VIAVISION

VOLKSWAGEN GROUP • SHAPING THE FUTURE OF MOBILITY

NO 08
October 2012

Nanotechnology

Small Particles – Big Effect

In order to get
a human hair to nano size you would
have to divide it 80,000 times.

Every ninth patent
in the field of nanotechnology in Europe
comes from Germany.

Editorial

Dr. Ulrich Hackenberg, Member of the Board of Management of Volkswagen Brand with responsibility for Research and Development.

Today nanotechnology is already employed in many different industry sectors – it also plays an important role in the automobile business. In this issue, *VIAVISION* explains what makes nanoparticles so useful, in which sectors of vehicle technology they are applied and how German nano research ranks internationally.

I wish all readers a happy read.

Nano Worlds

In the Realm of Molecules

If you divide a millimetre into one million parts, you have reached the nano scale. In order to get a human hair to nano size, for example, you would have to divide it 80,000 times. Nanoparticles have specific characteristics because of their small size. Every material that is reduced to the size of nanoparticles changes its mechanical, geometrical, chemical, optical or electronic properties. One reason for this is that the reduction changes the relation between volume and surface area. If you divide, for example, a big cube into many small ones then the increased surface area of the many small cubes is greater than the surface area of the big cube – although the volume is unaltered. Because of this effect one gram of nano crystalline powder can have a surface area as large as a football field.

New properties:

Mechanical
Nano materials are especially hard and resistant to breaking because the particles are so small that deformation within them cannot take place. The material thus does not yield but stays stable.

Chemical
The surface area of nanoparticles that are especially large in relation to their volume increases their ability to respond to chemical reactions. This is why they can act as catalysers and accelerate chemical processes.

Geometrical
At the nano scale not only are the particles tiny but also the distances between them, once they are set into a structure. Their permeability can be exactly defined, in order to make them more resistant to water or corrosion, for example.

Optical
Nanoparticles are so small that they reflect very little or even no light at all. Thus, an anti-reflection nano coating can be put on smooth surfaces.

Electronic/magnetic
The mobility of the charged particles is limited by the small size of nanoparticles. Thus the desired electronic charges or magnetic polarities can be maintained stably.

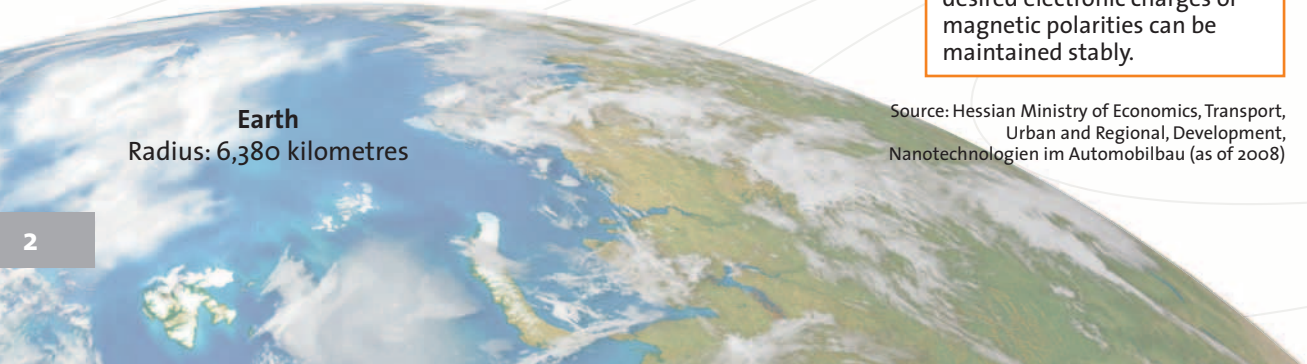
Source: Hessian Ministry of Economics, Transport, Urban and Regional, Development, Nanotechnologien im Automobilbau (as of 2008)

Proportions:

The nano world is almost unimaginably small: one nanometre relates to one metre like the radius of a hazelnut to that of the earth.

Source: Baylab Plastics (as of 2012)

Hazelnut
Radius: 0.000006 kilometres (six millimetres)

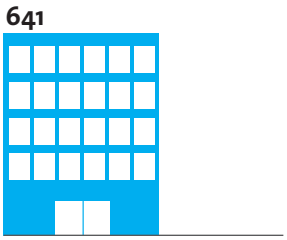


Earth
Radius: 6,380 kilometres

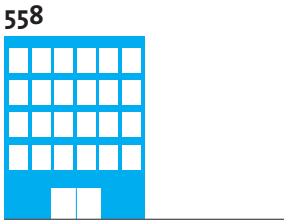
Pictures: freshidea – Fotolia.com; knipseline / PIXELIO

Nano in industry and research:
(number of institutions*)

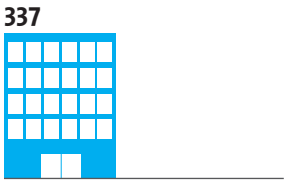
*There are a total of 1,996 facilities in Germany operating in the field of nanotechnology, of which many are active in multiple fields of operations. The products listed are examples.



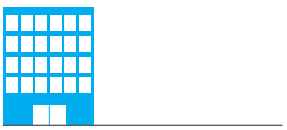
Chemistry/materials
- self-healing lacquer
- residue-free adhesive connections
- electroconductive plastics



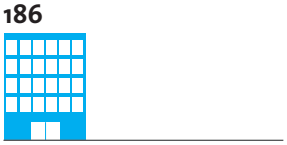
Mechanical engineering
- diamond coating for ultra-hard blades
- industrial rollers with non-stick properties
- film and fibrous sensors



Health
- contrast agents for magnetic therapy
- magnetic probes for tumour detection
- agents for drug delivery

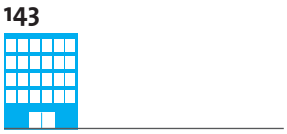


Energy
- efficient solar cells
- alloys for permanent magnets in wind power plants
- conductive membranes for fuel cells



Optics
- organic light diodes in printable materials
- glass fibre networks
- ultra-precise telescope mirrors

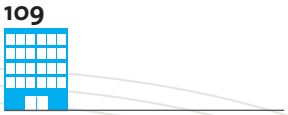
Information and communication technology
- flash memory with high storage density
- energy efficient electronics
- hard-disk storage with particularly small cells



Environmental
- nanoparticles for drinking water treatment
- ceramic filter parts for cleaning up industrial effluent
- nano-encapsulated active substances in plant protection products

Consumer goods
- glasses with light-dependent tone
- thermoregulatory clothing
- sunscreen

Construction
- ultra high-strength concrete
- anti-soiling and self-cleaning wall colours
- refractory building materials



Mobility
- fuel additives
- rubber compounds for ultra-durable tires
- scratch-resistant coatings

Textiles
- antibacterial clothing
- textile integrated MP3 players or organic LEDs
- heated textiles

Safety technology
- absorbent gels for the neutralization of hazardous substances
- bulletproof clothing
- sensors for the detection of biochemical warfare agents

The areas in which nanotechnologies are being researched, or used most intensively, can be seen by the number of networks, research institutes, universities and companies that work with the minute particles in Germany. The variety of application examples shows that it is a so-called cross-cutting technology, that is employed virtually everywhere in industry.

Sources: Federal Ministry of Education and Research (twice), Competency Map Nanotechnology in Germany (as of September 2012); nano.DE-Report 2011

Bionics

The idea of searching for technical innovation by observing nature is not new: even Leonardo da Vinci designed his flying machines in accordance with those principles employed by flying birds. Today the neologism bionics, a composite of the words 'biology' and 'electronics', signifies the adaptation of biological knowledge into technological applications. The manufacture of car paint, for example, is inspired by the butterfly. Its wings shimmer in different tones, depending on the angle of vision, because light is reflected from different levels within the surfaces.

Picture: Sunny07 - Fotolia.com

Invisible Ingredient

How Nanoparticles Improve the Car

You cannot see them with the naked eye; an electron microscope is needed. So you could easily overlook that nanoparticles are already well established in our surroundings. They are put to use in the automotive industry too, where many different materials are assembled into one product. Here, researchers and developers have three goals: making the car increasingly safe for the car driver and passengers, increasing driving comfort, and reducing environmental impact. On the following four pages *VIAVISION* shows how the exterior of the car has evolved using the small particles and which nanotechnologies have found their way into the interior of the vehicle.

Mechanical
Chemical
Electronic/ magnetic
Geometrical
Optical

Picture: Volkswagen

Hot forming of steel (car body)

The body of a car must be particularly stable and resistant, in order to protect the people inside in case of an accident. This is why steels are used here, that have an extremely high stability due to the hot forming process.

Nano: High-strength steel is produced in a hot forming process. For this, it is coated with a protective varnish of nanometre sized glass and plastic particles and then heated to 950 degrees Celsius. Without coating, greater friction, dirt and corrosion would occur during the forming process.

Advantage: The nano protective coating facilitates the use of high-strength steel for vehicle bodies.

Sources: Hessian Ministry of Economics, Transport, Urban and Regional, Development, Nanotechnologien im Automobilbau (as of 2008); Volkswagen; ThyssenKrupp (both as of 2012)

Clear coat (car body)

Clear coat protects the base coat of a car from external factors. It is applied at the end of the painting process and ensures brilliant colours and scratch resistance.

Nano: Ceramic nanoparticles are embedded into the clear coat, which connect when the paint dries. They form a dense network of ceramic particles on the surface.

Advantage: The clear coat is more stable and less prone to damage. In addition, the ceramic nanoparticles increase the shine of the coloured base coat.

Source: Hessian Ministry of Economics, Transport, Urban and Regional, Development, Nanotechnologien im Automobilbau (as of 2008)

Ultra-thin aluminium films (lights and mirrors)

Mirror and headlight reflectors are made of aluminised glass or plastic.

Nano: The aluminium layer is vapour deposited. In this process a reflective coating, less than 100 nanometres thick, is created.

Advantage: Less aluminium is needed during the vaporisation of glass and plastic parts than in conventional coating processes, thus saving materials and cost.

Source: Hessian Ministry of Economics, Transport, Urban and Regional, Development, Nanotechnologien im Automobilbau (as of 2008)

Tread (tyre)

The tread of a tyre, which is most stressed due to its direct contact with the road, consists of about 30 percent carbon black, silica and carbon. These fillers, combined with rubber, reduce abrasion and rolling resistance, and prolong the life of the tyre.

Nano: Carbon black and silica are processed in nanometre size. Thus the interaction between the nanoparticles and the rubber molecules increases.

Advantage: The tread material deforms less under load, thus lowering rolling resistance and fuel consumption.

Source: Hessian Ministry of Economics, Transport, Urban and Regional, Development, Nanotechnologien im Automobilbau (as of 2008)

Nanotechnology is employed as standard in more and more cars, for example in the new Golf.

Particle filter (catalytic converter)

Particle filters bind particulate soot generated during combustion and prevent them from reaching the outside air along with the exhausts.

Nano: Modern catalytic converters filter the exhaust with a metallic fabric, in the pores of which nano-sized precious metals are applied. There, the soot particles are deposited and burned at 200 degrees Celsius.

Advantage: The nano structures increase the surface area for the catalytic process, thus binding significantly more pollutants.

Source: Hessian Ministry of Economics, Transport, Urban and Regional, Development, Nanotechnologien im Automobilbau (as of 2008)

Cockpit (dashboard)

The glass instrument panel protects the display from dust and dirt.

Nano: Glass with microscopically small air pockets or anti-reflection coatings, in the nanometre range, refracts less light on the surface.

Advantage: Scattering effects and reflections are less common.

Source: Hessian Ministry of Economics, Transport, Urban and Regional, Development, Nanotechnologien im Automobilbau (as of 2008)

Magnetic sensors (assistance systems)

Magnetic sensors in the car ensure the car's handling adapts to certain situations. They recognise, for example, the speed of the motor or the tyre pressure by changes in the magnetic field and convert the data into an electrical signal. These assistance systems use the information to change the driving dynamics, if necessary.

Nano: Magnetic sensors based on the giant magnetoresistance effect (GMR) consist of multiple nanometre thin layers, which are alternately magnetic and non-magnetic. A change in polarity of one of these layers creates an electrical resistance, which is many times higher than that of conventional magnetic sensors.

Advantage: GMR sensors are much smaller and provide for relatively clear, consistent and measurable results, even given large temperature variations.

Sources: ITWissen.info (as of 2012); Hessian Ministry of Economics, Transport, Urban and Regional, Development, Nanotechnologien im Automobilbau (as of 2008)

Picture: Volkswagen

Lithium-ion battery (engine)

For hybrid and electronic cars, lithium-ion batteries offer an alternative to lead or nickel-metal hydride batteries. They are lighter, smaller and have better performance. The so-called separator is located within the batteries. This membrane divides the positive and the negative poles in order to prevent short-circuits. It is permeable for certain ions which start the electro-chemical reaction that releases electric energy.

Nano: Separators are coated with ceramics. This coating consists of the smallest metal oxide particles which are fused together.

Advantage: Unlike the plastic separators that were used previously, the ceramic separator keeps its original shape under high temperatures and is not flammable.

Source: Hessian Ministry of Economics, Transport, Urban and Regional, Development, Nanotechnologien im Automobilbau (as of 2008)

Textiles (seat upholstery)

A spray that is applied to the cushions carries fragrances – that of new cars for example.

Nano: The microcapsules contained within the spray are so small that they penetrate the fabric – no matter whether leather or cloth – and stick between the fibres. The fragrance in these capsules is released whenever a seat is occupied.

Advantage: The desired fragrance does not require continual restocking.

Source: Hessian Ministry of Economics, Transport, Urban and Regional, Development, Nanotechnologien im Automobilbau (as of 2008)

Air filter (air conditioning)

The cabin air filter cleans the air entering the car from pollen, dust and odours.

Nano: The filtration surface area is increased by the employment of nanofibres. At the same time, the microscopic fibres create almost no drag, thanks to their small size. This way air enters the car without great pressure loss.

Advantage: The filters work more efficiently because of the greater surface area and allow more air to enter the car, thanks to the lower air resistance – saving energy.

Source: Hessian Ministry of Economics, Transport, Urban and Regional, Development, Nanotechnologien im Automobilbau (as of 2008)

Driving Innovation

Vorsprung durch Nano

Nanotechnology is seen as a key technology because it does not focus on a particular industrial sector, but is applicable almost everywhere. The impact it has on the economy and competitiveness of a country is high. New products not only provide more jobs, but also a strengthening of the respective business location.

Leading nanotechnology nations:

1. USA

2. Japan

3. Germany

Lux Research has created an international ranking based on factors like research budgets or number of natural science students.

Source: Lux Research (as of 2012)

Research and development spend:
(share of total revenues in percent)

Revenue:
14.3 billion euros
Research and development spend:
1.4 billion euros

GDP:
2,404 billion euros
Research and development spend:
67 billion euros

Revenue:
1,186 billion euros
Research and development spend:
29.4 billion euros

Spending on research and development can be seen as a measure of innovation in a sector, country or company. The more that is invested, the more innovation is driven, which then provides more jobs and increases competitiveness.

Sources: Federal Ministry of Education and Research, nano.DE-Report 2011; Ernst & Young (as of 2012); Report on Research and Innovation 2012

Race for patents:
(share of all registered patents in Europe in percent)

Between 1989 and 2009, more than 160,000 nanotechnology patents were registered in Europe. Every ninth comes from Germany.

Source: Federal Ministry of Education and Research, nano.DE-Report 2011

* The research quota of states is displayed as the ratio of research spend to gross domestic product; the value refers to the year 2009.

Imprint

www.viavision.org.uk, www.viavision.org

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Published by
Verlag Rommerskirchen GmbH & Co. KG
Mainzer Straße 16 -18, Rolandshof,
53424 Remagen
Phone: +49 (0)2228/931-0
www.rommerskirchen.com

Printed by
L.N. Schaffrath GmbH
Marktweg 42-50, 47608 Geldern