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# Commercial applications of nanoparticles

Professor Barry Park

Commercialisation of Nanomaterials: Processes, Issues and Management
Burlington House – 7th June 2017

# Market Sectors

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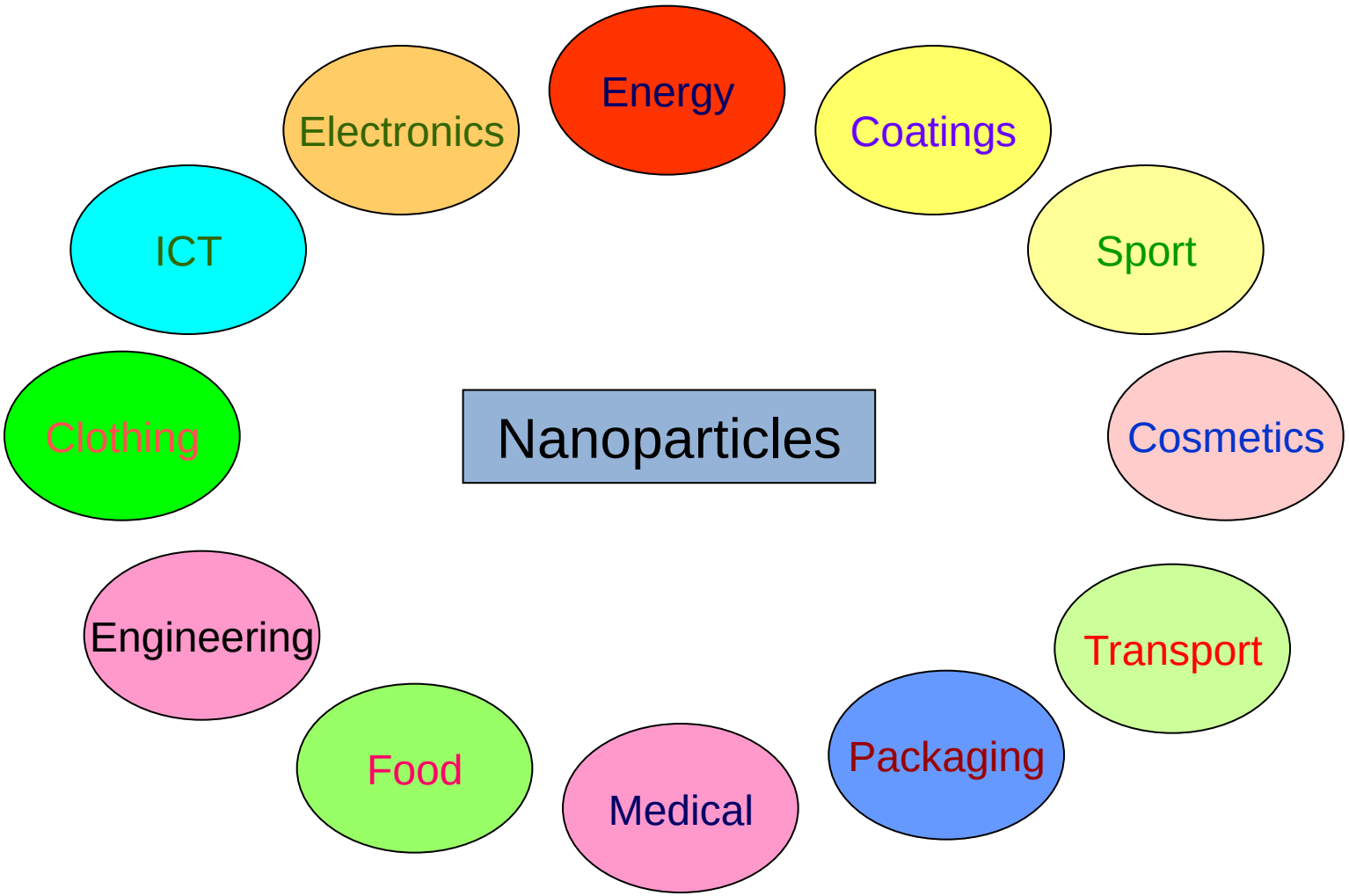

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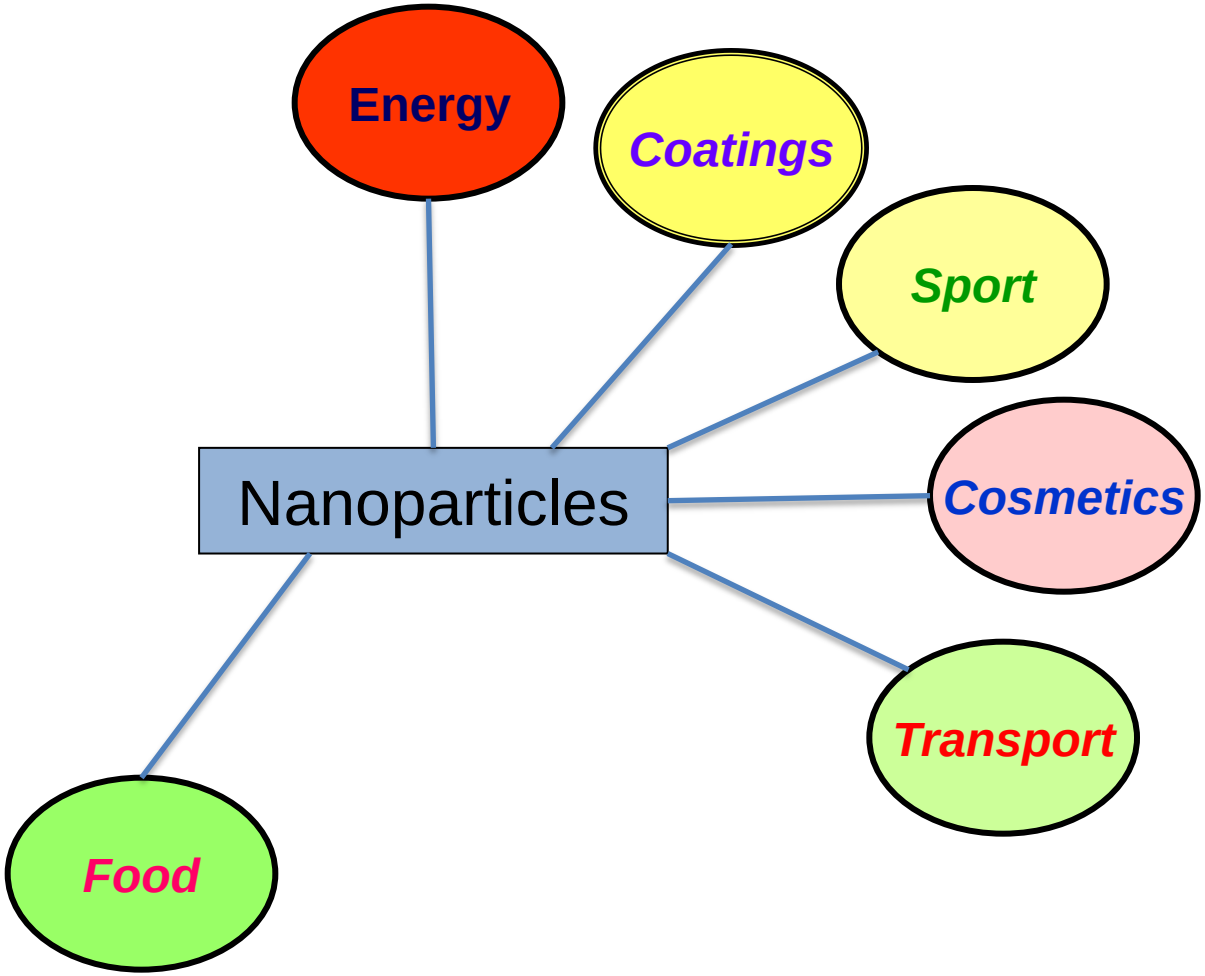

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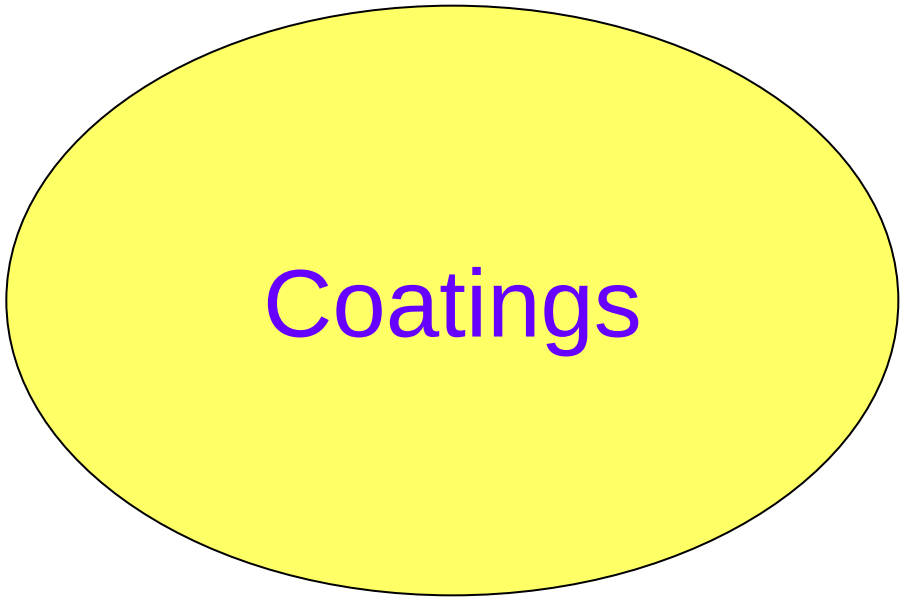

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# Photocatalysts on glass

In 2001, Pilkington Glass announced the development of the first self-cleaning windows, coated with a thin transparent layer of ***nanoparticulate titanium dioxide in anatase crystal form***

This coating acts to clean the window in two stages, using two distinct properties: ***photocatalysis and hydrophilicity***

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# Pilkington's ***Activ™*** Clear was the world's first true self-cleaning glass

- In sunlight, **photocatalytic activity of titanium dioxide** causes the coating to chemically break down organic dirt adsorbed onto the window

- When the glass is wet by rain or other water, **hydrophilicity** reduces contact angles to very low values, causing the water to form a thin layer rather than droplets, and this layer washes dirt away

- ***Activ™*** Clear also dries off faster leaving the glass clean and with reduced streaks, which gives beautifully clear views and makes it ***ideal for all the exterior glass surfaces*** in the home

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# ***Activ***™ Blue/Bronze and ***Activ***™ Neutral

***Activ***™ Blue/Bronze and ***Activ***™ Neutral (now ***Activ SunShade***™ Neutral) combine all the benefits of ***Activ***™ Clear with solar control performance for a cooler internal environment, making them the perfect choice for conservatory roofs and walls

http://www.pilkington.com/en-gb/uk/householders/types-of-glass/self-cleaning-glass

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The original self-cleaning glass
- Ideal for windows and skylights

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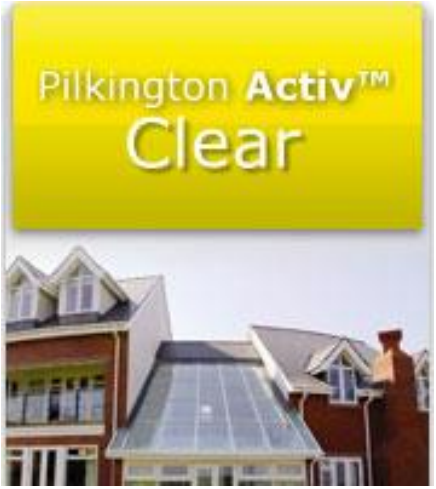


The original self-cleaning glass
- Ideal for windows and skylights


An attractive blue tinted glass that combines self-cleaning with solar control
- Ideal for conservatory roofs

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The original self-cleaning glass
- Ideal for windows and skylights


An attractive blue tinted glass that combines self-cleaning with solar control
- Ideal for conservatory roofs


A neutral coloured glass that combines self-cleaning with solar control
- Ideal for conservatory verticals

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All is made clear….

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# This technology can also be applied to concrete

The brilliant white concrete of the Jubilee Church in Rome (La Chiesa del Dio Padre Misericordioso) is expected to stay clean thanks to the addition of *photocatalytic titanium dioxide* as an additive to the concrete

# $NO_x$ Reductions

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- An innovative $NO_x$ abatement technology, ***photocatalytic street paving and paint***, is claimed to reduce significantly ambient $NO_x$ concentrations
- Trials carried out in Italy and China report up to 50% reduction in $NO_x$ concentrations
- The paving contains ***nanoparticulate titanium dioxide*** which in the presence of sunlight causes $NO_x$ emissions which pass over the surface of the paving to be oxidised to nitrates
- These nitrates are washed away during rainfall
- The paving is claimed to be suitable in areas where there is high concentration of $NO_x$ emissions and lots of UV light

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# Scratch resistant coatings for cars

PPG Industries developed scratch-resistant coatings by incorporating ***silica nanoparticles*** into an organic matrix that allows the nanoparticles to migrate to the surface when the paintwork is baked, merging into the cross-linked structure to provide a hard surface

http://corporate.ppg.com/Innovation/Innovation-at-Work/Achievments/Ceramiclear-team-shines-with-automotive-clearcoat.aspx

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In 2002, PPG introduced the first scratch resistant clearcoat to the automotive marketplace. Since then, scratch resistant clearcoats have rapidly become the standard in the automotive industry


Mercedes-Benz was the world's first vehicle manufacturer to offer this more scratch-resistant clear lacquer

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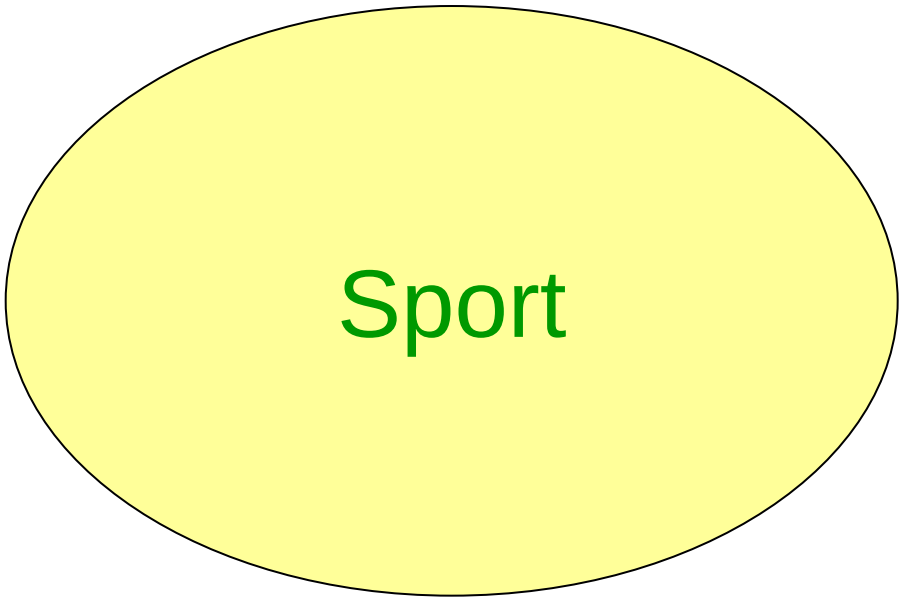

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# Tennis Racquets

- Wilson's nCode was the first racquet in the world to be manufactured using nanotechnology
- Wilson claimed that from their laboratory tests, nCode racquets are twice as strong, twice as stable and up to 22% more powerful than conventional racquets
- These findings, known by the number series 2-2-22, were claimed to provide compelling evidence of nCode's superiority

The nCode process involved injecting *nanoparticulate silicon dioxide* into the voids that naturally occur between individual carbon fibres

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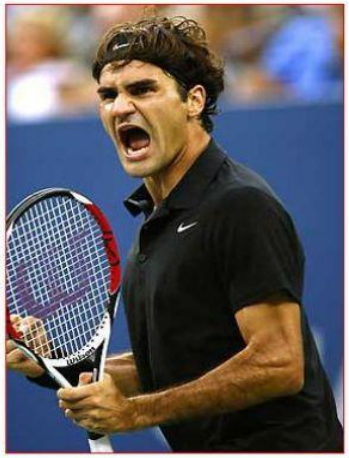

Building on the nanotechnology platform that began with **Wilson's** top selling nCode line, [K]Factor now takes the process to the next level by introducing Karophite Black, created when bonding Carbon Black, Graphite and $SiO_2$ together at the nano level, creating a denser and stronger racquet matrix

By placing Graphene in the shaft of the racquet, **Head** has been able to take the weight saved in that area and redistribute it to the tip and grip areas of the frame. By placing more weight in these spots, the racquet can generate more kinetic energy during the shot, providing more power with less effort in the swing

Examples of recent racquets used by Roger Federer and Andy Murray

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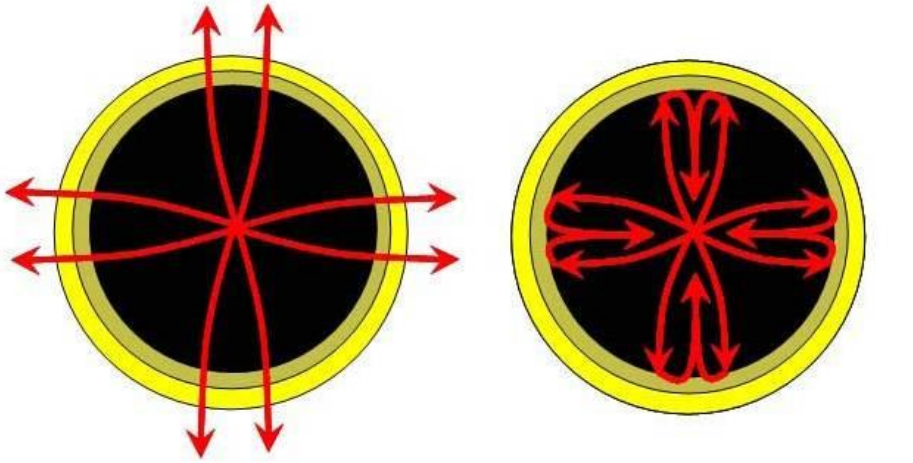
# Tennis balls

Wilson manufactures the 'Double Core tennis balls' which are coated in platelet-shaped ***clay nanoparticles*** in the inner core

The clay nanoparticles provide a tortuous path making it more difficult for air to escape and creating a longer lasting superior ball



Ordinary tennis ball

Tennis ball with nanocomposite gas barrier

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… as used in the Davis Cup

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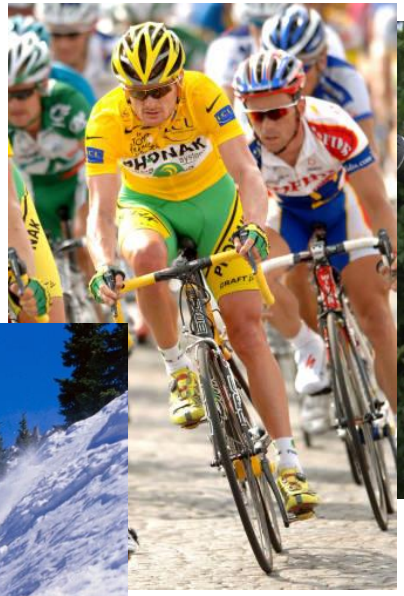

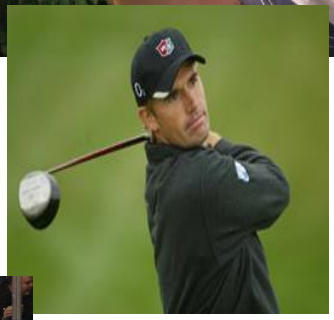


Range of sporting goods based on nanoparticles

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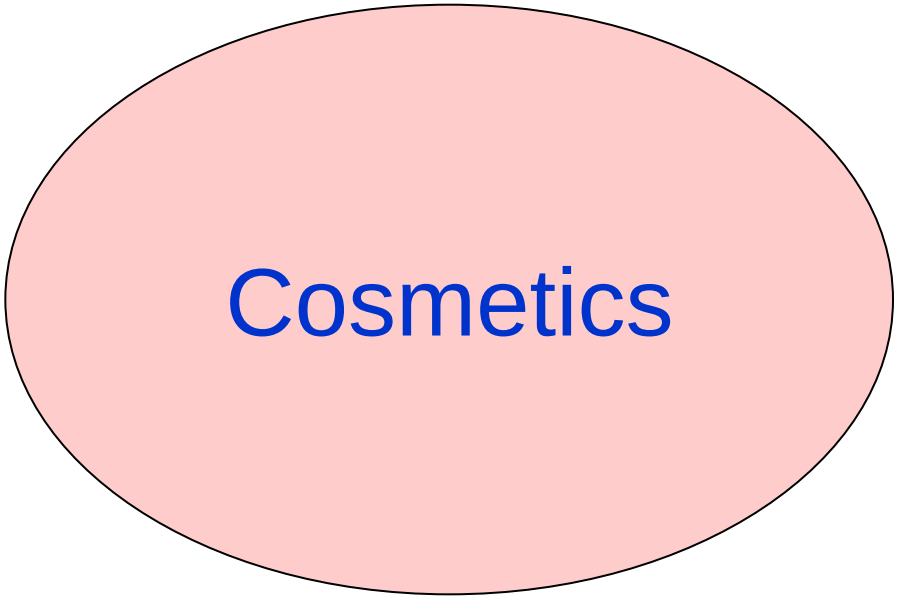

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# UV absorbers in sunscreens – major use of nanomaterials in cosmetics

***Nanoparticulate titanium dioxide in rutile crystal form*** is used in sunscreens to reflect and scatter UV light

Not only does it protect the skin from UV light extremely well, the nano-form also delivers the added benefits of being easier to spread and also appearing transparent - so reducing whiteness

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# UV absorbers in sunscreens

**Delivering broad spectrum UVA and UVB protection with zero skin whitening, Optisol™ is unlike any other inorganic sunscreen active on the market**


Developed by Oxonica and now supplied by Croda, **Optisol™** is a *manganese doped nano titanium dioxide* which provides broad spectrum protection for all day use

# UV absorbers in sunscreens

## - Products containing **Optisol™**

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**The UK's No1 long wear sun protection:**
**"just one application of Soltan Once gives 8 hours protection from the sun"**


http://www.boots.com/en/Soltan/

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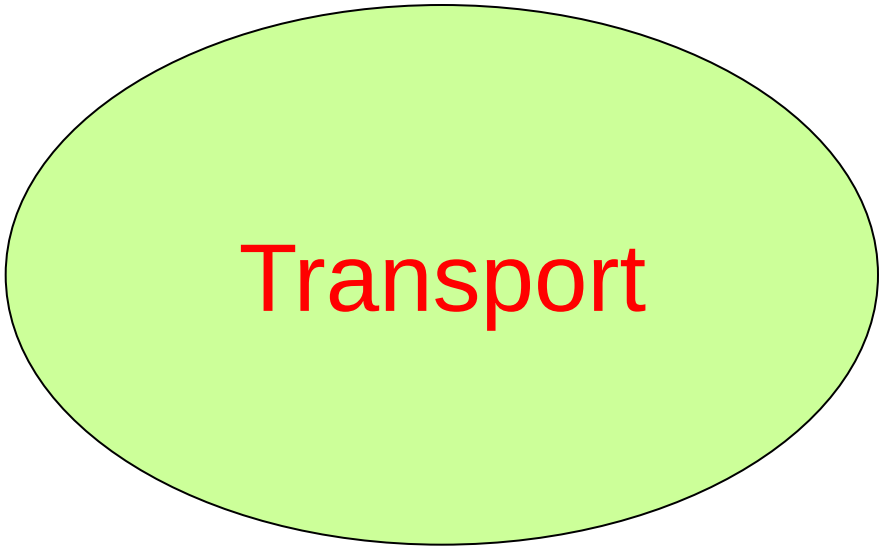

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# Nanomaterials in vehicle tyres

Originally rubber tyres were white, which reflects the natural colour of rubber

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# Nanomaterials in vehicle tyres

In the early 1900s, Binney & Smith began selling their ***carbon black*** chemicals to Goodrich Tire Company, as it was found that the use of ***carbon black*** in rubber manufacturing significantly increased the durability and strength of the rubber leading to significant increase in abrasion resistance

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**Worldwide Carbon Black Market is forecast to be valued at c.$29 billion with production over 16 Million Tonnes by 2022 with c.70% going into tyre manufacture**


http://www.grandviewresearch.com/industry-analysis/carbon-black-market

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In addition to Tyres and Industrial Rubber Products, *carbon black* is used in Plastics, Electrostatic Discharge (ESD) Compounds, High Performance Coatings and Toners and Printing Inks

**These different applications use carbon blacks exploiting different physical characteristics including particle size, structure, surface chemistry and aggregate/agglomerate distribution**

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# Diesel fuel additive

Envirox™ fuel ***combustion catalyst*** is a scientifically and commercially proven diesel fuel additive based on ***nanoparticulate cerium oxide***

It lowers fuel costs by reducing fuel consumption with a corresponding reduction in greenhouse gas emissions ($CO_2$) and particulates

Developed by Oxonica and supplied now by Energenics


http://www.energenics.co.uk/

Stagecoach

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**“Stagecoach was the first major transport group to pioneer the use of Envirox™ and we have a major strategy right across our business to reduce the carbon footprint of our operations. The fuel additive also makes good financial sense for our business. Using the fuel additive is one of the many ways we are delivering greener, smarter travel to our customers.”**

**Sam Greer, Director - Stagecoach UK Bus**

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**Stagecoach emissions savings estimated as c.25,000 tonnes of $CO_2$ per year plus c.£4m reduction in fuel costs per year**

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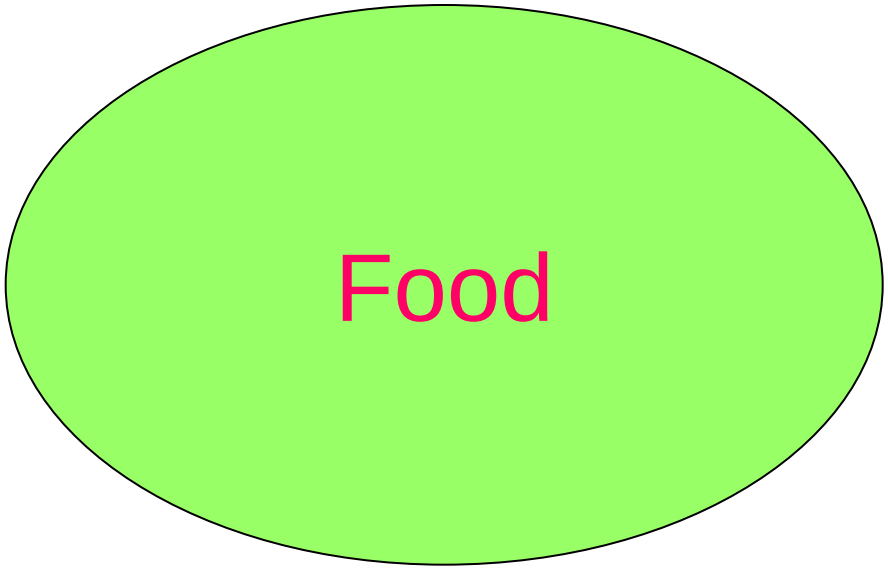

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- Food products ***naturally*** contain nano-size ingredients

- Also, the production of food involves processing and treatments in the course of which ***nanostructures are produced***, although these are nothing to do with engineered nanoparticles

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***Nanoparticulate silicon dioxide and titanium dioxide*** are both licensed for use in food in Europe and have E-numbers, E551 and E171 resp.

↓

***Silicon dioxide*** *(silica)* is used as a processing aid or as a thickening agent

and

***Titanium dioxide*** *(titania)* has been used in sugar glazing in confectionary

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# New "formulation" of sodium chloride *"Soda-Lo"* constructed of micro spheres based on nanocrystals

SODA-LO® is an innovative salt product that enables salt content to be reduced in food without loss of flavour or structure

SODA-LO® is able to encapsulate flavours, bioactives and colours

*Tate & Lyle licensed SODA-LO® from Eminate Ltd, a wholly owned subsidiary of the University of Nottingham*

http://www.tateandlyle.com/ingredientsandservices/chooseaningredientorservice/americas/pages/soda-lo%C2%AEsaltmicrospheres.aspx

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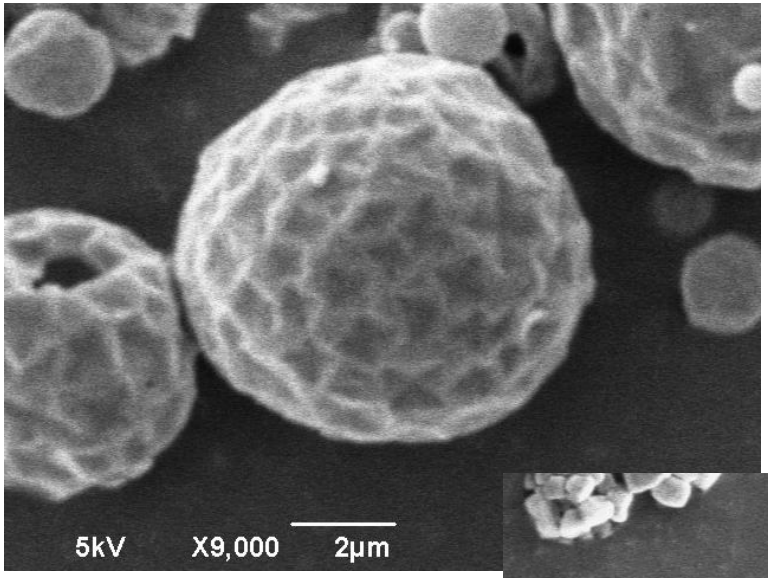


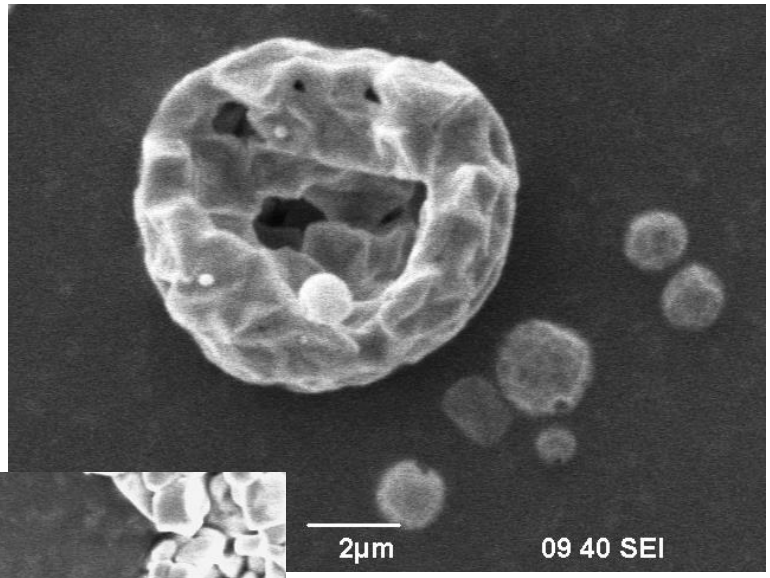


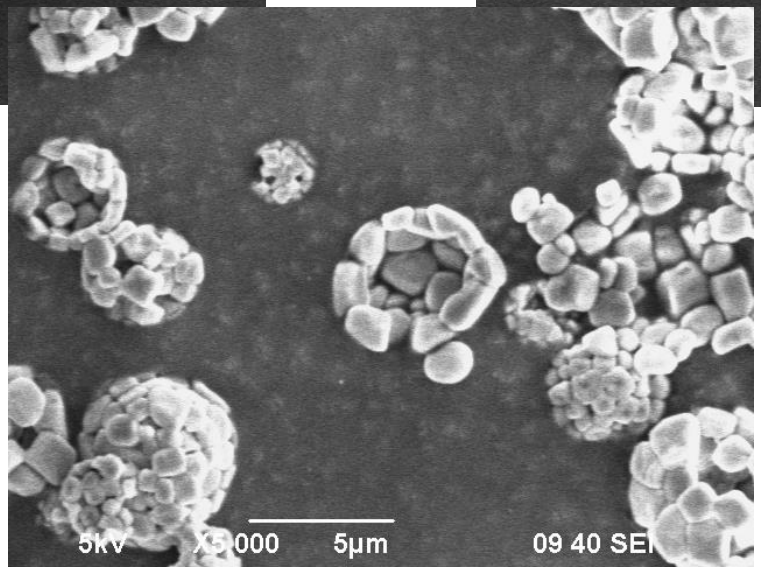


soda-lo®
salt microspheres

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SODA-LO® properties include:

- fine powder for >12 months
- no clumping
- remains free flowing
- greater flavour impact than table salt
- no issues of contaminating tastes
- based on existing food ingredients
- clean label

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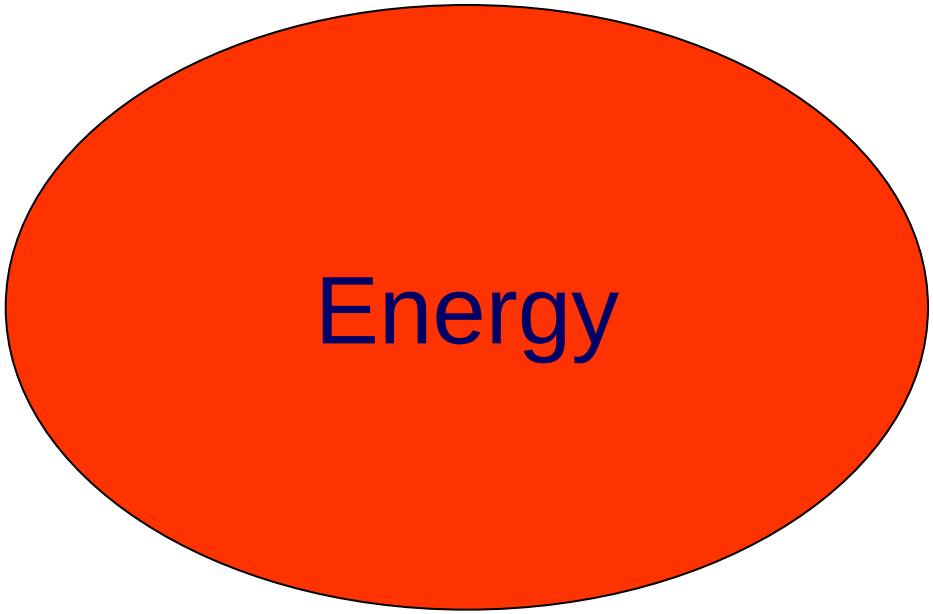

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Energy market segments where nanotechnology is foreseen to have major application:-

- Nano-optimized ***batteries***
- Nano-optimized ***fuel cells*** and hydrogen storage
- ***Supercapacitors***
- Applications of ***superconductivity***
- ***Catalysts*** for energy technologies
- Nano-optimized ***photovoltaics***
- Microenergy ***harvesting***
- ***Thermo-photovoltaic*** cells

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# Batteries

**Altairnano**'s research into the electrochemistry of battery materials discovered that *nanostructured lithium-titanate*, when used to replace graphite as the anode in conventional lithium-ion batteries, results in distinctive performance attributes required by power-dependent energy storage applications

Altairnano announced this fundamental breakthrough in battery technology in 2005


http://www.altairnano.com/

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# Batteries

With the growth in demand for battery powered cars, there is a growing demand for lithium batteries

More recently, many companies including Panasonic, Samsung, LG Chem, Apple, and Tesla have sought to use various nanomaterials including nanostructured silicon, carbon nanotubes and graphene as electrode components in lithium batteries


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# Solar Panels

- Solar panels incorporating nanotechnology are more efficient than standard designs in converting sunlight to electricity, promising inexpensive solar power in the future

- Nanostructured solar cells already are cheaper to manufacture and easier to install, since they can use print-like manufacturing processes and can be made in flexible rolls rather than discrete panels

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# Conclusions

**…….products containing nanoparticles have already been developed for use in many different applications in many different market sectors**

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…….products containing nanoparticles have already been developed for use in many different applications in many different market sectors

**This talk has only been able to give a taste of what's out there, but hopefully it has shown the diversity of applications and at least some of the types of nanoparticles being used**

# And, what about the future?

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- How and where will graphene and/or carbon nanotubes be used?

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    - What more can nanotechnology bring to medicine?

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- Was Richard Feynman correct 40 years ago when he explained that there was no physical impediment preventing materials from being fabricated by manipulating their individual atoms?

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***The answers to these and many other questions offer exciting prospects for the future of nano based products***

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# Thank You

# Questions?