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The Future of Plastics and Nanotechnology

Nanotechnology is an exciting technological advancement that has the potential to contribute significantly to the future of plastic. Through nanotechnology, special Nano composites can be created that will

be more dent, heat, and scratch resistant. Yet, the thermoplastic resins used to create the plastic can still be processed with the same equipment currently used to process resins.

According to a report last year by BCC Research, the global market for nanofiber-based products rose from \$128.3 million in 2011 to \$151.7 million in 2012, an increase of 18%. While the current market is relatively small, BCC expects it to grow at a compound annual growth rate (CAGR) of 30.3% from 2012 to 2017, reaching global revenues of \$570.2 million by 2017.

A Closer Look at Nanotechnology

Nanotechnology involves being able to understand and to control matter at the amazingly small dimensions of one to 100 nanometers, with one nanometer being equivalent to one-billionth of a meter. As a point of reference, a sheet of paper is about 100,000 nanometers thick. With nanotechnology, an object can be imaged, measured, modeled, and manipulated right down to each nanometer. At this very tiny level,

Nanotech in plastics

Standing on the shoulders of dwarfs

Type "nano" in Google, and your computer explodes. Use the word "nano" in a blog or marketing campaign and you're bound to get attention. For some nano is a symbol of the evil dangers of new technologies; for others it's the key to the future. But what is nanotechnology? And what is its use for the plastic & rubber industry?

What is nanotechnology?

Nanotechnology is an umbrella term for all materials, devices and technologies with at least one dimension between 1 and 100 nanometers. 1 nanometer equals 10⁻⁹m. The distance is inconceivable: the width of a DNA helix and about twenty times the size of a water molecule. Yes, that means small. Very, very small.

0.1-0.5 nm < DNA helix < 2.5 nm < bacteria < 100nm < a red blood cell < 10,000 nm < a human hair < 100,000 nm < an ant < 5,000,000 nm

Size matters

On the nanoscale new doors open and otherwise impossible functionalities suddenly can be applied. To understand this, think about what happens when you replace Duplo® with Lego®. When your bricks are smaller, there are much more interesting things you can start building. Actually in case of nanotech, the bricks are the size of molecules, which are the basis of life itself, meaning that manufacturing at the nanoscale corresponds to manufacturing of the natural scale.

Nano in figures

Nanotech gets worldwide attention. The US, Japan, China, Germany, France, South-Korea and the UK are the major players in nano R&D, based on their patent activity.

Historically, nanotech found its first applications in electronics, optics, medicine & cosmetics. Although the nanotech developments in the plastic industry lagged behind initially, the amount of nanotech patenting in the plastic industry has rapidly increased since the beginning of the new millennium.

Where is nano used?

This might all sound bizarre and irrelevant for your day-to-day life. But nanotech is already a part of your life, even though we are often unaware of it. It's in the sunscreen you use on the beach, it's in the medication you take. It makes batteries more efficient. It makes four-de France bicycles lighter. It gives a more natural look to LED lights. So nanotech is not such a magic as it might seem at first sight.

batteries, pharmaceuticals, bicycles, sunscreen, LED

Why?

The most important question related to the use of nanotech in plastics is "Why?" Generally speaking there are 5 major functionalities that nanotech can offer plastic materials.

- smart**: Nanotech is used for automation of functionalities or enhanced intelligence in materials. It can be used to manufacture smart materials that use self-healing, self-cleaning or self-sealing.
- electric**: Nanotech can be used to manipulate electrical properties such as electrical conductivity or anti-static characteristics.
- optical**: Nanotech is used to absorb UV and IR radiation, for light scattering, improved thermal stability, improved thermal resistance or conductivity, to improve color & to create crystal clear materials.
- mechanic**: Nanotech can reinforce materials, improve tensile strength & dimensional stability, avoid scratches, and make super-light materials.
- chemical**: Nanotech can change the chemical reactivity of a material. For the other way around, improve its chemical resistance. This includes anti-microbial barrier and fire resistance properties.

Which nano?

The family of nano-sized fibers that are mixed in plastics to improve their functionalities (so called nano-fibers) is ever growing and expanding. The current list of nanofibers starts off with 'old' nanofibers like carbon black & titanium dioxide; over those that have more recently found their place in the plastic industry like nanotubes & carbon nanofibers, to those that still have a high science-fiction factor like nanocellulose & quantum dots.

Nanofibers can be roughly grouped in fibers shaped like plates (e.g. nanoclay), tubes (e.g. carbon nanotube) and 3-dimensional nanofibers (e.g. nano-silica). There are also some peculiar nanofibers like POSS, an unusual cage structure, and tree-shaped dendrimers.

The future of nano?

When will the future opportunities for application of nanotech in plastics be? We would put our money on one of the following four:

- Use nanotech in bioplastics to make them as performant as oil-based plastics.
- Wait for graphene to make its breakthrough in the coming decade.
- Transfer the knowledge from nanotechnology developments in high tech areas like semiconductors & electronics to plastics.
- Use nanotechnology to make smart plastics.

the chemical, physical, and biological properties of materials are different than when in their bulk form. These new properties, therefore, can be used in different ways.

The plastics industry uses nanotechnology in a variety of ways. Materials reinforced through nanotechnology are used in thermoplastics because they are capable of resisting heat, provide dimensional stability and are capable of conducting electricity. Plastic nanotubes also are being created with nanotechnology. These nanotubes are flexible, lightweight and durable, and are being used in the automotive, aerospace and chemical industries. Finally, special nanocomposite foams have been created and are expected to replace solid plastic because they are much lighter.

Nanotechnology Concerns

Since nanotechnology is a relatively new concept, there are still concerns associated with it. For example, critics of the nanotechnology maintain that certain substances may become toxic when manipulated at this small scale. Further, critics fear some of these manipulated substances could cause harm to the immune system if inhaled, absorbed through the skin, or otherwise digested.

Concerns involve predictability, the impact on the health of employees and consumers and the impact on the environment. Predictability is an issue because no one really knows how these nano materials will behave over time. The behavior of materials at the nanoscale is not the same as those observed at larger scales. George Kimbrell from the International Center for Technology Assessment explained the “scientific consensus on nanomaterials is that nano does not mean merely tiny, but rather materials that have the capacity to act in fundamentally different ways.”

Of special concern is the health of employees involved in manufacturing products incorporating nanomaterials. For the manufacturing employees who will have the most extensive exposure to nanomaterials, there is a real health risk in handling such

Opportunities for Pakistan's

Plastics Sector: Enterprising

Companies can now team up with University Researchers and utilise the Higher Education

Commission's grant from the National Technology Development Fund to develop salable products based on Nano Tech. The NTDF is a Rs.2.94 Billion amount from which each applicant can avail a grant of Rs. 14.00 Mil.

<http://hec.gov.pk/english/services/students/TDF/Pages/Intro.aspx>



small materials. Due to their extremely small size, nanomaterials have the ability to move throughout the environment unnoticed. Inhaled nanomaterials can flow through the body undeterred by the human body's natural defenses that would usually serve to block larger particles.

There is simply no way of knowing how each and every nanomaterial will behave once inside the body or what long-term effects it may have. Many have equated the potential risk of nanomaterials to human health to those created by asbestos. The study of the potential health risks of nanomaterials has its own name – nanotoxicology.



Nanospider™ Electrospinning Technology by Elmarco

Uses for Nanotechnology

Through the use of nanotechnology, the plastics industry hopes to achieve several amazing new accomplishments. For example, it may be possible to create auto body paints that are completely scratch-resistant. Or, many materials and products currently in use can be reduced further in size while improving efficiency. Memory chips the size of a postage stamp, yet capable of holding the data equivalent to 25 DVD's, is also on the horizon through the use of nanotechnology. Similarly, solar panels that can be manufactured at a much lower cost than they currently are may be able to be produced with nanotechnology.

Currently, nanotechnology is used in the creation of numerous materials.

Industrial Nanofiber Production with Elmarco

Elmarco Nanospider™ equipment (NS equipment) is designed for the production of all sorts of organic and inorganic nanofibers. The product range goes from nanofiber equipment for laboratories to enable the development process, over production lines for low to moderate production volumes, to industrial scale high volume production.

Materials reinforced through nanotechnology are used in thermoplastics, as they are capable of resisting heat, are flame retardant, provide dimensional stability, and are capable of conducting electricity. These nanocomposites are used in such places as the body side molding of vehicles, automotive parties, and fuel-line components. They are also used with hard drives in order to make them more conductive.

Plastic nanotubes are also being created with nanotechnology. These nanocomposites are generally 50 to 150 nanometers in diameter and are used to conduct electricity. While these nanotubes have the current carrying capacity of copper, they are extremely flexible. They are also very lightweight and durable. This technology is expected to be able to lead to the creation of conductive paints, caulks, coatings, sealants, fibers, and adhesives. The thick sheets and tubes are also considered to be potentially valuable to the automotive, aerospace, and chemical industries.

Finally, special nanocomposite foams have already been created. Over time, these foams will likely replace solid plastic because they are much lighter, yet look the same as solid plastics. Potential uses for these foam nanocomposites include coffee cups, fast food containers, home insulation, carpet padding, disposable diapers, seat cushions, and packaging material.

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