

# The graphene sandwich

**Multilayer stacks made of graphene sheets have become feasible, says s ananthanarayanan**

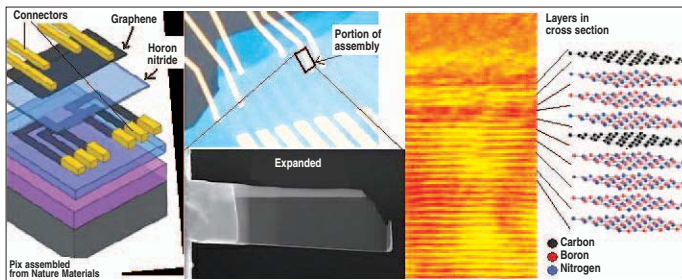
**GRAPHENE** is a one-atom thick layer of carbon atoms and has versatile electrical and mechanical properties. A stack of such layers, with an insulator in between, would have wide-ranging industrial applications. Scientists at Manchester and Liverpool report in the journal *Nature Materials* that a "side view" electron microscope picture shows good quality surfaces in a stack of 10 graphene sheets built by them.

The atomic structure of carbon has endowed the element with unique properties. As the carbon atom tends to form chemical bonds with four other atoms, including other carbon atoms, carbon can be the base of a huge number of complex molecules. As carbon has low atomic weight, these molecules are liquid at usual temperatures and form the bases of life forms as we know them.

The atomic structure also enables carbon to interlock with other carbon atoms for stable crystal structures, diamond being the form of carbon with celebrated hardness and luster. But apart from three-dimensional structures in a chemical combination or crystals, carbon is able to form a two-dimensional "raft", with a "honeycomb" structure and this is the form in which it exists in graphite or charcoal. Graphite, in fact, consists of a large number of sheets of graphene, one on the other, carbon can be the base of a huge number of complex molecules. As carbon has low atomic weight, these molecules are liquid at usual temperatures and form the bases of life forms as we know them.

The bonds between carbon atoms in the two-dimensional lattice are created by a sharing of "outer shell" electrons but the adhesion of one layer to the next arises only from weak forces between neutral atoms. The sheets, thus, tend to glide over one another, which is why graphite, in *lead pencils*, easily sheds carbon to the paper. But the electronic bonds in the lattice itself are robust, and graphene, for its weight, is a material 200 times as strong as steel! In addition, graphene has excellent electric and thermal conduction properties, which make it a promising material to use in electronic circuits.

Silicon, the base element for transistors and other wonders of modern electronics, also has atomic structure like carbon, with four "outer shell" electrons. While this enables silicon to form crystals with electrical semiconductor properties, including a two-dimensional structure, its greater atomic weight prevents the formation of the variety of molecules that can participate in life



Andre Geim



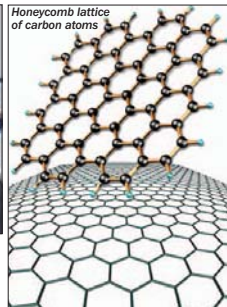
Kostya Novoselov

processes. Carbon, on the other hand, is a candidate for playing a strong role in the field where silicon excels and there has been great interest in integrating graphite into micro-electronics.

## Working with graphite

The difficulty in using graphene in practical devices has been the challenge of isolating a single-atom layer of the material. In principle, a layer of graphene can be scraped off a slab of graphite or can be "grown" by sputtering carbon on to a base that allows graphene to form. In 2004, Professor Andre Geim of the University of Manchester and Professor Kostya Novoselov of Chernogolovka, Russia (both are co-authors of the present paper in *Nature Materials*) demonstrated a method of peeling layers of graphene off a block of graphite by using adhesive tape. The process is repeated for successively thinner layers, and finally the adhesive tape is dissolved in acetone and the graphene flakes, which include mono-atom layers, is deposited on to a silicon wafer.

While very thin layers, even single-atom layers of graphene can thus be produced, the interest is in depositing the layer on a substrate for further manipulation. There is also interest in depositing mono-atom layers of other materials, typically an insulator, on the layer of graphene to create a stack of graphene layers that are very narrowly separated. Structures like this could be designed to have specific electrical and properties. Along with superior electrical and



Honeycomb lattice of carbon atoms

thermal properties, graphene is sensitive to electrical and magnetic fields in a way that allows it to be used as a transistor, a capacitor, a converter of mechanical stress into electric effects or even a transparent conductor. Hence the great interest in preparing uniform layers of thin sheets of graphene and other materials.

Such a formation of layers has been elusive. Various other materials get trapped between layers and what is created is not a true stack of mono-atom layers, held together by inter-atomic forces, but a stack that is glued together by contaminants. Stacks have been prepared with layers of graphene and boron nitride, which also appears as a two-dimensional sheet. But an inspection of the layered stacks, using electron microscope methods, shows that a number of hydrocarbons form and cover the surfaces, leaving only occasional patches of mono-atom layers effectively in contact with only inter-atomic forces in action. This observation has been discouraging for prospects of creating useful stacks of mono-atom layers, to tap into their great potential.

## Another viewpoint

The Manchester group notes in its paper

that the present method of inspection of mono-atom layers is by electron microscopy, that is "top view" or directed through the stack of layers. In this view, the defects in the different layers get superimposed and the images are difficult to analyse. The group, therefore, prepared and readied a sample stack for examination "from the side" or along the cross section. The stack was prepared by first depositing a layer of boron nitride on an oxidised silicon wafer. Subsequent layers were prepared on separate silicon wafers, peeled off and transferred on top of the first crystal. Each new surface was cleaned of contaminants by etching and heating. As graphene layers were being laid alternately over boron nitride layers, connectors of gold or titanium strips could be attached to each layer.

When the stack had been built, a suitable point for view of the cross-section was chosen using an electron micrograph of the surface. The portion of interest was protected by depositing a narrow platinum strap. A beam of charged particles was then focused on the stack, for grinding a trench around the area protected by the strap and the piece so cut out was lifted out of the stack for study, "from the side". The analysis "from the side" enabled the measurement of the quantity of hydrocarbon contaminants, or of carbon, which was the graphene sheet, at each layer.

The results of the analysis of this different view was dramatically different from what the "top view" revealed. The analysis at the level of individual layers showed that the contaminants tended to segregate into isolated pockets, leaving the interfaces of the layers flat and free from contamination. The measurement of spacing between the graphene and boron nitride planes "suggests that the interface between graphene and BN cannot contain more than a small fraction of a monolayer of adsorbates, that is, the interface is practically clean and atomically sharp", says the paper. It concludes that it is possible to assemble new structures with different mono-atom layers and also that "side view" electron microscopy would be a useful tool to assess the quality.

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# A question of prevention

**Pelvic Inflammatory Disease is adding another dimension to problems involving infertility among women, says prabhjeet singh sethi**

FOR women on the verge of motherhood, there is no denying that the feeling is one of inexplicable ecstasy. Caught up in this glow, impotency would be the last thing on her mind but, of late, Pelvic Inflammatory Disease is adding another dimension to sexually transmitted diseases to give many women probably the worst setback of their lives. Pid is an infection in the womb, fallopian tubes and other reproductive organs that traps a woman in the slush of infertility and can only be averted through early treatment or premeditated safety measures.

This disease raises its ugly head when micro-organisms like bacteria affect the female reproductive organs. Generally, a soiled cervix encourages these micro-organisms to enter the vaginal cavity, thus affecting the fallopian tubes, including in multiple sex partners or with those with a history of a sexually transmitted disease increases the chances of contracting Pid. Keeping age in mind, females between 15-24 years are highly susceptible to this disease because the cervix of those below 25 years is much too weak to battle diseases that encourage Pid.

Outbreak has been far more common in the West but, of late, cases are being discovered in the subcontinent. "A woman with multiple sexual partners may contract Pid. In fact, urine infection is another strong reason behind its evolution. Given the generally poor hygienic conditions in this part of the world, things might get worse, which is why I advise patients to stay clean," says Anubha Singh, gynaecologist and infertility specialist.

Generally, in these cases it is always important to realise that prevention is better than cure. In Pid, the fallopian tube gets tainted, resulting in the non-formation of the embryo after intercourse. "Maintaining the originality of the tube is important, because in such cases things are bound to go from bad to worse. For all young women, regular counselling with a gynaecologist may prove instrumental in avoiding Pid," says Singh.

The USA records the highest cases of this disease — nearly a million women contract Pid every year. Researchers have also analysed that one in every eight adolescent girls indulging in sexual intercourse is bound to get infected.

One needs to be careful if one has a past history of any sexually transmitted infection. Even the recent insertion of an intra uterine device could lead to Pid. According to doctors, the most common symptoms are:

- Fever.
  - Vaginal discharge with strange attributes — colour, smell or texture.
  - Pain in the lower abdomen.
  - Post-intercourse bleeding.
  - Lack of appetite.
  - Inter-menstrual bleeding.
- "There is, of course, the possibility that one may not experience such symptoms, which is why I recommend routine check-ups," adds Singh.



Anubha Singh

# My magical mystery cure

**Hallucinogenic drugs showed great promise as therapeutic treatments before they were banished from the clinical scene in the 1970s. Now they're back, and erica rex jumped at the chance to volunteer in trials**

**A SYMPHONIC** note in three strands of deep-red light trickling like water in my right visual field. Deeper tones were huge blue clouds in the middle distance, pouring from above. A prolonged violin solo turned the sky yellow and brought with it a comet's tail of body parts flying from the upper left of my visual field to the lower right, disappearing behind me.

This happened within the first hour of my swallowing a capsule of psilocybin, the psychoactive ingredient in "magic mushrooms". I'd volunteered to be a scientific-research-subject at the Johns Hopkins University School of Medicine's Behavioural Pharmacology Research Unit as part of a clinical trial to test the hypothesis that psilocybin can help cancer patients regain a sense of existential meaning in the face of their disease. This study is designed to measure how well the drug does in alleviating the anxiety and depression associated with cancer. There are currently only two such clinical studies under way using this drug, both of them in the USA. Another is scheduled to begin in the UK early next year. The drug is not legally available for any other use in either country.

I was diagnosed with breast cancer in 2009. A year on from a lumpectomy and radiation therapy, now on aromatase inhibitors, my prognosis seemed good. But rather than cheerfully getting on with life, I was spending most days at my desk crying. I began searching the web for a way to kill myself that

wouldn't be either messy or too painful.

Both in the UK and the USA, where I had my surgery, medicine excels at finding cures for disease and saving lives. All that excellence has created a kind of void, wherein treatment of the disease has trumped the human needs of those being treated. My demoralisation is common among cancer patients. We obsess about survival and what the future holds. The system isn't structured to help doctors to help us. As a result, it's a good thing for me that after a long banishment from the clinical scene, hallucinogens are making a comeback.

Prior to their 1970s prohibition, psilocybin and LSD were prescribed to around 40,000 research subjects, among them people with cancer, alcoholics and those suffering from depression and obsessive-compulsive disorder. The results showed remarkable promise in helping people overcome pain, fear, compulsive behaviours and psychological isolation. Following a dose administered in a proper clinical setting, hallucinogens diminish symptoms and improve therapeutic outcomes for months, even years, afterwards. Many patients undergo a psychological epiphany, wherein they feel a union with the universe and sense life has meaning beyond what's happening in the physical body.

Scientists have been waiting a long time for the tide to turn. "We had 30 years to practice exactly what we tell study subjects before their psilocybin sessions," said Bill Richards, one of the researchers at the Behavioural Pharmacology Research Unit who successfully treated terminally ill patients with hallucinogens at the Maryland Psychiatric Research Centre from the early 1960s until the centre was shut down in 1977. "Trust, let go, be open."

Volunteers for the psilocybin scientific research trial visit the Baltimore clinic twice, receiving a low dose of psilocybin on one visit and a moderately high dose on the other. We're screened for mental, emotional and physical problems before we're officially



ALTERED STATE: Erica Rex took part in trials of psilocybin, the active ingredient in "magic mushrooms".

admitted into the study. Giving psilocybin to people who have underlying psychiatric disorders or schizophrenia can be catastrophic. Many volunteers are sent home after a day. "Set and setting" are key factors in the hallucinogen-assisted therapy equation. "Set" refers to "mindset" — the patient's mental and emotional attitude towards the hallucinogenic experience. "Setting" is the physical and social environment — the room or space itself and the people who are present with the subject during the experience.

"Set" must include a willingness to move towards repellent or frightening thoughts and images, rather than trying to flee from them. Part of the "second" experience includes complete trust in the guides, trained psychotherapists who remain throughout the entire session. The images and feelings can be beautiful and transcendent, or terrifying and disgusting — or all of these over the course of the day. Four different psychotherapists and the study's coordinator interviewed me for hours. They asked questions such as, "If you had to spend the day being nauseated, could you tolerate it?" and "Do you ever think there are people or other beings who are transmitting secret coded messages to you alone?"

I filled in more than 50 pages of questionnaires, including assessments of optimism and pessimism, pain scales, depression scales, queries about my lifestyle and my habits, as well as one called

Assessment of Spirituality and Religious Sentiments. My blood pressure was monitored every 15 minutes for two hours. The physical exams often uncover maladies subjects themselves aren't aware of. Bland diets, heart arrhythmia or slightly off-par liver function will get you excluded, as well as traces of alcohol or drugs. All feelings and experiences — from childhood trauma to attitude to internal conflicts — are subjected to scrutiny. The guides have to know as much as possible so they can be supportive if complex or painful feelings arise.

They often do. I met Roland Griffiths, professor of behavioural biology and of neuroscience and the study director, after each day's battery of tests. "You have to approach this experience with radical curiosity," he said. Then he'd ask me, "What do you think about God? Where do you see we die? I didn't know the answers. By the end of the third day, I felt as though I had been flayed. But I passed, and I was in."

When my session day arrived, I was brought to a softly lit, comfortably decorated lounge, invitingly laid down on a sofa and listen to music. Then I swallowed a purple capsule of psilocybin. Some time later, when I was deeply within the world of the drug and the imagery it evoked, I found myself inside a steel industrial space. I became aware of my animosity towards my two living siblings. A woman sitting at the end of a long table, wearing a net cap, white clothes and working busily, turned and handed me a Dixie cup.

"You can put that in here," she said. So I did. The cup filled itself with my bilious, sibling-directed feelings. "We'll put it over here," she said, and placed it on a table at the back of the room. Then she went matter-of-factly back to work, along with now-numerous busy women. At that point, my guide Fred asked me what was happening. I recounted the scene and then I began to laugh out loud. My own laughter appeared to me in a mingling blue, cloud-dark sky as an effusion of twinkling gemstones. I was in two places at once, both in the session room, talking to my guide, and in the other world of the drug, with its own aesthetics and its own logic.

As the months have passed, I've realise what I did

gain is immeasurable. Since my session, my mood has improved and my sense of myself as a person occupying a certain space in the universe, has altered. Later on, when talking about my hallucinations with the clinicians and my guides, I found they provided me with some profound truths about my life, my feelings and my sense of myself. My tendency to judge myself with a kind of murderous harshness has ebbed. I'm now able to feel more compassion towards myself. I no longer spend days worrying about the future, and about whether I'll have a cancer recurrence, or whether I'll die alone.

Psilocybin works by providing a neurochemical bridge between spiritual guidance and talking therapy. The drug's therapeutic value depends entirely upon the patient's feelings and perceptions during the session and the way he/she processes the memories afterwards. The drug allows patients a mini-holiday from their own egos, a span of time to exist without that nattering part of us that constantly worries about things such as, "How will I survive now that I don't have a job?" and "I wonder if my ex has started seeing somebody else."

"The drug is a skeleton key which unlocks an interior door to places we don't generally have access to," Dr Richards said. "It's a therapeutic accelerator." Treatment with hallucinogens cannot — and probably will not ever — be given as a daily pill. Patients will have one or possibly two sessions in a clinic or hospital setting, and no more. The powerful images and emotions require preparation and guidance throughout the experience, which generally lasts from four to six hours. Set and setting have to be honoured. Giving hallucinogens any other way is a recipe for paranoia, anxiety and disaster." Dr Richards said. The therapeutic value of these drugs depends entirely upon the patient's feelings and perceptions during the session and the way he or she processes the memories afterwards. Patients who undergo a transcendent peak while taking psilocybin describe it as among the most meaningful events in their lives.

In the UK, a clinical trial using psilocybin to treat depression is due to begin in January 2013. David Nutt, director of the Neuropharmacology Unit in the Division of Brain Sciences at Imperial College London, is in charge. When I asked him about the therapeutic obstacles presented by legal bans against psychoactive drugs, he said, "We'll change the law. I hope he's right."

The Independent, London