GLOBAL FASHION 2014
19-21 NOVEMBER

GRAPHENE: a revolution in textile & fashion design

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Abstract

Graphene is the two-dimensional sheet constituted by carbon atoms and creating a hexagonal lattice ordered.

In 2004, Andre Geim, Konstantin Novoselov and collaborators in the University of Manchester (UK) and the Institute of Technology in Microelectronics Chernogolovka (Russia), succeeded in isolating graphene sheets. The development of this technique, called exfoliated graphene, led to the Nobel Prize in Physics 2010.

From a material science point of view, graphene presents singular properties, the most prominent are:
Material quasi two-dimensional.
Low density.
High level of transparency.
High electrical and conductivity resistance.
High thermal conductivity.
High modulus of elasticity, good resistance to deformation.
Graphene is stronger than diamond.
Graphene can be used as electronic and temperature-sensor.
Water repellency.

Textile applications

Intelligent textiles: (E- textiles and Smart textiles), temperature sensors, electrical sensors.
Graphene can replace synthetic fibres (polyester, nylon), due to the lightness, greater elasticity and greater conductivity resistance.
Waterproof clothes.
Cytotoxicity effects.
Graphene can reduce weight in clothes, and decrease the storage volume of them.
Ecological manufacturing technology, without any organic solvents, free from oil by-products.

Keywords

Graphene, E- textiles, smart textiles, electrical properties, thermal properties, cytotoxicity effects, waterproof, sport clothing, pregnant clothing, biscrolled yarns.

Article classification

General review

An overview of the history of textile fibres

Throughout human history, textiles have been integral to daily life.

Natural fibres have been used for apparel and home fashion for thousands of years, with the use of wool going back over 4,000 years.

The Industrial Revolution of the eighteenth century was a breakthrough for the textile sector, since due to the discovery of the Watt´s steam engine, new machines led to the mechanization of the work in the textile industry. Examples of these machines are the developed of the spinning-jenny for spinning of textile fibres and the Jacquard loom.

Another revolution in this sector was the discover of synthetic fibres at the start of the 20th century. The first commercial production of rayon fibre in the United States was in 1910 by the American Viscose Company.

The first commercial production of acetate fibre in the United States was in 1924 by the Celanese Corporation.

The first commercial production of nylon in the United States was in 1939 by the E. I. du Pont de Nemours & Company, Inc. It is the second most used man-made fibre in this country, behind polyester.

The first commercial production of acrylic fibre in the United States was in 1950 by E. I. du Pont de Nemours & Company, Inc.

The first commercial production of polyester fibre in the United States was in 1953 by E. I. du Pont de Nemours & Company, Inc.
Polyester is the most used man-made fibre in the U.S.

The first commercial production of triacetate fibre in the United States was in 1954 by the Celanese Corporation.
Domestic Triacetate production was discontinued in 1985.

The first commercial production of spandex fibre in the United States was in 1959 by E. I. du Pont de Nemours & Company, Inc.
It is an elastomeric man-made fibre (able to stretch at least 100% and snap back like natural rubber).

Spandex is used in filament form.

The first commercial production of an olefin fibre manufactured in the U.S. was by Hercules Incorporated.
In 1966, polyolefin was the world's first and only Nobel-Prize winning fibre.

The first commercial production of micro fibre in the U.S. was in 1989 by E. I. du Pont de Nemours & Company, Inc. Today micro fibres are produced in a variety of synthetic fibres (i.e. polyester, nylon, acrylic, etc.)

The first commercial production of lyocell in the U.S. was in 1993 by Courtaulds Fibres, under the TencelÂ¬ trade name.
Environmentally friendly, lyocell is produced from the wood pulp of trees grown specifically for this purpose. It is specially processed, using a solvent spinning technique in which the dissolving agent is recycled, reducing environmental effluents.

In the XXI century, advances in textiles have been directing to the development of smart textiles and E- textiles, by employing fibres equipped with specific properties, including the electrical ,thermal and waterproof.

Examples of textile fabrics that are currently marketed and used in the manufacture of smart textiles are as follows:

Polartec® Aqua Shell® - Polartec® Aqua Shell® fabrics, made by Malden Mills, feature the warmth of Polartec® thermal fabrics, combined with bodyhugging 4-way stretch and a windproof membrane. They are designed to replace neoprene and spandex skins for many water sports by providing far greater comfort and increased warmth per weight. The 4-way stretch provides a comfortable, non-restrictive fit along with easy donning and doffing. The polyester construction provides a high warmth-to-weight ratio. Polartec® Aqua Shell® fabrics are also odor- and itch-resistant and non-chafing, have outstanding sun protection (UPF 30+), and dry faster than neoprene.

Polartec® Power Dry® - Polartec® Power Dry® keeps skin dry. Anti-microbial finish. Dries quickly. Very breathable base layer for all activities. Polartec¨ Power Dry¨ fabrics are designed to keep your skin dry when you sweat. All fabrics in this series feature a patented bi-component knit construction that uses different yarns on either side of the fabric. This creates two different surfaces: one that is optimized to move moisture away from the skin, the other to dry quickly.

Polartec® Power Shield - Polartec® Power Shield fabrics represent the next generation of technical outerwear - body armor against the elements. This clothing concept goes beyond traditional 2 -layer systems, which feature fleece insulation and a waterproof/breathable shell, to a single layer that protects against abrasion and cold, wet weather. They feature a smooth, tightly woven nylon face for abrasion resistance equal or superior to the best shells, but without the stiffness and noise. They also have a polyester velour back that traps air and provides a high warmth-to-weight ratio. Garments made from Polartec® Power Shield" fabrics are designed to replace traditional fleece and PTFE shell systems for most outdoor clothing applications, reducing the weight and number of layers needed to insulate and protect. They are ideal for skiing,

Texollini Fabrics - Developed by Texollini, This collection of circular knit fabrics contain a variety of fine gauge to heavier gauge constructions including jerseys, novelties, jacquards French terries, piques, interlocks, ribs, thermals, ponte de romas, ottomans, pointelles, textures, sheers, all with or without Lycra®/spandex. The fabrics are made from a variety of fibres and yarns, and many constructions contain the latest technical fibres for the ultimate in quality and performance. Texollini's line of fabrics are targeted for use in sportswear, activewear, performance wear, intimate apparel, and swimwear, with targeted specialty fabrics developed for use in the military, safety & protective, industrial, and medical applications.

THERMORE® PRO - This new standard in thermal technology is specifically developed by Thermore for the most demanding outdoor activities. The insulation is water-repellent, incredibly soft, lightweight, and is made with 50% recycled fibres. This insulation technology represents the next step in recycled performance, water-repellency and warmth, and meets the same level as specialized virgin polyester products. The insulation offers cost-effective high performance qualities and reasonable lead times.

The new revolution: GRAPHENE

Graphene is the new material of the future that will revolutionize all sectors, including the textile sector, both from the technical point of view and from the design of intelligent clothing.

You may be wondering just asking about the graphene. Sheldon Cooper, from the famous TV series The Big Bang Theory, is an expert in this subject.

More seriously, graphene is the name given to a flat monolayer of carbon atoms tightly packed into a two-dimensional (2D) honeycomb lattice, and is a basic building block for graphitic materials of all other dimensionalities.

In 2004, Andre Geim, Konstantin Novoselov and collaborators in the University of Manchester (UK) and the Institute of Technology in Microelectronics Chernogolovka (Russia), succeeded in isolating graphene sheets. The development of this technique, called exfoliated graphene, led to the Nobel Prize in Physics 2010.

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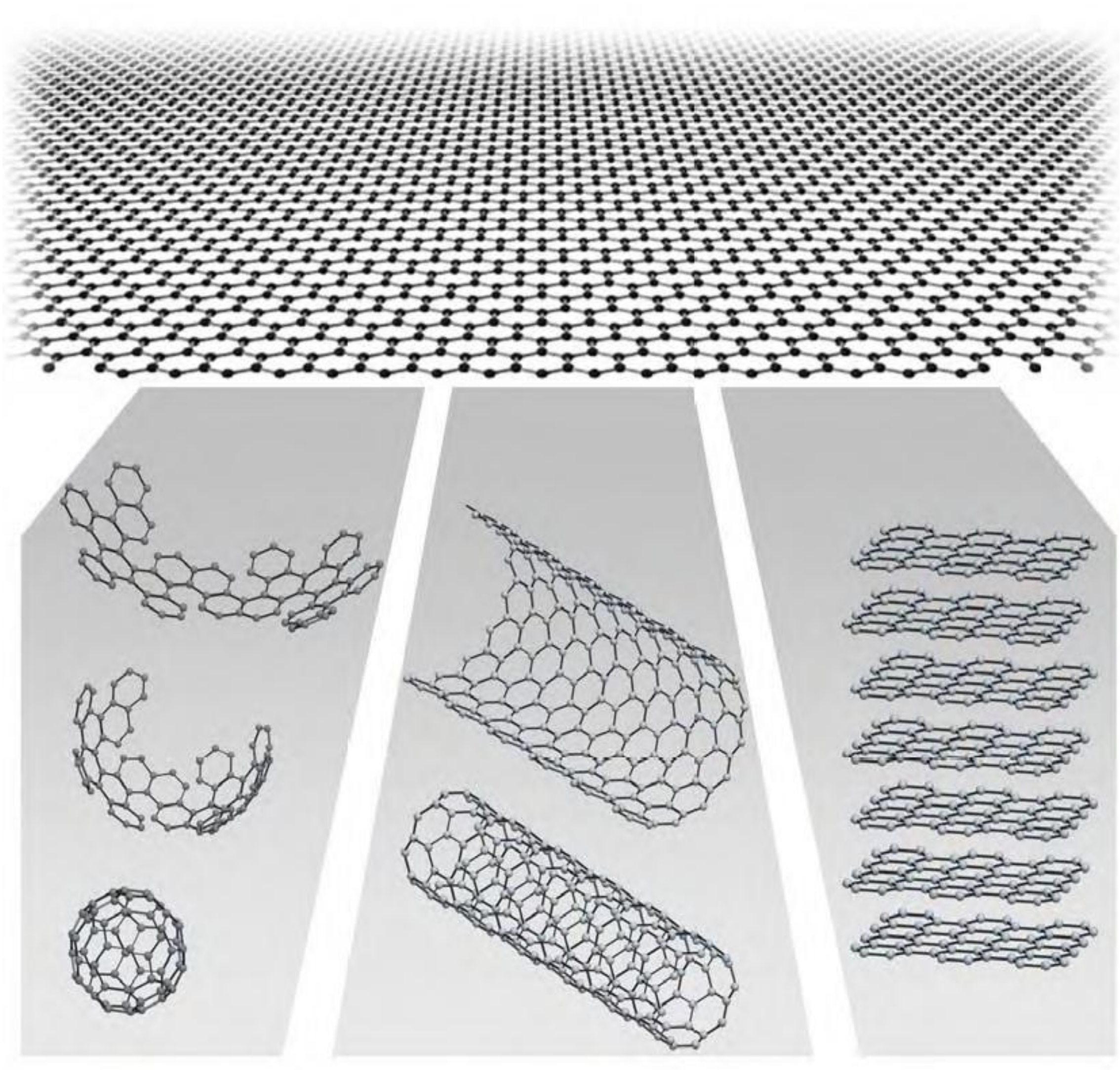
– High modulus of elasticity, good resistance to deformation.
– Graphene is stronger than diamond.
– Graphene can be used as electronic temperature and electrical sensor.
– Graphene has strong cytotoxicity toward bacteria.
– Is impermeable to gases
– Water repellency.



Graphene is a 2D building material for carbon materials of all other dimensionalities. It can be wrapped up into 0D Bucky balls, rolled into 1D nanotubes or stacked into 3D graphite.

The principal characteristics of graphene and its potential application in the textile industry are described below.

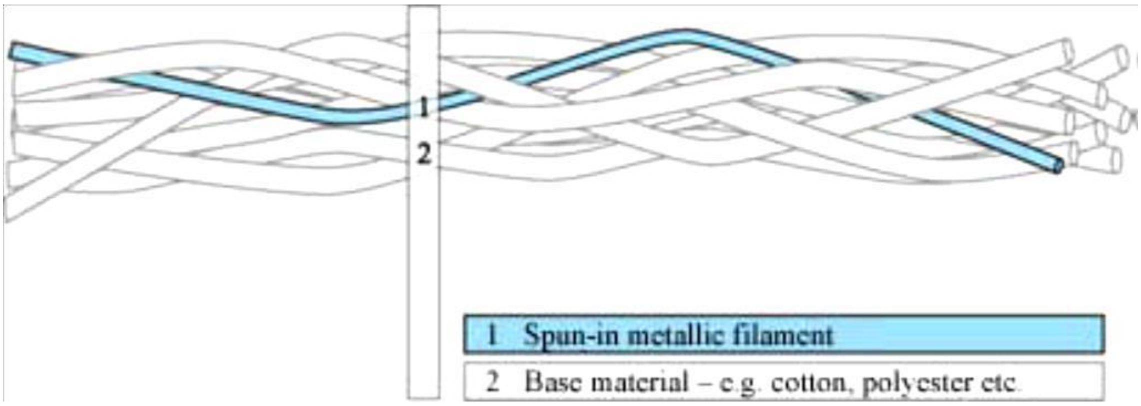
The unique properties of graphene, such as the high elasticity, mechanical strength, thermal conductivity, very high electrical conductivity and transparency, make them it an interesting material for stretchable electronic applications.The graphene fibres can be used to introduce chemical sensing properties into textile materials by means of a screen printing method. This method has been described by Ewa Skrzetuska , Michał Puchalski and Izabella Krucińska. Department of Material and Commodity Sciences and Textile Metrology, Lodz University of Technology, 90-924 Lodz, Poland.

E-textiles and smart textiles

Fibrous textile materials containing conductive fillers have recently attracted much attention for their use in a widerange of applications, especially in E-textiles and smart textiles (Cakir, 2011; Cherenack, Zysset, Kinkeldei, Münzenrieder,& Tröster, 2010; Mattila, 2006; Robert, Feller, & Castro, 2012; Shim,Chen, Doty, Xu, & Kotov, 2008; Tao, 2001; Yang, Lightner, & Dong,2011).

E-textiles are fabrics that enable computing, digital components and electronics to be embedded in them. Electroconductive textiles can be made using graphene textile fibres woven into the construction of the textile.

Smart Textiles are defined as textile products such as fibres and filaments, yarns together with woven, knitted or non-woven structures, which can interact with the user.



Especially for clothing, tactile properties such as stretch, recovery, drape, shear and handle are quite important. For this reason the fibres that are used should be fine and fabrics should have a low weight per unit area. Graphene fibres have all these properties.

Graphene is more suitable for E-textiles because it can be conducting and semiconducting and applied as a dye to make electrically conducting textiles (Dong et al., 2012; Fugetsu, Sano, Yu,Mori, & Tanaka, 2010; Khan, Young, O'Neill, & Coleman, 2012; Shinet al., 2012; Yu et al., 2011).

Mohammad Shateri-Khalilabad, Mohammad E. Yazdanshenas from the Department of Textile Engineering, Yazd Branch, Islamic Azad University, Yazd, Iran has explored electro conductive cotton textiles using graphene.

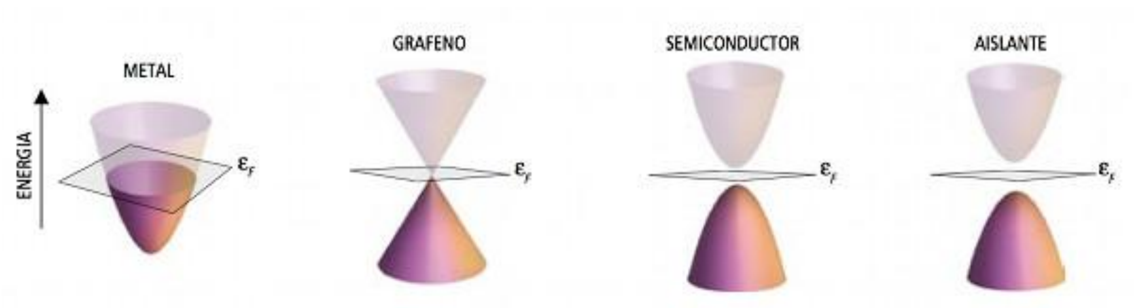
Applications based on the graphene electrical and thermal conductivity

It will focus on the application of graphene fibres to maternity clothing and sports wear, bringing news from the point of view of design and use.

In both sectors, a garment that is highly elastic sought due to the functionality you should have these items, as the athlete needs of the property and also pregnant. Because graphene has a high modulus of elasticity, they will be able to perform highly elastic garments designs, providing comfort to the user.

It is interesting to link the high elasticity of graphene with its high electrical conductivity, which will apply to maternity wear sensors that allow for fetal monitoring, capturing vital signs that can be sent to a mobile phone or a PC, get notified instantly with real-time alerts if there are changes in the fetal heart rate, this allowing the pregnant woman to be monitored without having to go to the gynecologist.

This same property of high electrical conductivity allow to create intelligent sportswear provide clinical trials data monitoring in athletes textiles.



Thereby facilitating monitoring in pregnant women, can decrease the number of people who have to go to consultation, reducing the costs for this type of diagnostic test.

This application of graphene leads to the concept of smart clothing. Smart textiles are able to sense stimuli from the enviroment, to react to them and adapt to them by integration of functionalities in the textile structure. The stimulus as well as the response can have an electrical, thermal, chemical, magnetic or other origin. As I have explained in the monitoring of pregnant women, the response has and electrical origin due to the high electrical conductivity of graphene.

Stretch sensors are predominantly used for sensing and monitoring body parameters, as the textile is in contact with the skin over a large body area. This means that monitoring can take place at several locations on the body. For instance, these sensors can be used for determining: heart rate, respiration, movement and pressure blood.

A Flemish consortium of universities and companies, among them the textile department of Ghent University, developed a prototype suit called Intellitex. It is a biomedical suit meant for the long term monitoring of heart rate and respiration of children at the hospital.This suit isn´t made of graphene, but it will be very interesting to developed a prototype with this kind of fibre.

On the other hand, graphene can be used as electronic temperature-sensor, in thermographic analysis. It's a very interesting application, because it is a noninvasive measurement technique that is increasingly used to detect certain types of tumors, circulatory problems or muscular problems. As can be seen, it is important to detect muscular problems in athletes combined with modern design of the garments . Early identification of tumors, is a very interesting application for prenatal screening, combined modern design clothes for pregnant.

Graphene fibres can maintain body heat quite well, and they are very waterproof, therefore opens an interesting alternative to wetsuits and neoprene clothing. Also, allow such garments were much lighter, because graphene stands out for its lightness, which does not make it less resistant. On the other hand, water sports clothing should also emphasize the speed of drying with this type of fibres.

Currently neoprene clothing is invading the streets. By graphene fibres, neoprenes improve its elastic properties, and water repellency. Also you get better maintain body heat.
This improved graphene fibre, neoprene would be very interesting for snow clothes.

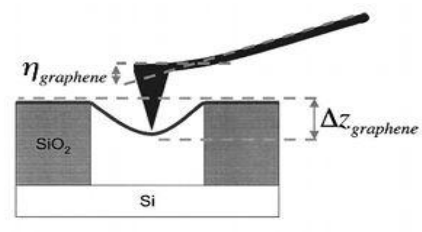
Low density

Because of its low density, it can make garments with easy fabrics that will bend and little storage space in the stores, which will reduce storage costs.

Hardness

The extreme hardness of graphene, combined with its ability to mold and its lightness makes it ideal for use in the manufacture of bulletproof vests, bicycle helmets, Formula 1 and many protective elements that are used in various sports, achieving that become much lighter and safer.
Graphene is the thinnest material in the universe and the strongest ever

The remarkable properties of graphene reported so far include high values of its Young's modulus (~1,100 GPa)2, fracture strength (125 GPa)2, thermal conductivity (~5,000 W m−1K−1)3, mobility of charge carriers (200,000 cm2 V−1 s−1)4 and specific surface area (calculated value, 2,630 m2 g−1)



Cytotoxicity graphene efects

Graphene has strong cytotoxicity toward bacteria. Another application can be highlighted for maternity clothes is its ability to create coatings that prevent the growth of bacteria on the surface of the fabrics, thus protecting the pregnant against possible diseases transmitted by bacteria.

This type of protection will be very useful in gynecologists, nurses and midwifes clothing who assist the birthing woman in order to avoid spreading bacterial infections in newborns.

Shaobin Liu, †School of Chemical and Biomedical Engineering Nanyang Technological University, Singapore and other researchers, has researched on the antibacterial activity of four types of graphene-based materials toward a bacterial model; Escherichia coli.

These authors propose that a three-step antimicrobial mechanism, previously used for carbon nanotubes, is applicable to graphene-based materials.

As a result of its investigations the researchers concludes that graphene-based materials kill bacteria by the destruction of bacterial membrane.

GRAPHENE synthesis

Since it was first prepared in the nineteenth century graphite oxide has been mainly produced by the Brodie, Staudenmaier and Hummers methods. All three methods involve oxidation of graphite in the presence of strong acids and oxidants.

There are a number of methods for generating graphene and chemically modified graphene from graphite and derivatives of graphite. Sungjin Park and Rodney S. Ruoff from the Department of Mechanical Engineering and the Texas Materials Institute, University of Texas at Austin, describe the use of colloidal suspensions to produce new materials composed of graphene and chemically modified graphene.

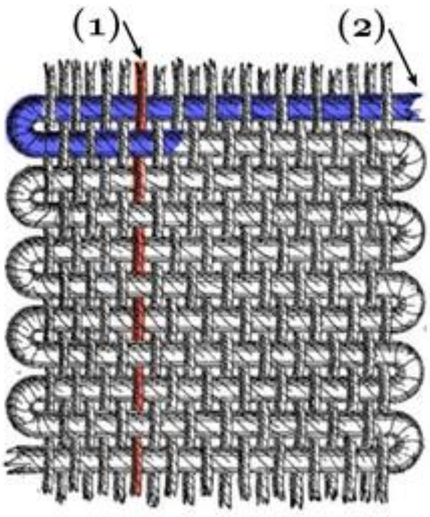
Graphene has been made by four different methods. The first was chemical vapour deposition (CVD) and epitaxial growth, such as the decomposition of ethylene on nickel surfaces. These early efforts (which started in 1970) were followed by a large body of work by the surface-science community on 'monolayer graphite'. The second was the micromechanical exfoliation of graphite. This approach, which is also known as the 'Scotch tape' or peel-off method, followed on from earlier work on micromechanical exfoliation from patterned graphite. The third method was epitaxial growth on electrically insulating surfaces such as SiC and the fourth was the creation of colloidal suspensions.

The fourth method has been described by Sungjin Park and Rodney S. Ruoff from the Department of Mechanical Engineering and the Texas Materials Institute, University of Texas at Austin. They have used colloidal suspensions to produce new materials composed of graphene and chemically modified graphene.

GRAPHENE threads

Textile technology allows to produce high quality graphene threads, so it is possible to mount the threads of warp with this type of fibre.

It is shown a graphic in which the arrangement of warp and weft yarns is shown in a tissue sample.



Number 1: Warp

Number 2: Weft

Burnham, Dorothy K *Warp and Weft: A Textile Terminology.* Royal Ontario Museum. ISBN 0-88854-256-9

A new type of strong and flexible yarn made from graphene oxide that could be ideal in “smart” wearable textiles has been developed by researchers in Australia and Ireland. As well as being strong and highly conducting, the yarn has the highest ever capacitance reported to date for such a graphene-based structure.

Smart textiles will require electronic yarns and fibres that are strong, flexible and light. Such fibres, which will play the part of electrodes in these textiles, will also need to store energy efficiently if they are to act as integrated capacitors and batteries. Although researchers have made much progress in this field by developing yarns from carbon nanotubes and graphene, most of these fibres are still far from ideal. In particular, the best capacitance values reported to date (of 265 F/g) still fall far short of the theoretical value of 550 F/g for graphene-based structures.

Now, Gordon Wallace of the University of Wollongong in Australia and colleagues have made yarns and fibres from graphene oxide and reduced graphene oxide that are not only highly flexible and lightweight but that have an unrivalled electrochemical capacitance of as high as 410 F/g.

The researchers used a novel wet-spinning technique to produce unlimited lengths of highly porous yet dense, mechanically robust and flexible graphene yarns from liquid crystals of very large graphene oxide sheets. The yarns, which could be directly used as the building blocks for supercapacitors in fully functioning smart textiles, are very strong, with a Young’s modulus that is greater than 29 GPa. They also have a high electrical conductivity of around 2500 S/m and a very large surface area – about 2600 m2/g for graphene oxide and 2210 m2/g for the reduced material. The high capacitance of 410 F/g per graphene oxide electrode (in a practical two-electrode configuration set up) comes thanks to the fact that ions can travel fairly fast and without resistance in the fibres.

Carbon nanotubes spin a yarn:

Researchers in US are the first to produce electrically conducting yarns from webs of carbon nanotubes and various powders and nanofibres. The yarns, made by a technique called biscrolling, are very strong and can be woven, sewn, knitted and braided into a variety of structures. They could find applications in intelligent textiles.

Some of the most interesting and potentially useful materials are restricted in their application due to the limited manner in which they may be processed. For example it is not uncommon for useful materials to be produced in a powder form, when a single crystal or flexible wire morphology would be much more practical. Fortunately a team of researchers working at the University of Texas at Dallas have developed a method of producing yarn that contains high powder concentrations such that functional fibres can be produced for weaving, sewing, knotting, and braiding [Lima et al., Science (2011) 331, 51].

Ray Baughman and colleagues at the Nanotech Institute at University of Texas in Dallas have developed a new approach that exploits carbon nanotube (CNT) sheets, or webs, instead of polymers to transform nano- or micron-sized powders into electrically conducting, sturdy yarns.

The researchers began by overlaying the "host" CNT sheets with "guest" powders using an electrostatic powder-coating gun and then twist-spinning the guest-host stack to form a biscrolled yarn. The technique is in fact adapted from traditional textile-spinning methods that have been around for millennia and involves drawing 10 nm diameter multiwalled carbon nanotubes from a "forest" of similar length tubes deposited on a substrate while applying a twist at the same time.

Biscrolling process: This new technology is used to make yarns of graphene ribbons.

Depending on the final application desired, the twisting produces different-shaped structures – known as Archimedean, dual-Archimedean or Fermat scrolls. These structures are similar to the spirals commonly found in nature – for example, those seen in nautilus shells and the now-extinct ammonites.

The difference between the structures is as follows: Archimedean is where a sheet edge is buried deep in a scroll; dual-Archimedean means that the sheet edges are buried in different interconnected scrolls; in Fermat biscrolling, twisting starts from the centre of a symmetric spinning wedge, the edges of which then wrap in opposite directions around the scroll score.

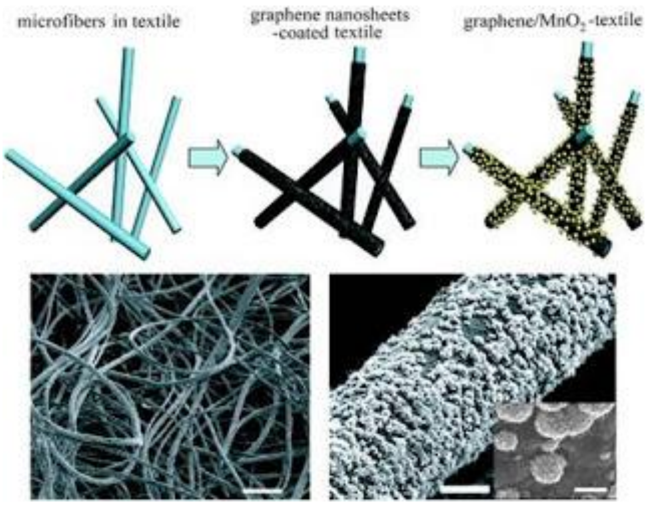
CNT sheets are ideal for making such yarns; its sheets are nearly as light as air (they have a density of around just 1.5 mg/cm3) but are stronger than steel, with a specific strength that can reach 560 MPa cm3/g when densified. This is much higher than the values for Mylar and Kapton films used for ultralight air vehicles that have a strength of about 125 MPa cm3/g. The yarns can also happily be washed in an ordinary washing machine without suffering any measurable damage.
The observed mechanical properties enable yarn knottingand weaving and sewing of biscrolled multifunctional yarns into textiles.

Making superconducting wires:
The biscrolled yarns can be made from a variety of powders that can be chosen according to the final application. For example, Baughman and colleagues made superconducting yarn by biscrolling a mixture of magnesium and boron powders (up to 99 wt%) as the guest on CNT sheets, and then thermally annealing the biscrolled yarn. The technique has the added bonus in that it avoids the 30 or more drawing steps needed in conventional powder-in-tube methods to produce millimetre-sized, iron-clad, superconducting wires from a magnesium/boron/CNT precursor.

The team also made biscrolled yarns containing up to 98 wt% graphene oxide nanoribbons that were then converted to graphene nanoribbon yarn by reducing the graphene oxide. These yarns could be used to make weavable anodes for flexible lithium-ion batteries, says Baughman. The researchers showed that they could make electrodes for lithium-ion batteries using $LiFePO_4$ (an environmentally friendly, inexpensive, high-performance lithium-ion battery cathode) as the guest powder.

The batteries perform well, with a high gravimetric electrical conductivity of 8 S cm2/g, are flexible and mechanically robust. These properties mean that they could be used in applications like energy storage and energy-generating clothing – so-called intelligent textiles. The high gravimetric electrical conductivity also makes for lighter batteries because biscrolled yarn cathodes no longer require the conventional aluminium current collector and conducting particle binders that can bump up electrode weight by over 30%.

Also, in Spain, Electrocatalysis Group researchers, Synthesis, Electrochemistry and Polymer Characterization (GESEP) Alcoy campus of the Polytechnic University of Valencia are developing new textile surface modified with graphene.



GRAPHENE coatings used to water repellency

Graphene can make fibres waterproof.

Physicist James Dickerson and a team of researchers at Vanderbilt University have created two ways to apply thin graphene sheets that either make them super-hydrophobic or super-hydrophilic. These alternate arrangements, termed "rug" and "brick," make the water bead up and run off or spread out and form incredibly thin sheets. Potential applications are watersport clothing that cause water drops to just bounce off and towels that could repel water.

On the same line, graphene nanomembrane has applications ranging from waterproof clothing.

Researchers led by Hyung Gyu Park at ETH have developed a nanomembrane with remarkable abilities to restrict the passage of molecules. The substance is expected to find a wide variety of uses to clothing.

Park's group produced the material from two overlaid layers of graphene, making a membrane less than one nanometer thick; 100,000 times thinner than a human hair.
Using two layers of graphene corrects for any defects in the graphene sheet, improving its stability and ensuring that properly sized pores can be etched into the material.

After developing techniques to fabricate the membrane, the researchers were able to etch precisely-sized pores in it using a focused electron beam. The thinness of the nanomembrane makes it extremely efficient in filtering fluids, rapidly passing small molecules with little energy expenditure and retaining larger ones.

Another interesting application is the development of lightweight, breathable, waterproof fabrics.

Breakthrough in nanofabrication

The researchers not only succeeded in producing the starting material, a double-layer graphene film with a high level of purity, but they also mastered a technique called focused ion beam milling to etch pores into the graphene film. In this process, which is also used in the production of semiconductors, a beam of helium or gallium ions is controlled with a high level of precision in order to etch away material. The researchers were able to etch pores of a specified number and size into the graphene with unprecedented precision. This process, which could easily take days to complete, took only a few hours in the current work.

A key advantage of the tiny dimensions is that the thinner a membrane, the lower its permeation resistance. The lower the resistance, the higher the energy-efficiency of the filtration process. However, before these applications are ready for use on an industrial scale or for the production of functional waterproof clothing, the manufacturing process needs to be further developed. To investigate the fundamental science, the researchers worked with tiny pieces of membrane with a surface area of less than one hundredth of a square millimetre. Objectives from now on will be to produce larger membrane surfaces and impose various filtering mechanisms.

Examples of comercial e- textiles

The following are a few examples of garments develop by experienced Textronics®, based in new e- textiles in which graphene is the future:

Textronics® is made up of a team of experts in the fields of Textiles and Electronics. Their goal is to seamlessly integrate micro electronics with textile structures – changing the way people benefit from technology in sport. They specialize in wearable electronics that can be used to enhance sport performance.

Sports & Fitness

Health & Wellness

Military & Safety

USA Weekend – “The Next Big Things”

Wired Gadget Lab – “Best of Gadget Lab 2006”

Textronics Inc. wearable textile sensors are marketed under the award winning NuMetrex brand. NuMetrex® was the first commercial offering of e-textile sensors. The NuMetrex® heart sensing sports bra continues to get rave reviews from press and consumers who have worn the product.

Purchase NuMetrex clothing at www.numetrex.com

The integration of electronics (graphene sensors) with textiles brings a new frontier in functionality to one of the most common materials in daily lives.

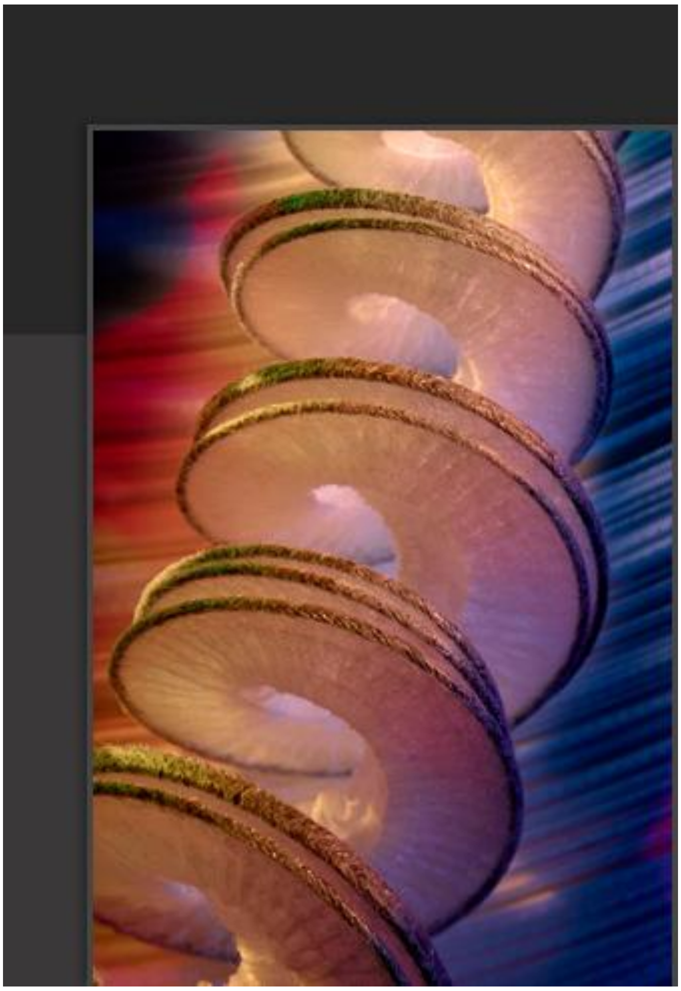
Core Technologies

The materials including fibres, films and coatings that react to electrical, optical or magnetic signals providing embedded intelligence to knit, woven or non-woven textile structures. Some of proprietary technology and intellectual property is Textro-Sensors® which can be described like a non-invasive physiological monitoring system for dual heart rate/respiration measurement. The features are and electrical signal sensing or optical method to sense motion and monitors heart rate and respiration. It should be point out that skin contact isn´t required, so it could be very interesting for pregnant clothing. On the other side, these clothing are simple and comfortable.

Another innovative product develop by this team are the Textro-monitoring® Systems. This system is a new fabric-based system useful for monitoring motion, such as motion generated by a geometric change in the body surface in response to physiological activity like respiration and heart rate. The measurements are non-invasive do not require electrodes to contact the skin.

The new system consists of a fabric, which exhibits light transmission and reflection properties that can be placed strategically in a garment. The amount of light transmitted thought the fabric relative to the amount of light reflected by the fabric changes when the fabric stretches in response to a dramatic motion like respiration or a subtle motion like the beating of the heart. These properties of light transmission and reflection properties are already present in graphene, so could be possible to include graphene in Textro-monitoring®.

Other Textro-monitoring® systems include methods for sensing the electrical signals generated by the body via textile electrodes in a unique design configuration which produces high quality signal sensing.



Adidas Wearable Sports Electronics (Textronics, Inc)
4 Hillman Drive, Suite 130
Chadds Ford, PA 19317

Applications in Sports & Fitness of NuMetrex

The NuMetrex heart sensing sports bra and cardio shirt integrate special sensing fibres directly into the garment. This eliminates the need for a separate heart monitoring chest strap.

Health & Wellness

The textile sensors can be incorporated into a wide range of garments. The unique sensors are capable of capturing medical quality data from the body for use in health monitoring, preventive care, exercise physiology and weight loss.

The personal health monitoring market is poised for rapid growth due to mega-trends including aging, technology and health care costs. These textile sensors are capable of capturing medical quality data from the body for use in health monitoring, preventative care, exercise physiology and weight loss. They can be seamlessly integrated into a wide range of garments to form a comfortable and user friendly interface between the body and health and wellness systems. These monitoring products provide benefits to fitness enthusiasts, medical patients and address the large opportunity to help aging boomers live better longer.

Textro-Polymers®

Description

A conductive polymer matrix with predictable dynamic conductivity change with stretch.

Features

Nearly zero hysteresis provides predictable resistance change during elongation

Senses small to very large elongations

Very wide resistance-range performance

Applications

Sports and patient monitoring

Security systems

Sensors

Switches

Pull controls

The ability to change a conductive pathway's resistance is a basic functionality in electronic circuits and is typically associated with volume controls, switches, and sensors.

Textro-polymers®

Textro-polymers, which can take the form of a fibre, a film, or a coating, provide a predictable dynamic conductivity change with stretch. In some of the embodiment or formulations developed, these composite materials undergo a change in resistance of over nine orders of magnitude. By adjusting the properties of the composite, can be alter the magnitude of the resistance change as well as the profile of the elongation response.

Typical Electrical Properties

The typical electrical properties achieved with this technology platform include the following:

– Low resistivity in the relaxed state (< 10K Ohms)
– High resistivity in the stretched state (> 1012 Ohms)
– The ability to tailor the resistivity profile

Applications

Textro-polymer® is appropriate for switches and controls that are activated by mechanical movements like bending, stretching, and tugging. For example:

– Textile-based motion-activated switches and controls
– Strain gauges
– Motion sensors or motion detectors
– Sports fitness motion sensing garments for training
– Physical therapy or rehabilitation devices
– Alternative device-activation mechanisms
– Occupancy detection for car seats or beds

Carbon nanotube

To conclude this review of graphene, now proceed to describe the application of carbon nanotubes, since this carbon could be replaced by graphene

Safety fears about carbon nanotubes, due to their structural similarity to asbestos, have been alleviated following research showing that reducing their length removes their toxic properties.

First atomically described in the 1990s, carbon nanotubes are sheets of carbon atoms rolled up into hollow tubes just a few nanometers in diameter. Engineered carbon nanotubes can be chemically modified, with the addition of chemotherapeutic drugs, fluorescent tags or nucleic acids opening up applications in cancer and gene therapy.

Substituting carbon nanotubes by graphene nanotubes, could be made smart textiles that could act in chemotherapy treatments for cancer patients.

The apparent structural similarity between carbon nanotubes and asbestos fibres has generated serious concerns about their safety profile and has resulted in many unreasonable proposals of a halt in the use of these materials even in well-controlled and strictly regulated applications, such as biomedical ones. Because of this similarity to asbestos fibres with carbon fibres, the use of graphene would be more advisable

Conclusion

Graphene will be the future in the textile development, especially in sports clothing and pregnant clothing, due to manufacturing, mechanical and technical properties: elasticity, electrical conductivity, thermal conductivity, hardness, water repellency and cytotoxicity effects against bacteria.

As we can see, it will be a revolution, cause the textiles will be more lightness, greater elasticity and other properties and will be used as an intelligent fibre in E- textiles and Smart textiles, bringing many benefits in clothing development and design.

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Angewandte Chemie
Professor Kostas Kostarelos. UCL School of Pharmacy

ISBN: 978-989-20-5337-0