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.

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.

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 associated with it.

Masterbatches also offer an advantage because of the reduced cost and flexibility associated with them. 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 associated with it.

Furthermore, processing conditions that can be used to enhance one property may not be ideal for other properties. 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 use. The number of current and potential future applications exploiting the remarkable strength, flexibility, lightweight and electronic properties of graphene are almost unlimited.
Several challenges remain concerning the best route to achieve optimised synthesis processes and the ability to scale up these processes for industrial production.

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.