Tiny particles with big benefits

Nanotechnology and nanomaterials

2nd edition

AmCham EU

SPEAKING FOR AMERICAN BUSINESS IN EUROPE

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What is nanotechnology?

Nature had it first

Humans are at last discovering how nature works at the nanoscale, and are now applying this knowledge to produce innovative products and applications.

The use of nanomaterials and nanotechnology in general is at the forefront of innovation, with the potential to transform industry and everyday life in many sectors to benefit consumers, workers, patients, and indeed all of society.

The lotus flower cleans itself, repelling water and dirt; leaving the flower in its natural, magnificent state. How is this possible? Nanostructured surfaces.

The shell of the abalone sea snail, commonly known as mother of pearl, has a self-repairing ability such that when it cracks, it reforms bonds that reinforce its structure and make it famously resilient. How is this possible? Nanoscale crystalline architecture.

"Nature was nano before nano was cool."

Henry Fountain,
New York Times

Geckos climb effortlessly on slippery surfaces at every angle, even hanging upside down as if they were glued to the surface, seemingly without the hindrance of gravity. How is this possible? Nanoscopic hairs on their feet.

So what are nanotechnology, nanomaterials and the nanoscale?

"Nano" is derived from the Greek word for dwarf. One nanometre is one billionth of a metre.

Nanoscale

Size range from approximately 1 nanometre to 100 nanometres (1nm = 9-10m)

Nanotechnology

The application of science at the nanoscale to make size and structure-dependent properties and phenomena, distinct from those associated with individual atoms, molecules or bulk materials.

Nanomaterials

Definitions are being developed across the globe. The International Organization for Standardisation (ISO) has developed generic definitions for this new area of industrial innovation. These definitions however are not suitable to be used in a regulatory context.

In the EU, nanomaterials are defined, within an EU recommendation[1], as material objects with any external dimension in the nanoscale, including their agglomerates and aggregates.

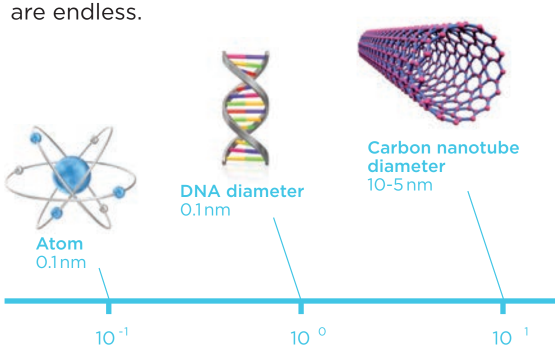
[1] European Commission Recommendation of 18 October 2011 on the definition of nanomaterial (Text with EEA relevance) (696/2011/EU)

AmCham EU welcomes a harmonized European definition which can be tailored to sector specific regulation. We believe that the EU should take into account international efforts such as those led by ISO and the OECD when adapting the definition to each sector.

Benefits of the nanoscale

Material at the nanoscale can have different and novel properties compared to its bulk form. The larger surface area increases the material's interaction with the surrounding environment. As a result, materials could change their colour or transparency; their electrical conductivity; their basic physical properties, such as hardness, melting point or their chemical properties, such as reactivity.

These changes could then lead to different behaviour, such as increased strength and much less weight; materials may absorb more heat, become fire-resistant, or gain self-cleaning qualities. By working with materials at the nanoscale, we are able to convert these unique "properties" into benefits and use them to our advantage. The possibilities are endless.

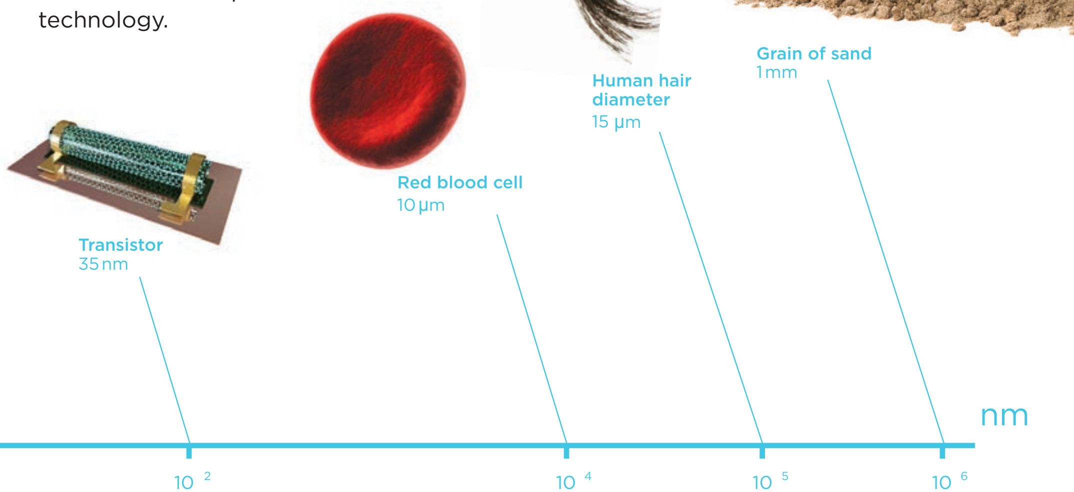


Nanotechnology in everyday life

Some applications are well known, such as sunscreen, but nano is so much more than that. Nanomaterials are now being used in aerospace applications, the automotive industry and transport, construction, energy generation and storage, environmental remediation, healthcare, information technologies, security and many other consumer applications, from tyres and smart textiles to toothpaste. Scientists are at the crux of finding new ways to use nanotechnology and nanomaterials… just as the lotus flower, gecko and abalone have been doing for thousands of years.

As with every new horizon mankind has conquered, we need patience, imagination, research and discipline to make the most of the benefits and avoid the pitfalls. This brochure highlights a few selected examples from different sectors which demonstrate the potential of this new technology.

> “Nature had it first, but industry can make it last.”



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Nanotechnology in everyday life

Silicon nanotechnology

Silicon nanotechnology has been used in computer chips for nearly two decades, beginning with the 180 nanometre process in 1999.

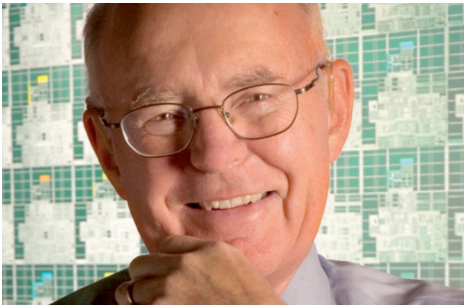
In 2011, the latest 22 nanometre computer chips were launched. This technology has transformed the modern transistor into one of the world's most resource efficient tools, as chips can now have over 2 billion transistors built on them. Today's transistors ensure that trillions of computer chips, the building blocks for computers and other digital devices worldwide, consume less power. As computing moves into a wide range of "smart" devices ranging from laptops and desktops to smart phones, tablets and intelligent systems, the miniaturisation or rather "nanoaturisation" of computer chips is the epitome of resource efficiency and sustainability.

When compared to the first billion PCs and servers installed between 1980 and 2007, the next billion PCs and servers installed between 2007 and 2014 will consume half the energy and deliver 17 times more computing capacity.

Environmental safety and health

Electrical equipment, including transistors in microprocessors, has many nanoscale features and structures although they are not considered to be "nanomaterials".

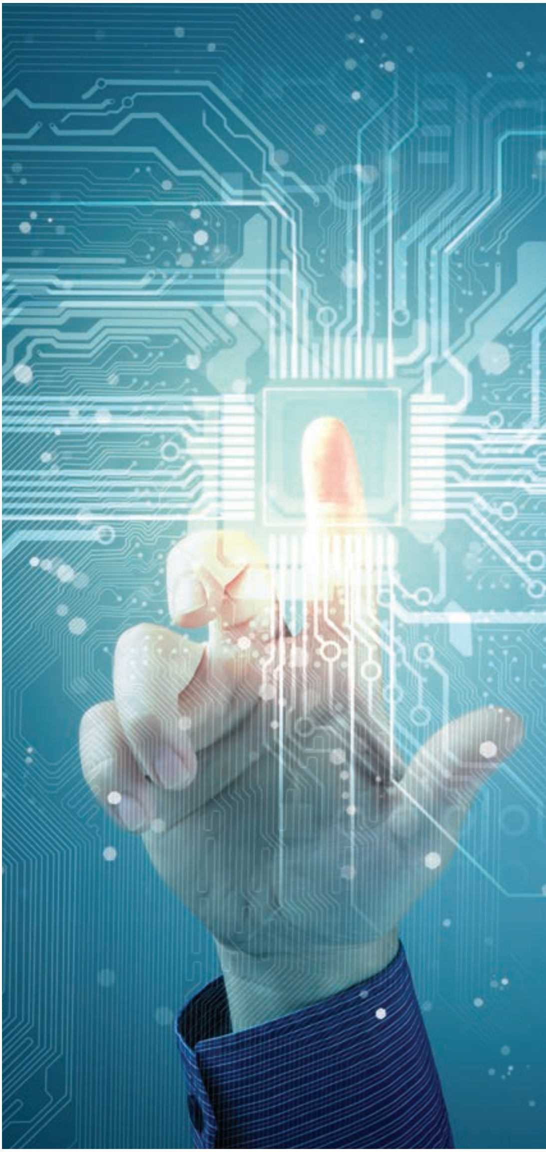
These nanoscale structures are formed from the specific combination of substrate layers of an integrated circuit. They are not, and cannot become, free, discrete nano objects. They are manufactured with conventional processes, are strongly bonded, encased in silicon dioxide and packages and do not pose any potential hazards.



In 1965, Gordon Moore made the bold prediction that the number of transistors on a chip would double approximately every two years. This trend, popularly known as Moore's Law, is still alive and we are also witnessing the growth of functions on a chip due to the introduction and use of new materials and transistor structures. These developments are driving innovation in the semiconductor industry which, in turn, is creating better and more complex devices while reducing power, cost and size at the same time.

Did you know?...

- Compared to the first microprocessors introduced in the 1970's, a 22 nanometre computer chip runs over 4000 times as fast and each transistor uses about 5000 times less energy. The price per transistor has dropped by a factor of about 50,000!
- If cars had improved at the same rate, they would go over 500,000 km/hour and be able to circumvent the Earth 100 times on a tank of petrol. The price of a car would be less than a candy!



Monitoring devices

There are numerous potential benefits for the use of nano technology in monitoring applications to improve health and safety in buildings.

This includes devices that provide more effective fire detection, reduce airborne contaminants and monitor the performance of heating equipment. Monitoring devices use the same integrated circuit nano-manufacturing processes as those used to detect smouldering fires in buildings, or by automotive suppliers to detect leaks.

Big improvements

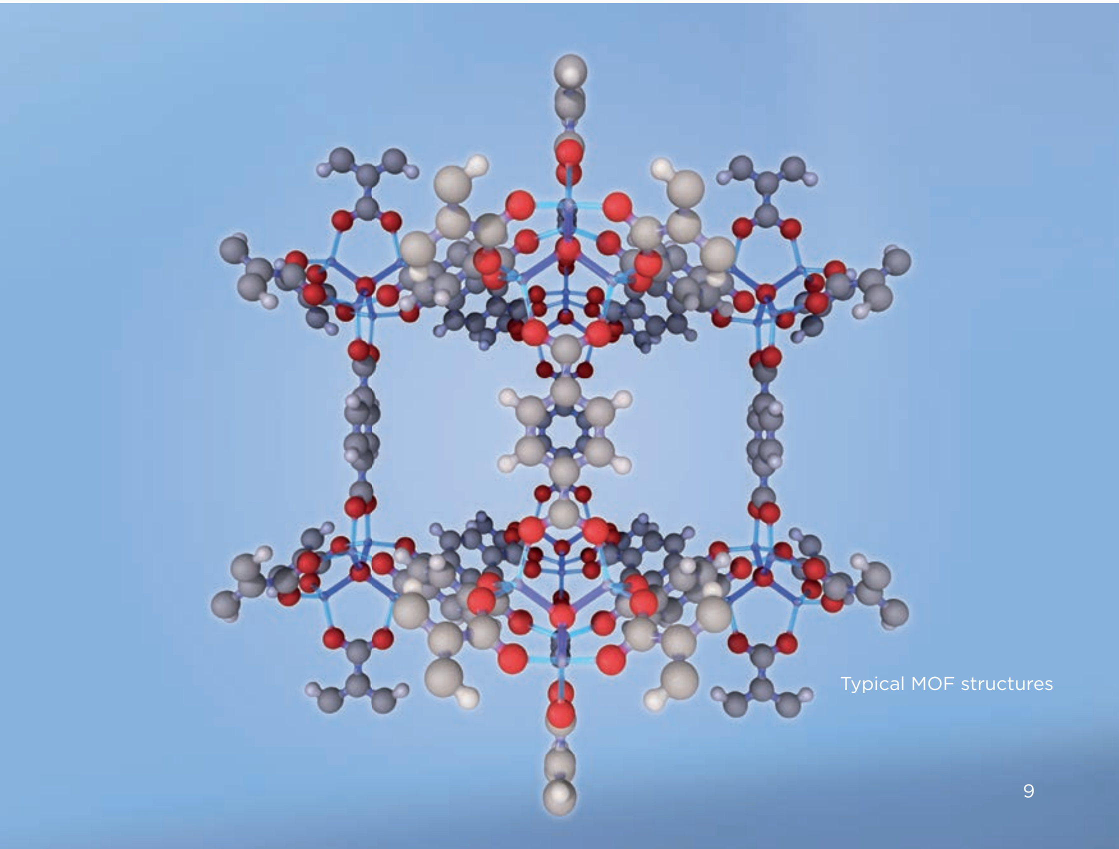
This nano-enabled technology promotes the early detection of gases and particulates and provides reliable measurements of toxic gas concentrations down to parts per million. Specific nano-particle catalysts selectively break apart the target gas molecules, enabling their concentrations to be measured electrically. These highly sensitive detectors have a long product service life, even using minute amounts of precious metals.

In other monitoring applications, nano-structured compounds known as metal-organic frameworks (MOFs) not only enable advanced chemical detection, but can also purify the air of harmful organic compounds that may contribute to the so-called "Sick Building Syndrome" found in poorly ventilated buildings.

These applications usually apply minute amounts of nanomaterials, based on a crystalline structure with specific pore sizes in the form of a three-dimensional grid. These nano-structures have tremendous storage potential based on the variety of metal clusters and organic ligand. As they have been used in composite structures and bound onto a suitable matrix for many years without incident, there are no specific safety concerns potentially related to free nanoparticles.

Nanotechnology in monitoring applications keeps us safer and healthier

Nano-enabled monitors can play an important role in keeping our buildings cleaner and safer. Early detection of gas leaks and fires with minimal or no false alarms is critical to providing occupants of buildings with additional time to evacuate. Advanced devices with higher detection capabilities can guarantee human safety and avoid property damage while reducing the cost of false alarms. MOFs can also significantly improve indoor air quality by removing mould, volatile organic compounds, industrial chemical fumes and other particulates.



Typical MOF structures

Transportation applications

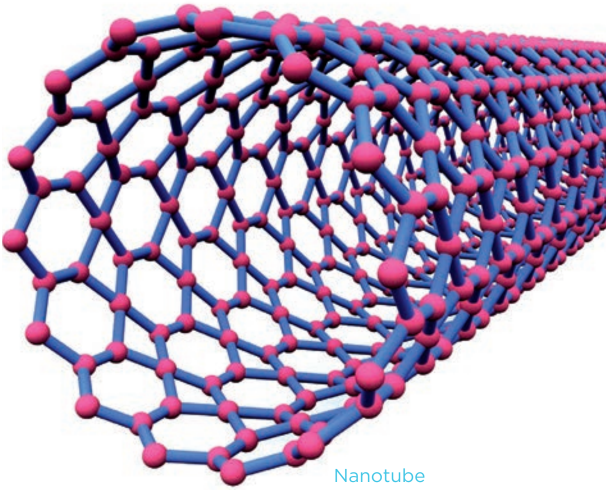
The aerospace industry has an interest in using nanotechnology for improving material strength, electrical conductivity and thermal conductivity of polymer composites in next-generation helicopters.

Nanotube

Nanotechnology enhanced thermal conductivity enables metal gearboxes to be made of composite materials. This allows gearboxes to be protected from corrosion and eliminates the need for internal cooling. By preventing a loss of lubrication, this technology can also ensure that gearboxes are safe for use during extreme conditions. Furthermore, transmissions with nano-management of heat could eliminate the need for lubricants, resulting in safer, cleaner products.

Nanomaterials contribute to safer aircraft

Nanomaterials provide improved structural properties compared to the current use of composite materials. Applications that use this technology also have the potential to improve the capability, airframe structure and safety margin of helicopter rotor blades and design and manufacturing flexibility, to produce cheaper, safer and more robust aircraft.



Nanotube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Car tyres

Tyres have a wide range of performance requirements. They must carry the load of the vehicle, provide sufficient grip on the road, transmit steering forces to guide the vehicle, absorb shocks, provide durability for use at high speeds and over long periods of time, as well as have as the lowest possible impact on fuel consumption.

Due to these demanding requirements, the tyre industry is an intensive R&D sector. Each year it invests %3.5 of its annual turnover in innovation. The capability to innovate is therefore a crucial component of the industry's competitiveness. Tyres are complex composites which may contain more than 200 different materials. As shown in the image on the opposite page, tyres are composed of metal and textile reinforcements and mixtures of rubber.

Carbon black and silica are now characterised as nanomaterials, but have been used as reinforcing fillers in tyres since the beginning of the 20th century

Reinforcing fillers are used to provide more strength to the rubber compounds. Carbon black was introduced in the tyre industry in 1912. Its use as a reinforcing filler provides improved grip and wear performance of tyres, increasing their longevity by up to 50 times.

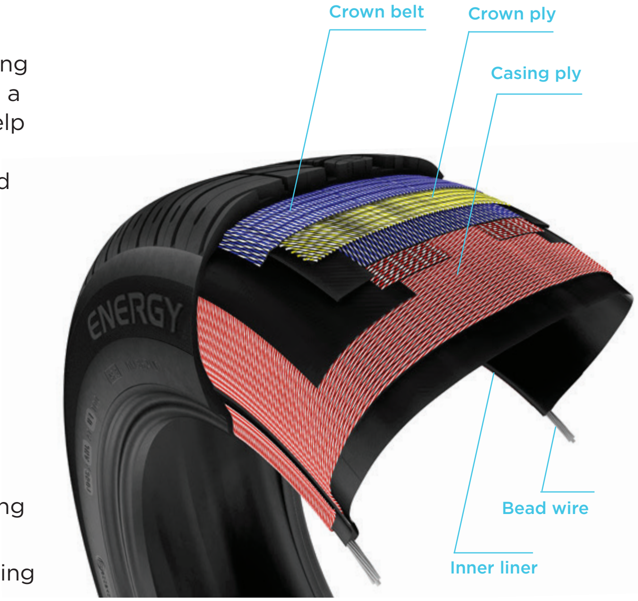
A tyre manufactured without the use of reinforcing fillers would not be strong enough to carry the load, handle the weight, or deliver the performance required by today's vehicles. It would especially not meet today's high speed operating requirements.

Another benefit of the compound strength is its ability to transmit forces through the tread of the tyre. This can greatly improve traction and reduce stopping distance for the vehicle, thereby increasing road safety.

Developments in silica usage as a reinforcing filler in the tread compound in the last 20 years have significantly reduced vehicle fuel consumption without compromising other performances or properties.

In 2012, the Tyre Industry Project, uniting CEOs from 11 of the largest tyre companies which decided to join forces to improve the contribution of tyres to sustainable development, developed an industry-specific best practices guide for nanotechnology under the umbrella of the OECD.

This guide is available in the report "Nanotechnology and Tyres: Greening Industry and Transport.[2]". Providing a risk management framework can help tyre companies and manufacturing sites to develop risk assessment and management strategies.



Using nanomaterials in tyres is resource-efficient

Reduced fuel consumption results in CO_2 emission reductions

- Today the road transportation sector accounts for %18 of global CO_2 emissions, of which %20 are due to tyres because of their rolling resistance.
- Without new technologies, including the development of nanomaterials, CO_2 emissions are forecast to increase significantly in line with the expected increase in the number of vehicles worldwide. There were 800 million vehicles on earth in 1990, forecasts say that by 2030 there will be 1.4 billion, mainly in emerging countries.

Use raw materials wisely

- The worldwide production of tyres is about 1.2 billion per year. The doubling of production without new technology would require twice as many raw materials.

Looking ahead: Expectations with the development of nanomaterials

- Significant decrease of tyre wear rate which will prevent the consumption of additional raw materials in spite of the increasing number of vehicles.
- Significant decrease of tyre weight and with it the quantity of raw material used in tyre production.
- Significant decrease of tyre weight and with it the quantity of raw material used in tyre production.

The tyre industry is committed to the further development of nanomaterials and nanotechnologies which do not present risks to human health or for the environment. Consumers worldwide are shifting toward the use of green tires, which are eco-friendly, durable, provide grip, reduce carbon emissions, and are fuel-efficient. Manufacturers are continuing to develop green tires that minimize roll resistance and increase performance.

[2] http://www.oecd-ilibrary.org/science-and-technology/nanotechnology-and-tyres_-9789264209152en

Energy storage

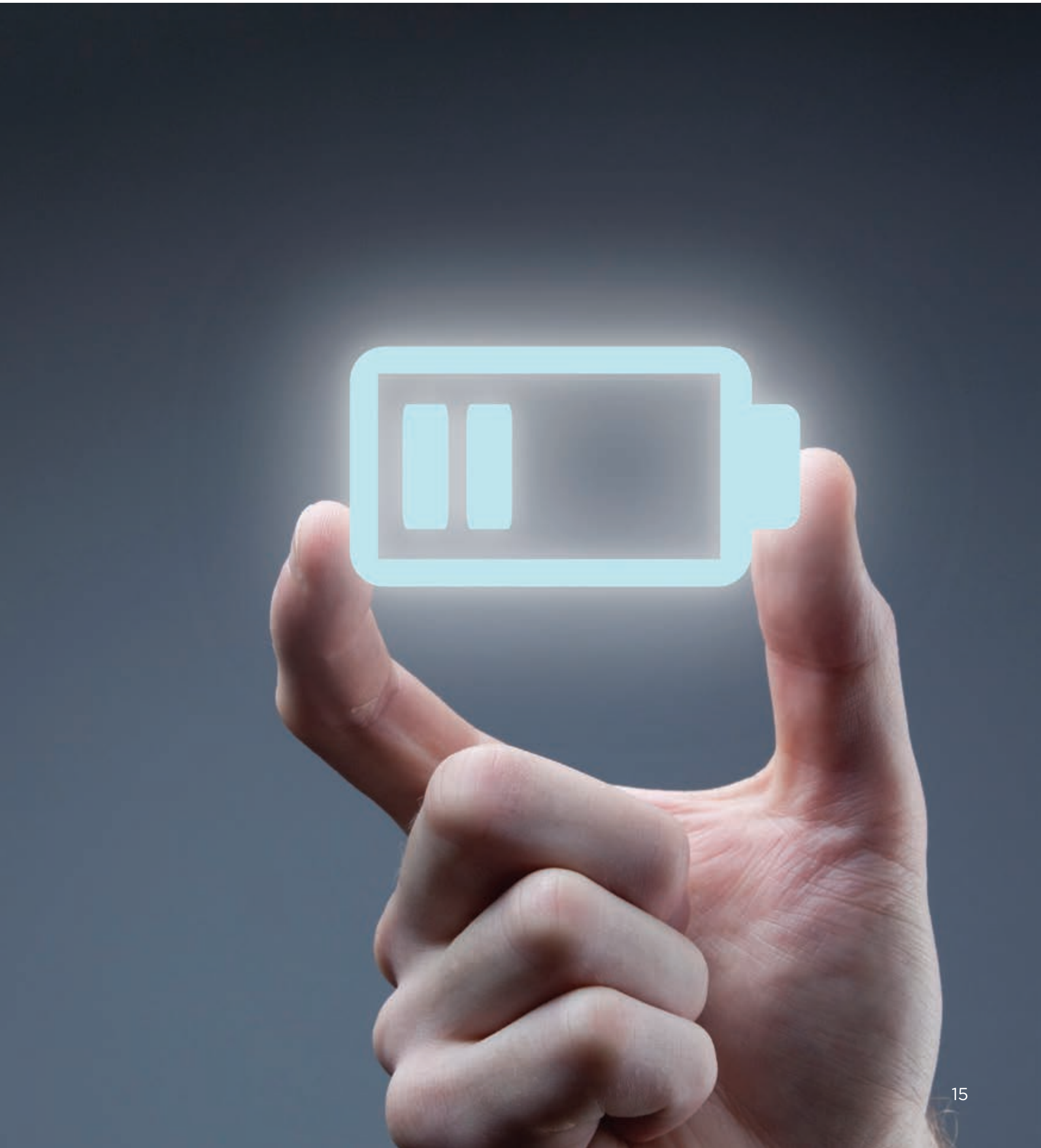
Energy storage is more important today than at any other time in human history. Nanotechnologies provide the potential to enhance energy storage and efficiency across a variety of applications, from powering electronic devices, to storing electricity from renewable sources, to being a vital component of plug-in vehicles.

Lithium-ion batteries

Lithium-ion batteries boast the optimum combination of long run time and long life, which sets them apart from the competition. Nanomaterials used in the development of these batteries can improve their safety and increase their energy capacity by up to %30 more than existing technologies based on graphite materials.

Carbon black, which has been used in Lithium-ion batteries since its early days, acts as a conductivity enhancer to improve power capability. However, by reducing the electrode particle size into a nanoparticle, scientists have successfully achieved an improvement in the energy storage component of the electrode.

Using nanotechnology has also been shown to reduce stresses caused by volumetric expansion and contraction during the charging and discharging cycles of the battery.



Medical devices

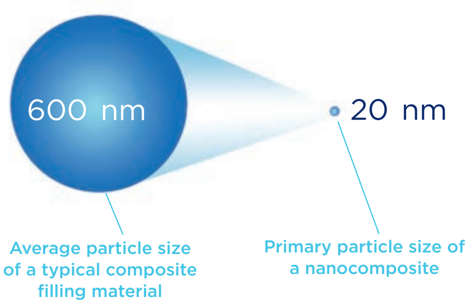
As consumers we want our fillings to look natural and last a long time. Nanotechnology has enabled the development of a new class of tooth-coloured filling material, the nanocomposite, which provides dentists with a material that can be used for fillings on any teeth.

The nanocomposite is aesthetic enough to be used as a filling on front teeth and strong enough to withstand the rigors of chewing in the back.

Similar technology has also been used in other dental products, such as fluoride releasing filling materials that help fight decay and in adhesives that are used to bond filling materials to the tooth.

New and Improved

Traditional composites use a filler that is typically much larger than the nanoparticles found in the nanocomposite. These larger particles cause significant roughness of the composite surface over time resulting in a loss of polish.



The nanocomposite is built from individual and unique clusters of nanometre-sized particles that are chemically bound within the filling material.

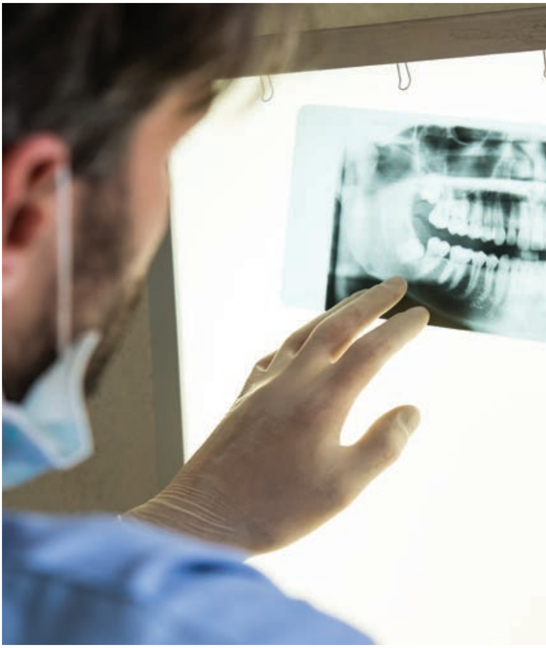
The combination of nanoparticles and nanoclusters provides a filling material with high wear resistance, making it excellent for dental restoration. This combination also provides a material that retains its smoothness over time allowing it to retain polish for a long time to continue to be aesthetically pleasing.

Safety first

Dental products using nanotechnology are classified as medical devices. The safety of all dental materials, including those incorporating nanotechnology, must be carefully evaluated according to the requirements of the relevant legislation, international standards and national guidance. Once assessments indicate that a nanocomposite is safe for its intended use, it can be marketed.

Improved public health and addressing the needs of an ageing society

The demand for affordable, aesthetic dentistry continues to grow. This trend is fuelled, in large part, by ageing populations worldwide. The Oxford Institute of Population Ageing has projected that by the year %50 ,2030 of the population in Western Europe will be over 50, while one-quarter of the developed world will be over 65. As developing nations become more affluent, their oral healthcare needs improve. These changing demographics will have an impact on the types of restorative materials that the dental profession will need to effectively meet these changes, whether it involves enhancing the aesthetic performance of filling materials, or improving the bonding agents that adhere the filling to the tooth. Nanotechnology is playing a key role in delivering tomorrow's dental products.



Under current legislation such as the general product safety directive, REACH, CLP, biocides, medical devices, etc, the industry is already obliged to put safe products on the market. Incorporating specific provisions aspects on nanomaterials during recasts may ensure consistency, but it is not necessary to adopt additional legislation.

3

Nanotechnology policy in the EU

Europe has sought an integrated and responsible approach to regulating nanomaterials and nanotechnologies for more than a decade: the first Communication 'Towards a European Strategy for Nanotechnology'[3] was adopted in 2004. At the same time, the European Commission considers nanotechnologies one of six key enabling technologies driving innovation in the EU. Continuing the development of a harmonised regulatory approach is imperative to minimise market barriers and foster the development of nanotechnology across the Single Market.

Consistent and coherent regulation

The Second Regulatory Review on Nanomaterials[4] in 2012 addressed the regulatory challenge of 'ensuring that society can benefit from the innovation and competitiveness of nanotechnology and a high level of health, safety and environmental protection.'[5]

Balancing these two objectives requires that regulations be based on scientific evidence and risk assessment approaches that properly account for hazard and exposure. It requires legislative responses to be proportionate, technically suitable to ensure enforceability and harmonised at the highest possible level.

AmCham EU welcomes the European Commission conclusion in this review that substances in nanoform are no different than other substances, in that 'some may be toxic and some may not'. Since REACH applies to substances in any form, including nanoform, it remains the best possible framework for the risk management of nanomaterials.

The extensive list of relevant legislation below demonstrates that the manufacturing and use of nanomaterials does not happen in a regulatory vacuum and there is already a comprehensive body of requirements safeguarding this area of industrial innovation.

Multi-sector

REACH
Worker protection
General product Safety
Industrial pollution
Water
Waste
Industrial accidents

Sector-specific

Medicines
Medical devices
Cosmetics
Novel food
Biocides
Specific (waste) streams: electrical and electronic equipment, automotive, packaging, batteries

There is no scientific evidence available today which demonstrates that nanomaterials should be subject to additional regulations. Nevertheless, the Commission commissioned in 2013 an impact assessment of the relevant regulatory options which addressed 'potentially inadequate action on health and environmental risks of nanomaterials and potentially suboptimal consumer choices as a result of lacking of information available to authorities, users, distributers, workers and consumers'[6].

In December 2016 the European Union Observatory for Nanomaterials (EU-ON) was created, as a tool to increase transparency on nanomaterials on the EU market. Its main stated goal is to offer better access to relevant and understandable information about nanomaterials for both European citizens and experts.

The Commission is also considering modifying some of the technical provisions in the REACH Annexes as it examines the possibility for more specific requirements for nanomaterials[7].

A key enabler of EU innovation

Nanotechnologies are considered to be part of the new industrial revolution: their potential is extremely promising and could provide a competitive edge for the European and American economies in the future. Unsurprisingly, the EU has identified nanotechnologies as Key Enabling Technologies – technologies forming the backbone of Europe's 2020 Strategy designed to deliver sustainable, smart and inclusive economic growth and competitiveness. Technology and innovation are essential to solving many environmental problems and nanotechnology may deliver resource-efficient solutions for the future.

Revenue from nano-enabled products grew worldwide from 200€ billion in 2009 to 1.5€ trillion in 2014[8], and are forecast to reach 4€ trillion by 2018[9]. Europe is well-positioned to harvest the growth potential of nanotechnology. 3.475€ billion has been invested into nanoscience research and Europe's industrial base is well placed to turn this investment into tangible economic benefits.

As a Key Enabling Technology, nanotechnology has the potential to boost the competitiveness of EU industry and the evolving regulatory framework will be instrumental in determining whether the EU becomes and/or remains an innovation leader. To make this happen, Europe must continue to create a suitable regulatory environment which supports nanotechnology development and innovation.

Working together...

Nanomaterials and nanotechnologies have rightly been identified on both sides of the Atlantic as having huge economic potential. Any further regulatory measures on nanomaterials should be adopted on the basis of sound science to demystify the public debate and increase popular acceptance. The EU must get the balance right to responsibly manage risk and enable innovation, in order to bring the benefits of nano to European citizens.

AmCham EU welcomes the creation of the EU observatory and is looking forward to it providing science-based substantial information.

[3] https://ec.europa.eu/research/industrial_technologies/pdf/policy/nano_com_en_new.pdf
[4] http://ec.europa.eu/nanotechnology/pdf/second_regulatory_review_on_nanomaterials_-_com(572_(2012.pdf
[5] http://europa.eu/rapid/press-release_IP947-08-_en.htm
[6] http://ec.europa.eu/growth/sectors/chemicals/reach/nanomaterials/index_en.htm
[7] http://ec.europa.eu/environment/chemicals/nanotech/reach-clp/index_en.htm
[8] http://investingnews.com/daily/tech-investing/nanotech-investing/nanotechnology-future-outlook/ https://www.nsf.gov/news/news_summ.jsp?cntn_id=130586
[9] https://portal.luxresearchinc.com/research/report_excerpt/16215

AmCham EU speaks for American companies committed to Europe on trade, investment and competitiveness issues. It aims to ensure **a growth-orientated business and investment climate in Europe**. AmCham EU facilitates the resolution of transatlantic issues that impact business and plays a role in creating better understanding of EU and US positions on business matters. Aggregate US investment in Europe totalled more than **2€ trillion in 2016**, directly supports more than **4.5 million jobs in Europe**, and **generates billions of euros annually** in income, trade and research and development.

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