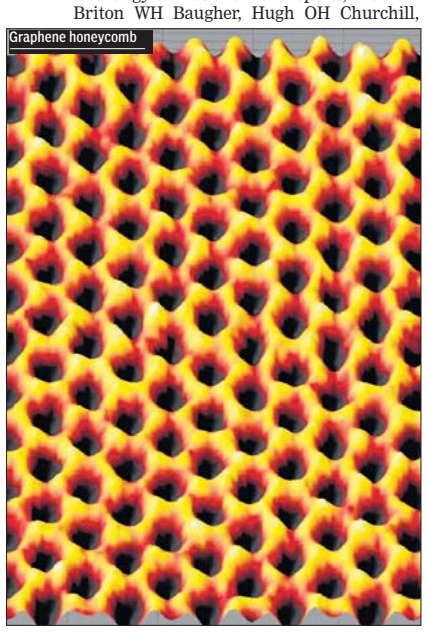
Inducing imitation and innovation

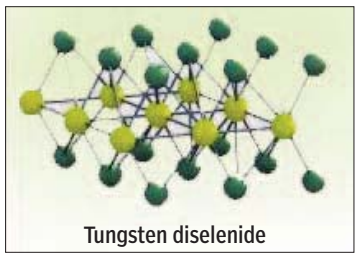
THE ATOM-THIN SHEETS OF GRAPHENE HAVE INSPIRED SOLAR CELL MATERIAL TO TAKE THE SAME FORM, SAYS

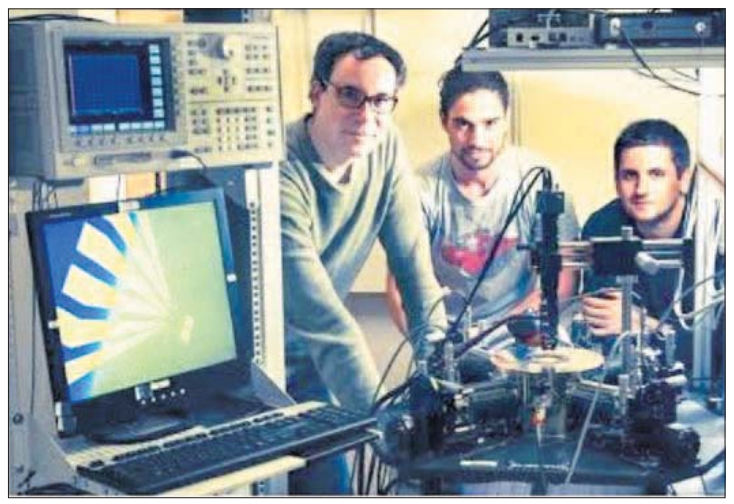
S ANANTHANARAYAN

Graphene is a form of carbon that shows a crystal structure in two dimensions and displays remarkable mechanical, electrical and optical properties. But for all that, it cannot be used as a solar cell material because the disposition of the carbon atoms in graphene is not suited to emitting electrons when excited by light radiation. On the other hand, the element silicon is suited for solar cells, but silicon wafers are bulky, rigid and opaque.

Andreas Pospischil, Marco M Furchi and Thomas Mueller, at the School of Photonics at Vienna University, report in *Nature Nanotechnology* that atoms of tungsten and selenium combine to form graphene-like, ultra-thin layers and the layers of these elements also display photovoltaic properties. The material, tungsten diselenide, appears to have come of age because the same issue of *Nature Nanotechnology* carries two more reports, one from Briton WH Baugher, Hugh OH Churchill,


Graphene honeycomb


Tungsten diselenide


Thomas Muller, Marco Furchi and Andreas Pospischil.

Yafang Yang and Pablo Jarillo-Herrero, from MIT, and another from Jason S Ross, Philip Klement, Aaron M Jones, Nirmal J Ghimire, Jiaqiang Yan, DG Mandrus, Takashi Taniguchi, Kenji Watanabe, Kenji Kitamura, Wang Yao, David H Cobden and Xiaodong Xu1, from Washington, Tennessee, Germany, Japan and China, and both reports are of essentially the same application.

The properties of graphene arise because of the electronic structure of the carbon atom, which has four electrons in the outermost electron shell. It is this electronic structure that gives the carbon atom itself its versatility. As atoms tend to combine so that they have a stable, eight-electron outer shell, carbon atoms can form bonds with four adjacent atoms that have an electron to spare, and the adjacent atoms can well be other carbon atoms. Carbon, thus, forms the extremely hard diamond crystal, where carbon atoms lock all four bonds in a three dimensional lattice, or a soft form where carbon atoms make only three bonds in the form of sheets made up of hexagons, the "honeycomb lattice". This second form is graphite, where the sheets are stacked with feeble binding forces and the easily slide over one another. This two dimensional form is unique to carbon and single sheets are now realised as graphene. Diamond is great for mechanical strength, but graphene, with its unused bond, is a good conductor.

But the property of putting out electrons when exited by light is a different property, more common at the surface of metals where the outermost electrons of the atoms are relatively less strongly bound. In such cases, photons of light can knock some of these outer shell electrons free of the mother atoms, leaving them free to move so long as they do not meet an atom that has lost an electron, when the free electron recombines. Some materials can be treated with impurities, the atoms of which have either one more or one less outer electron, and when excited by light, what is set free is either an electron, or a "lack of an electron", which is called a "hole".

If there is a junction of these two kinds of material then the free electrons can cross over, but not the holes, and the sides get oppositely charged, which means the electrons would flow through a conductor, to go back to the other side, and we would have a photocell. The element silicon happens to be one such. It has the correct forces holding down the peripheral electrons, which help it react to light, and also a carbon-like crystal structure, which helps create conditions to harvest electricity. But, as we have noted, silicon is bulky, rigid and opaque, and also expensive.

An alternative material of promise has been *tungsten diselenide*, where an atom of tungsten forms a chemical bond with two atoms of selenium. Tungsten is a metal that is able to participate in forming bonds with the help of as many as six peripheral electrons.

Selenium can also form bonds by accepting or sharing different numbers of electrons. When tungsten biselenide forms crystals, it turns out that the stable form is a sheet, of a layer of tungsten atoms sandwiched between two layers of selenium atoms. This is also a very thin sheet, like the sheet of graphene, and it shares the properties of transparence and flexibility.

The three groups of researchers featured in *Nature Nanotechnology* have worked on tungsten bislenide sheets and, by proper doping of crystals with impurities, have brought about the conditions of electrons that are pumped out when a junction is exposed to light, piling up on one side, which would drive a current.

The experimenters demonstrate that the material can be used to efficiently generate a current when exposed to light, or to change the junction from conducting to non-conducting, by turning a beam of light on or off and also to make the junction emit light when a current is passed. These properties would enable the device to work as a photocell, as a switch or as a display system. As the material is light and flexible, it could be mounted anywhere and in any shape. As the material is transparent, it would allow the bulk of the light falling on it to pass through, at the same time generating electricity from a small part that it absorbs. More layers could be used to block more light and generate more power.

When used as a switch, the beam of light that activates the switch could also signal the state of the switch by illuminating the relevant signboard. And when used as a display, the image would appear on a transparent screen, that is, without blocking the view. Digital information in a rapidly fluctuating light beam could be used to drive a switch that would imprint the signal on to a current.

Alternately, an electrical digital signal could be converted into an optical signal.

With rapid advances in production of two dimensional crystals, in bulk and at low cost, these applications would profoundly impact "future developments in solar, lighting and display technologies", say the authors of the first paper cited.

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DEGREE OF ACTION

TAPAN KUMAR MAITRA EXPLAINS THE INFLUENCE OF PESTICIDES ON THE ACTIVITY OF SOIL MICROFLORA AND FAUNA

Pesticides incorporated into the soil may change the composition of its microflora. Organochlorine insecticides in the doses recommended for controlling soil-inhabiting pests do not have a negative influence on the number of soil micro-organisms. Rapidly decomposing organophosphorus insecticides in the recommended doses stimulate the development of separate groups of micro-organisms, and in increased doses first cause suppression, and then stimulation of soil microflora.

A varying sensitivity to the action of organophosphorus insecticides has been noted in soil micro-organisms. When the cellular structure of the micro-organisms is more complicated, an increased sensitivity to these compounds is observed. At the same time, these insecticides act as a variability factor of the micro-organisms involving their morphological, cultural and physiological characters.

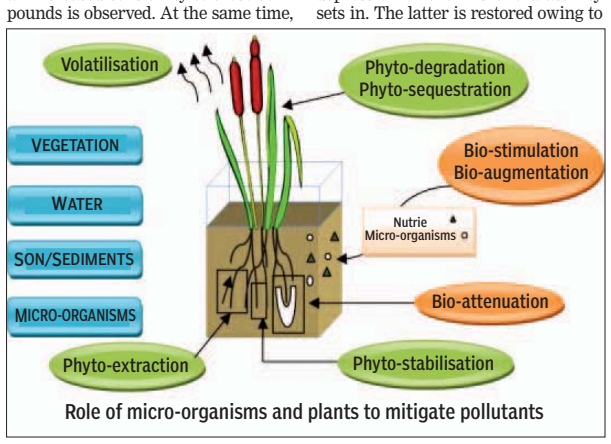
Soil fungicides and fumigants, as a rule, have a negative effect on soil microflora. The biological activity of the soil or the intensity of soil respiration (the absorption of 0_2 and the evolution of $C0_2$) may be used as a general parameter showing how pesticides act on soil microflora.

The change in the activity of soil enzymes in definite conditions characterises the effect of pesticides on the microbiological activity in the soil. The effect of pesticides on biological processes in the soil comes to light most clearly only upon a repeated or multifold application of the toxicants.

Herbicides decompose comparatively rapidly in soil and their use in recommended doses as a whole does not affect soil microflora negatively. When herbicides are incorporated into the soil, especially in increased doses, a temporary regrouping occurs in the composition of the microflora.

The action of herbicides on separate groups of micro-organisms manifests itself differently within the limits of each systematic group. After incorporation of the herbicides, a short period of depression of the microflora activity sets in. The latter is restored owing to the appearance of resistant mutant forms or to the formation of enzymes that hydrolise the herbicide.

The nature of herbicide action on soil microflora depends in many respects on the features of the structure and properties of the substances. Herbicides that are derivatives of phenoxycarboxylic acids (2, 4-D, MCPA, 2, 4-DB, MCPB, MCPP) do not have an inhibiting action on soil micro-organisms in their recommended doses. It has been established that phenoxybutyric acids (MCPB, 2, 4-DB) are much more toxic to soil micro-organisms than the phenoxy-acetic analogues corresponding to them.



Role of micro-organisms and plants to mitigate pollutants

During the first four weeks after its incorporation, 2,3,6-TBA lowers the activity of some species of soil microorganisms, inhibiting the process of nitrification. Sodium trichloroacetate (TCA) immediately after introduction may inhibit active soil microflora, while dalapon stimulates its activity. Picloram, even in large doses, does not suppress the development of the main species of soil bacteria and fungi, nor affect the evolution of CO_2 by the soil and the hydrolysis of urea. It must be stressed that it is just the indifference of soil microflora to picloram that explains its prolonged toxic action.

Herbicides that are triazine derivatives do not affect the development of most soil micro-organisms in their conventional doses. Simazine and atrazine somewhat stimulate the activity of Azobacter and Clostridium pasterianum without affecting Nitrosomonas, but to some extent inhibit the oxidation of nitrites to nitrates under the action of Nitrobacter. The development of ammonifying, denitrifying micro-organisms and rhizosphere microflora is stimulated under the action of these substances. The inhibiting action of simazine manifested itself in the development of soil algae.

The most sensitive were blue-green algae. Carbamates and thiocarbamates initially suppress the activity of micro-organisms. Isopropyl-N-phenyl carbamate can inhibit the activity of nitrifying bacteria. Urea derivatives in conventional doses do not inhibit the development of soil micro-organisms, but do exhibit a rather strong algicidal action.

The nature and degree of action of pesticides on soil fauna are due to the properties of the substances, their content in the soil, the composition of the fauna and to soil and climatic conditions. In some cases, pesticides stimulate the reproduction of soil fauna, in others they cause its suppression and extermination.

Unstable, rapidly decomposing pesticides are less dangerous to soil fauna. Persistent compounds upon their surplus accumulation are a great danger. Organochlorine insecticides such as HCH, heptachlor and toxa-phene in their usually recommended doses act weakly on or are completely harmless to earthworms, nematodes, and Oligochaeta (Ehchytracidae), but are toxic to soil arthropods (springtails, mites). Organophosphorus insecticides have a short action on soil fauna.

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What abetted Genghis Khan

SCIENTISTS, WRITES **STEVE CONNOR**, BELIEVE A SUDDEN PERIOD OF WARMER WEATHER ALLOWED THE MONGOLS TO INVADE WITH SUCH SUCCESS

A study has found that a long period of warm, wet weather spanning several decades helped one of history's most fearsome tyrants to conquer most of Asia and Eastern Europe and form the largest continuous land empire the world has known. Genghis Khan owes his place in history to a sudden shift in the Asiatic climate from the cold, arid period that immediately preceded his ascent as leader of the Mongol empire, to the warmer, wetter weather that allowed his horsemen to expand out from Central Asia.


Sculpture of Genghis Khan by Dashi Namdakov.

Scientists studying ancient Siberia pine trees in central Mongolia that date back nearly 2,000 years believe Khan's rise to power coincided precisely with a period of unusually heavy rainfall over a couple of decades that allowed the arid grasslands of the Asian Steppe to flourish. Richer, more productive pastures for the herds of war horses on which the Mongols depended for their nomadic lifestyle helped Khan's invading armies to take territory as far east as China, as far south as Afghanistan and as far west as Russia and Hungary, the researchers said.

Tree rings, which record periods of good and bad plant growth, show that the years from about 1180 to 1190, which immediately preceded Khan's rule, suffered an intense drought that probably stoked the political turbulence that helped him to come to power. After this period, the tree rings show a period between 1211 and 1225 of sustained rainfall and mild weather that coincided precisely with the meteoric rise of Khan's empire, said Amy Hessl, a tree ring expert at West Virginia University. "The transition from extreme drought to extreme moisture right then strongly suggests that climate played a role in human events. It wasn't the only thing, but it must have created the ideal conditions for a charismatic leader to emerge out of the chaos, develop an army and concentrate power," she said. "Where it's arid, unusual moisture creates unusual plant productivity, and that translates into horsepower. Genghis was literally able to ride that wave."

The tree rings show that the normally cold, arid steppes of Central Asia experienced their mildest, wettest weather in more than 1,000 years at the time when Khan rose to power and established his enormous land empire with the help of his sons. A study of the rings, published in the journal *Proceedings of the National Academy of Sciences*, shows that the climate soon reverted to its cold, dry state, which led to droughts and lower grassland productivity. The tree rings also show a disturbing modern trend. Since the mid-20th century, the region has warmed rapidly and the drought years recently have been more extreme than at any time in the tree-ring record, according to Neil Pederson, a tree-ring scientist at Columbia University's Lamont-Doherty Earth Observatory, who led the study.

Each Mongolian horseman in Khan's army is said to have had up to five horses, which provided a supply of meat as well as transport. Higher grass yields would have also caused a boom in camels, yaks, cattle, sheep and other livestock, Pederson said. "The weather may literally have supplied the Mongols with the horsepower they needed to do what they did… Before fossil fuels, grass and ingenuity were the fuels for the Mongols and the cultures around them.

"Energy flows from the bottom of an ecosystem, up the ladder to human society. Even today, many people in Mongolia live just like their ancestors did. But in the future, they may face serious conditions."

Genghis Khan died in 1227 but his sons and grandsons continued to conquer more territory and eventually controlled what became modern Korea, China, Russia, Eastern Europe, Southeast Asia, Persia, India and West Asia — before the empire began to fragment.

THE INDEPENDENT

PLUS POINTS

Gut instinct

The last time you noticed a grasshopper in your garden munching away at leaves, did you think of the massive damage it causes to agricultural crops across the world? But getting rid of the pest is not an option because it plays a positive role in recycling nutrients by decomposing plant matter.

The feeding habits of herbivorous pests like grasshoppers have always been a matter of concern as well as interest to scientists. Just by the choice of food, they can alter the plant community of a region. Knowledge about their feeding habits can be important for control efforts and restoration of damaged areas. "Accurately determining the feeding preferences of grasshoppers can help us understand the magnitude of plant damage, and consequently, whether or not control of grasshoppers is needed in a given area," says Alina Avanesyan, researcher at the University of Cincinnati, USA.

Her process involves dissecting the insect's gut and isolating DNA from the tissue. This DNA is a combination of the DNA of the grasshopper and that of the plants it has consumed. The plant DNA is then enriched in this mixture by an inexpensive and routine technique — Polymerase Chain Reaction.

The DNA obtained acts as a "bar code" for individual plants and can accurately mark out the plant

consumed by the insect. It can be used for a variety of purposes, for example to determine how long food has been digested and to explore the sequence of multiple plant species consumed and feeding preferences. Scientists can also use it to compare specific feeding patterns of different grasshopper species and uncover behaviour that might lead to intensive crop damage in certain areas.

"The findings will help us understand the diet of a range of different insect species, and this information could be used to design cropping systems and landscapes to minimise pest damage," said Hari Chand Sharma, entomologist with the International Crops Research Institute for the Semi-Arid Tropics, Patancheru, Andhra Pradesh.

MANUPRIYA/CSE-DOWN TO EARTH FEATURE SERVICE

Saving a crushed egg

Conservationists in New Zealand are celebrating after an extremely rare kakapo chick hatched from a cracked egg held together by nothing more than tape and glue. The bird joins a global kakapo population of just 125 birds — but what makes these animals so unique and why are they worth saving?

To describe a kakapo as concisely as possible you'd say that it is a species of flightless parrot, one that is ground-dwelling, nocturnal and thoroughly rotund. However, this barely even scrapes the surface of the kakapo's strangeness — a quality that is in no small way thanks to the fact they developed in the isolated environment of the islands of New Zealand. This evolutionary upbringing accounts for some the bird's odder physical characteristics, with the abundance of

food and an absence of ground-based predators encouraging the kakapo (the name translates as "night owl") to sacrifice the power of flight in favour of becoming more "thermodynamically efficient" — that is to say, they piled on the pounds and at two to four kilograms are the heaviest parrot around.

However, kakapos compensate for their inability to fly with superb camouflage and a tendency to freeze completely when startled. These two traits combine to form a pretty good defence against the unwanted attention of eagles (who find their prey mostly by movement) but they unfortunately made the bird easy pickings for the cats and rats introduced by European settlers. These predators decimated kakapo populations and it's now the responsibility of the New Zealand government's Kakapo Recovery Plan to save the species.

JAMES VINCENT/THE INDEPENDENT