Chemistry and Industry for
Teachers in European Schools

CHEMISTRY CHANGES EVERYTHING

Nanotechnology in Action

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Education and Culture

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CITIES (*Chemistry and Industry for Teachers in European Schools*) is a COMENIUS project that produces educational materials to help teachers to make their chemistry lessons more appealing by seeing the subject in the context of the chemical industry and their daily lives.

The CITIES project is partnered by the following institutions:

- Goethe-Universität Frankfurt, Germany, http://www.chemiedidaktik.uni-frankfurt.de
- Czech Chemical Society, Prague, Czech Republic , http://www.csch.cz/
- Jagiellonian University, Kraków, Poland, http://www.chemia.uj.edu.pl/index_en.html
- Hochschule Fresenius, Idstein, Germany, http://www.fh-fresenius.de
- European Chemical Employers Group (ECEG), Brussels, Belgium, http://www.eceg.org
- Royal Society of Chemistry, London, United Kingdom , http://www.rsc.org/
- European Mine, Chemical and Energy Workers' Federation (EMCEF), Brussels, Belgium, http://www.emcef.org
- Nottingham Trent University, Nottingham, United Kingdom, http://www.ntu.ac.uk
- Gesellschaft Deutscher Chemiker GDCh, Frankfurt/Main, Germany, http://www.gdch.de
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Other institutions associated to the CITIES project are:

- Newcastle-under-Lyme School, Staffordshire, United Kingdom
- Masaryk Secondary School of Chemistry, Prague, Czech Republic
- Astyle linguistic competence, Vienna, Austria

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NANOTECHNOLOGY IN ACTION – SELF-CLEANING MATERIALS

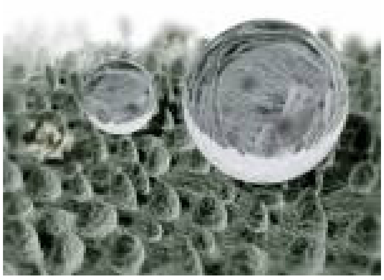
"The humble lotus – it has a lot to answer for!"
Introduction

Wouldn't it be wonderful if we never needed to use soap and water ever again? Well, this is perhaps going a bit far, but there are now certain materials available which are self-cleaning. This opens up a whole range of uses, particularly in the building industry and in fibres.

?

When did this all begin?

Work began in the early 1970s, when Wilhelm Barthlott, working at the University of Bonn in Germany, discovered what is called the "lotus effect". He wondered why the leaves of the lotus plant were always so clean, irrespective of the environment in which they were located. This led him to investigate the surface of the leaves in minute detail, with the use of electron microscopy.



He knew that the leaf's surface was waxy, but the close-up images revealed tiny 'bumps' on the surface, just a few microns across (between 10^{-6} and 10^{-8} metre diameter.)

Is this really chemistry?

It has long been known that wax repels water, so it should come as no surprise that a waxy lotus leaf has this effect. This is referred to as "hydrophobia" – literally 'water hating'. What was less well known was that the surface of the leaf is much more water-repellent than the simple presence of wax can explain. Water droplets position themselves on the surface of the leaf at a particular angle: the so-called 'contact angle'. It seems that the tiny bumps on the surface of the leaf cause this contact angle to increase well beyond 150°. This, in turn, allows the water droplets to collect as a tiny sphere, so that as little of the droplet is in contact with the leaf's surface as possible, causing the droplet to have virtually no adhesive attraction to the leaf. The overall effect that the droplets roll off the leaf's surface very easily. This is called 'superhydrophobic' behaviour.

(Photograph from http://www.botanik.unibonn.de/system/lotus/en/prinzip_html.html)

Barthlott explained that when droplets of water touched the dirt particles, the dirt became wet and similarly superhydrophobic, when in contact with the bumps.

This allowed the dirt to roll off the leaf's surface in just the same way as the water.

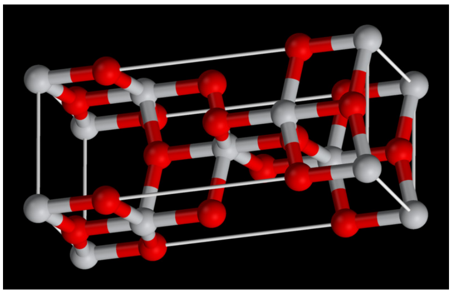
(Photograph from http://www.botanik.unibonn.)

So you want to try something out?

Take a peach and hold it under a water tap with the water running. See how the water runs off the surface without wetting the peach. The minute fibres trap air between them and this increases the contact angle, so that the water droplets do not penetrate the hairy surface. This is a hydrophobic effect.

Extensions

Several years later, Barthlott realised that if a synthetic material could be made to have these superhydrophobic properties, this could be applied to the surface of all sorts of items, with the effect of self-cleaning!
After many years of research, the German multinational Sto AG put these ideas into practice with the introduction of a paint used on the façades of buildings



It was not long before scientists started looking for substances with the opposite characteristics to the superhydrophobic materials. Not surprisingly, these are called 'superhydrophilic'. One of the best superhydrophilic substances known at present is titanium dioxide (Titanium(IV) oxide) – sometimes called titania. This substance has been used as a white pigment in paints for many years. It is also one of the prime ingredients of sunscreen. It also has been used as a food colouring material (E171). Titanium dioxide, TiO_2 exists in three forms. The best form for superhydrophilic use is anatase.

(photographs from Wikipedia.)

In 1967, Akira Fujishima, working at the University of Tokyo, Japan discovered that titania had the ability to decompose water, in the presence of ultraviolet light, into hydrogen and oxygen.

The chemistry is quite complex, but in essence, the titania acts as a catalyst in the presence of UV light (it is 'photocatalytic'). Being a transition element, electronic transitions within titanium ions are relatively easy if the right amount of energy is available; UV light has sufficient energy to make this possible. Further work has shown that organic materials (including bacteria) will also break down to carbon dioxide and water when exposed to ultraviolet light and titania.

How are these self-cleaning materials produced?

Methods vary, as might be expected. These will depend greatly on the articles being produced. For glass and ceramic applications, a very thin layer of titania is baked onto the surface. These layers are of the order of 10^{-6} to 10^{-9} metres thick – far too thin to be visible and too thin to have any noticeable effect on transmission of light.
Other coatings are being developed all the time, some of which do not require the presence of light in order to function, thus increasing the range of applications.

So, what are the benefits?

- Stain-resistant clothing/fabrics
- Conservation of water (saved by not having to wash windows, paintwork, masonry
- Conservation of detergents – and hence petroleum, from which it is derived
- Avoidance of river pollution by the over-use of detergents
- Energy efficiency – saving on electricity for washing windows etc
- Energy efficiency – saving on electricity for lighting, if windows are always clean
- Anti-fogging coatings on windows/car windscreens/spectacles
- Anti-bacterial/anti-odour coatings in bathrooms/kitchens

Are there any known risks?

Possibly carcinogenic to humans, if inhaled.
[2006, http://monographs.iarc.fr/ENG/Meetings/93-titaniumdioxide.pdf]
Has been found to cause slight lung fibrosis. Carcinogenic in rats.

Future developments

- Reducing drag on vehicles (for reduced fuel-consumption)
- Reducing drag on swimwear (for increased speed in races)
- Medical equipment?

Intrigued by what you have read? – want to find out more?

Go to the following websites:

http://members.ziggo.nl/scslai/lotus.pdf

http://www.sciam.com/article.cfm?id=self-cleaning-materials

http://aspdin.wifa.uni-leipzig.de/institut/lacer/lacer05/l05_19.pdf

http://news.bbc.co.uk/1/hi/sci/tech/4696434.stm

http://www.technologyreview.com/Nanotech/20306/

http://www.saint-gobain-recherche.com/anglais/tuiles.htm