Content Unit

[Nano in everyday life]

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Last processing date: [01.12.2021]

Nano in everyday life

First introduction

Did you know that geckos have tiny little hairs on their feet, so that they can stick to even and very smooth surfaces? They use these special structures on their toes to climb up walls and windows. Do they use a special glue for that? When you have a closer look, these toes are completely glue-free. They stick to the wall due to the nano-sized structures that creates a special bonding. Scientists all over the world are trying to learn more about the geckos' toes to use it, for example, for robots that can climb houses and rescue people from burning buildings. Understanding this and other examples from nature helps design new materials for our lives. Nano is everywhere.

Practical relevance – This is what you will need the knowledge and skills for

Here you will find out, that nature uses nanotechnology for amazing features of animals and plants. And that we as humans are very eager to learn from them. Moreover, you will see, that even when you are not aware, nanotechnology can pop up in your everyday life. From brushing your teeth, to cleaning your sink, to what you are wearing. After going through this unit you will be amazed on how often you will walk by everyday items and think: This works because of nanotechnology!

Overview of learning objectives and competences

In the first learning objective we will have a look at what nanotechnologists can learn from mother nature. The following learning objectives will highlight nanotechnology in the different areas of everyday life. From applications in kitchens and homes to functional textiles and use in cosmetics, nanomaterials appear frequently in our regular lives.

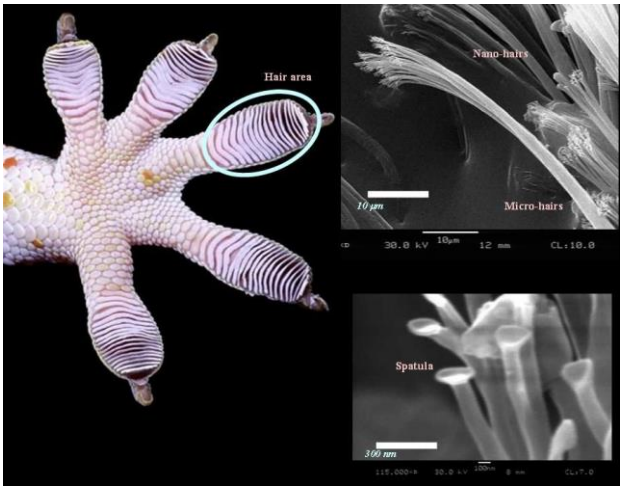
Learning objectives	Fine objectives
LO_NanoineverydayLife_01: Idols in nature	FO_NanoineverydayLife_01_01: You will learn more about what is so special about the Geckos' toes FO_NanoineverydayLife_01_02: You will learn how a chameleon can change its colour FO_NanoineverydayLife_01_03: You will learn how a plant keeps their leaves tidy
LO_NanoineverydayLife_02: Nanotechnology in kitchen and homes	FO_NanoineverydayLife_02_01: Easy to clean surfaces FO_NanoineverydayLife_02_02: Touchscreens FO_NanoineverydayLife_02_03: Nanotechnology in food FO_NanoineverydayLife_02_04: Lightweight constructions
LO_NanoineverydayLife_03: Nanotechnology in textiles	FO_NanoineverydayLife_03_01: Nanosilver has antimicrobial functionality

	(sportswear/masks/…) FO_NanoineverydayLife_03_02: Nanotechnology for raincovers FO_NanoineverydayLife_03_03: UV protection in clothing
LO_NanoineverydayLife_04: Nanotechnology in cosmetics	FO_NanoineverydayLife_04_01: Sun protection with nanomaterials FO_NanoineverydayLife_04_02: Whiter and healthier teeth by nanotechnology FO_NanoineverydayLife_04_03: Black pigments in mascara and eyeliner

1.LO_NanoineverydayLife_01: Idols in nature

In the action film *Mission: Impossible*, secret agent Ethan Hunt climbs up a glass building with gecko gloves. The idea is based on the adhesion principle of real geckos, which can walk up glass walls or upside down without much effort and without falling.
To do this, they use the so-called Van der Waals forces. These forces form between individual atoms and molecules. The charge in the atoms shifts in such a way that they act like small magnets and attract each other.
To be able to use this effect, geckos have millions of so-called “setae” on their feet, hair-like tips, each of which in turn ends in a bundle of very fine tips. This surface forms a bond with the surface on which the gecko moves, based on Van der Waals forces.

Remember
Van der Waals forces Van der Waals forces occur when the charges in atoms spontaneously shift in such a way that they act like small magnets and attract each other.



Chameleons also use nanotechnology. Within a few minutes, chameleons can radically change their skin colour. This ability can be very useful, especially for camouflage against enemies. Behind the play of colours are nanocrystals, which are in the skin of the reptiles. They have two superimposed layers of specialised skin cells, so-called iridophores, which reflect light with the help of nanocrystals.

The nanocrystals are arranged in the form of a grid in the upper skin layer of the chameleons, which is only fully developed in the males. They are also smaller than in the lower skin layer. The colour of the chameleon depends on the distance between the crystal layers and can thus be varied.

The nanocrystals are close together when relaxed, which leads to the reflection of short-wave blue light. Due to the yellow pigments in the animals' skin, the chameleon appears green in the mixed colour when relaxed.

When the reptile is stressed, the structure of the crystals changes so that they are up to 30 percent further apart than in a relaxed state. Now, long-wave red light is reflected and the animal changes colour from yellow to orange.

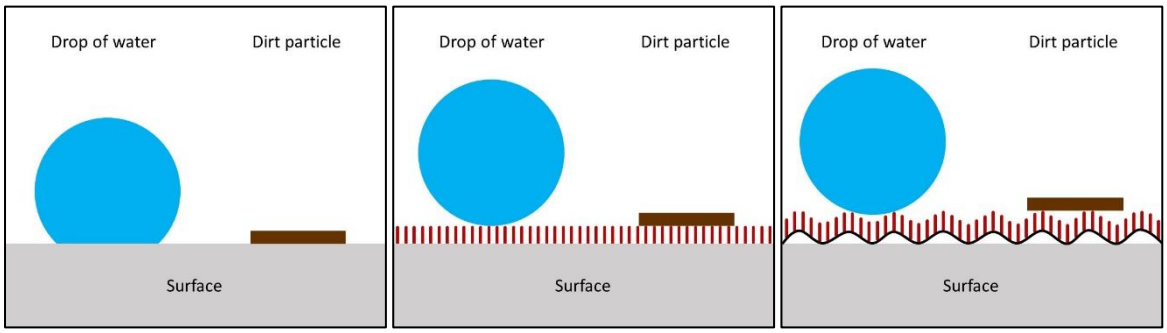
However, the lower, much thicker iridophore layer of the chameleon has another function. Due to the larger and chaotically arranged cells, mainly light in the infrared range is reflected. As a result, the reptiles do not heat up so quickly and can survive even in areas with strong sunlight.

Excurse

Reflection and transmission of light

When light in the form of different wavelengths hits an object, part of the light in a certain wavelength range is absorbed by it. The remaining radiation is reflected, and the object appears in the colour of the reflected light.

There are also phenomena in the plant world that are based on nanotechnology. The large leaves of the lotus plant are famous for the fact that water simply rolls off them. Dust and dirt are carried away, so that the surface is cleaned without leaving any residue. The so-called "lotus effect" is also found in nature in other plants and animals, such as dragonflies and butterflies. Their surfaces are covered with fine nubs of wax crystals. When dirt particles and water are on the leaf, they rest on the tips of the nubs. Since the drop of water only rests on the elevations of the wax crystals, most of the drop surface is in the air. The repulsive effect of the air increases the surface tension in the drop, making it spherical. Due to the reduced surface area that the water drops touch on the plant leaf, it rolls off without problems and picks up dirt particles.



The contact area is largest on a smooth surface.

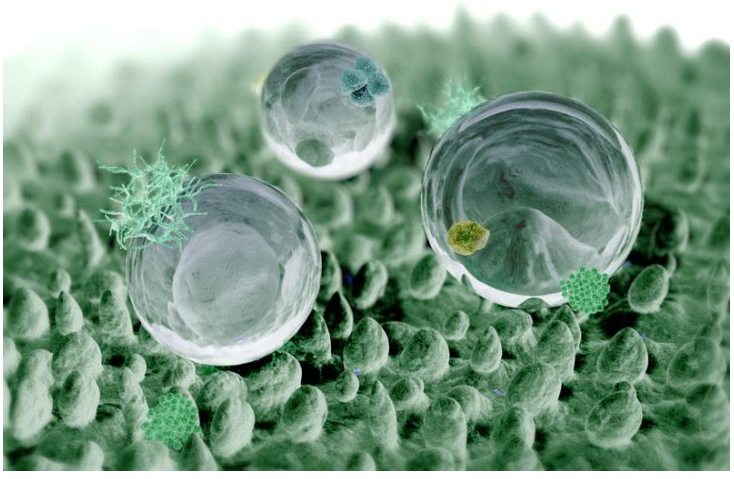
The wax nubs significantly reduce the contact area.

The uneven surface of the leaves and the wax nubs make the contact area even smaller.

Definition
Surface tension Surface tension is the phenomenon that occurs in liquids because of molecular forces to keep their surface area as small as possible.

2.LO_NanoineverydayLife_02: Nanotechnology in kitchen and homes

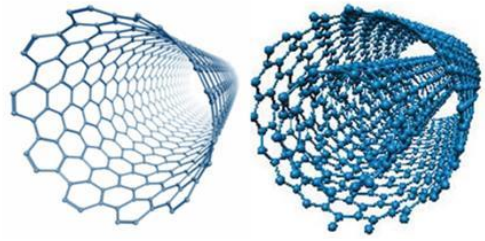
The previously discussed lotus effect is not only used in the animal and plant world to clean surfaces. There are also numerous applications for so-called nanocoatings at home. Coated windows virtually clean themselves when it rains, while conventional windows continue to get dirty. In addition to windowpanes, wood and furniture are also frequently sealed with nanotechnology products. This prevents dirt, water, oil, and grease from melting onto the surface. Nano cosmetics for household items, based on the hydrophobic coatings for cars, is very popular at the moment. With the help of nanotechnology, special sealants have now also been developed for textiles, which have a dirt-, oil- and water-repellent effect.



Definition
Hydrophobicity The term hydrophobic comes from ancient Greek and literally means "water-avoiding". By definition, hydrophobicity describes the association of non-polar molecules or groups in an aqueous environment, due to the tendency of water to

exclude non-polar groups or molecules. As a result, they can no longer mix with water and usually cause it to bead up on surfaces.

Nanotechnology is also used in everyday technology. In the meantime, the introduction of the multi-touch screen is more than 10 years ago, and the multi-touch display has also established itself as a standard in industry. Good electrical conductivity combined with high optical transparency is one of the core requirements for the touchscreen. Transparency is made possible using a transparent conductive film (TCF). Initially, ITO (indium tin oxide) was used almost exclusively for this purpose. This could be processed by etching or laser irradiation.
The further development of the technology brought with it additional requirements. To meet them, the ITO films were replaced by alternative technologies due to their low UV stability and lack of mechanical flexibility. These include metal mesh (mostly copper-based), silver nanowires (AgNW), PEDOT (conductive polymer) or sensors based on copper wires. Since these materials also have different weak points, transparent conductive films based on carbon nanotube hybrids have been developed. This material is also highly conductive and transparent, can be processed very easily and is therefore very flexible to adapt to the user surface.
Carbon nanotubes are individual tubes made of carbon. They have diameters in the range of typically 1 to 50 nanometres, are extremely stable and have high strength. Depending on the design, the single-walled or multi-walled tubes can range from insulating to semi-conductive to fully conductive.



SW = Single wall **MW = Multi wall**

If, for example, carbon nanotubes in the form of a screen-printable paste are combined with a film of silver nanowires, the result is the desired CNT hybrid film.
The combination of the two materials uses the advantages of the individual components, making the hybrid material more conductive and transparent than the two individual materials.

Important

Carbon nanotubes (CNT)

Carbon nanotubes (CNT) are molecular nanotubes made of carbon. The carbon atoms here adopt a honeycomb-like structure with hexagons. The diameter of the tubes is typically in the range of 1 to 50 nm, but tubes with a diameter of only 0.4 nm have also been produced.

Nanotechnology is often associated with high-tech, such as computers or spaceships. But the food industry also benefits from the tiny helpers.
A milkshake whose taste can be influenced by how long it is shaken. This idea could soon become reality. The so-called nanocapsules, which are between ten and one hundred nanometres small, consist mostly of fat molecules. They can be filled with vitamins, flavours, or dyes as desired and prepared in such a way that they only dissolve when exposed to certain stimuli, such as mechanical force.
The nanocontainers are particularly interesting for so-called "functional food", i.e. all those foods that are already artificially enriched with vitamins and nutrients. In Australia, for example, a bread baked with fish oil was brought to market, whose cholesterol-lowering omega-3 fatty acids only unfold in the stomach.
Another idea would be to enrich dairy products with calcium, as it is needed for many different bodily functions. However, the increase in calcium leads to the milk becoming lumpy after a certain amount. Nanocontainers could also help here by packing the calcium into a capsule made of proteins.

However, nanoparticles in food are no longer a novelty. They have been in some foods for years without being noticed.

Titanium dioxide particles are widely used and are mainly used in baking agents, but also in sweets, chewing gums and chocolates. The additive makes the coating of the food glossy and smooth. Silicon dioxide is typically used as an anti-caking and free-flowing aid, especially in powdery foods of all kinds such as coffee whitener, soup, or spice powders. In ketchup, silicon dioxide causes it to flow better from the bottle.

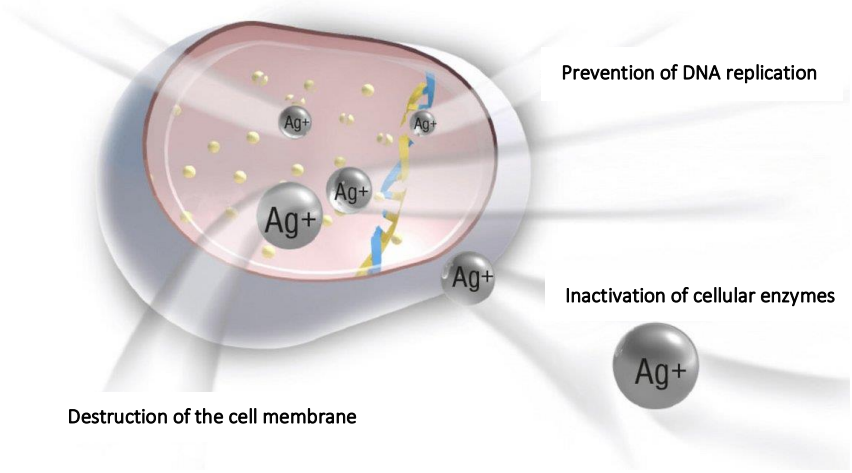
Remember
Nanoparticles in food Particles in the nanometre range can change the properties of food, for example to make it more free-flowing or liquid.

Nanoparticles offer interesting new possibilities in areas of lightweight construction through the development of very resilient, durable and at the same time extremely lightweight composites.
Composite materials result from the combination of different types of materials. In the process, the positive properties of the different components are combined with each other. In the case of CFRP (carbon fibre-reinforced plastic), carbon fibres are combined with different resins. The carbon fibres cause the material to attain high rigidity and strength. In addition, the reinforcing fibres ensure high vibration resistance, low thermal expansion, as well as permanent temperature resistance and freedom from corrosion. The most significant advantage, however, is the excellent strength-to-weight ratio of the material.
Lightweight components, which have to withstand high loads, benefit enormously from this property. Carbon fibres make it possible to reduce the weight of structural components in vehicles by up to 80 %.
Weight reduction in motor vehicles is of great importance, especially with regard to environmental and climate protection. The weight savings through CFRPs ensure significantly lower fuel consumption of vehicles, which goes hand in hand with decreasing CO_2 emissions.
In addition, the mass reduction ensures that smaller-dimensioned brakes and engines still deliver the same driving performance.
In addition to its low weight, the functional material also has excellent mechanical properties. By specifically aligning the carbon fibres in the direction of the load, the strength can be increased enormously and the amount of material used can be reduced.
These high-tech materials can not only be found in automobiles or planes, but also in recreational objects such as bicycles or badminton rackets.

Important
Carbon fibres Due to the excellent ratio of weight to strength, carbon fibres are often used in lightweight construction. Weight savings of up to 80 % can be achieved.

3.LO_NanoineverydayLife_03: Nanotechnology in textiles

Silver in its pure form is quite inert. Silver ions (Ag+), on the other hand, are highly reactive and able to interrupt vital processes in bacterial cells, which ultimately kills them. This property is used in the textile industry, among others. In contrast to conventional antibiotics, the ions do not only attach themselves to a specific cell area, but simultaneously prevent various cell activities. This property makes it possible to fight even antibiotic-resistant bacteria with nanosilver. Besides bacteria, silver ions also render other microbes such as viruses and fungi harmless. Nanosilver is therefore not only antibacterial, but also antimicrobial.



https://www.lamilux.de/hub/hygiene-und-forschung/was-ist-nanosilber.html

In addition, significantly lower concentrations of active ingredients are required than for (metal-)organic biocides. In addition to preventing the transmission and spread of pathogenic germs, this also prevents the development of sweat odour, because sweat itself is almost odourless. The typical odour is only produced by the metabolisation of components of sweat by bacteria that naturally colonise our skin. However, clothing containing nanosilver does not disturb the healthy bacterial flora of the skin.
The effect of nanosilver has also been successfully used in textiles for some time. Applications for antimicrobial textiles include workwear (hospital & care, food processing), sportswear and underwear or technical textiles (ventilation systems, filtration, wiping cloths).
There are different methods to combine the nanosilver particles with fibres. On the one hand, nanosilver can be mixed into a polymer (masterbatch) before it is spun into fibres. This method is used, for example, with polyester and cellulose acetate fibres, which results in a particularly firm integration in the fibre. The antibacterial effect thus lasts for a particularly long time. Alternatively, nanosilver can be applied as a surface coating to the fibre surface. The strength of the binding and thus the duration of the effect can vary greatly here. Weakly bound particles are detached after just a few washes and end up in the sewage treatment plant.

Definition
Antimicrobial Antimicrobial substances (such as nanosilver) are chemical substances that reduce the infectivity and reproductive capacity of microorganisms such as bacteria, viruses, or fungi or kill them.

Nanocoatings can also make textiles more resistant to environmental influences. Water- and dirt-repellent nanomaterials are inspired by the lotus leaf and are often found in raincoats. They have a rough (in the micro- and nanometre range) as well as hydrophobic surface and contain nanometre-thin coatings of silanes or siloxanes. Temporary coatings can also be sprayed on, for example with an

impregnation spray. This results in even non-functional materials becoming water-repellent and self-cleaning.

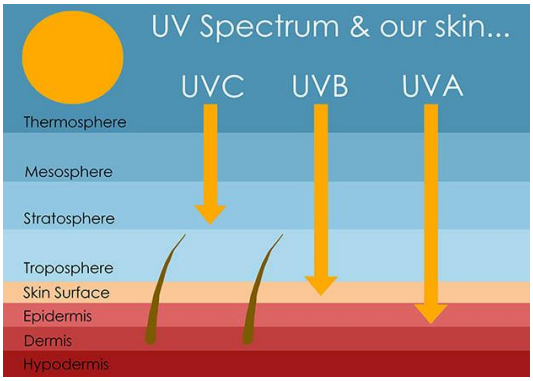
Excourse
Silanes and siloxanes Silanes and siloxanes are hydrophobic molecules made of silicon or silicon and oxygen, respectively, which have a water-repellent effect.

Ultraviolet radiation in the form of UV-A and UV-B radiation is a component of natural sunlight. In addition to the often-desired tanning of the skin, however, the radiation can also lead to painful sunburns and even genetic damage. Since protection by sunscreen is often not sufficient, especially for outdoor athletes, people with particularly fair skin, small children or people who work on a construction site, it is important to be additionally protected from the harmful radiation by suitable clothing.
As a rule of thumb, the more densely the textiles are woven, the higher the protective effect. In addition to the well-known nanoparticles titanium dioxide and zinc oxide, tungsten compounds such as tungsten oxide can also be considered as an alternative. This is because tungsten compounds can not only be used as a coating to shield X-rays or even space radiation, but are also suitable for absorbing UV radiation.
Compared to titanium dioxide, the tungsten compounds used for these applications are considered harmless to human health.
Materials for awnings or sunshades can generate higher UV protection by supporting nanoparticles. Fibres based on synthetic polymers can be protected from degradation reactions that are otherwise accelerated by UV irradiation by using nanocoatings. In this way, the material remains stable and functional for longer.

Definition
UV light Visible light lies in the wavelength range from 750 nm (red) to 380 nm (violet). Ultraviolet (UV) radiation, which covers the wavelength range from 100 nm to 380 nm, is the most energetic part of sunlight. It is not visible to humans and cannot be perceived by other sensory organs.

4.LO_NanoineverydayLife_04: Nanotechnology in cosmetics

UV radiation from the sun is composed of UV-A and UV-B rays. UV-B rays are significantly stronger than UV-A rays and cause sunburns. They damage the outermost skin layer and the DNA in these cells. UV-A rays are weaker, but penetrate deeper into the skin and cause the skin to age faster. Since both types of radiation are considered carcinogenic, it is important to protect the skin when exposed to high levels of light.



Among other things, nanoparticles are used as filter substances in sunscreen. There are two different types: chemical, and mineral or physical UV filters.
Chemical filters convert the UV rays on the skin into heat, while mineral filters reflect the sunlight on the skin. Mineral sun creams often use titanium dioxide or zinc oxide particles in the nanometre range. The addition makes the cream easy to spread and - unlike creams with larger zinc oxide particles - it does not form a tough, white layer on the skin.
However, as the nanoparticles come into direct contact with the skin, there is a certain health risk. In vivo and in vitro studies have shown that zinc oxide nanoparticles can be acutely toxic in the lungs and cell- and genotoxic in human nerve cells.
For this reason, the particles are coated wafer-thin with silicon dioxide, the main component of sand. The protective coating prevents zinc ions from dissolving from the oxide, which have a toxic effect in high doses. If they are inhaled, for example, they can cause inflammation in the lungs. The nano-shell reduces the genotoxicity of the unprotected zinc oxide particles by a factor of three.

Important

Filters in sun creams

Two different types of UV filters are used in sun creams. Chemical ones convert the radiation into heat, while mineral ones reflect it.

There are possibilities to use nanoparticles not only on but also in the body. One example is particles in toothpaste.
Minerals are constantly dissolved out of the tooth enamel, which consists of 95% hydroxyapatite (calcium phosphate), and stored again. This is the de- and remineralisation of the tooth. If the environment of the tooth becomes too acidic, for example due to acidic foods such as fruit, the loss of minerals predominates and the enamel partially dissolves.
To counteract the breakdown of enamel, nano-hydroxyapatite is added to some toothpastes.
The synthetic hydroxyapatite is chemically very similar to natural tooth enamel, which is why it combines with it as if it were part of it. Together with proteins from saliva, the hydroxyapatite crystals form the biomaterial. A two to three micrometre solid layer is formed on the tooth, which closes small, damaged areas and protects the underlying tooth material from further attack.
The applied hydroxyapatite behaves in the same way as natural tooth enamel and is worn away and swallowed over time. Hydroxyapatite is considered harmless, and there is currently no evidence of danger or risk for nano-hydroxyapatite, especially since it is not permanently insoluble.

Definition

De- and Remineralisation

The process of demineralisation and remineralisation takes place several times a day and describes the breakdown and reconstruction of the tooth enamel. If the degradation is predominant, the teeth lose calcium and cracks form.

In the cosmetics industry, nano-sized colour particles in eyeliners or mascaras guarantee a particularly long shelf life. In most cases, the deep black pigments in eye make-up consist of tiny carbon particles. These are formed during the incomplete combustion of petroleum products, including fluidised catalytic cracker, coal tar, ethylene cracker and some vegetable oils. In cosmetics (especially eye

make-up), carbon is used as a pure colourant, which means that it does not need to be mixed with more other substances. Regular carbon black is often toxic, possibly carcinogenic, and also often contains impurities such as arsenic, lead, mercury, sulphur and polycyclic aromatic hydrocarbons, which is why it should be avoided in cosmetic applications.

An example of a certified carbon black pigment is called “Black 2”, which must meet limits for impurities present. This makes it possible to use the deep black nanopigments in the cosmetics industry.

Excourse
Pigments Pigments are coloured compounds that are insoluble. Since the particles are insoluble in water, they are always in the form of a suspension. This distinguishes them from dyes, which are soluble in the application medium.

1.Save knowledge

Summary

Whether in nature, in your own home, in textiles or in cosmetics - there are exciting effects to be discovered everywhere that are based on nanotechnology. Many applications, such as self-cleaning surfaces, are inspired by nature.
Carbon nanotubes are used, among other things, in the development of touchscreens and their unique properties open completely new dimensions for technology. But nano has also become indispensable in the food industry. For example, silicon dioxide particles in ketchup make it flow better out of the bottle.
Another important area is lightweight construction. Here, carbon fibres can save up to 80 % of the weight while maintaining the same stability, which leads to significantly lower emissions in the automotive industry, for example. Nanotechnology can also protect the environment.
In medicine, the antimicrobial effect of nanosilver is used to fight bacteria, viruses, and fungi. The Ag+ ions attach themselves to the microbes and thus prevent cell activity.
To protect one's body, it is important to protect oneself from UV rays when exposed to high levels of sunlight. Mineral nanofilters in sunscreen can reflect incoming radiation and thus protect the skin. The small particles also do a great job in cosmetics such as toothpaste or make-up.
Since many materials behave differently in the nanometre range than in their regular form, there are hardly any limits to what can still be researched and developed through nanotechnology.