Nanotechnology for food packaging

Improved material properties and new monitoring systems for food safety

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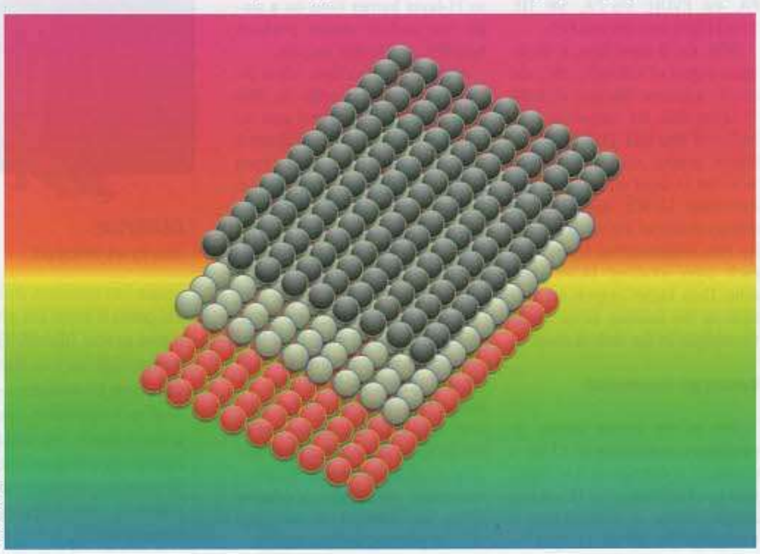
Nanotechnology is the science of very small particles in the nanometer range. Comprehensive research and development has resulted in many applications suitable for food packaging. This article reviews the use of nanoparticles in this market segment and discusses the growing concerns regarding health, safety and environmental impact.

The revolution of nanotechnology has introduced new opportunities for the food sector. This includes new methods of increasing barriers in this section of the packaging industry as well as the development of nano-monitoring systems and sensors for food safety.

The size of nanoparticles can change the properties of packaging materials without affecting the transparency and processing properties. In order to control microbial growth, detecting and delaying oxidation, improving colour, flavour, and transparency the properties of nanoparticles can be engineered for special applications.

Multi-layered nanomaterials for functional applications



Source: Idvac Ltd.

Introduction

There is a continuous consumer demand for fresh, authentic, convenient and flavoured food products. The competitive food market is always looking for new processes and technologies to offer new products which prolong shelf life, freshness, quality and high safety.

It is well known that the largest part of flexible materials used in the packaging industries is plastics made from fossil fuels which are practically undegradable. Therefore, packaging materials for foodstuff, like any other short-term storage packaging material, represents a serious global environmental problem. The application of nanocomposites promises to expand the use of edible and biodegradable films. It will help reduce the packaging waste associated with processed foods and will support the preservation of fresh foods, extending their shelf life.

The use of nanomaterials in food packaging is already happening. An example is bottles made with nanocomposites that minimise the leakage of carbon dioxide out of the bottle. This increases the shelf life of carbonated beverages without having to use heavier glass bottles or more expensive cans. Other examples include slim shake chocolate with silica nanoparticles, fat soluble nutrients with nanoencapsulated materials and food storage bins with silver nanoparticles embedded in the plastic to kill bacteria.

The research and development budget spent worldwide on nanotechnology exceeded USD 15 billion in 2008 and it is expected to be at least USD trillion by 2020.

However, the food industry was slow and cautious in implementing the results of research works. The main reason lays in the dominating public opinion towards the introduction of new nanomaterials in the food chain, particularly when it comes to the issue of "nanofoods". In addition, there is no international law making nano labelling mandatory around the globe. This makes it difficult for the consumer to identify which food products contain nano ingredients.

What is nanotechnology?

Nanotechnology uses particles, molecules or structures in the 1 to 100 nanometer scale to engineer functional systems at the molecular or atomic level. A nanometer is one billionth of a metre (10^{-9} m). The human hair is roughly 100,000 nanometers wide. The nano size particles allows them to exhibit novel and improved physical, chemical, mechanical and biological properties that are different from the properties of bulk materials.

This field of science provides scientists with a new understanding about the properties of materials in the atomic scale which can be implemented to engineer new products with a wide range of performances.

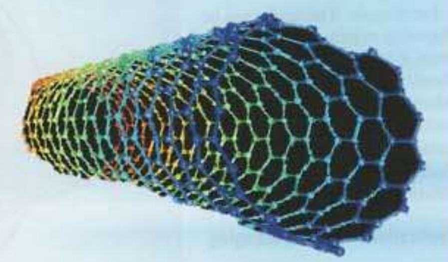
For example, if molecules can be aligned in orderly array on a substrate, it can function as innovative chemical and biological sensor or enhance surface barriers. Nanostructured polymers, ceramics and metals can improve physical, mechanical and chemical properties of materials.

Nano-wax on fruits and vegetables

Applications of nanopackaging

However, ossible applications for food contact materials using nanotechnology can be summarised as follows:

- a) Nanomaterials to improve packaging properties such as gas barrier, transparency, flexibility and mechanical properties.
- b) Nanocomposite material to manufacture biodegradable polymer. Material such as inorganic nanoclay particles is introduced into the biopolymeric matrix and surfactants to produce biodegradable polymers.
- c) Nanocomposites material which typically contains clay nanoparticles to improve barrier properties of bottles and films. United States Food and Drug Administration (USFDA) has approved the use of such nanocomposite in contact with foods.
- d) Nano-waxy edible coatings or films, which are currently used on a wide variety of foods. This includes products such as fruits, vegetables, meat, chocolate, cheese, candies, bakery products, and French fries. These coatings or



Carbon nano tubes

films serve as moisture, lipid, and gas barriers.

Nanolaminates consists of two or more layers of nanomaterials that are physically or chemically bonded to each other. A variety of different adsorbing substances could be used to create the different layers, including natural polyelectrolytes (proteins, polysaccharides), charged lipids (phospholipids, surfactants), and colloidal particles (micelles, vesicles, droplets). It is possible to incorporate active functional agents such as anti-microbials, anti-browning agents, anti-oxidants, enzymes, flavours, and colours into the films. These functional agents increase the shelf life and quality of coated foods.

Nanomaterials such as nano silver, nano magnesium oxide, nano copper oxide, nano titanium dioxide and carbon nanotubes can be used in antimicrobial food packaging to prevent spoilage of foods.

Nanosensors

There are many examples of applying nanosensors in the food sector including:

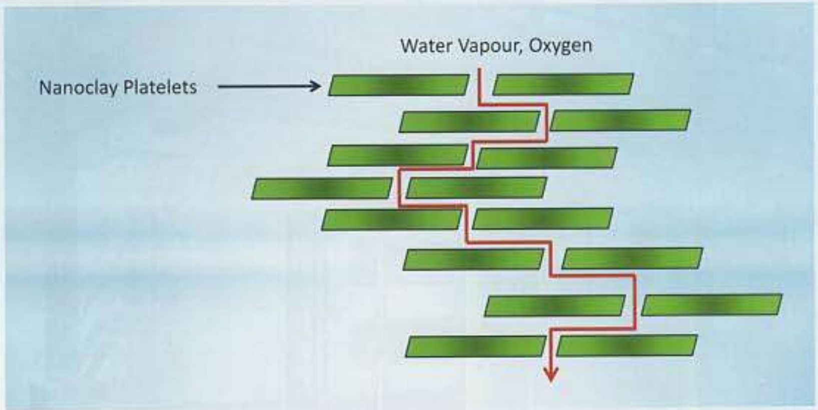
- a) Development of nanosensors for pathogen and contaminant detection in food products. The currently used technologies to detect microbes especially pathogens in food products usually take 2 to 7 days
- b) Development of nanosensors that can record environmental changes and track processing and transportation of food product. For example, such packaging can monitor temperature or humidity over time and then provide relevant information of these conditions by changing colour
- c) Development of encapsulation and delivery systems to carry, protect and deliver functional food ingredients to their specific site of action
- d) Development of nanosensors for sensing and signalling microbial and biochemical changes then to release antimicrobials, antioxidants and enzymes to extend shelf life of a package

Nanoclay in food packaging

Nanoclay-based films are currently available in the market and there are already manufacturers supplying them commercially. Nanoparticles of clay are engineered into packaging films such as polyamide to block oxygen, carbon dioxide and moisture from reaching the food to prevent spoilage. Such films have a combination of properties which include high strength and toughness, abrasion resistance, chemical resistance, and resistance to cracking. Nanoclay is also able to produce lighter, stronger and more heat resistant film.

The embedded nanoparticles prevent gases from penetrating the film and keep moisture from escaping. The dispersal of nanoclay into the polymer matrix affects the barrier properties of a homogeneous polymer film in a specific way creating a tortuous path for gas diffusion. Because the filler materials are essentially impermeable inorganic crystals, gas molecules have to act perpendicular to the film surface. The result is a longer mean

Nanoclay for barrier and other applications



Nanoclay gas barrier mechanism

path for gas diffusion through the film in the presence of fillers.

However, the tortuous path allows the manufacturer to attain greater effective film thicknesses while using smaller amounts of polymer. Nanoparticulate fillers may also influence the barrier properties by causing changes to the polymer matrix at the interfacial regions. It is worth mentioning that the manner in which the polymer–clay nanocomposite is fabricated can play quite a relevant role in how the clay platelets are distributed throughout the matrix and, therefore, the barrier properties of the resulting materials.

Health and safety

The issue of food safety is an important one in the food packaging industry. Nanoparticles are more reactive and mobile, and are more likely to be more toxic than bulk materials. Hence, the ingredients of any nanoparticle used in food packaging or food processing must undergo a full safety assessment by the relevant scientific institution before being allowed to be used for public consumption. The main concern is the migration of nanoparticles or other substances from packages to packaged food.

Currently a number of products, such as nanoclay barrier coatings, are approved for indirect food contact. They are used primarily for dry and moderately dry food application. However, consumers are still concerned about the ethical or moral issues of using nanoparticles in food packaging and processing. There is also a public demand for mandatory labelling of products that contain nanomaterials. Their aim is that consumers have to be informed during the decision for or against a certain product. In order to manage any risks associated with nanotechnologies in the food industry regular dialogues have to continue between consumer, environmental institutions, businesses, and politicians.

Conclusion

Some of the most promising applications discussed in this article of engineered nanoparticles in food packaging materials possess very high gas barriers, antimicrobial properties and detection capabilities. International research and development works indicates clearly that innovative development in nanotechnology for food packaging can benefit consumers and industry.

The application of nanotechnology shows considerable advantages in improving the properties of packaging materials and processed food. This means foods with enhanced health and fresher packaging functionalities such as flavour, texture, shelf life, transportability, reduced costs and nutritional traits. Smart food packaging, incorporating nanosensors, could even provide information on the state of the food inside and alert consumers when a product is no longer safe to eat.

However, there is a requirement for mandatory labelling of products that contain nanomaterials so that consumers are fully informed.

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