Rose petals for solar power

YET AGAIN NATURE SHOWS THE WAY TO MAKING THE BEST USE OF SUNLIGHT, WRITES **S ANANTHANARAYANAN**

The solar cell takes in light energy and turns it into electricity. Vegetation makes use of light energy, too, but to drive chemical changes to build carbohydrates. While the solar cell is a recent entrant, plants have been in the business for ages and have evolved to capture and use as much of the light that falls on them as possible.

Ruben Hünig, Adrian Mertens, Moritz Stephan, Alexander Schulz, Benjamin Richter, Michael Hetterich, Michael Powalla, Uli Lemmer, Alexander Colsmann and Guillaume Gomard from the Karlsruhe Institute of Technology in Karlsruhe, Germany, and the Centre for Solar Energy and Hydrogen Research, Stuttgart, report in the journal *Advanced Optical Materials* that they have been able to isolate and reproduce the surface structure of the petals of the garden rose to create a surface that helps solar cells reduce how much light they lose to reflection and, hence, a 13 per cent increase in their efficiency.

The authors explain that an early instance of an anti-reflecting surface, which was studied, is that of the eye of the moth, which needs both to see in the dark as well stay out of sight of predators. The moth's eye surface, or the cornea, is provided with an array of protrusions, of the dimensions of the wavelength of light, which make for a great part of light falling on the surface to pass through, in place of being reflected and lost. While this feature of the moth is effective to admit more light and also show no reflection, plant surfaces can go a step further by also rearranging the light waves that they pass so that the waves can be better used by the underlying light mechanism, the authors say.

Light, as we know, consists of a combination of electric and magnetic waves, each being the cause and also the effect of the other as they pass through vacuum, in space, or the air, or glass, or water, etc. We can imagine that the passage of the waves, particularly their speed, depends on how electric or magnetic fields behave in different media. And in the case of all media, the effect is that the speed of light is less than what it is in vacuum and, for most materials, less than what it is in air. This is why a light beam bends when it enters glass or water, and it is thanks to this that we have cameras, telescopes and the magnifying glass.

Apart from affecting the speed and the direction of light, these properties of materials also affect how much of incident light would pass through or reflect off a surface. For all materials, hence, a part of the light that falls on a surface is not transmitted but is reflected. This is so for almost all the angles at which light strikes the surface, with more reflection when the angle is shallow. Some of the light is thus always lost to reflection by the normal cornea of the eye, the leaf surface, which needs light to create sugars, and, what is vital now for industry, the surface of the photo cell. Hence the great interest and value in developing "anti-reflecting" or AR surfaces, to capture all the light falls on them.

In taking up the study of AR capabilities in plants, the researchers first carried out a survey of different plant surfaces to see which one was the best. The result of the survey is shown in the graph in the top left in picture 1, which shows how the proportion of reflection drops as we move from a plane glass sheet to the surface of different kinds of leaf or petal, and reflection is the least, about eight per cent, in the case of the rose petal. As shown in the inset on the top right of the same picture, the surface of the rose petal has protrusions packed close together, some 19 microns high and 32 microns wide, or nearly a half wider than they are high.

The experimenters copied the micro-pattern of the petals' surface onto a silicone polymer mould. The mould was then used to create the same pattern on the surface of a glass substrate, as in the lower half, picture 1, The reflection properties of this surface were then compared with those of a similar glass sheet with a simple cover with no micro-pattern. As shown in the graph in picture 2, while the level of reflection is low and about equal when light fell directly on the surfaces, this changes as the slant increases and, at glancing angles, the level of reflection is many times lower for the rose structure treated surface. The trials also showed that this was so over all colours of the spectrum, which makes the rose petal structure a very attractive template for light collection.

The study of the micro-pattern on the surface of the moth cornea, published in 2006, includes a discussion on the reason why the micro-pattern reduces the extent of reflection. As stated earlier, the reflection of light waves from transparent surfaces happens because of the difference of the speed of light in vacuum, or air, and the material whose surface it is. It is the steep change in the material properties and, hence, the speed of light, when light moves from vacuum or air to other materials, that brings about reflection rather than passage through the transparent material.

This is where the microstructure comes in. As the structures are of the same dimensions as the wavelength of light, they are able to affect the speed of light and as the waves move from the peaks of the micro-protuberances to their base they experience a gradual change of speed, in place of the sudden change when they strike a plane surface. For the same reason, the pattern on the rose petal, now transferred to the experimental glass sheet, is able to ease the transition from air to glass and reduce the proportion of light that is reflected.

The study also showed that the rose petal structure, which behaved like an array of micro-lenses, had the effect of making light diverge within the underlying medium, a light focusing effect, which increased the extent of its path and the efficiency of conversion in a solar cell. In trials that were carried out with organic solar cells, the experimenters report an efficiency rise of 13 per cent when the rose petal structure was used. This was with light falling normally on the solar cell. At glancing angles, the rise in efficiency was as high as 44 per cent. "While standard micro lens arrays show both AR and light-trapping properties, the rose structure enhances these effects through auxiliary nanofoldings…" the authors of the paper say. Further, with natural structures, higher "width to height" ratios are possible, apart from the ease of fabrication by simple replication, they say. There is need to gain "further knowledge about the contribution of the nanofolding, in particular its impact on the broadening of the propagation angle distribution," they add.

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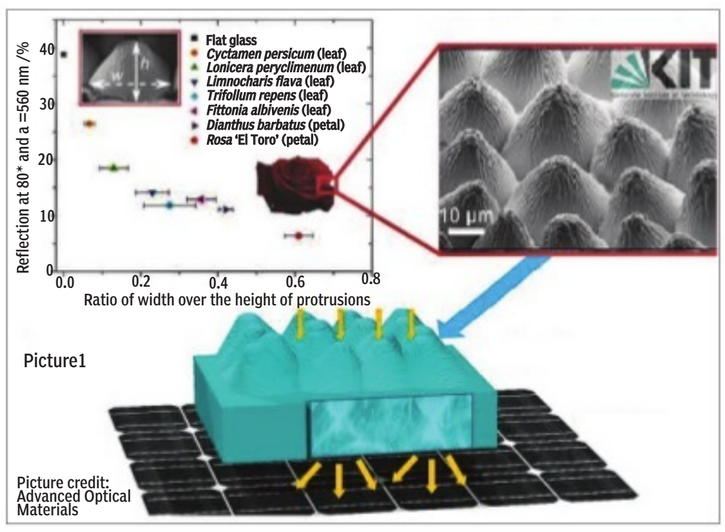
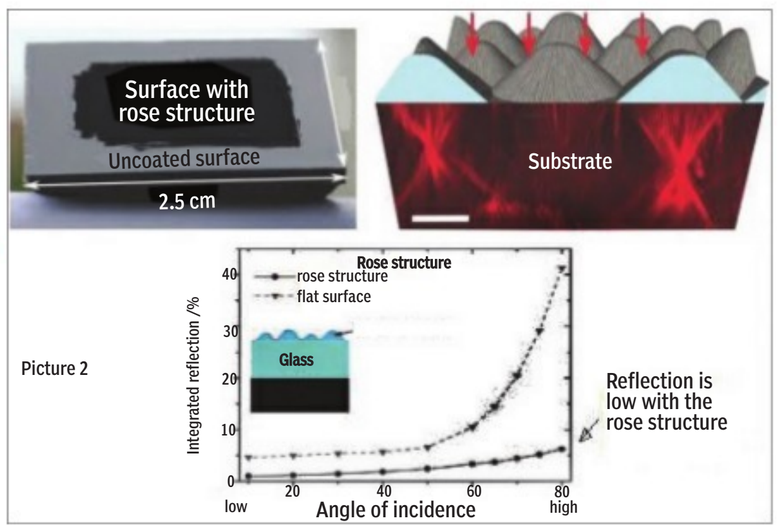


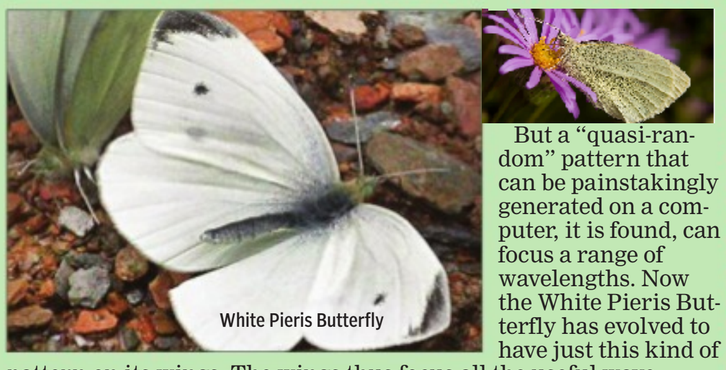


More help for the solar cell

The moth, which forages at night, is an evolutionary predecessor of butterflies, which are colourful and active in daylight. Butterflies appear to have lost the light-capturing feature of the moth cornea. But there is a species of butterfly that has a feature that is useful in the application of solar cells.

As butterflies need to conserve weight, they have lightweight wings and limited muscular resources. The muscles used to take to flight hence need to warm in the sun before they can be used. The White Pieris Butterfly, however, is found to get started, even on cloudy days, before other kinds of butterfly.

The reason is the angle at which it holds its wings, but mainly a nano-pattern that covers the surface of the wings. Striations with spacing of the order of the wavelength of light, ruled on a reflecting surface, can focus light. Each wavelength, however focuses at a different angle, and this may not be useful to collect sunlight, which has many wavelengths. And a random pattern would not be of any use at all.

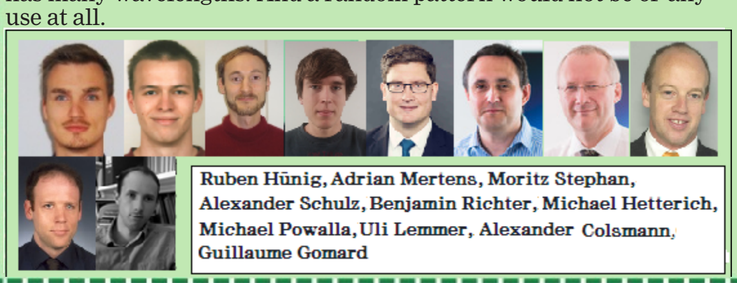


But a "quasi-random" pattern that can be painstakingly generated on a computer, it is found, can focus a range of wavelengths. Now the White Pieris Butterfly has evolved to have just this kind of pattern on its wings. The wings thus focus all the useful wavelengths of the sun's warmth on to the utterfly's muscles and it takes to flight before others can.

Thee pattern on the wings have been peeled off and used with solar cells, resulting in a huge increase in output, and also with the addition of very little weight.

Another development is that the patterns on Blu Ray discs, which are a complicated coding of text matter or images, also have a quasi random character. These have also been found good for focusing a range of wavelengths on to solar cells, with the advantage that they can be mass-produced.

While these are methods of getting more light to fall on the solar cell, the Karlsruhe/Stuttgart-rose petal advance is to help the solar cell make the best of the light that it does.



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CELL DIFFERENTIATION

TAPAN KUMAR MAITRA EXPLAINS HOW SPERM AND EGG CELLS ARE GENERATED BY MEIOSIS

Meiosis lies at the heart of gametogenesis — the process of forming haploid gametes from diploid precursor cells. But male and female gametes differ significantly in structure, which means that gametogenesis must consist of more than just meiosis.

In males, meiosis converts a diploid spermatocyte into four haploid *spermatids* of similar sizes. After meiosis has been completed, the spermatids then differentiate into sperm cells by discarding most of their cytoplasm and developing flagella and other specialised structures.

On the other hand in females, meiosis converts a diploid *oocyte* into four haploid cells but only one of them survives and gives rise to a functional egg cell. This outcome is generated by two meiotic divisions that cleave the cytoplasm of the oocyte unequally, with one of the four daughter cells receiving the bulk of the cytoplasm of the original diploid oocyte. The other three smaller cells called polar bodies, degenerate. The advantage of having only one of the four haploid products develop into a functional egg cell is that the cytoplasm that would otherwise have been distributed among four cells is instead concentrated into one egg cell, maximising the content of stored nutrients. An important difference between sperm and egg formation concerns the stage at which cells acquire the specialised characteristics that make them functionally mature gametes.

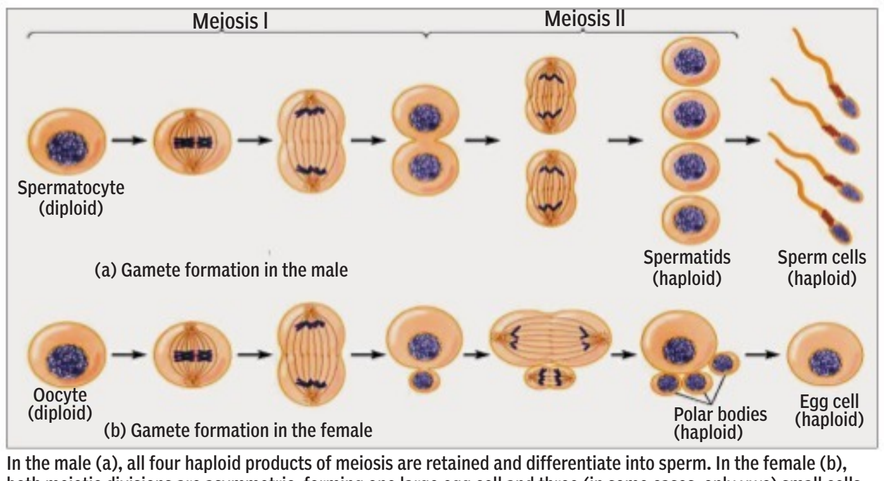
During sperm cell development, meiosis creates haploid spermatids that must then discard most of their cytoplasm and develop flagella before they are functionally mature. In contrast, developing egg cells acquire their specialised features during the process of meiosis. Many of such features of the egg cell are acquired during prophase I, when meiosis is temporarily halted to allow time for extensive cell growth. During this growth phase, the cell also develops various types of external coatings designed to protect the egg from chemical and physical injury. The amount of growth that takes place during the phase can be quite extensive — a human egg cell, for example, has a diameter of about 100 µm, giving it a volume more than a hundred times as large as that of the diploid oocyte from which it arose.

After the growth phase has been completed, developing oocytes remain in prophase I until resumption of meiosis is initiated by an appropriate hormonal signal. In amphibians, the resumption is induced by the steroid hormone progesterone. Its presence leads to an increase in the activity of the protein kinase, MPF. MPF is a Cdk-cyclin complex that controls mitotic cell division by triggering passage from G2 into M phase. It also controls meiosis by triggering the transition from prophase I to metaphase I. Progesterone exerts its control over MPF by stimulating the production of Mos, a protein kinase that activates a series of other protein kinases, which in turn leads to the activation of MPF.

In response to the activation, the first meiotic division is completed. In some organisms, the second meiotic division then proceeds rapidly to completion; in others, it halts at an intermediate stage and is not completed until after fertilisation. In vertebrate eggs, for example, the second meiotic division is generally arrested at metaphase II until fertilisation takes place. The molecule responsible for triggering metaphase II arrest is Mos, the same protein kinase that regulates the transition from prophase I to metaphase I.

By the time meiosis is completed, the egg cell is fully "mature" and may even have been fertilised. The mature egg is a highly differentiated cell that is specialised for the task of producing a new organism in much the same sense that a muscle cell is specialised to contract, or a red blood cell to transport oxygen. This inherent specialisation of the egg is vividly demonstrated by the observation that even in the absence of fertilisation by a sperm cell, many kinds of animal eggs can be stimulated to develop into a complete embryo by artificial treatments as simple as a pinprick. Hence, everything needed for programming the early stages of development must already be present in the egg.

Normally, this developmental sequence is activated by interactions between sperm and egg that involve specialised features of sperm and egg cell structure. In animal sperm, enzymes released from a membrane-bound sac called the acrosome, located at the front end of the sperm, dissolve the egg cell's outer coats, and species-specific proteins on the sperm's surface bind to receptors on the egg cell.



In the male (a), all four haploid products of meiosis are retained and differentiate into sperm. In the female (b), both meiotic divisions are asymmetric, forming one large egg cell and three (in some cases, only ywo) small cells called polar bodies that do not give rise to functional gametes. Although no indicated here, the mature egg cell has usually grown much larger than the oocyte from which it arose.

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Hobbits were real'

SCIENTISTS SAY HUMANS WIPED THEM OUT. **JOHN VON RADOWITZ** REPORTS

It may not yet be enough to convince a jury, but mounting evidence suggests ancestors of modern humans wiped out the world's only known population of hobbits. Standing three feet, five inches tall, this race was using stone tools on the Indonesian island of Flores 50,000 years ago but then mysteriously vanished.

Scientists now believe modern *Homo sapiens* humans were using fire in the hobbits' cave at least 41,000 years ago. The discovery of hearths in the Liang Bua cave indicates that hobbits and modern humans both occupied the site within 11,000 years of each other. Researchers are searching for more evidence that will remove any remaining alibi modern humans might have. If the two species came together at the same place and time it could explain the hobbits' extinction.

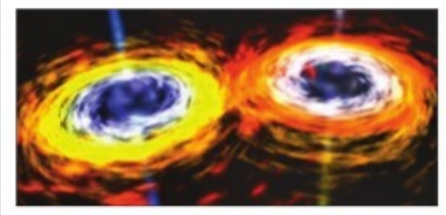

The cave in Flores, where scientists found evidence of both 'hobbit' and modern human occupation.

An international team of scientists uncovered the remains of a previously unknown species of small-statured human, *Homo floresiensis*, in Liang Bua cave in 2003. Known as "hobbits" after the characters invented by *Lord of the Rings* author JRR Tolkein, the creatures were originally thought to have lived as recently as 12,000 years ago. Later experts dated the bones at between 190,000 and 60,000 years old, while the most recent hobbit stone tools were thought to be 50,000 years old.

Although they used stone tools, there is no evidence that the hobbits had mastered fire. The hearth remains found in the cave were most likely left by modern humans, scientists said. Lead researcher Dr Mike Morley, from the University of Wollongong in Australia, said, "We now know that the hobbits only survived until around 50,000 years ago at Liang Bua. We also know that modern humans arrived in Southeast Asia and Australia at least 50,000 years ago, and most likely quite a bit earlier. This new evidence, which is some of the earliest of modern human activity in Southeast Asia, narrows the gap between the two hominin species at the site."

The new findings were published in the *Journal of Archaeological Science*.

PLUS POINTS



New gravitational wave

An international team of scientists recently announced a belated Christmas present for the world of astronomy as it confirmed the detection of gravitational waves from a second instance of two black holes colliding. This latest finding opens the door on a new age of astronomy.

The observation from a global team that involves many researchers from the UK, including the University of Sheffield, was of two black holes orbiting each other over 25 times before merging into a more massive spinning single black hole 21 times the mass of the sun. Unlike the discovery of first gravitational waves detected in September 2015, the latest discovery is of at least one of the black holes spinning. This suggests there is a rich population of binary black holes in the universe, whose properties are gradually starting to emerge. Gravitational-wave astronomy is no longer a field of single detections, but of regular observations.

Dr Ed Daw from the University of Sheffield's Department of Physics and Astronomy, who has been researching gravitational waves since 1998, said, "The detection of the collision of one pair of black holes was amazing; the detection of a second one is spectacular, because it hints that there are lots more of these things out there. But it also raises more questions — what made these black holes? How many of these things are there? Can we start to really test general relativity in detail?"

Soy diesel

Unlike conventional diesel, fuel made from soybeans does not directly damage lung cells, according to a lab study. "Some of the soybean biodiesel presently being used in Brazil does not exhibit direct adverse effects on human lung cells nor (does it) induce inflammatory response," says the paper, published in the August

issue of the journal *Toxicology in Vitro*. To assess the toxic effects, researchers from Brazil and Puerto Rico exposed lung cell cultures to particles emitted by the combustion of four types of fuel: commercial diesel from fossil fuel sources, pure soy-based biodiesel, soy-based biodiesel with additives and ethanol with additives. After exposure, the scientists counted the proportion of cells that survived to assess the fuels' toxicity and measured the quantity of cytokines the cells produced.

Adriana Gioda, a chemist at the Pontifical Catholic University of Rio de Janeiro in Brazil and co-author of the paper, says this study is the first demonstration that soy-based biodiesel does not cause a significant toxic reaction in lung cells.

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Cosmic date

The National Aeronautics and Space Administration's Juno spacecraft is spinning toward Jupiter for the closest encounter with the biggest planet in our solar system and late on 4 July fired its main rocket engine to slow itself down from a speed of 150,000 mph to slip into orbit around Jupiter. On autopilot, this delicately choreographed move came without any help from ground controllers.

The spacecraft was travelling through a hostile radiation environment and rings of debris and dust, "making for very serious hazards", said chief scientist Scott Bolton, but it should be able to withstand the harsh conditions because it's "built like an armored tank".

The spacecraft's camera and other instruments were switched off for arrival, so there wouldn't be any pictures at the moment it reached its destination, but Nasa released a series of images taken the week previous during the approach showing Jupiter glowing yellow in the distance, circled by its four inner moons. Scientists have promised close-up views of the planet when Juno skims the cloud tops during the 20-month, $1.1 billion mission.

The fifth rock from the sun and the heftiest planet in the solar system, Jupiter is what's known as a gas giant — a ball of hydrogen and helium — unlike rocky earth and Mars. "What Juno's about is looking beneath that surface," Bolton said. "We've got to go down and look at what's inside, see how it's built, how deep these features go, learn about its real secrets."

There's also the mystery of its Great Red Spot. Recent observations by the Hubble Space Telescope revealed the centuries-old monster storm in Jupiter's atmosphere is shrinking.

THE INDEPENDENT