

# Response from the London Centre for Nanotechnology to the House of Lords call for evidence: Nanotechnology and food.

---

Report written by Dr. Thierry Bontoux

## Introduction

This white paper is the response of the London Centre for Nanotechnology (LCN) to the Call for Evidence sent by the sub-committee chaired by Lord Krebs and appointed by the House of Lords Science and Technical Committee on Nanotechnology and Food. The purpose of this paper is to demonstrate that nanotechnology is not new in food processing. It will also list new products used in food production and describe some of the major applications of nanotechnology in packaging.

## General Background

The **London Centre for Nanotechnology** is a UK-based, multidisciplinary research centre bridging the physical and biomedical sciences. It has a management structure that allows for a clear focus on exploitation and commercialisation. It brings together two world-leading institutions in nanotechnology, namely **University College London** and **Imperial College London**, in a unique operating model that accesses the combined skills of multiple departments, including medicine, chemistry, physics, electrical and electronic engineering, biochemical engineering, materials and earth sciences, and two leading business centres.

The LCN building in Bloomsbury, opened officially in November 2006, is the only nanotechnology focussed building at the heart of a major metropolis. The facility comprises investments of £14 million for the building and £7 million for equipment and provides a complete range of interdisciplinary tools for bio- and non-bio nanotechnology, including senior staff with clinical expertise. A £2.4 million grant from EPSRC enabled the procurement of a scanning transmission electron microscope – the first of its kind in the UK and one of few in the world - now installed on the Imperial College site in South Kensington.

Operating funds come from a range of private and public sector sources, including the UK research councils, the EU, private companies such as STS/Sumitomo, and charities such as the Wolfson and Gatsby trusts. Nonetheless, UK government remains the most important funding source, and the LCN has been able to win large numbers of contracts, with values ranging between several thousand and several million pounds. For example, the LCN won a Science and Innovation award (£5.6M) to develop new nanometrology capabilities – key for the engineering and quality assurance needed for nanotechnology to achieve its commercial promise - on behalf of the UK.

LCN is organised around three application themes:

- **Information Technology:** The computing and communications needs of society continue to grow and have become increasingly complex. Approaches based on current technology are limited and a variety of new methods are being sought by LCN staff to circumvent these limitations, applying nanotechnology-driven paradigms such as quantum computing and spintronics.
- **Healthcare:** Society's need for healthcare continues to grow. Expenditure on healthcare in Europe is typically the largest item on a nation's balance sheet. LCN is uniquely placed; it has access to a vast bio-medical expertise, enabling new paradigms in healthcare. Under development are specialised sensors and novel cancer-diagnosis systems, as well as new insights into cellular biophysics and novel research techniques.
- **Planet Care:** Climate change is probably the single largest threat to society in the 21<sup>st</sup> century. The LCN uses its expertise ranging from biology to chemistry and materials science to conduct research in novel photovoltaics, new approaches to exploring current energy supplies, new materials for the nuclear industry and to store efficient hydrogen storage at room temperature.

## State of the Science and its Current use in the food sector

### What is Nanotechnology

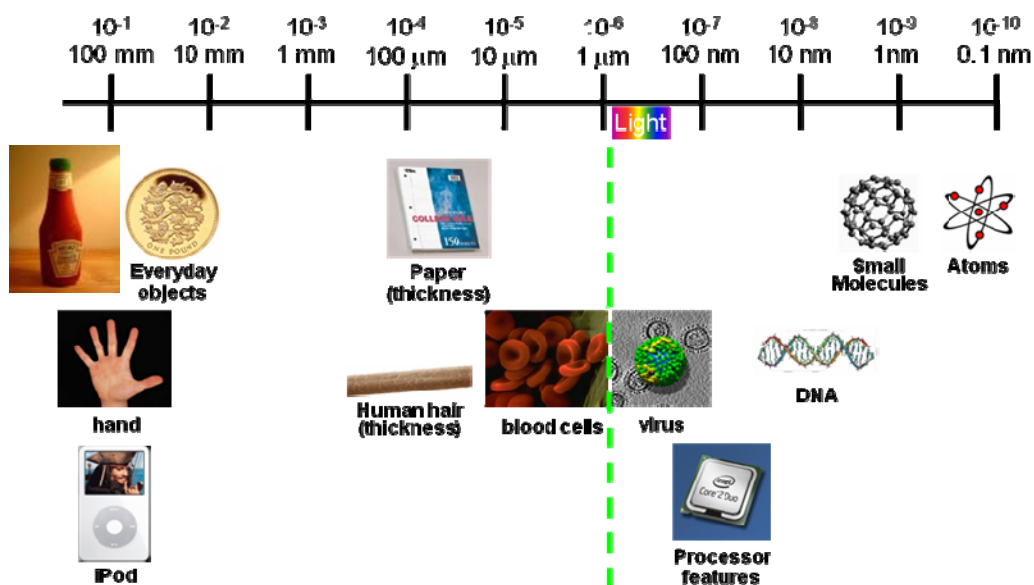


Figure 1: How Small is Small  
(courtesy of Dr G.Charras - LCN)

There is often a misunderstanding about what nanotechnology is. The general idea is that nanotechnology refers to novel engineered “nano” structures that never existed before in nature. Because it has only recently been branded as a science of its own, it generates both fear and fascination.

We should consider how commercial IT brands use the term “nano” as a synonym of positive progress and how, on the opposite side, the cosmetic and the food industries often fear to speak about it. The commercial fascination is easily symbolized by the “iPod Nano”, and a simple search on Internet will show many products using “nano” to brand high-tech electronics. The fear of nanotechnology can hardly be better described than with respect to the food industry. The public has lost trust in the regulatory authorities in general as well as in the food industry. It is fortified in its opinion by rare but dramatic events such as the baby powder milk poisoning last year in China.

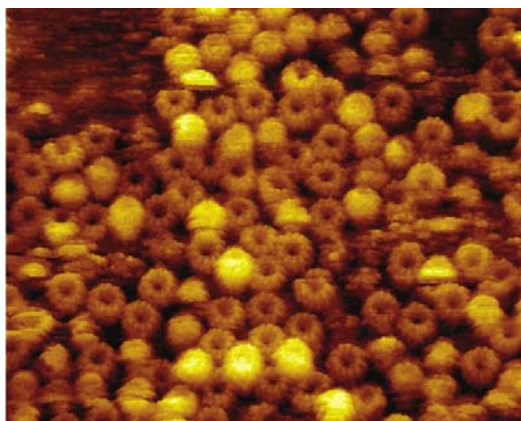


Figure 2: Molecular ATPase turbines visualised at the nanoscale  
Courtesy Stahlberg, H. et al.

Even if these two different perceptions of nanotechnology seem widely divergent, they have one thing in common: they see nanotechnology as a new science providing completely new products to the market, and it is human nature to consider that what is new is frightening. Activists try to mobilise public opinion against novel technology while the food industry conceals its use of nanotechnology to avoid alarming its clients. A rational approach that goes beyond stereotypical perceptions is needed to deal with the real meaning of nano-science and

technology. In particular, nanotechnology does not necessarily imply nano-engineered particles.

We start by considering what “Small” is. Figure 1 compares the different scales of usual objects and links them to the nano-scale. There is a clear borderline between macro / micro scale and “nano” objects. This demarcation is the wavelength of visible light. Until the 1980s, scientists used either optical or electron microscopes to obtain direct images of the small-scale world. The latter microscopes could only produce images of small structures, usually in vacuum and generally destroying them in the process. The optical microscope however could lead to “in vivo” studies but could not “see” structures smaller than the wavelength of the light used to illuminate the samples. This is the origin of the  $1\mu\text{m}$  boundary between traditional and nanoscale science. This limit was only overcome with the invention of the Scanning Tunnelling Microscope (STM) in the 1980s. The STM gave scientists and engineers the means to observe conductive surfaces at the atomic scale. They started to manipulate atoms one by one and develop “micro” electronics that soon became “nano” electronics. However, the main disadvantage of the STM is that it uses an induced current between the scanned surface and its “optics”. The later invention of the Atomic Force Microscope (AFM) really made the difference and launched nanotechnology in the form we know it today. It allows us to “see” objects smaller than a micron without damage. It uses a pin to probe the surface of samples in a similar way



Figure 3: home-built AFM at the LCN  
Courtesy Bart Hoogenboom

as a blind person can “see” or read using his hands. The AFM found many applications in electronics and in biology. It gave birth to the modern understanding of biological nanostructures, enabling us to see cells and sub-cellular structures with unprecedented resolution (Figure 2).

Today, there are many other types of equipment used to study nano structures, but none has had an impact comparable to that of the AFM. They all have in common that they are used across disciplines, in nanoelectronics, in chemistry and biology. **Nanotechnology is not one branch of science, but a platform technology that gathers tools enabling scientists to study and manipulate objects below the 1 $\mu$ m optical limit.** There is thus not one nanotechnology but a full range of nanotechnologies, comparable to the extremely broad meaning of the concept “engineering”.

It has been rather common to associate electronics, genetics, and cell biology with nanotechnology, because during the last few years it has led to incredible developments in those fields. However, well before the word nanotechnology was even invented, there were other disciplines such as Chemistry, Biochemistry, Virology and Condensed Matter Physics (physics of solids and liquids) that had already dealt with nanoscale structures but were not capable of directly and easily seeing the objects they studied. In other words the concept of nanotechnology is new in everyone’s minds but the studies and its applications are as old as modern science.

One illustration can be found in what most of us consider as basic and very traditional food: chocolate. The recipe to achieve the transformation of cocoa seeds into chocolate



Figure 2 : A chocolate Melanger - Probably one of the oldest nanotools in food processing. Courtesy [Sanjay Acharya](#)

is certainly one of the oldest processes based on nanotechnology. It aims to create small crystals of cocoa of only one specific type and whose building blocks measure approximately 6.5 nanometres across. The online encyclopaedia Wikipedia describes the process in the following way<sup>1</sup>:

*“Making chocolate considered “good” is about forming as many type V crystals as possible. This provides the best appearance and texture and creates the most stable crystals so the texture and appearance will not degrade over time. To accomplish this, the temperature is carefully manipulated during the crystallization.*

*Generally, the chocolate is first heated to 45 °C (115 °F) to melt all six forms of crystals. Next, the chocolate is cooled to about 27 °C (80 °F), which will allow crystal types IV and V to form. At this temperature, the chocolate is agitated to create many small crystal “seeds” which will serve as nuclei to create small crystals in the chocolate. The chocolate is then heated to about 31 °C (88 °F) to eliminate any type IV crystals, leaving just type V. After this point, any excessive heating of the chocolate will destroy the temper and this process will have to be repeated. However, there are other methods of*

chocolate tempering used. The most common variant is introducing already tempered, solid "seed" chocolate.

Two classic ways of manually tempering chocolate are:

- Working the molten chocolate on a heat-absorbing surface, such as a stone slab, until thickening indicates the presence of sufficient crystal "seeds"; the chocolate is then gently warmed to working temperature.
- Stirring solid chocolate into molten chocolate to "inoculate" the liquid chocolate with crystals (this method uses the already formed crystal of the solid chocolate to "seed" the molten chocolate)."

We chose to give this example only to demonstrate that nanotechnology is not novel as such and that nanostructures are not necessarily as dangerous or frightening as some members of the public believe. On the other hand, not all food engineering based on nanotechnology is necessarily as safe as manufacturing chocolate. The next chapter will look into the actual use of nanotechnology in food production.

## Nanotechnology in our foods today

To underline that nanotechnology does not refer to only one specific type of technology, we shall use "nanotechnologies" from now on instead of "nanotechnology". Nanotechnologies can be found in the food manufacturing processes at different levels:

- Nanotechnologies can be incorporated into the food itself to create specific properties.
- Nanotechnologies can be used in packaging: several examples of such products are already available on the market.
- Nanotechnologies can be used to develop new materials and methods to manipulate and process foods, but this will not be treated in this report.

## Nanotechnologies in foods

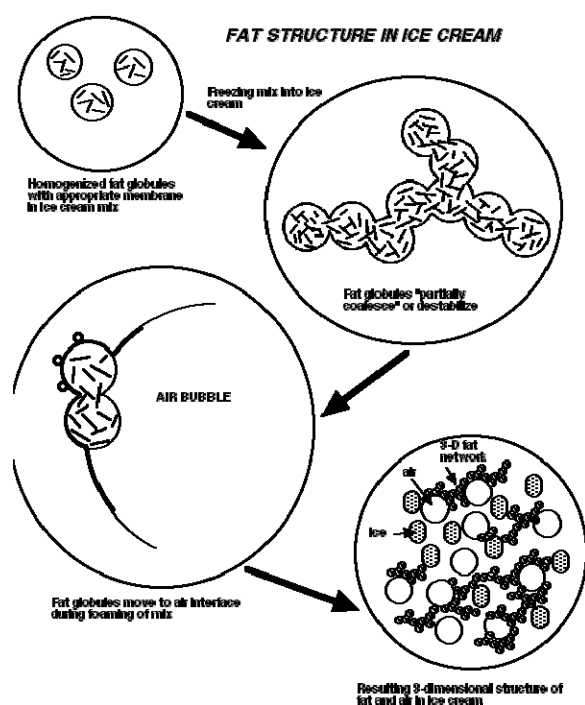


Figure 3: Fat structure in ice-cream  
courtesy of Professor H. Douglas Goff – University of Guelph

The first important point is that nanotechnologies have been used in food manufacturing for a long time without being named as such. One example is the addition of emulsifier to traditional manufacturing processes. For instance, to cut costs and meet consumer requirements, the food industry needs to reduce the quantity of fat and cream in the manufacturing processes of dairy product. Ice-creams need to be made with less cream, and since water is much less expensive than cream, the simple idea is to replace cream by water. However, ice creams made from water alone have

never been considered as “delicatessen”; even sorbets need cream for unctuousness. This is where nanotechnologies come into action, even though ice-creams are not identified as nanofoods. Emulsifiers, such as lecithin, are used to mix products that previously needed cream to thicken.

Ice-cream is a complex nanostructure. It is at the same time a foam and an emulsion: it can be simplified as an emulsion of frozen water and air meshed into a foam of fat. The introduction of emulsifiers has had many positive effects on the structure and the conservation of the frozen dairy product. Emulsifiers are added to ice creams to replace the milk proteins found in cream, to actually reduce the stability of the fat emulsion, by placing proteins on the fat globules surface, leading to thinner membranes more prone to coalescence during whipping. When the mix is subjected to the whipping action of the barrel freezer, the fat emulsion begins to partially break down and the fat globules begin to flocculate or destabilise<sup>ii</sup>. The air bubbles which are being beaten into the mix are stabilised by this partially coalesced fat. If emulsifiers were not added, the fat globules would resist this coalescing, the air bubbles would not be properly stabilized and the ice cream would not have the same smooth texture.

Beside the bulk introduction of chemical in the manufacturing process, there is intense research on the nanostructures of traditional food, to understand and optimise the stability of the product while further reducing their costs. Today’s ice-creams are barely made with cream but nearly exclusively with water, thanks to chemical/nano-engineering. The same principle applies wherever emulsifiers are used. In general, nanoscale studies can contribute to the creation of better and cheaper food. Think of chocolate mousses that remain stable in time, even after days opened or kept outside of a refrigerator. We should also mention a famous brand of chocolate sweets which “do not melt in the hand but only in the mouth”, and tomato ketchup sauces that, although being made only from natural ingredients, can stay fresh for up to 8 weeks once opened, and for several months if unopened. Any normal tomato purée would encounter phase dissociation only hours after processing. The only way to preserve those sauces for such a long times is by engineering their inner structures at a molecular level (i.e. nanoscale). Here again, the understanding of what happens at the nanometre scale is key to conservation and enhancement of gustative properties. Although being simple and basic foods, they all are the result of chemical and molecular engineering and, therefore could all be considered as “nanofoods”.

Nanotechnologies can also be used to protect and deliver essential nutrients. Food processing relies on techniques that potentially degrade nutrients such as vitamins. They need to be protected from heat and acidity. Encapsulation is a reliable way to do so, also enabling faster absorption by the organism. It is used in two types of manufacturing: food enrichment<sup>iii</sup> and food supplements. Encapsulation concerns vitamins, preservatives and enzymes, but there are many new candidates for encapsulation, sometimes thousands of times smaller than living cells. For instance, Omega-3 additives are enclosed in nano-capsules of 30-40 nm to enhance their absorption by the organism and thus their effectiveness. The Woodrow Wilson International Center<sup>iv</sup> for Scholars maintains a list of products available to the general public and openly advertised as containing nanostructure or issued from nanotechnology. It shows that while food manufacturers have a certain reluctance to speak about nanotechnology, the sport food supplement industry is much more open about it.

In both cases, encapsulation presents many benefits for the industry and possibly for the general public. Nanocapsules can be incorporated in food to deliver nutrients while being rapidly assimilated by the body because of their size. The nutrient properties of food are better preserved because they are undamaged by the digestive process. The NovaSOL technology from the German ingredients firm Aquanova<sup>v</sup> is used to encapsulate vitamins A, D, E, K,  $\beta$ -carotene, ascorbic acid, Omega3 fatty acid, lipoic acid, and lutein. The NovaSOL technology involves encapsulation of the ingredients in artificial micellae which measure just 30 nm, imitating the absorption process of nutrients by the human organism. Using the same technology, Aquanova has also found a way to extend the use of the preservatives sorbic and benzoic acid in foods with a high pH using its NovaSOL nanotechnology. Sorbic and benzoic acid are commonly used as preservatives, but until now their usefulness has been limited to the more acidic end of the pH scale, since performance decreases above pH4 and above pH6 they are almost totally ineffective. In the case of sorbic and benzoic acid, encapsulation enables pH-independent performance through the whole acidity scale. Thus, whereas in the past the preservatives were only suitable for use in sour-tasting products, they can now be used to protect against microbial spoilage in milder tasting products as well.

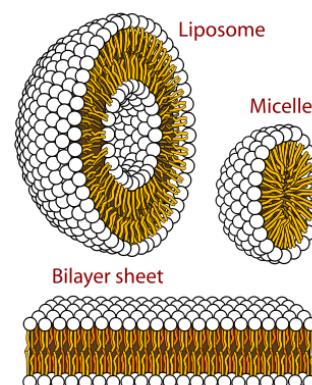


Figure 4: schematics of Micellae  
Courtesy of Wikipedia

Another example of an encapsulated supplement is Driphorm<sup>®vi</sup>, a dry powder form of fish oil produced by Nu-Mega. This Australian-based company advertises numerous other potential applications for their patented encapsulation technology:

- Infant nutrition - infant formulas and moist solid preparations
- Bread and bakery products
- Cereals - muesli bars, breakfast products
- Dairy - frozen confection, yoghurts, fromage frais, milk
- Supplements - capsules, dietary products
- Beverages and juices
- Animal Feeds
- Fruit

Nu-Mega recommends encapsulation because nano-size dispersions, emulsions and filled micellae are not subject to sedimentation, resulting in better product life span and storage. As their size is much smaller than the wavelength of light, they can be incorporated in clear and transparent foods without causing clouding.

Aquanova and Nu-Mega are no exceptions. The European industry is very active in this field. Groups like Nestlé, DANONE, Kraft, BASF, Bayer, Associated British Foods invest millions in research linked to nanotechnology<sup>vii</sup>. It is likely that the result of such research and investment will be used throughout the food production chain. In fact, there is already evidence of such practices in the usage of Transglutaminase (TGase). TGase is an enzyme that acts as a catalyst to promote cross-linking between

proteins. It has a significant impact on properties of proteins such as: ability to gel, thermal stability and water holding capacity; thereby improving the functional characteristics of foods such as elasticity, binding ability, mouth feel, flavour, texture, and so on. This enzyme is very often used in non-dairy products and mousses, foams and jellies in association with Na-caseinate.

The number of examples of nanotechnologies used for food processing could be extended over several pages. Most of them would concern modifications of molecular and protein properties, and some are obviously linked to nanoengineering, like Nanocapsules. It is not the purpose of this report to give an exhaustive list of the application of nanotechnologies. **However, we have demonstrated that nanotechnology in food is not science-fiction but a reality, and that there is not one type of nanotechnology applicable to the food industry, but several different approaches derived from traditional physics, molecular chemistry and biology.**

### Nanotechnology & Packaging

Food packaging has three aims:

- To contain
- To protect
- To inform – this will not be treated here because it is not directly linked with foods and toxicology.

There is no such thing as simple packaging today. Traditional materials such as paper and wood disappeared long ago to be replaced by more convenient materials such as plastics. The same is happening again now, but less visibly due to the similarity in appearance of the new materials with plain plastics.

### Contain & Protect

The primary purpose of packaging has always been to contain raw or processed food. This has not changed today, but the search for profitability and mass production has led to the development of increasingly sophisticated technology. This involves lighter, stronger, and smarter materials that are cheaper to produce. For instance, new materials can now provide longer shelf life by improving the barrier function of food packaging, reducing gas and moisture exchange and limiting exposure to UV light. Although those new materials look like many of their predecessors, most of them are the direct consequence of “nanotechnology” studies. Thousands of examples could be listed here.

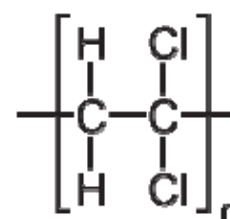


Figure 5: Molecule of PVC

The first evidence we shall give is used by everyone and is considered as a must-have in any kitchen: the Cling Films. Although the original film was invented by accident in 1953, long before the term “nanotechnology” existed, what makes them so popular is a direct consequence of a nanoscale phenomenon.

Cling films are made of polyvinylidene chloride (PVC). It forms a remarkable barrier against water, oxygen and aromas. It has superior chemical resistance to alkalis and acids, and is insoluble in oil and

organic solvents. It has very low moisture retention and is impervious to mould, bacteria, and insects. Therefore, it has been widely used in all food industries for packaging and is most commonly employed in wrapping films of 100µm thickness. Non-PVC alternatives are now being sold, because of the risk transfer of plasticisers from PVC into food. It is indeed problematic for PVC to achieve full polymerization of the material, which could contain remnants of the vinyl chloride monomer. To achieve the full polymerisation and to develop new and better materials, engineers need to understand the dynamic of polymerisation, which involves studies at a molecular scale. In July, 2004 the composition of Cling films was changed to Low Density Polyethylene (LDPE). SC Johnson® claimed that this change was the result of an initiative to look for more sustainable and environmentally acceptable plastic. The new film does not contain chlorine. However, LDPE does not possess the same qualities as barrier to oxygen, aroma, and flavour molecules that vinylidene chloride copolymers do, making the new product a lower quality plastic wrap, as it is not as useful in protecting from spoilage or flavour loss.

In daily household practice, the films are interesting for their physical properties that originate from nanoscale behaviours, although most people never realise it. The “clinging” property is not due to any coating or glue sprayed onto the film, but to the molecular attraction between two layers of films. The chains of polymers try to bind together between layers when wrapped one against the other. The second interesting property of such films is their ability to block oxygen from reaching the foods. The chains of polymers form a mesh within the material, tight enough to block the way to molecules of gas. Hence, when optimising the manufacturing and changing the composition of the films, engineers have studied the nanoscale properties and structures of the chains of polymers, using the nanotechnology platform, although being recognised as chemistry by the public.

Durethan® films are another example of a material using nanotechnology and openly advertised as such. These films are manufactured by Bayer and have nano silicate platelets incorporated into a polyamide (PA) matrix. Contrary to the PVC films, the PA films are not as impervious to oxygen but are less hazardous to human health than PVCs. They tend to be preferred for industrial applications for this reason. Silicates are simple nanoscale clay structures, the same particles used in tooth paste or gum and gel manufacturing. The Nanoparticles of clay interact in various ways with the plastic film. They act as nuclei for crystallisation of the polymer and improve the microstructure of the film. They also form a labyrinth of nano layers that O<sub>2</sub> molecules have to go through before reaching the foods packed inside. The molecules are forced to make long detours and their penetration is thus slowed down.

Similar usage of clay nanoparticles has been developed by Nanocor to create plastic bottles that do not interact with alcohol stored in beer. This new plastic development resulted in extending the shelf life of the packed beers up to six months by minimising the loss of carbon dioxide and impeding the penetration of oxygen into the beverage.

Mitsubishi Gas Chemical (MGC) and Honeywell Specialty Polymers both are using Nanocor’s nanoclays in nylons as barrier layers in multi-layer PET bottles and films for food packaging. MGC’s MXD6 nylon nanocomposite, called Imperm N, is commercially used in Europe in multi-layer PET bottles for beer and other alcoholic beverages<sup>viii</sup>. It is also being used for small carbonated soft-drink bottles, such as for Perrier® carbonated water.

Honeywell aimed its Aegis nylon 6 nanocomposites initially at PET beer bottles. In late 2003, a version containing an oxygen scavenger made a commercial splash with the introduction of the 1.6-liter Hite Pitcher beer bottle from Hite Brewery Co. in South Korea. Aegis is the barrier layer in this three-layer structure, which is said to provide a 26-week shelf life<sup>ix</sup>.

Honeywell aims at using other Aegis nano-composites grades (without oxygen scavenger) as replacements for EVOH<sup>1</sup> in films and pouches. Such grades are reportedly lower in cost than EVOH, provide a better barrier, and also have better puncture resistance and good clarity. (Because of their size, nano-particles do not interfere with light transmission.)

To conclude this list of actual application of nano-composites designed for food packaging, we mention DuPont De Nemours, which has released a new additive to plastic films "DuPont Light Stabilizer 210" aiming to reduce damaged by UV radiation in transparent packaging<sup>x</sup>. It contains titanium dioxide with better properties than benzophenone and benzotriazole. In addition titanium dioxide is not prone to migration according to the manufacturer.



Nano-based materials have also been introduced for antimicrobial purposes. There are several products on the market nano-engineered to prevent bacteria to develop. They range from refrigerators sold by LG, Daewoo and Samsung, to kitchenware (made for example by Nano Care Technology Ltd), but also including containers like Camelbak<sup>®</sup> or baby cups made by Baby Dream<sup>®</sup>. This is only a

short list and the nomenclature could be extended far beyond the few brands we have listed here. They all incorporate nanocrystals specifically identified for their antibacterial properties. There are four main different type of substances used:

- Silver: Silver ions and silver compounds show a toxic effect on some bacteria, viruses, algae and fungi, this effect is shared with heavy metals like lead or mercury, but without the high toxicity to humans that are normally associated with these other materials. Silver has been used since antiquity in medicine to cure wounds without any side effects; silver compounds were used to prevent infections during World War I, before the advent of antibiotics. Silver nitrate solution was a standard of care but was largely replaced by silver sulfadiazine cream (SSD Cream)<sup>xi</sup>. SSD creams became the "standard" of care for the antibacterial and antibiotic treatment of serious burns until the late 1990s<sup>xii</sup>. Silver can be found today in the form of nanocrystals with sizes ranging from 15nm to 100nm, with no evidence of toxicity for human being. Silver Nanoparticles are heavily used in food packaging and storage containers today.
- Silicon Dioxide: it is most commonly known as sand or quartz. In its nano form, fumed silica has a very strong thickening effect. Its primary particle size is 5 - 50 nm. The particles are non-porous and have a surface of 50 - 600 m<sup>2</sup>/g. Density 2.2 g/cm<sup>3</sup>. Inhaling finely divided crystalline silica dust (or fumed silica) in very small quantities over time can lead to silicosis, bronchitis or (much



<sup>1</sup> Ethylene Vinyl Alcohol, commonly abbreviated EVOH, is a formal copolymer of ethylene and vinyl alcohol.

more rarely) cancer, as the dust becomes lodged in the lungs and continuously irritates them, reducing lung capacities (silica does not dissolve over time). However this is more a side effect of inhaling dust into the lungs rather than a direct effect of silicate dioxide chemical and physical properties. Such particle sizes are naturally present in the environment and if not inhaled, pure silicon dioxide is inert and harmless. Pure silicon dioxide produces no fumes and is insoluble *in vivo*. It is indigestible, with zero nutritional value and zero toxicity. When silica is ingested orally, it passes unchanged through the gastrointestinal tract, exiting in the faeces, leaving no trace behind.

- Titanium Dioxide: has widely been used as a white pigment for paint, but recently found new applications in nanoengineering. Titanium Dioxide is being used for its antibacterial properties and as a UV protector in cosmetics and in food packaging. Generally considered non-toxic, nanoparticles have sizes ranging from 20 nm to 200 nm. However, several researchers reported evidence that it led to deterioration of health in some animals<sup>xiii</sup>. The European Chemistry Industry Council and the America Chemistry Council (groups funded by the chemical industry) initiated toxicology studies. The studies exposed rats, mice and hamsters to pigment-grade TiO<sub>2</sub> (PG-TiO<sub>2</sub>, 0, 10, 50 and 250 mg m<sup>-3</sup>) or ultrafine TiO<sub>2</sub> (UF-TiO<sub>2</sub>, 0, 0.5, 2 and 10 mg m<sup>-3</sup>) for 90 days and the lung burdens and tissue responses were evaluated at the end of the exposure period and for up to 1 year after exposure. They show very different results between species, always linked to exposure of high doses of TiO<sub>2</sub> absorbed either by inhalation or absorption through food, but never in a way that could lead to a conclusion regarding usage of TiO<sub>2</sub> in food processing<sup>xiv</sup>.
- Zinc and Zinc Oxide: **Zinc is a nutrient that is critical to human health**, but it is also an active chemical component that needs to be correctly dosed. Excessive absorption of Zinc can lead to poisoning and death, but this is also the case with many other types of nutrients. Furthermore, in the case of Zinc and Zinc Oxide, it is not the size of the particles that will influence the toxicity of the Zinc when absorbed. Zinc dissolves easily into the gastric acid and becomes Zinc chloride.

## Conclusion

In this report we have provided evidence that nanotechnologies have traditionally been used in the preparation of food, albeit under different names such as 'colloid chemistry' and 'materials science', Nanotechnology does not necessarily mean nano-engineering, and many of the chemical modifications made to proteins in food should also be considered as nanotechnology. At the same time, it is true that nano-engineering approaches are introducing novel food additives and adding functionality to food packaging. Regulatory and legislative bodies should be aware of the full range of these applications when debating the use of nanotechnology in food.

## About Dr Thierry Bontoux

French born and living in the UK since 2006, Thierry Bontoux has an industrial background, having held

positions in France and the UK at senior level. His role at the LCN is to develop the connections and relations of the institute with industry. He has a scientific background with a PhD in laser engineering from the University of Osaka (Japan). During his PhD, he studied the simulation of light propagation equations in refractive media and the bi-stability of light in media with non-linear refractive indexes. Dr Bontoux moved to the UK in 2006 to join AeroMobile Ltd, a start-up company based in Crawley (West Sussex), to become director of administration and procurement. He joined the London Centre for Nanotechnology in early 2009.

---

<sup>i</sup> <http://en.wikipedia.org/wiki/Chocolate>

<sup>ii</sup> <http://www.foodsci.uoguelph.ca/dairyedu/icstructure.html>, Professor Douglas Goff, University of Guelph Canada

<sup>iii</sup> <http://www.nu-mega.com/>

<sup>iv</sup> <http://www.wilsoncenter.org/>

<sup>v</sup> <http://www.aquanova.de/>

<sup>vi</sup> <http://www.nu-mega.com/>

<sup>vii</sup> ETC Group 2004; Innovest 2006; Renton 2006; Wolfe 2005

<sup>viii</sup> <http://www.mgc.co.jp/eng/products/nop/nmxd6/index.html>

<sup>ix</sup> <http://www.ptonline.com/articles/200411fa2.html>;

<http://www51.honeywell.com/sm/polymers/products-sub/flex-pkg-resins.html>

<sup>x</sup> [http://www2.dupont.com/Titanium\\_Technologies/en\\_US/products/dls\\_210/dls\\_210\\_landing.html](http://www2.dupont.com/Titanium_Technologies/en_US/products/dls_210/dls_210_landing.html)

<sup>xi</sup> Chang TW, Weinstein L (December 1975). "Prevention of herpes keratoconjunctivitis in rabbits by silver sulfadiazine". *Antimicrob. Agents Chemother.* **8** (6): 677–8. PMID 1211919. PMC: 429446

<sup>xii</sup> Atiyeh BS, Costagliola M, Hayek SN, Dibo SA (March 2007). "Effect of silver on burn wound infection control and healing: review of the literature". *Burns: journal of the International Society for Burn Injuries* **33** (2): 139–48. doi:10.1016/j.burns.2006.06.010. PMID 17137719

<sup>xiii</sup> <http://annhyg.oxfordjournals.org/cgi/content/abstract/49/6/461> (Hext & Al.) March 24, 2005; Wang J & Al. Toxicology Letter 168(2): 176-185.

<sup>xiv</sup> <http://www.cefic.org/files/Downloads/New%20studies%20verify%20that%20Titanium%20Dioxide%20is%20safe%20product,%20April%202004.pdf>