.CNT projects relating to energy and the environment concentrate on specific applications in energy conversion, energy storage and energy saving. They include, for example, innovations in fuel cell and battery technology, membranes for energy-saving seawater desalination and gas separation, and CNT-based inks for solar cell development.



Developing efficient and sustainable energy technologies is a key challenge in the 21st century.

Reliable and economical energy supply is the backbone of any modern national economy. In view of the finite nature of energy resources such as coal, oil and gas, there is an urgent need for action to secure future energy requirements around the world. In view of the risk of drastic climate change, the problem caused by the emission of climate-damaging greenhouse gases from fossil energy sources is equally great. Inno.CNT aims to make a significant contribution to the urgently needed restructuring of the energy supply situation.

Inno.CNT is developing innovative solutions for energy conversion.

Because of their properties, carbon nanotubes offer a wide variety of opportunities to optimize energy supply with the aid of environmentally friendly technologies. One example is the Inno.CNT project **CarboInk**, which is focused on the development of innovative inks to create a new kind of solar cell. This technology not only makes the production process very much easier, it also improves the conductivity and mechanical resistance of flexible solar cells. Consequently, the photovoltaic harnessing of solar energy will become not only less expensive but also significantly more efficient. With the two Inno.CNT projects **CarboFuel** and **CarboPlate**, the emphasis is on improving fuel cell technology. Through the development of new bipolar plates and gas diffusion layers, pioneering progress can be made that will enable more economical use of fuel cells – for example in environmentally friendly decentralized heat and electricity production in houses, and in the construction of electrically powered vehicles.

Carbon nanotubes can also play a role in energy storage and energy saving, and can help to improve seawater desalination.

Carbon nanotubes can also make a major contribution to the storage and conservation of energy. The Inno.CNT project **CarboPower**, for example, is working on the development of new lithium-ion batteries that will be made significantly more effective through the use of CNTs in terms of their cycle stability, high-current behavior and energy density. This can open up new applications for high-performance batteries in a wide variety of different applications – for example, in modern electric vehicles or as an effective storage unit for renewable energy sources such as wind power. The Inno.CNT project **CarboMembran** aims to make drinking water supplies safer in many parts of the world. The idea is, using carbon nanotubes, to develop innovative membranes that play a key role in seawater desalination and the separation of CO₂ gas. These membranes work far more energy-efficiently and with much higher productivity than existing systems.



Renewable energy sources will benefit from CNT-based materials

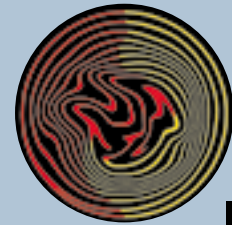
Carbon nanotubes may help to reduce the dependence on expensive imported energy resources.

Further progress in the conversion of alternative energy resources will help Germany to secure prosperity across broad sections of the population. On the one hand, this will cut the volume of expensive imported energy and, on the other, will help to secure and create jobs in Germany, for example, by exporting technologies for climate-friendly energy systems. Carbon nanotubes can provide a major stimulus to these technologies.

Fuel cells as a basis for a decentralized, climate-friendly energy supply.

Carbon nanotubes can play a big part in the development of fuel cells. Experts predict that, by the year 2025, through the quiet fuel-cell revolution, an era of decentralized power and heat generation will begin. Many houses will then have their own small fuel-cell power plants. Equipment builders will be offering mini-power generators for apartments, and vehicles will be increasingly equipped with fuel-cell systems. The opportunities for environmental and climate protection and for economic development are enormous. Carbon nanotubes can make an important contribution to this.

Mobility: State-of-the-art materials for energy-efficient transport



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In the field of mobility, the focus is on new composite materials for vehicles and the aerospace industry. Carbon nanotubes can create new material characteristics that will result in significant improvements in both energy efficiency and environmental and climate friendliness in the transport sector. Inno.CNT is working on extremely lightweight, high-strength materials that can be used, for example, in aircraft fuselages that are subjected to enormously high mechanical loads, and in satellite construction. Furthermore, CNTs will also pave the way for a wide variety of innovations in the design of car body structures and surfaces.

Energy-efficient materials encourage environmentally friendly mobility.

Modern life would be inconceivable without mobility. But traffic and transport systems must be constantly adapted to the changing needs of man, markets and the environment. Apart from the demands made on efficient environmental protection, the safety of the means of transport is always key. This is where innovative high-performance materials can provide a major stimulus.



Carbon nanotubes allow the development of ultra-lightweight composite materials for aircraft construction.

Innovative CNT-based materials can contribute to an improved energy balance in the mobility and transport sector.

Materials based on carbon nanotubes have revolutionary properties. They are much lighter than aluminum, but also exceptionally strong, which is why they will play a key role in future in the automotive industry, in aviation and in space travel. They will open the door to technical solutions that are simply not possible today, for example, by enabling weight savings to be made that will result in much reduced energy consumption and lower emissions – but without any sacrifice of safety or comfort.

High-performance CNT-based materials will boost innovative strength in one of the most important sectors of German industry.

The transport and mobility segment is one of the cornerstones of Germany's economic power, its exporting capacity and its prosperity. One in nearly every seven jobs in this country depends either directly or indirectly on the vehicle industry, which means that every boost to this industry through innovation is of crucial importance for Germany as a manufacturing country. The high-tech CNT-based materials that are being developed in the innovation alliance's mobility projects open up very interesting prospects indeed. They will speed up innovativeness by considerably improving product quality and, at the same time, have a positive impact on the environment and the climate. In the automotive industry for example, rugged, ultra-light

composite materials for body parts can lead to improved energy consumption combined with greater safety and optimum comfort. Advances made here also have enormous potential in other applications – for example in environmentally friendlier air travel and in the design of larger, more efficient wind turbines made of new composite materials.

Inno.CNT projects in the mobility segment have enormous application potential.

To make the innovative potential of carbon nanotubes available to the field of mobility, Inno.CNT also has four projects dealing with solutions for modern, environmentally friendly mobility. In the **CarboAir** and **CarboCar** projects, innovative composite materials are being developed for use in aircraft and automobile construction. The **CarboSpace** project is focused on the development of materials that comply with the extreme load-bearing requirements in space travel. As a result, significant improvements will also be possible in satellite construction. Finally, the **CarboRoad** project is specialized in the production of CNT-reinforced plastics with highly diversified potential applications.

Carbon nanotubes will enable more economical, climate-friendly road and air transport.

In Germany, the use of plastics in cars is already saving more than 400 million liters of fuel a year and consequently reducing greenhouse gas emissions by some 1.2 million tons of CO₂. New synthetic materials with integrated carbon nanotubes are opening up all kinds of new possibilities for further weight reduction without sacrificing either safety or comfort. In parts subjected to particularly high loads, for example, nano-structured foams have twice the flexural resistance but weigh only half as much. In aircraft construction, too, weight can be significantly reduced with CNT-based materials – with all the benefits for energy consumption and environmental impact that this brings. Furthermore, because of their mechanical stability, low weight and electrical and thermal conductivity, CNT-based materials are an interesting option in space travel and satellite construction.



Lightweight construction: Varied solutions for structural applications



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Carbon nanotubes also have tremendous innovation potential in lightweight construction. High-strength CNT-based particle foams are being developed so that safety elements – e.g. in vehicles or protective suits – can better withstand extreme loads. Another example of the application of CNTs in this field is a special concrete that boasts significantly higher strength and elasticity. Carbon nanotubes thus open up outstanding additional design potential, for example in the construction of very tall, slender buildings. They can also make buildings highly resistant to earthquakes.



Lightweight CNT-based materials will play a major role in nearly all sectors of industry.

In the field of lightweight construction, Inno.CNT has initiated five projects aimed at developing lightweight plastics and composite materials, ultra high-strength concrete and metals with exceptional mechanical load-bearing properties. The results of these activities will lead to a wide variety of applications in many different areas of industry. Because two thirds of all new product developments are entirely or partially dependent on the characteristics of the materials from which they are made, the innovations derived from the Inno.CNT projects covering lightweight construction have outstanding market potential. Quality specifications – especially for products and technical solutions in the construction industry – are constantly rising, while the pressure on costs increases, with the result that new system solutions will be born from the combination of new materials with improved processing techniques.



CNT-based high-strength concrete will provide increased scope for architectural design.

Pioneering new developments with carbon nanotubes in lightweight construction have high market potential.

The development of new, high-strength particle foams with carbon nanotubes, especially to enhance passive safety in vehicle construction and to produce more efficient safety equipment, is the subject of the Inno.CNT project **CarboProtekt**. Such foams are able to absorb a considerable amount of deformation energy and can therefore significantly enhance safety. Two other Inno.CNT projects, **CarboTube** and **CarboElast**, are working on the development of plastic parts for the construction segment as well as sealants

based on elastomers. With their carbon nanotube content, such materials have significant advantages as regards friction, lubrication and wear resistance, and they also offer improved electrical and mechanical properties. The fourth project in the innovation alliance is **CarboMetal**, which focuses on the incorporation of CNTs into metals – primarily lightweight metals – to increase their strength. This will give rise to new alloys for a wide variety of materials for use in components that are subjected to extremely high mechanical loads.



Carbon nanotubes could revolutionize vehicle construction.

High-strength concrete based on carbon nanotubes will mean greater stability and safety; it will also opens up new dimensions in architecture.

In its **CarboBau** project, Inno.CNT is working on the development of an ultra-high-strength concrete in which the carbon nanotubes add extra stability and elasticity to this versatile construction material. This will open the door to the construction of graceful yet very stable concrete buildings and provide architects with entirely new design options. Using this ultra-high-strength concrete, skyscrapers and bridges can be built in sizes and shapes that would be inconceivable today. The new material will also make significant advances in earthquake protection, especially in heavily populated areas in parts of the world that are at constant risk from these natural phenomena.

Quake-proof buildings made of high-strength CNT-based concrete are needed in many regions of the world.

Natural disasters frequently lead to incalculable tragedies, and place an ever-increasing burden on national economies throughout the world. In the first half of 2008 alone, they caused damage costing around 50 billion dollars, with earthquakes being one of the main factors. Erecting quake-proof buildings is therefore one of the major challenges for many countries around the globe.

Extremely lightweight but very strong CNT-based materials get ideas off the ground.

One example from an infinite number of projects: the microdrone – a small, remote-controlled flying object made from extremely light but very strong carbon nanotubes, weighs only 3.6 kg but can carry a load of about 1.2 kg. It can, for example, carry a camera to inspect high buildings, bridges or wind turbines, track down sources of fire or capture breathtaking pictures of sporting events such as downhill skiing.



New perspectives with CNT-based composites

Research and development targets in cross-sectional projects, with enormous benefits for man, the environment and society



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The cornerstones of the innovation alliance CNT are the cross-sectional technologies, which are being tackled in three comprehensive projects. Their key task is to create the technological basis for all application developments and to make carbon nanotubes and intermediate products containing carbon nanotubes available in adequate quantities, suitably modified and in the right quality. The projects focus on three areas: catalyst and production technology, modification and functionalization, and dispersion.

CarboScale: The basic principles of optimum-quality CNT production.

The CarboScale project is focused on the technical production of carbon nanotubes of high purity and top quality. The development of new generations of highly active catalysts plays a key role in the “fluidized bed process”, which makes it possible to develop new carbon nanotube structures that are tailored precisely to the needs of specific applications. These include, for example, single- and double-wall carbon nanotubes as well as agglomerates of carbon nanotubes with a readily dispersible structure. Because the catalysts exert a significant influence on the morphology and product properties of the carbon nanotubes, strict technical standards must be put in place to ensure production of the necessary quantities to a consistent, specified quality. The CarboScale project is also very much involved with process engineering. Here, it is a case of matching catalysts, reactors and operating conditions perfectly to each other in ongoing testing procedures.



The cross-sectional technologies will provide the basis for application-oriented solutions.

CarboFunk: Tailor-made CNT surfaces for optimum integration of the carbon nanotubes into the surrounding material.

To enable carbon nanotubes to display their outstanding electrical, thermal and mechanical properties to the full, perfect bonding between the carbon surface and the surrounding material is essential. The type of bond is spe-

cific to each individual material, and is often governed by the intended application, so that different surfaces and thus different forms of bonding are required for one and the same material. The **CarboFunk** project has the job of solving this problem. The key task is to functionalize the CNTs, which basically means chemically modifying the surface of the carbon nanotubes to enable them to be optimally incorporated in a wide variety of materials to suit the particular application. To do this, innovative processes must be developed that can be scaled up for industrial utilization and allow large-volume production.



Intensive inter-project cooperation between the alliance partners is a guarantee of success for Inno.CNT.

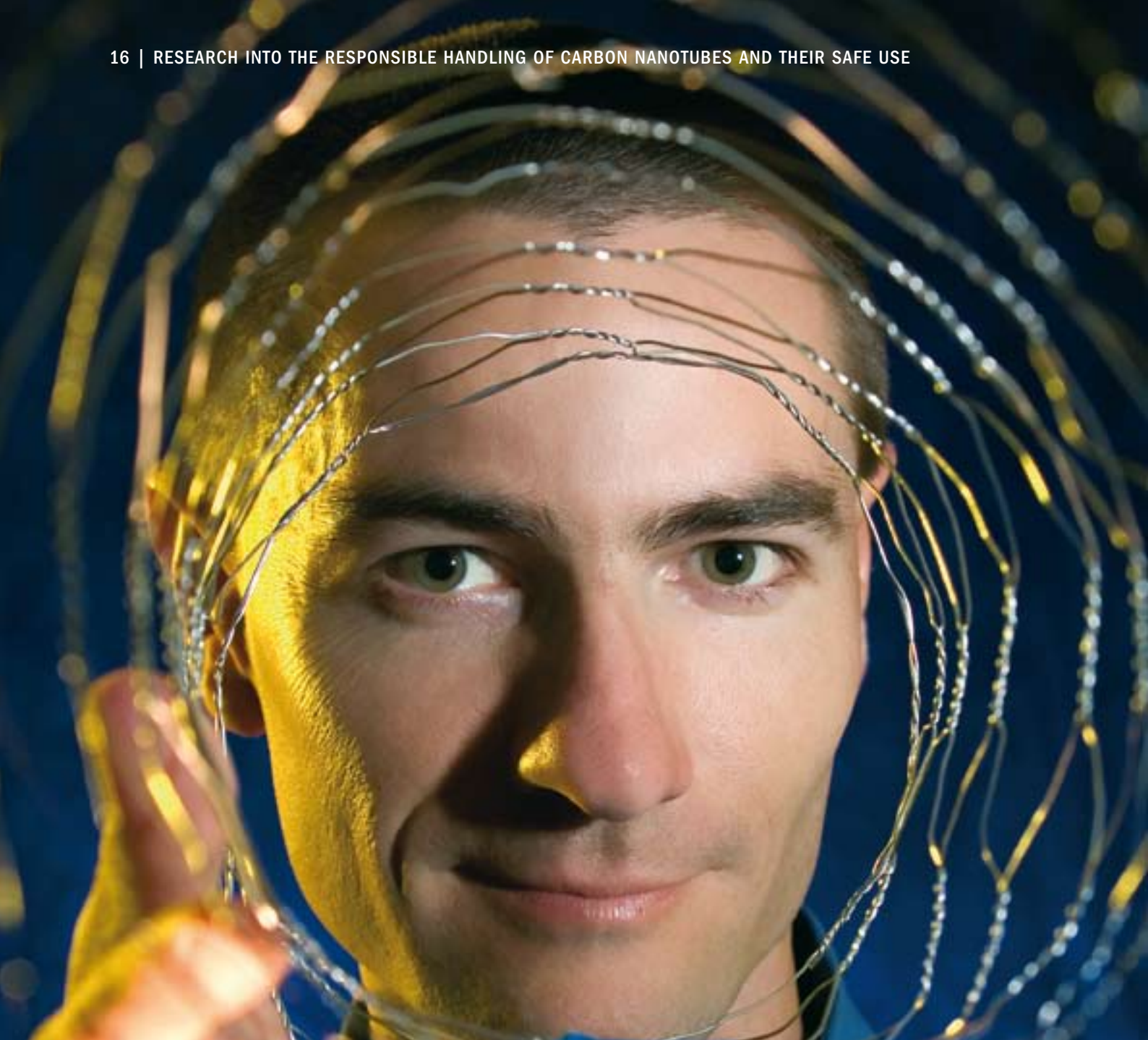
CarboDis: Processing of carbon nanotubes into application-specific intermediate products.

Another challenge is to ensure the correct distribution of the carbon nanotubes in the material. This criterion is, for example, responsible for the high conductivity of such materials even at low carbon nanotube contents, and is thus important if carbon nanotubes are to fulfill their potential in the final application. The task of the **CarboDis** project is to gain a better understanding of the incorporation of carbon nanotubes into different polymer structures. A dispersion process ensures that the carbon nanotubes, which are generally in an entangled and ag-

glomerated state, can be incorporated independently and selectively into the polymeric material. The various partners involved in this particular project will carry out work on dispersing CNTs in all the basic types of polymer – thermoplastics, thermosetting plastics and elastomers – so that adequate results and know-how can be provided for every class of material. This will result in a broad working and knowledge platform describing the fundamental relationships between the dispersion quality of the carbon nanotubes, and the characteristic properties of the basic polymer materials and the CNT-containing composite materials.

Conclusion:

The technical results obtained from the three cross-sectional projects will benefit all the members of the alliance, because specifically manufactured CNT-based materials will be made accessible at low cost for any of the potential applications.



Research into the responsible handling of carbon nanotubes and their safe use



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Carbon nanotubes will provide convincing solutions to many present-day problems that will lead to more efficient, more attractive and safer products which will also be more climate-friendly and have little or no environmental impact. At the same time, it is also important to establish whether processing carbon nanotubes and using CNT-based products over their entire lifecycle has any potential effects on human health and the environment. This is the task of the Innovation alliance's CarboSafe cross-sectional project. It sets out to establish methods and measures to ensure safety in the processing and use of carbon nanotubes.

A transparent safety concept will create trust and confidence in CNT products.

To ensure the safety of carbon nanotubes and the products based on them, potential risks have to be evaluated and adequately communicated. A prerequisite for this is a sound knowledge of possible exposure routes and the action of carbon nanotubes in contact with biological systems. The development of test methods to determine the exposure and to characterize carbon nanotubes is another important module. The innovation alliance CNT will tackle these challenges in a cross-sectional project called **CarboSafe**. The

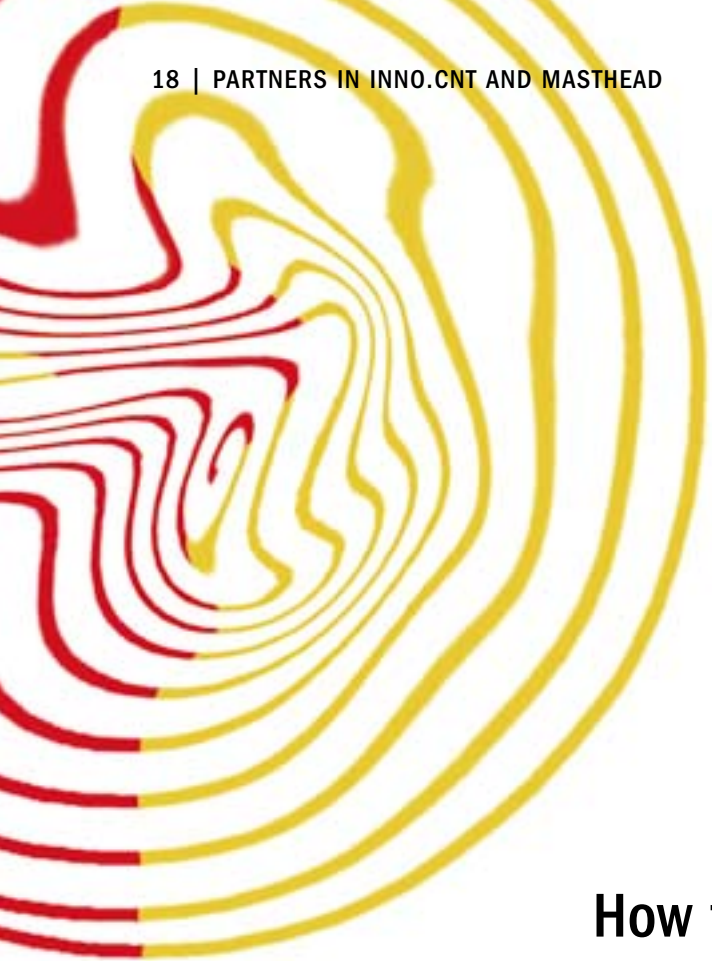
basic objective is to develop reliable measuring technologies for unambiguously determining the release rates of nanoparticles in the lifecycle of CNT-based products. Furthermore, the CarboSafe project aims to identify the ecotoxicological potential of carbon nanotubes and to accurately estimate the risk potential with the aid of newly developed measuring technologies. The findings obtained here will supplement a number of other studies and projects that currently deal with the safety aspects of carbon nanotubes. They include, for example, the TRACER project supported by the BMBF, which

will provide an important basis for the CarboSafe project. TRACER has been involved with the risk assessment of CNTs along the entire value chain since 2006, and aims to derive recommendations for handling carbon nanotubes during their production and processing, and during the use of potential end products.

Inno.CNT will also foster open, transparent and continuous dialogue with the general public. After all, frank and timely communication will be decisive in terms of the future social impact of this technology.

Overview of the Inno.CNT architecture

Area of application	Project	Objective
Energy and the environment	CarboPlate	Improve the bipolar plates in PEM fuel cells using CNT composites
	CarboFuel	Engineer optimized electrodes for fuel cells, industrial electrolysis with carbon nanotubes as catalyst carriers
	CarboPower	Substitute classical conductive carbon black by CNTs as the electrically conductive material
	CarboMembran	Develop CNT-based mixed matrix membranes for seawater desalination and gas separation
	CarboInk	Develop innovative electrically conductive inks for new kinds of CNT-based solar cells
Mobility	CarboAir	CNT modification and improvement of fiber composites for heavy-duty lightweight construction
	CarboCar	Develop and evaluate function-integrated CNT-modified thermoplastic parts for automotive and aeronautical applications
	CarboSpace	Develop CNT-modified materials for aerospace applications
	CarboRoad	Manufacture structural components made of CNT-reinforced thermoset fiber/plastic composites
Lightweight construction	CarboTube	Develop injection molding and extrusion applications, such as thermally conductive tubing, electrically conductive cable sheathing, rocker panels and electronic housings based on CNTs
	CarboElast	Develop CNT-modified elastomeric materials that are readily dispersed and easy to process
	CarboBau	Develop ultra high-strength concrete and dry mortar systems with the aid of CNTs
	CarboMetal	Incorporate CNTs into metal matrices to significantly improve material properties
	CarboProtekt	Tap new fields of application for CNT-based thermoplastic and thermoset polymer foams
Cross-sectional technologies	CarboScale	Cost-effective production of CNTs with differing structures on an industrial scale
	CarboFunk	Develop processes for functionalizing CNT surfaces
	CarboDis	Develop tailor-made dispersion technologies for CNTs in thermosetting, thermoplastic and elastomeric systems
Safety	CarboSafe	Methods for determining exposure, identifying the ecotoxicological potential of CNTs and developing suitable measuring technologies



How to contact us

You can find more information at www.inno-cnt.de or by phone at +49 1805-133 422*

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