Graphene nanocomposites for new thermoplastic materials

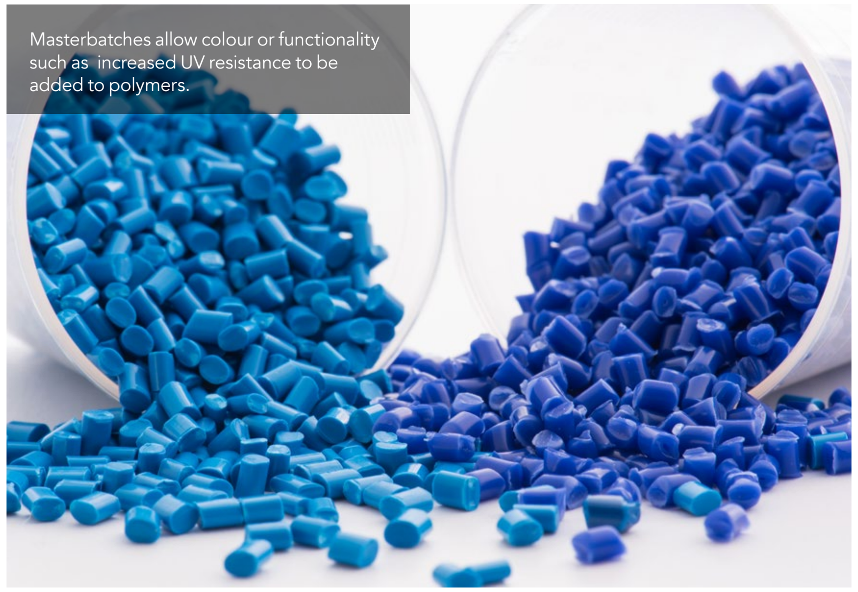
Graphene has been the subject of intensive investigation, in view of its potential applications in a variety of technological fields, ranging from next-generation solar cells and hydrogen storage materials to super-capacitors and high-end composite materials. The peculiar two-dimensional structure of graphene can also be used to enhance and tailor the physical properties of existing materials through its incorporation in suitable matrices. Colloids Ltd, in collaboration with the University of Manchester, are exploiting the unique properties of graphene to develop new polymer/graphene nanocomposites and to upscale their production to address current and future market challenges.

The isolation and characterisation of graphene in 2004 was one of the most remarkable and far-reaching advances in materials science in recent years. Andre Geim's and Konstantin Novoselov's ground-breaking experiments regarding the two-dimensional material graphene, which led to the award of the Nobel Prize in Physics in 2010 to the two University of Manchester scientists, has sparked a remarkable resurgence of interest in this material (whose existence has been theorised as far back as 1947) and in its potential for applications in chemistry, physics and technology.

Graphene is composed of carbon atoms, similar to its allotropes diamond and graphite, but it has a very simple structure in which a single-sheet of carbon atoms are arranged in a hexagonal honeycomb lattice. It is therefore a genuinely two-dimensional system, and its structural, mechanical, chemical and electrical properties are crucially related to this feature.

The number of current and potential future applications exploiting the remarkable strength, flexibility, lightweight and electronic properties of graphene are almost unlimited. Biomedical applications (drug delivery and biosensors), electronic components for wearable technologies, materials for energy production and storage and filtration devices for water purification are just a few of the current uses of this intriguing material. In 2013, the European Union established a one billion euro grant to explore potential future graphene applications.

One of the most efficient methods to exploit the extraordinary properties of graphene is by combining it with existing materials, to obtain composites with enhanced physical properties. Colloids Ltd, in collaboration with the University of Manchester, are exploring new ways to produce polymer/graphene nanocomposite materials and to develop sustainable processes for their production on an industrial scale.



Masterbatches allow colour or functionality such as increased UV resistance to be added to polymers.

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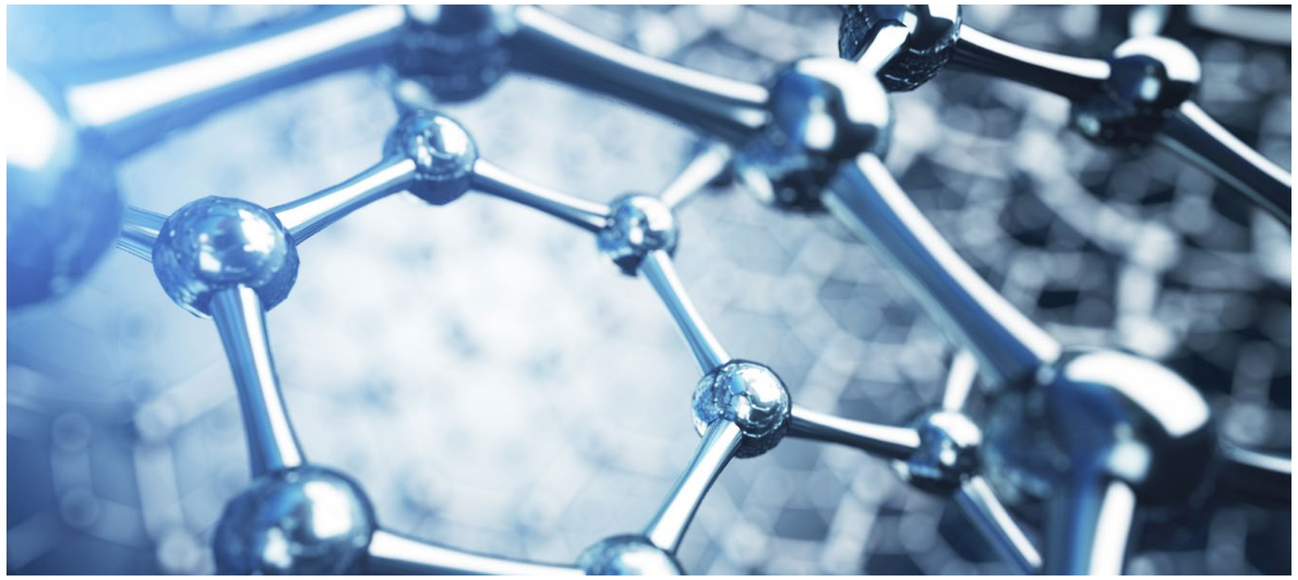
THERMOPLASTIC MATERIALS FOR INDUSTRY

Colloids have been at the forefront of thermoplastic materials development and marketing since 1967. Thermoplastics are polymeric materials that are mouldable at elevated temperatures and solidify upon cooling. Their structure comprises polymeric chains linked by intermolecular forces, which weaken with increasing temperature to give a viscous liquid. In this state, thermoplastics can be reshaped using various polymer processing techniques. Colloids specialise in providing a wide range of masterbatches for use in the thermoplastics industry.



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Masterbatches are solid or liquid additives for plastics, which are used to colour plastic materials or to impart specific properties, like resistance to UV radiation and oxidation, improved stability, fire resistance, conductivity and degradability. They are concentrated mixtures of pigments or other additives, which are incorporated into a carrier resin at high temperature and then cooled and cut into granules. The use of a masterbatch is often preferable to obtaining a fully compounded plastic material, because of the wider selection of colours and properties obtainable and, typically, because of the reduced cost and flexibility compared to a fully compounded plastic. Masterbatches also offer an advantage to on-site compounding, which can be complicated by the need to achieve a full dispersion of the pigments or additives in the plastic matrix and frequently results in ineffective incorporation of additives in the polymer matrix.

MARKET AND APPLICATION OF MASTERBATCH

Masterbatches can be used in a number of applications in which plastic materials are convenient and cost-effective and where functionality is key. In agriculture, they can for instance be applied to the production of greenhouse films for controlled clarity and heat/light transmission, chemical resistance, mechanical strength and UV stability. In the electronics and electrical industry, masterbatches can be used to control the conductive, dissipative and anti-static properties of materials for electronic circuits. In the building and construction industry, they achieve material durability, strength and weather resistance, whilst strictly adhering to the requirements of building codes and regulations. One of the crucial advantages of the masterbatch-based production of plastic materials is the ability to adapt and fine tune the masterbatch properties and composition to obtain highly customised formulations satisfying specific requirements. This is particularly important in the electronics industry, the pharmaceutical industry and in cosmetics, in which safety, customer expectations and aesthetics all play a crucial role.

THERMOPLASTIC NANOCOMPOSITES

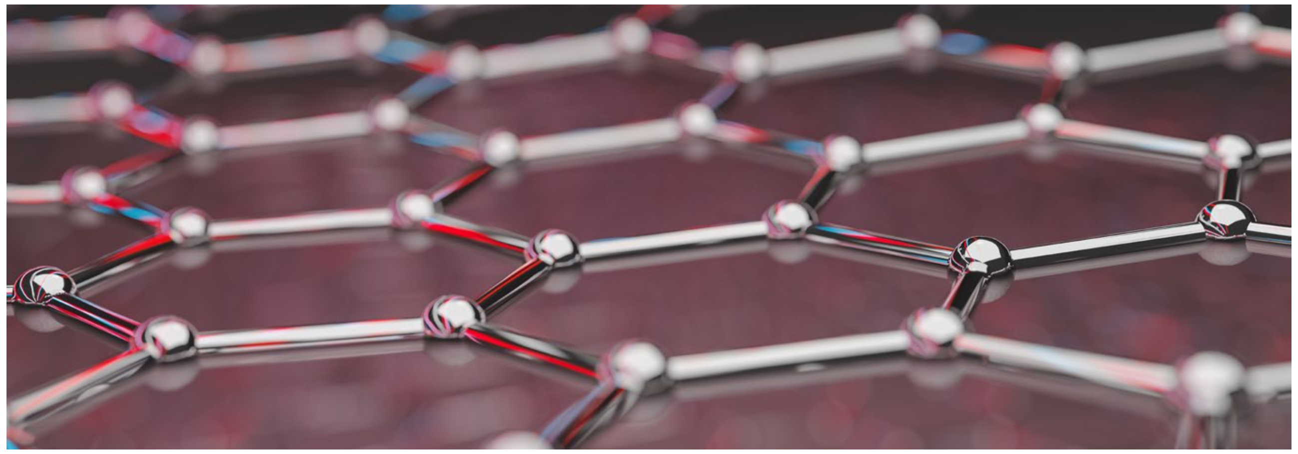
Incorporation of graphene (and other two-dimensional materials) nanoparticles into polymer matrices is a promising approach to further enhance the ability to tailor the properties of plastic materials for specific applications. Mechanical, electrical and thermal properties can all, in principle, be modified to address specific targets by formulating suitable nanocomposite synthesis processes. Several factors can influence the property enhancement, including the ability to obtain a homogenous dispersion of the two-dimensional material in the matrix, processing techniques, the orientation of the graphene nanoparticles and their aspect ratio and loading within the matrix. Furthermore, processing conditions that can be used to enhance one property may not be ideal for other properties.

The number of current and potential future applications exploiting the remarkable strength, flexibility, lightweight and electronic properties of graphene are almost unlimited.

For instance, surface functionalisation of the graphene nanoparticles generally improves the mechanical properties, but deteriorates the electrical properties of the nanocomposite. It is therefore very important to carefully optimise the synthesis conditions in order to obtain nanocomposites with the desired properties.

PROSPECTS AND CHALLENGES OF GRAPHENE NANOCOMPOSITES

Although the potential benefits of two-dimensional graphene nanocomposites have long been recognised, several challenges remain concerning the best route to achieve optimised synthetic processes and the ability to scale up these processes for industrial



Production Perig/Shutterstock.com

production. One of the major issues is the availability of high-quality graphene in quantities sufficient for the industrial production of the nanocomposites. The best quality graphene for the efficient production of nanocomposites is currently considered to be a material with the largest aspect ratio and a thickness of a few carbon layers in the nanoparticle structure. The dispersion of the nanoparticle filler within the polymer matrix should be homogeneous, in order to prevent the formation of aggregates, which can act as failure points. Bonding between the nanoparticles and the matrix should also be strong, so that stress can be transferred efficiently between them. Moreover, the nanoparticles should not exhibit wrinkles, impurities or defects, which could affect their properties. The chemical functionalisation of graphene and the inclusion of compatibilisers to enhance its dispersion can be used to promote nanocomposite formation, with the disadvantage, however, of requiring excessive use of chemicals and solvents.

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JOINING INDUSTRY AND ACADEMIA

To help address these issues and devise a robust approach to large-scale graphene nanocomposite production, Colloids are actively engaged with the University of Manchester and the National Graphene Institute. The objective of this enterprise is to create a link between the University's state-of-the-art research and industry.

The scope of the four-to-five-year project led by Colloids is to develop nanocomposites based on graphene and other two-dimensional materials to a broad range of thermoplastic materials, including polyolefins, polyamides and polyesters, and to understand how mechanical, thermal, electrical, rheological and gas-barrier properties (among others) are affected by the production process and by the materials used. As well as involving the University of Manchester's National Graphene Institute (NGI), the project also involves collaboration with the Graphene Engineering Innovation Centre (GEIC) and the Sir Henry Royce Institute. New processes for the synthesis of nanocomposites with enhanced properties compared to products currently available on the market will be proposed, developed and upscaled for industrial production.

The interest in graphene and in its applications as a "wonder material" in technology (as well as in fundamental science) has been steadily increasing following its initial isolation and characterisation. The next frontier in graphene science will be the ability to use this material efficiently and sustainably in mass-produced products for everyday use. The work initiated by Colloids will provide an important contribution to the diffusion and use of graphene materials as everyday commodities and high-performance materials in industrial and domestic settings.

The National Graphene Institute in Manchester.

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Behind the Research

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Research Objectives

Colloids are collaborating with the University of Manchester to further develop research into polymer/graphene nanocomposites.

Detail

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Bio

Colloids is a leading manufacturer and exporter of standard, speciality and bespoke black, colour & white masterbatches and performance enhancing additives which provides plastic with colour and functional properties. Colloids supplies the automotive, agricultural, E&E, construction, pipe, geosynthetic and consumer markets, as well as polymer producers and compounders worldwide. Its head offices are located in Knowsley, UK.

Collaborators

Advanced Nanomaterials Group led by:
- Professor Robert J. Young
- Professor Ian A. Kinloch
- Dr Mark A. Bissett

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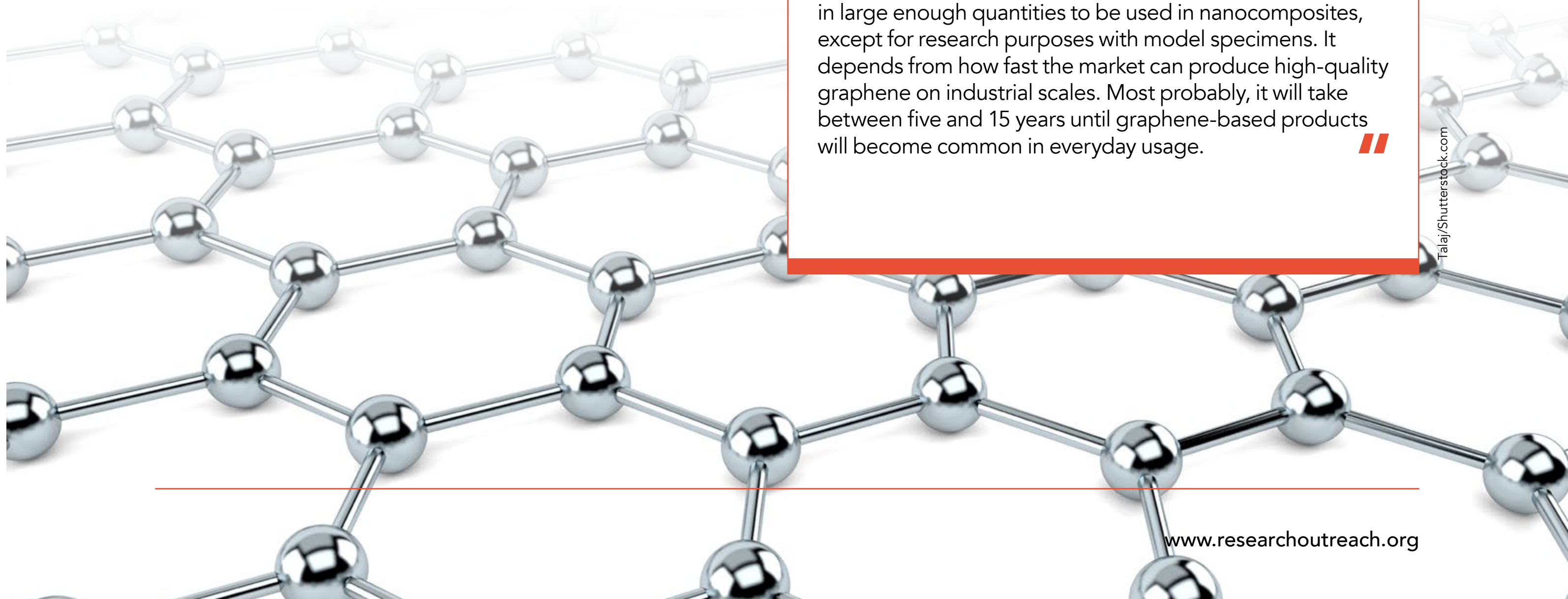
Personal Response

Which technological fields will benefit most from the results of your collaboration with the University of Manchester, and what timescales would you anticipate before graphene-based technologies and products will become common in everyday usage?

" The main goal of this research project will be to develop and upscale nanocomposites with enhanced properties compared to the current available products on the market. The main markets and technological fields that will benefit most from the results of the collaboration between Colloids and the University of Manchester are: automotive, aerospace, industrial, electronic, transport, packaging, civil engineering and agricultural market sectors. Target output from the research will be Colloids ownership of applicable IP but with also the softer benefits of being a recognised partner to the University, upscaling of internal skills, recruitment of skilled personnel, etc.

Regarding the timescales before graphene-based technologies and products will become common in everyday usage: there are several methods that can produce high-quality graphene with good properties. They cannot, however, be scaled up to produce graphene in large enough quantities to be used in nanocomposites, except for research purposes with model specimens. It depends from how fast the market can produce high-quality graphene on industrial scales. Most probably, it will take between five and 15 years until graphene-based products will become common in everyday usage. "



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