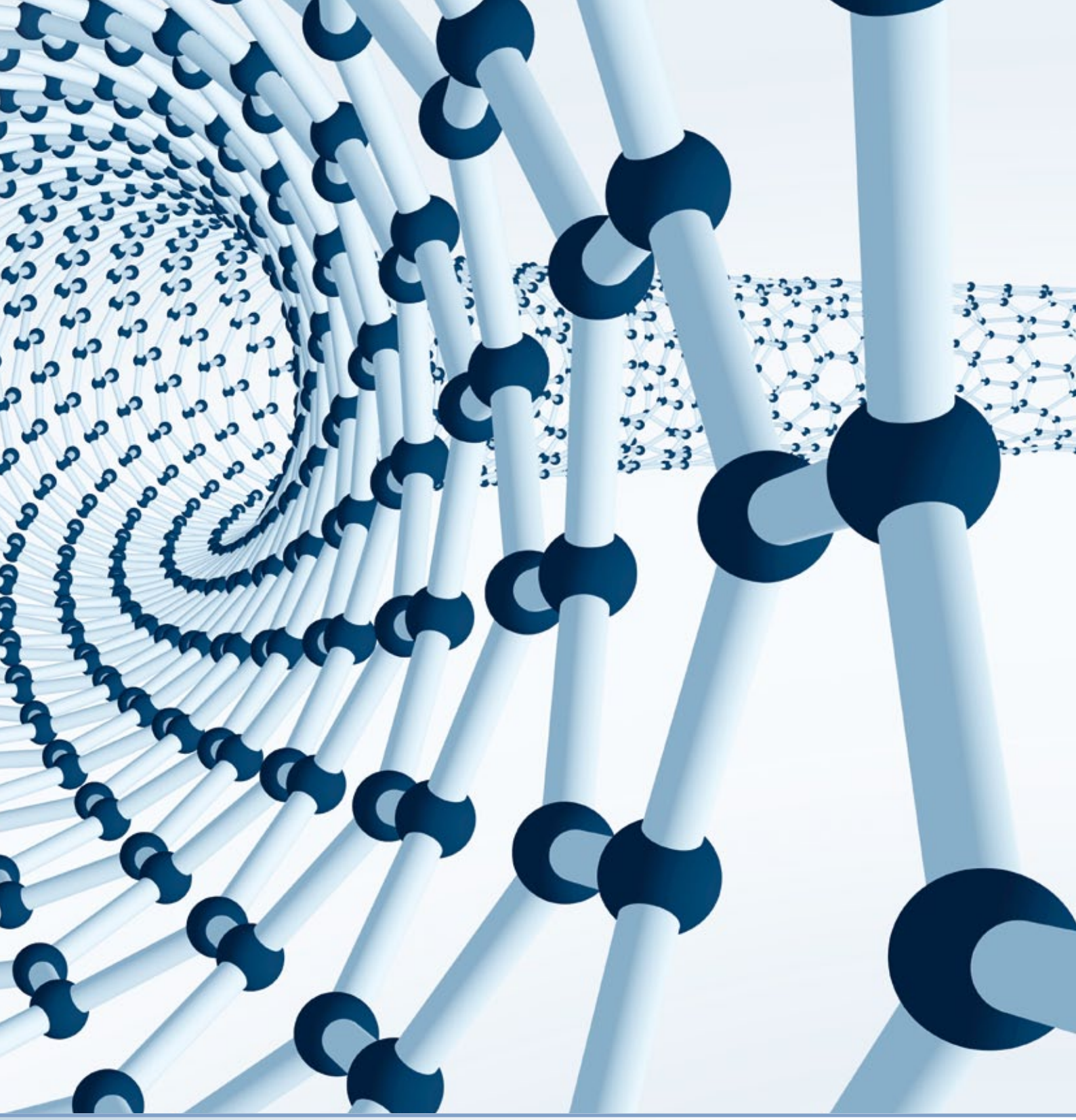

Innovation Alliance CNT – Carbon Nanomaterials Conquer Markets

Inno.CNT
INNOVATIONSALLIANZ
CARBON NANOTUBES

Inno.CNT

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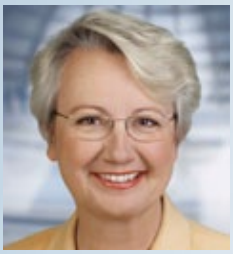


With its high-tech strategy for Germany, the federal government is boosting the innovative power of our country on a lasting basis. The core of the high-tech strategy is to unite all disciplines behind a common idea. In the newly updated high-tech strategy, we are focusing innovation policy even more intensely on very specific tasks and people's needs. Thus we are concentrating on five main areas: climate and energy, health, communication, mobility and security. These are the areas in which the most important issues of humanity in the 21st century will be decided, and materials technology plays a key role here.

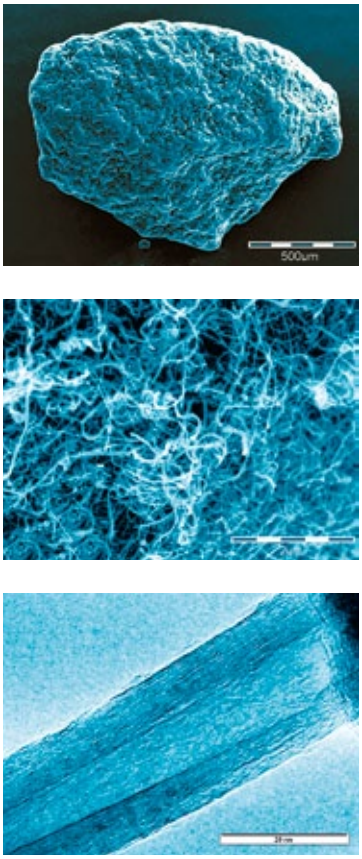
Carbon nanotubes (CNT) in particular are genuine drivers of innovation. Their unique properties enable them to open up new dimensions in materials technology and pave the way for innovation. Strategically, the Inno.CNT Innovation Alliance is thus extremely important. Inno.CNT is especially effective when it comes to bundling industry initiatives and establishing the basis for a lead market for this new technology. Important technical obstacles in CNT production have already been overcome thanks to the work of the Alliance, so that the focus is now on further application-based development, and the range of ventures has currently been expanded to include 27 different projects.

With regard to its structure and scope, the Inno.CNT Innovation Alliance is unique in Germany. Expert partners from science and industry, including numerous small and medium-sized companies, have banded together to produce a breakthrough for the promising CNT technology and to facilitate a wide range of applications in various industrial sectors. This enhances Germany's position as an innovative business center and ensures its competitive power.

Prof. Dr. Annette Schavan,
Member of the German Parliament
Federal Minister for Education and Research

Federal Ministry
of Education
and Research

Carbon Nanotubes – CNT: Microscopic carbon structures with exceptional properties



A close look at carbon nano structures: Agglomerate of entangled flexible multi-wall carbon nanotubes (top), enlarged section of an agglomerate (center) and detail view of a single multi-wall carbon nanotube (bottom).

With their many outstanding properties, carbon nanotubes (or CNT for short) 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, which will result in innovative products and applications. Over the last few years, the development of carbon nanotubes and their applications has advanced at a tremendous rate.

CNT: Microscopic carbon structures revolutionize materials technology

CNT are nanosized carbon based tubes with unique material properties, which allow the development of new materials with extraordinary qualities. As with fullerenes or layers of graphite, i.e. the graphenes, the walls of the carbon nanotubes consist exclusively of carbon and have a honeycomb structure with hexagonally arranged carbon atoms each of them connected by three bonds to its adjoining atoms. Carbon nanotubes come in either single-wall (SWCNT) or multi-wall (MWCNT) form. Among other properties, the microscopic tubes can fundamentally improve the mechanical and electronic characteristics of materials. Although CNT are long known in scientific literature, carbon nanotubes made a breakthrough after a publication in the renowned “Nature” journal in the early 1990s, which prompted scientists around the world, including in Germany, to intensively research the production processes, properties, and potential applications of CNT. Today, German CNT research holds a strong position, which needs to be maintained and expanded in light of heavy international competition. Based on these research results, Inno.CNT develops the fundamentals for technologies and applications for CNT-based products, which will make a vital contribution to the creation of new leading markets and therefore, to the competitiveness of the Germany economy.

The property profile of CNT frequently exceeds the characteristics of known materials

The mechanical properties of carbon nanotubes are particularly impressive. With regard to their weight, their specific strength is many times higher than steel or carbon fibers. As a consequence, the use of CNT will allow for the future manufacture of highly durable and ultra-light materials, which are still impossible to produce commercially at present. Furthermore, CNT have much higher electrical conductivity than copper and better thermal conductivity than diamonds, the best heat conductor known to man. It is the core objective of the Inno.CNT innovation alliance to utilize these properties in technical applications at an industrial scale. The alliance aims to develop innovative materials and applications on the basis of CNT with particular focus on areas of societal challenges such as energy and environment, mobility, lightweight design, and electronics in order to contribute to the establishment of new lead markets.

The Innovation Alliance CNT – Inno.CNT: A unique alliance of German science and industry

Inno.CNT

The Innovation Alliance CNT is a closely interlinked research alliance consisting of over 90 distinguished partners from science, small and medium sized business entities and large-scale enterprises that has been formed in Germany to develop the fundamentals for a lead market for carbon nanotubes (CNT). The alliance forges a link between pioneering technology and practicable applications in numerous industries along the value chain. Inno.CNT was established in 2008 initially with some 70 partners in 18 closely networked projects, which, in addition to basic technologies and safety research, focus on three main application areas. The original fourteen application projects are dedicated to energy and environment, mobility, and lightweight design. Thanks to the successful work within the alliance, Inno.CNT has grown to include currently 27 projects and now also covers another technical area, the newly added field of electronics. The alliance is sponsored by the Federal Ministry for Education and Research.

Fundamental improvements in mechanical, electronic, and thermal properties of materials

CNT have the potential to create novel materials and products in numerous applications 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 CNT, and of contributing to the establishment of new leading markets for Germany with this key technology. This will further support the leading international position Germany holds in utilizing CNT-based technologies and products. To leverage the market potential quickly and effectively, the alliance focuses on areas of high economic and societal relevance. Inno.CNT forms a part of the German government's High-Tech Strategy and as such has received sponsorship funds from the Federal Ministry for Education and Research as part of its WING program (Materials Innovation for Industry and Society) since 2008.

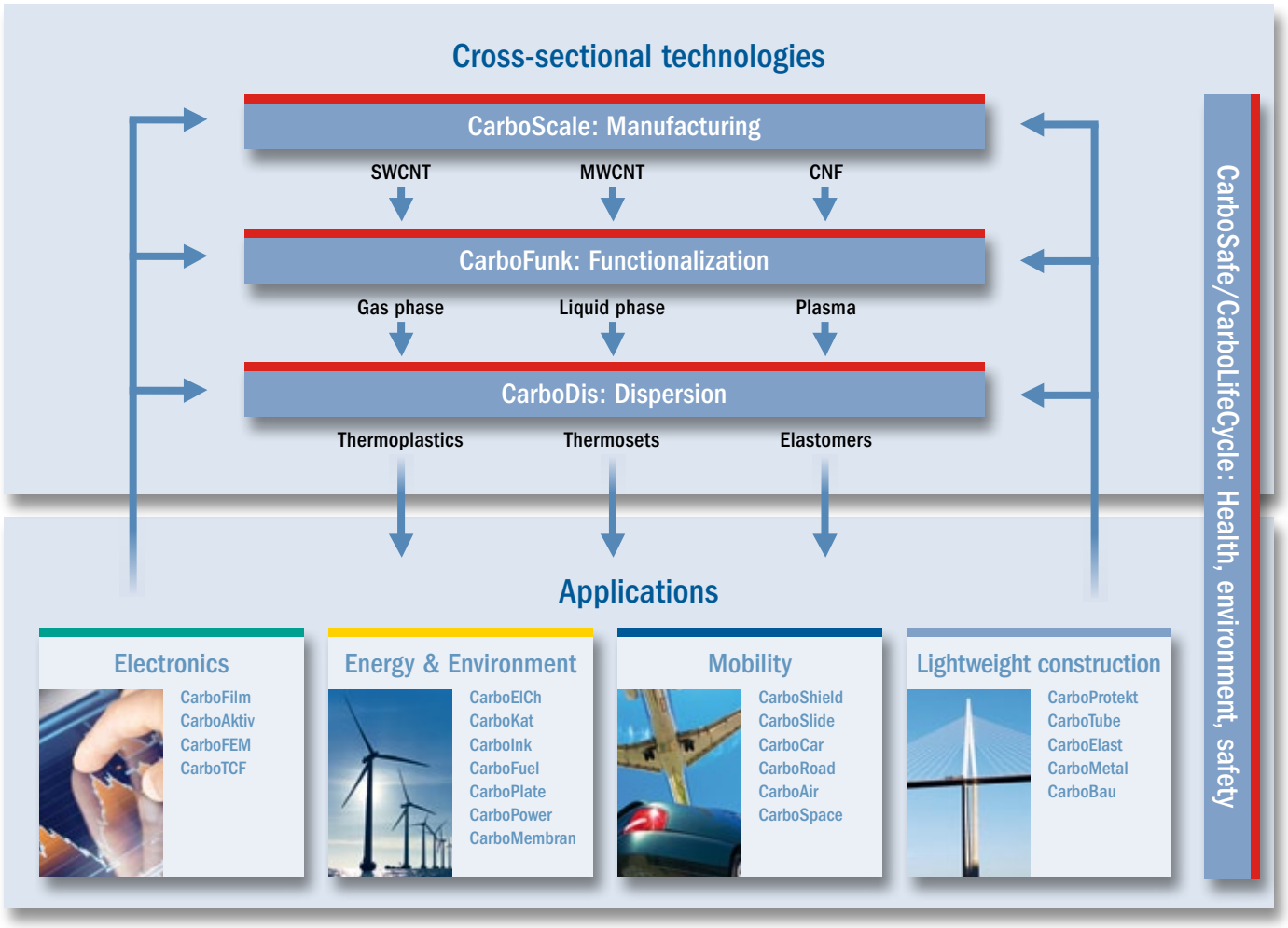
Inno.CNT: Shared goals as the basis for unique solutions

The innovation alliance stands for joint solutions with significant synergy effects. All in all, the alliance currently is consisting of 27 closely networked projects. Three of these are dedicated to developing fundamental solutions for the production, functionalization, and dispersion of CNT. Twenty-two projects deal with applications in the fields of energy & environment, lightweight design, mobility, and electronics, while another two are dedicated to the cross-cutting topics health and safety. In addition to the unique combination of industrial and scientific partners, the particular strength of the Innovation Alliance CNT is the intensive interlinking of projects, which means that the partners' expertise can be utilized to optimal effect, and powerful synergies can be generated. In particular, the interaction between the basic technologies and the specific projects in the four areas of application offers major opportunities. Through their clear link to practical applications and real markets, research results can quickly be converted to commercially viable solutions.

Active communication for public information

Inno.CNT fosters open and continuous dialogue with the general public to promote trust in future CNT-based applications. After all, factual and timely communication might play an important role in shaping the societal response to this technology.

Overview of the Inno.CNT architecture



“Carbon nanotubes have a signal effect for many industries”

Inno.CNT

In this interview, Dr. Péter Krüger, head of the Inno.CNT project cluster, talks about the goals, opportunities, and first results of the alliance. He also explains which applications and products will become feasible in the future with CNT and which contributions CNT will be able to make to the progress of numerous industries.

Where are the strengths of Inno.CNT and what are the goals of the alliance?

Dr. Péter Krüger: To begin with, Inno.CNT is made up of an exceptionally large number of well-known smaller and larger industrial corporations, leading research institutes, and universities. In all, the alliance is now consisting of some 90 partners, who now cooperate in 27 interlinked projects and have widely recognized expertise. Other decisive strengths of the alliance are the combination of industry and academia as well as the networking of partners across different projects. In the first phase behind us with initial 18 projects, we advanced fundamental technologies and safety research and we got first successes in several application projects. In order to optimize the potential of carbon nanotubes, we have added another eight application projects and one further safety research project to the alliance. With all this in mind, we will continue to pursue our ultimate goal, which is to ensure the rapid economic exploitation of our results for this comparatively young generation of materials.

Which fields of application does Inno.CNT focus on?

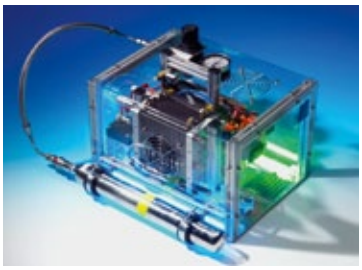
Dr. Péter Krüger: Alongside the basic technologies for the production, functionalization, and dispersion of CNT, the work of the alliance focuses on applications in the areas of energy and environment, mobility, lightweight design, and electronics. These fields represent the major societal challenges we have to address and are associated with energy and resource efficiency for sustainable use of our limited materials and energy sources, all of which are high priorities in practically every one of our projects. At the same time, we have to make sure that the new technological approaches and materials we develop can be used safely in terms of human health and environmental protection throughout their lifecycles. Solutions can only be found in joint approaches of science and industry and through intensive networking of partners across individual projects. This would not be feasible to the same extent if single projects were carried out separately. I am confident that other industry segments will benefit from the results of the Innovation Alliance CNT in the future, which will have a widespread positive impact on Germany as an industry location.

Which new fields of application can be opened up with CNT in the future?

Dr. Péter Krüger: Although the first results of our work are quite promising, the full potential of carbon nanotubes for industrial applications is far from exhausted. What is certain is that CNT will lead to a whole range of innovative materials with significantly improved properties for existing and new applications, particularly in the fields addressed by our alliance, which include energy and environment, mobility, lightweight construction, and electronics. CNT will allow for a wide range of new problem solutions and may impact additional product and application areas that are not yet fully known. We keep this consistently in mind as we are continuously trying to identify interrelationships and attempt, for example, to transfer the insights of our projects to other applications. I invite anyone who is interested to enter into dialog with us.

Dr. Péter Krüger,
Head of the
Inno.CNT project cluster

CNT technology potential boosts future economic development



Top: CNT offer new perspectives for environmentally friendly mobility, for example in electrical vehicles with high-tech battery drives.

Center: Improved fuel cells are a specific application example of CNT-based materials.

Bottom: Renewable energies will benefit from CNT materials.

Market studies have shown that CNT-based products and applications may open up a global market of the future with a potential value in the billions.* Practically all areas of the industry stand to benefit.

German economy benefits from product innovations on the basis of CNT

Interrelated innovations along the entire value chain are the driving force of economic success for all involved companies. As a high-tech industry location, Germany must consistently search for new technologies to remain competitive on an international scale. Two thirds of all technology-driven innovations depend on material aspects. To give two examples, the automotive industry – by far Germany's most important industry – accounts for some 20% of total industry revenues, with 60% of its 2009 revenues in the amount of €263 billion associated with export.** Machinery manufacture, which employs some 950,000 people and has a production volume of approximately €151 billion (2009), is the country's largest employer for engineers.*** Both industries are consistently working on innovations based on new materials that are a prerequisite to maintain their leading international position. Carbon nanotubes open up exceptional prospects in this regard, but the high technological potential of CNT will continue to influence economic dynamics in many other industrial fields as well.

New opportunities for environmental and climate protection

Based on its enormous potential, nanotechnology is widely seen as a solution for urgent energy and environmental problems. In May 2007, the British Environment Ministry presented an initial estimate of the potential of nanotechnology for climate protection. It stated that "higher fuel efficiency, improved insulating materials and innovations in photovoltaics, energy storage or hydrogen technology, may lower the United Kingdom's greenhouse gas emissions by up to 2 percent in a short term and by up to 20 percent by 2050, bringing a similar reduction in air pollution." Thanks to their extraordinary properties, CNT will make a key contribution to this improved environmental outlook. CNT will also play an essential role in sustainable energy supply by increasing the efficiency of renewable energies, for instance in photovoltaics, wind power, or energy storage.

New opportunities for environmental and climate protection CNT – future visions for medical tools

Innovative and improved diagnostic options depend heavily on advances in medical technology, which consequently requires medical tools of increasingly high performance. The impressive material properties of CNT-based materials may turn future applications in the area of medical technology into reality. Practical examples include high-powered computed tomography units with lower radiation exposure or electroactive materials that are able to change shape at low voltage and can perform mechanical tasks as small tools. These "actuators" not only have large potential to perfect medical interventions, but also open up numerous other applications in the aerospace industry, precision engineering, robotics, automation, and the automotive industry.

* BCC-Report, March 2007: "Carbon Nanotubes: Technologies and Commercial Prospects"
** VDA Annual Report 2010
*** VDMA, press release of Feb 10, 2010, "A glimmer of hope for civil engineering– industry expects low-level consolidation in 2010"

Electronics: High-tech applications for numerous key industries

Inno.CNT

The success of nearly all sectors of the industry today is closely associated with electronic systems, without which many applications would not even be feasible. At the same time, the complexity of these systems has increased tremendously over the past years. Innovative solutions that contribute to the control of demanding electronic applications and additionally offer preservation of natural resources are of eminent significance for the entire economy.

The development of increasingly more powerful electronic components, which at the same time is subject to the need for more cost-effective and application-specific production, will benefit from the opportunities offered by nanotechnology. Innovations on the basis of CNT with a high level of functional integration that offer both outstanding electrical conductivity and extraordinary mechanical properties are particularly promising. They range from displays to X-ray and microwave generators, photovoltaic applications, and high-resolution electron beam instruments.

CarboFilm: Innovations accelerate optoelectronics

Solar cells and displays require electrode materials that combine a high level of electrical conductivity with the greatest possible transparency. Doped metal oxide films, which frequently are based on the rare element indium, have dominated this market for the past forty years. Since this market is expanding heavily among growing requirements for additional flexibility and cost-effective, simple manufacturing methods, alternative materials are urgently needed. The objective of CarboFilm is to develop a novel composite material that combines the benefits of CNT with regard to flexibility, elasticity, and cost with the high conductivity and transparency of conductive oxides such as doped ZnO or SnO_2 or conductive polymers. As an additional advantage, the innovative composite material can even be applied to flexible substrates at low temperatures with imprinting or roll-to-roll techniques, which allows for further simplification of production processes.

CarboAktiv: Electrically conductive synthetic materials with a broad application range

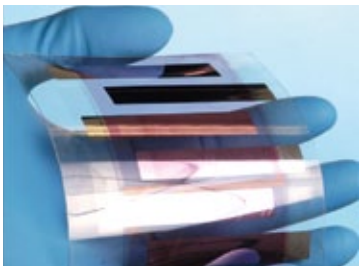
CarboAktiv focuses on making typically non-conductive synthetic materials partially conductive to improve the integration of mechanical and electronic functionalities in components. To give an example, this would make it feasible to implement electrical connections through parts of the component housing in all applications that include electronic components on or in synthetic housing. This not only opens up new perspectives for decreasing the size of encased electronic components, but also allows for saving or replacing material, resulting in positive effects for recycling based on a reduction of the material volume used in the final product. One of the important technological challenges is to reconcile the injection molding process for plastics production with the activation of electrical conductivity based on laser structuring and to come up with a closed process chain that would allow for a significantly shorter manufacturing process.

CarboFEM: CNT coatings revolutionize medical technology

The partners of the CarboFEM project are working on electron sources with CNT and graphene cathodes. Based on the particularly advantageous CNT nano-structures, they plan to produce aligned CNT arrays on metal substrates and to stabilize them mechanically for increased current density. Moreover, the project focuses on the development of graphene-based electron emitters consisting of a carbon atom layer that promise high emission currents as 2D C-systems. Ideally, the spacing of such electron emitters would be in the micro-range, which calls for the development of pronounced nano- and micro-structures.

CarboTCF: Transparent electrodes for touchscreens, OLEDs, organic photo diodes, printed transparent RFID

The demand for optically transparent electrodes is especially increasing in consumer applications. As a result, the market for transparent, conductive layers has grown disproportionally in the past years. Previous solutions based on polymers or indium are expensive and frequently have only limited service life. CNT layers represent an attractive alternative, since they can already be produced at a comparable price and have the potential to significantly improve the price-performance ratio. Layers made of CNT also open up entirely new design options and allow for creative and flexible applications, e.g. such as e-paper.



Top: CNT to boost the performance of solar cells and to simplify their production.

Bottom: Optically transparent, conductive layers made of CNT can be used in a wide range of consumer goods.

Energy and environment: Saving resources and protecting the habitat

Inno.CNT

A reliable and economical energy supply and the efficient use of resources represent the backbone of any modern industrial society. In view of the limited nature of energy resources such as coal, oil and natural gas and the rising energy demand of emerging national economies there is an urgent need for action to secure future energy supply around the world. In addition, climate change is forcing a restructuring of our energy supply, primarily for the further emission reduction of climate-damaging greenhouse gases such as CO_2. Limited resources must be used as conservatively as possible with more efficient processes such as optimized catalysis or improved material separation.

The seven projects in the Energy and Environment category focus on these tasks. Their goal is to improve existing applications with promising new developments in catalysis and material separation as well as energy conversion, storage, and optimized use and to generate entirely new applications in this field.

This includes innovations in the area of catalyst, fuel cell and battery technology, CNT-based inks for solar cell development as well as membranes for energy-efficient seawater desalination and gas separation.

CarboElCh: Environmentally sound production of important base chemicals

Up to seventy percent of all chemical products are associated with the base chemicals chlorine and sodium hydroxide solution. Accordingly, sodium chloride electrolysis is of enormous industrial significance, but current processes are highly energy-intensive and produce major emissions. A new process involving oxygen depolarized cathode (ODC) technology has been under investigation for a few years and has the potential to save 30-50% of the previously required energy, which would also drastically reduce the associated CO_2 emissions. However, this process is not yet ready for marketing due to the associated cost. Further technological breakthroughs will be required, particularly for highly active catalysts and for manufacturing ODC, to substantially increase the efficiency of the process while reducing investment and operating costs. The CarboElCh project pursues a promising approach involving highly active nitrogen-doped CNT for a decisive innovative leap.

CarboKat: CNT catalysts improve chemical reactions

Catalysts are indispensable for generating value in the chemical industry, since they accelerate processes and lower the share of undesirable waste products. Some eighty percent of all chemical products are manufactured with the help of catalytic processes. The CarboKat project focuses on the production of CNT-based catalysts, which may contribute to a significant reduction of energy and resource requirements. The work concentrates on industrially relevant reactions, which are used primarily for the production of high-quality base chemicals and synthetic fuels.

CarboInk: The next generation of solar energy

The development goal of the CarboInk project consists of electrically conductive, printable inks. The photovoltaics industry is particularly interested in the production of easily printable, thin and cost-effective conductors that guarantee the conduction of electrons. Due to rising resource costs and expense manufacturing processes, photovoltaic systems continue to be very cost-intensive. The reduction or replacement of silver as the main component of printing inks and pastes alone has the potential to generate enormous cost savings and would make environmentally friendly solar energy substantially more competitive. Moreover, CNT-based inks open up additional practical applications with vast marketing potential. Such innovative inks can be used, for instance, as printable heating systems on automotive windows, which are not discernible to the naked eye.

CarboFuel: Excellent perspectives for fuel cells

Increased energy efficiency has the potential to considerably reduce CO_2 emissions and to reduce primary energy imports. The advancement of fuel cells and optimized electrolysis for manufacturing industrial products plays a central role in this regard. The CarboFuel project integrates CNT into electrodes for electrolysis and fuel cell systems. This is expected to lead to essential performance increases that will also have a positive impact on energy efficiency. The production of electrodes for fuel cells and electrolysis cells will rely on the high electrical conductivity of CNT and the catalytic properties of CNT.

CarboPlate: Innovative solutions for energy conversion

Fuel cell technology represents an interesting alternative to conventional energy conversion systems. To move this technology toward mass market production, its production costs need to be substantially reduced. The CarboPlate project focuses on bipolar plates as a central element of PEM fuel cells. These are manufactured from highly conductive, carbon-filled synthetic materials, the so-called compounds, in injection molding processes. The use of CNT has the potential to optimize the associated material properties and processing characteristics. In addition to improving properties, the application of mass production technologies will reduce the price of bipolar plates so much that fuel cell technology can become profitable in mass market applications. Promising application areas of the innovative bipolar plates include PEM fuel cell systems associated with uninterrupted power supply (UPS) and decentralized energy converters for single-family or multi-family homes.

CarboPower: Improvements of lithium-ion batteries technology

The CarboPower project investigates the use of CNT as alternative conductivity additives to lithium-ion batteries in energy storage. The high electrical conductivity of CNT promises better battery durability with rapid charging and discharging. Furthermore, the project aims to improve the mechanical integrity of electrodes on the basis of the elasticity of CNT, which would again have a positive impact on the service life of batteries. The prerequisite for this objective includes the adaptation of the source materials to the requirements of the battery and the difficult optimization of electrode compositions. These accomplishments may allow for new applications in a wide range of fields such as modern electrical vehicles or as efficient interim storage for using renewable energies.

Innovative CNT-based catalysts have the potential to significantly reduce the energy and resource requirements of catalytic processes.

CarboMembran: Innovative membranes for clean drinking water

The CarboMembran project focuses on improving the drinking water supply in many parts of the world. Innovative CNT-based membranes will play an important role in seawater desalinization and in gas separation of CO_2. These membranes are far more energy-efficient and significantly more productive than previously known systems. CNT membranes have already been produced successfully at a micro-scale in the laboratory. CarboMembran is working on scalable processes to manufacture such membranes, which includes a dispersed version of CNT in thin-film membranes and PEBAX gas membranes.

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

Inno.CNT

Modern life would be inconceivable without mobility, but traffic and transport systems must be consistently adapted to the changing requirements of humans and markets. Increasingly, the focus of modern mobility is on requirements for environmentally compatible approaches with a high level of safety.

Materials technology plays a vital role in the development of energy-efficient concepts. High-strength synthetic materials and composite materials will make a lasting contribution to low material weight, which translates into energy savings. CNT-based materials have great potential to improve the energy balance of the mobility and transport sector. CNT-reinforced plastics and metals are especially lightweight, while offering high levels of stability and strength. These properties also are ideally suited to meet the extreme material requirements of the aviation and space industry.

As a result, the Inno.CNT projects concentrate on the development of innovative composite materials for aircraft and automotive construction, materials for the space industry, and CNT-modified coatings, which provide lightning protection for airplanes.

CarboShield: High-performance CNT coatings with improved discharge properties

For reasons of weight savings, the metallic outer shell of airplanes is increasingly replaced with carbon fiber-reinforced polymeric materials. One of the challenges associated with this trend is the decreased electrical conductivity of the shell compared to metal, which is particularly relevant with regard to lightning strikes. The CarboShield project aims to develop innovative protection systems, which eliminate the disadvantages of conventional coating systems during lightning strikes. This goal can be achieved by reducing the electrical puncture strength as a consequence of the homogenous distribution of electrically conductive CNT in the coating matrix. This step minimizes damage to the aircraft structure and reduces the weight of the protective system. Wind power systems can also benefit from these special coatings. Another focus area of the project is the development of improved insulating systems in coatings, which are used, for instance, in high-performance engines, generators, and air-cooled transformers.

CarboSlide: Plastic sliding bearings for optimized lubricant interaction

Lightweight applications in automotive construction increasingly are made of plastic, which includes highly stressed components such as sliding bearings. Due to the enormously high resulting temperatures, conventional plastic materials are not widely suitable for these kind of applications. It will take the development of a highly mechanically resistant bearing with a low friction value and high thermal stability to create a breakthrough for plastic sliding bearings. For this purpose, the CarboSlide project modified suitable synthetic materials with CNT to improve thermal conductivity and internal lubrication. These new materials may be used in shock absorbers, transmissions, and injection pumps in the future.

CarboCar: Finished surface structures offer numerous benefits

The work of the CarboCar project focuses on producing thermoplastic material systems that allow the use of fiber composites in new applications of the automotive and aeronautical industry. In cars of the future, the use of fiber composite materials will lead to substantial weight reduction. Additionally, highly conductive CNT can give such fiber composite materials sufficient electrical conductivity for electrostatic online coating. They also provide protection from lightning, which will allow for a reduction of heavy metallic lightning rods in the aerospace industry, resulting in major weight savings potential.

CarboRoad: Excellent market opportunities for CNT polymer materials

The CarboRoad project is addressing the challenge of transferring the unique properties of CNT to fiber composite materials. The work is expected to result in improvements for the entire process chain, ranging from the modification of the source material to applications and finished components. Markets for such innovative materials will include the machinery industry (surface coating of rollers with high thermal conductivity) and the sports and leisure industry (shock-absorbing racing bike saddle posts).

CarboAir: Custom-tailored fiber composite materials for aeronautical applications and wind power

The CarboAir project concentrates on innovative applications for the aeronautical industry and wind power plants. The project is making important contributions to the use of CNT in lightweight applications with high cyclical demands and tribological stress and will improve impact-resistance and flexural strength. In general terms, the project aims to improve the mechanical properties of epoxy resins for improved matrix stability and rigidity in composite materials, which will translate into higher fiber-parallel pressure-resistance and interlaminar shearing strength. The application project investigates five applications from the air, space, energy, security, and medical technology sector.

CarboSpace: Innovative solutions for aerospace

The space industry consistently demands more lightweight materials with special structural properties such as high rigidity and optimal elasticity. Additional integrated functions, such as fatigue monitoring, are of great interest as well. In light of this, the work of the CarboSpace project focuses on improving individual special properties of duroplastic composite materials by integrating CNT, while optimizing the entire property profile of the materials with regard to mechanical, thermal, and fatigue characteristics. Optical structures made of the new composite materials ideally should also have a high level of dimensional stability. The new materials will be used in earth and sky observation missions, which are exposed to severe temperature fluctuations and spatial radiation.

Top: CNT-reinforced motorcycle helmets are lighter and provide higher mechanical stability than conventional products.

Center: CNT-based materials are able to withstand the extreme conditions of aeronautics.

Bottom: CNT plastics improve the lubricant interaction in gear drives and injection pumps.

Lightweight construction: Innovations with major market potential

Inno.CNT

Conventional design materials currently used in aeronautical applications, the automotive industry, and machinery increasingly are reaching the limits of passive structures. Lightweight construction concepts on the basis of CNT offer enormous potential, including for use with extraordinary structural stresses. As high-strength, ultra-light materials used for lower-weight designs of cars and aircrafts, they make an important contribution to higher energy and resource efficiency and save substantial amounts of fuel.

However, lightweight construction also benefits other industries and applications. CNT-based particle foams offer improved traffic security, while specialty concrete offers additional design options and improved earthquake protection.

The five projects associated with the area of lightweight construction pursue the goal of developing lightweight plastic and composite materials, ultra high-strength concrete, and mechanically high-resilient metals.

CarboProtekt: Greater security with CNT foams

The objective of the CarboProtekt project is to enhance traffic security by developing custom-tailored CNT foams. The addition of carbon nanotubes will improve mechanical stability. At the same time, the innovative foams are able to adsorb a significant amount of deformation energy, which may result in considerably higher security. Specific developments of the CarboProtekt project include a bicycle helmet made of CNT-modified foams and an automotive bumper insert, which will greatly improve the protection of pedestrians.

CarboTube: Plastic materials with outstanding properties

CNT-based components for automotive and electrical applications as well as tubes and materials for cabling are at the center of the CarboTube project. It explores the capabilities of CNT to significantly improve antistatic properties, thermal and electrical conductivity as well as mechanical and thermo-mechanical characteristics. The CarboTube project also aims to develop and ensure the reproducibility of these product properties for large-scale production. This will require a systematic scale-up of compounding and processing steps from a laboratory scale to a production scale, which is reflected in the project. The projected final products include molded automotive parts that allow for electrostatic coating and no longer need a conductive primer and extensive surface treatments as well as tubes and cable applications with specific thermal and electrical conductivity. These have the potential to result in major cost savings.

CarboElast: High-performance sealants for multiple applications

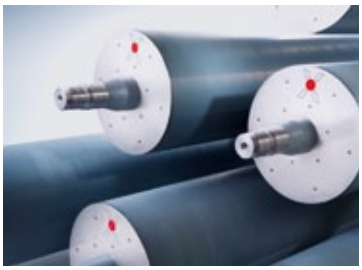
Security-related components that must withstand the highest demands, such as tires, drive elements, motor bearings, sealants, or hoses are made from elastomeric materials and partially thermoplastic elastomers. The Inno.CNT project CarboElast develops innovative CNT-modified elastomeric and thermoplastic materials with an improved performance range to expand existing applications with optimally dispersed CNT and to open up new fields of utilization. The project covers the entire value chain from the manufacture of special CNT preparations for elastomeric materials with a wide range of applications to compounding and model and real systems all the way to the production of demonstration components for high-performance sealants. The resulting insights will be applied to drive elements, tire surfaces, hoses, and motor bearings.

CarboMetal: Innovative lightweight construction concepts for metals

CNT also have the potential to substantially improve the weight, strength, and rigidity of metals. The objective of the CarboMetal project is to improve aluminum, magnesium, titanium, and copper alloys with CNT. The newly developed materials are to be used in innovative lightweight construction concepts in transport, turbine, and wind power technology. Further tasks of the project include the improvement of materials for optoelectronics, such as LED displays and laser diodes along with welding additive materials and low-abrasion components for engines and aerospace applications.

CarboBau: Limitless construction with innovative high-strength concrete

The CarboBau project of Inno.CNT focuses on the development of a new ultra high-strength concrete, in which CNT are to contribute to improving the mechanical properties and enhancing the durability of this versatile building material. At the same time, these improved characteristics make concrete more sustainable. The development would allow for concrete structures with more stable or more filigreed components, while maintaining their performance and even increasing their expected service life. For architecture, this opens up new design options in addition to tangible material savings. In the future, ultra high-strength concrete may be used for the construction of high-rises and bridges in forms and scales that are not feasible in the present.



Top: Innovative automotive bumper inserts made with CNT offer improved protection for pedestrians.

Center: CNT-reinforced composites have a wide range of applications.

Bottom: Materials optimized with CNT have enormous innovative potential for lightweight construction concepts in transport, turbine, and wind power technology.

Development of fundamental technologies: Tangible benefits for humans, the environment, and society

Inno.CNT

The cornerstones of the Innovation Alliance CNT are the cross-sectional technologies, which are being addressed in three overarching projects. Their key task is to create the technological basis for the application developments and to make carbon nanotubes and intermediate products containing carbon nanotubes available in adequate quantities, suitably modifications, and in the right quality.

CarboScale: The basic principles of top-quality CNT production

The focus of the CarboScale project is on the technical production of highly pure CNT in top quality. The development of modern generations of highly active catalysts for the so-called fluidized bed process plays a key role in this context. This method allows for the targeted development of new CNT structures, which are custom-tailored to the needs of specific applications. Since the catalysts have an essential impact on the morphology and product properties of the CNT, it is important to create mandatory technical standards that ensure the production of the required quantities in customizable and consistent quality. Another core aspect of the project is the process technology, in which all relevant parameters for CNT are precisely aligned to allow a tailored up-scaling to an efficient production process. The project also analyzes new CNT types that have just been identified and transfers their synthesis processes to the pilot scale. The work is supported with mechanistic analysis.

CarboFunk: Optimal integration of CNT into the surrounding material

In many cases, a customized bond between the carbon surface and the surrounding materials is indispensable to ensure that CNT can display the full range of their outstanding electrical, thermal, and mechanical properties in composites. These bonds are specific for every material. The CarboFunk project is dedicated to resolving this challenge. Its core objective is to functionalize CNT, meaning that the surface of CNT is chemically modified in such a way it allows for optimal integration into a wide range of materials and to optimize the intended corresponding applications. For this purpose, the project is developing processes that can be up-scaled to industrial use to allow for production in larger quantities.

CarboDis: Production of application-specific intermediates

The aim of the CarboDis project is to better understand and control the intentional integration of CNT into a variety of polymeric structures. So-called dispersion processes ensure that CNT, which typically exist in entangled and agglomerated form, can be dispersed and distributed in a customized manner into a polymeric base material. The various project partners are performing work to investigate the dispersion of CNT in all types of basic polymers, i.e. thermoplastics, thermosets, and elastomers, to provide adequate results and expertise in every material class. This knowledge will make it possible for CNT to unfold its full potential in the corresponding applications, for example in the form of electrical conductivity and/or high mechanical strength with low mass fraction of CNT additives.

Research and responsibility: Safe use of carbon nanotubes

The two comprehensive projects CarboSafe and CarboLifeCycle concentrate on questions that address the potential health effects and environmental impact during production, processing, use, and recycling of products that contain CNT. The project results will consist of methods and measures to guarantee the safety of CNT throughout their lifecycle.

CarboSafe: Contributions to the safety concept of CNT-based products

In order to guarantee the safety of CNT and products based on them, it is necessary to evaluate and appropriately communicate potential risks. This requires detailed knowledge of possible exposure paths and the effect of CNT in conjunction with biological systems. The development of the corresponding test methods for the determination of exposure and the characterization of CNT are essential parts of this approach. The cross-sectional project CarboSafe of the Innovation Alliance CNT addresses these challenges. The fundament of the project work is the development of well-grounded measuring technologies that are able to clearly detect the release rates of nanoparticles throughout the lifecycle of products based on CNT. Moreover, the CarboSafe project plans to identify the eco-toxicology potential of CNT and to arrive at a precise estimate of the risk potential on the basis of the developed measurement technologies.

CarboLifeCycle: Pursuing safety-relevant questions in the CNT lifecycle

The CarboLifeCycle project builds on the results of the CarboSafe project for further safety research. The core tasks of the project, in addition to further eco-toxicological considerations, include the development of personal measuring technology worn on the body, further refinement of measuring strategies, and measurements of potential exposure during the manufacture, processing, use, and the end of life of CNT and CNT-based products. The project also plans to advance the quantitative determination of functional groups on CNT and to validate eco-toxicological test systems with regard to potential long-term effects of CNT and their effects at the cell level.

Inno.CNT develops measurement methods (Figure 1) and measures for the greatest possible safety along the entire value chain. This includes the production of CNT (Figure 2), handling the source material (Figure 3), and the integration of CNT into different polymeric structures (Figure 4) along with the use of CNT-based products (Figure 5) and their disposal.

Questions?
We are here to help.

Inno.CNT

Inno.CNT emphasizes open, factually differentiated, and timely communication and looks forward to receiving your questions and suggestions. Please feel free contact us. For more information, visit our website at www.inno-cnt.de or call us at 01805-133 422*

Imprint

Published by:
Innovationsallianz CNT (Inno.CNT)

Concept, editing and design:
SpiessConsult GmbH & Co. KG, Düsseldorf

Photos:
Front and back page: medicalpicture GmbH
P. 3: Bayer MaterialScience AG
P. 4: Bayer MaterialScience AG
P. 6: Helmholtz-Zentrum Geesthacht
P. 7: iStockphoto, dpa GmbH, ZBT GmbH
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plainpicture GmbH
P. 16: Helmholtz-Zentrum Geesthacht
P. 17: plainpicture GmbH, TU Hamburg-Harburg,
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Status: January 2011

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E-mail: info@inno-cnt.de | www.inno-cnt.de

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