Flitting to green energy

THE WINGS OF A PARTICULAR SPECIES OF BUTTERFLY ARE SHOWING THE WAY TO IMPROVE SOLAR CELL PERFORMANCE, WRITES **S ANANTHANARAYANAN**

Tapas K Mallick, Katie Shanks, Richard H Ffrench-Constant and Senthilrasu Sundaram

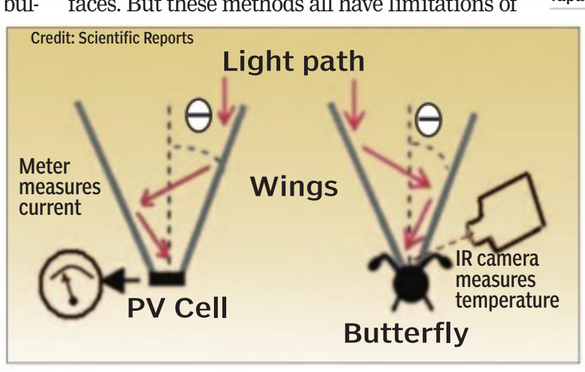
With the conversion efficiency of solar cells not rising above 20 per cent, getting more light to fall on solar cell panels is a way to make better use of this source of green power. The best way to do this so far has been with conical reflectors that funnel sunlight, but the arrangement is bulky and adds to the weight of the device. The discovery that a species of butterfly uses its wings to concentrate sunlight to prime its muscles for takeoff suggests that the process could be mimicked in solar panels.

Katie Shanks, Senthil Sundaram, Richard H Ffrench-Constant and Tapas K Mallick, at the University of Exeter in the UK, describe in *Scientific Reports*, a journal of the *Nature* group, their study of white butterflies of the family *Pieridae*, whose wings have surface nanostructure that has evolved for the most efficient reflection of the relevant band of frequencies.

The atoms of solar cell material have loosely bound electrons that can be knocked out by the energy of a photon of light. This causes a build-up of charges at the surface and if the charges are whisked away through a one-way circuit there is an electric current that can charge a battery, and the atoms of the material are ready to put out more electrons, and so on.

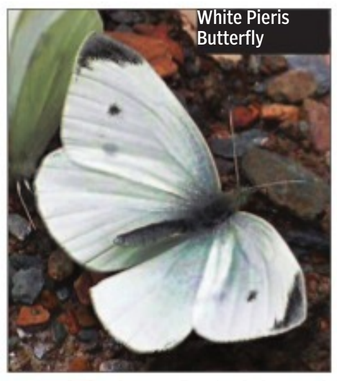
As what solar cells need is just light, even scattered light, not necessarily direct sunlight, they are effective even on days that are cloudy or overcast. However, for the actual conversion of light energy to electricity, it is not every photon that strikes the photovoltaic material that leads to an electron being pumped out. A large proportion of the photons get reflected, or transmitted or absorbed, only to warm up the solar cell, and only a fraction leads to the generation of electricity. Hence, the concern to make sure that as much light as possible gets to strike the cells.

The way "lightfall" is maximised or concentrated in solar cell panels, the University of Exeter paper observes, is with the help of mirrors and lenses. The concentrators are tyically a V-shaped pair of reflectors, either of polished metal or reflective film or polymer coatings on plastics or even vacuum metalising on suitable surfaces. But these methods all have limitations of the choice of materials, how well the materials can be shaped and, most of all, in the case of the most effective solutions, of the weight. While the reflectance of the surface is important, what is often vital is the power-to-weight ratio. There has, thus, been great interest in finding a lightweight material that can be easily applied and shaped, the paper says.



Butterfly wings

An instance in the natural world of specifically concentrating solar radiation has been observed in the case of the white butterflies of the genus *Pieris*. Butterflies need to conserve weight and, apart from lightweight wings, they also conserve muscular resources that need to be warmed before they can propel the wings for flight, especially when the weather is cooler. As butterflies are cold-blooded, they hence need external heat, like that of sunlight, to be able to get started. Here, it has been seen that on cloudy days, when there is less direct sunlight, the *White Pieris* is able to take to flight before other species.



The Exeter paper notes that this ablility has been related to the "V"-shaped wing position that the White Pieris adopts, a behaviour the authors like to call "reflectance basking". They note that the high reflectance of the wings has been recorded in other studies that have found specific patterns of beads that contain the compound "pterin" on the wings. It has even been shown that removing these beads from the wing surface promptly reduces the reflectance of the wings by a third. The arrangement of pterin beads on the wings also shows a "quasi-random" pattern, the authors say, and this kind of arrangement has been recently found to help use interference effects of light to concentrate light over a range of frequencies.

The Exeter group hence undertook detailed investigation into the mechanism of the butterfly wing concentator towards developing a related method for application in solar cells. They first checked whether the wings did, in fact, concentrate warmth on the thorax, the relevant body part of the butterfly. And then, whether there was a particular angle of the "V" that could be adopted for use in solar cells. Next, did the wings also serve to concentrate optical frequencies that would be of use in solar cells? And finally, could the whole butterfly wing or parts of it, like a layer of removed scale cells or an imitation, be used directly to improve the working of solar cells?

The results of the trials were that while the wings did positively concentrate heat at the thorax of the butterly, the use of the wings, held at the correct angle, also concentrated visible light and did substantially increase the efficiency of photovoltaic, ie, solar cells. On carrying out a survey of different butterfly wings, it was found that the forewing of the large white butterfly was the most effective and a whole wing attached to a one centimetre-square solar cell increased its output by 42.3 per cent. And given the low weight of the wings, the improvement of the power to weight ratio was a dramatic 17-fold increase. What is more, it was found that even a single cell layer peeled off the wing, on to a strip of adhesive tape, resulted in the full high reflectance. This allays the reservation that had been expressed, that it was perhaps the actual complex structure of butterfly wings that brought about their action. That a monolayer was equally effective suggests that such a layer could be used as an even lighter weight concentrator for solar cells.

Quasi random

The action of the butterfly wing in concentrating all frequencies of light in the range that affects solar cells appears to arise from the way the pterin beads are arranged on the surface. A regular, repeating pattern of rulings or other patterns on a reflecting surface gives rise to multiple waves of light from each ruling or, in this case, the pterin beads. Light from the different reflecting points would then reach other places in the form of waves at different stages of wave motion, and they would reinforce at some places or annihilate at other places. A regular pattern, at the scale of the wavelength of light waves, would then act to concentrate particular wavelengths of light, but not all wavelengths.

A random arrangement, without any pattern, on the other hand, would not select frequencies and the surface would be reflective in all directions and not concentrate light at any place. A third possibility is a *quasi-random*, or *quasi-periodic* pattern. This kind of pattern has a *long-range* periodicity and the effect is that it can select not specific frequencies but a range of frequencies — which is exactly what is relevant for the concentrator for solar cells.

Creating such patterns at the dimensions of the frequency of light waves on any commercial scale would be quite impractical. But it is fascinating that the forces of evolution, over the millions of years that butterflies have been around, have fashioned these patterns on the White Pieris butterfly's wings, which happen to be just right for use with solar cells!

Apart from the clear value, in bringing about 43.3 per cent improvement in the output and a 17-fold increase in power-to-weight ratio, the authors of the paper also observe that the arising of the quasi-random pattern "supports the idea that any given problem may first have been solved by nature". While butterflies are now providing us with a way to improve solar cell performance and tackle global warming, it is ironic that global warming is busy wiping out biodiversity and driving species to extinction — and infinite riches of technological evolution with them.

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The Blu Ray CD

THE value of the quasi-random pattern in light manipulation in a range of frequencies, with application for solar cells, was reported by a group from North Western University, Illinois, in 2014. The group reported that the sequence of "pits" and "lands" (ie, no pit) as engraved on Blu Ray discs formed a pattern that had a quasi-random character.

Blu Ray is the latest convention for coding compact discs and uses indentations that are of the dimensions of the wavelength of visible light. There is elaborate coding, with error detection devices, etc, which destroys the regular, periodic character of the original matter. However, the pattern is not entirely random and appears to retain the "long range" periodicity that makes for resonance with a range of frequencies.

Creating a "quasi-random" sequence with indents of the correct dimensions for use with solar cells is impractical. However, as Blu Ray discs are mass produced, they may turn out to be the inexpensive solution. There does not appear to be a study, as yet, of how butterfly wings and Blu Ray discs may compare in practice.

BETWEEN HEAT & WORK

TAPAN KUMAR MAITRA EXPLAINS THE COMPLEXITIES OF BIOGENETICS

The principles that govern energy flow are incorporated in an area called thermodynamics. While the prefix *thermo* suggests a limitation to heat (that, indeed, is its historical origin), the sum total takes into account the processes that convert energy from one form to another. Specifically, thermodynamics concerns the laws governing the energy transactions that inevitably accompany most physical processes and all chemical reactions. Bioenergetics, in turn, can be thought of as *applied thermodynamics* – namely, the application of thermodynamic principles to reactions and processes in the biological world.

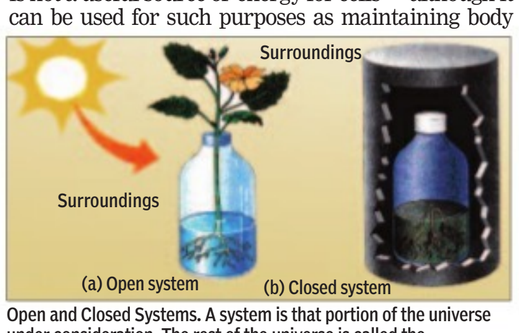
It is useful to define energy not simply as the ability to do work but specifically as the ability to cause change. Without energy, all processes would be at a standstill, including those we associate with living cells. Energy exists in a variety of forms that are of interest to biologists. Think, for example, of the energy represented by a ray of sunlight, a teaspoon of sugar, a moving flagellum, an excited electron, or the concentration of ions or small molecules within a cell or an organelle.

Energy is distributed throughout the universe but, by convention, the restricted portion that one wishes to consider at the moment is called the *system* — the rest is referred to as the *surroundings*. Sometimes the system has a natural boundary, such as a glass beaker or a cell membrane. In other cases, the boundary between the system and its surroundings is a hypothetical one used only for convenience of discussion, such as the imaginary boundary around one mole of glucose molecules in a solution.

Systems can be either open or closed, depending on whether or not they can exchange energy with their surroundings. A *closed system* is sealed from its environment and can neither take in nor release energy in any form. An *open system,* on the other hand, can have energy added to or removed from it. The levels of organisation that biological systems routinely display are possible only because cells and organisms are open systems and biological systems specifically require a constant, largescale influx of energy from their surroundings to both attain and maintain the levels of complexity that are characteristic of them. That is why plants need sunlight and we need food.

The problem of keeping track of system variables and their effect on energy changes can be simplified if one or more of these variables are held constant. Fortunately, this is the case with most biological reactions because they usually occur in dilute solutions within cells that are at approximately the same temperature and pressure during the entire course of the reaction. These environmental conditions, as well as cell volume, are generally slow to change compared with the speed of biological reactions. This means that three of the most important system variables that physical chemists usually concern themselves with — temperature, pressure and volume — are essentially constant for most biological reactions.

The exchange of energy between a system and its surroundings occurs in two ways: as *heat* and *work*. Heat is energy transfer from one place to another as a result of a temperature difference between the two places. Spontaneous transfer always occurs from a hotter place to a colder place and heat is exceedingly useful for many machines and other devices designed to accomplish mechanical work. However, it has only limited biological utility because most biological systems operate under conditions of either fixed or only minimally variable temperature. Such *isothermal* systems lack the temperature gradients required to convert heat into other forms of energy. As a result, heat is not a useful source of energy for cells — although it can be used for such purposes as maintaining body temperature or attracting pollinators.



Open and Closed Systems. A system is that portion of the universe under consideration. The rest of the universe is called the surroundings of the system. An open system can exchange energy with its surroundings, whereas a closed system cannot. The open system can use incoming energy to increase its orderliness, thereby decreasing its entropy. The closed system tends toward equilibrium and increases its entropy. All living organisms are open systems, exchanging energy freely with their surroundings.

Work, on the other hand, is the use of energy to drive any process other than heat flow. For example, work is performed when the muscles in your arm expend chemical energy to lift a book, when a corn leaf uses light energy to synthesise sugar, or when an electric eel draws on the ion concentration gradients of its electroplax tissue to deliver a shock.

To quantify energy changes during chemical reactions or physical processes, we need units in which energy can be expressed. In biological chemistry, energy changes are usually expressed in terms of *calorie* (cal), which is defined as the amount of energy required to warm one gram of water to one degree Celsius (specifically, from 14.5° to 15.5° Celsius) at a pressure of one atmosphere (again, note that the unit of energy measurement, like the very term *thermodynamics,* is based on heat but is applied generally to all forms of energy).

An alternative energy unit, the *joule* (J), is preferred by physicists and is used in some biochemistry texts. Conversion is easy: one cal = 4.184 J, or one J = 0.239 cal.

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'Frozen primordial soup'

PHILAE LANDER DATA SHOW COMETS COULD HAVE BROUGHT 'BUILDING BLOCKS OF LIFE' TO EARTH, WRITES **STEVE CONNOR**

Organic molecules that could have contributed to the chemical building blocks of life have been discovered under the icy surface of comet 67P/Churyumov-Gerasimenko, according to scientists. An instrument on board the small robotic laboratory *Philae*, which landed on the comet last November has detected an organic polymer with a similar composition of carbon, hydrogen and oxygen found in the biological molecules of living organisms, they said.

The finding is further evidence in support of the theory that comets may have deposited the building blocks of life on the surface of early earth some 4.5 billion years ago, effectively creating the "primordial soup" that kick-started evolution, said Ian Wright, a planetary scientist at the Open University. "What we are looking at here is frozen primordial soup and we believe that life evolved from something called primordial soup, but the trouble is it no longer exists on earth.

This comet's primordial soup has been frozen for about 4.5 billion years," he said. "We have long speculated about the composition of comets but now we can put some names to the compounds that are actually there and it helps to explain how comets may have contributed to the organic compounds that they may have brought to earth."

The *Philae* lander managed to collect data on the composition of the dust just beneath the comet's surface about 20 minutes after it landed, when its batteries were still capable of sending the information back to the *Rosetta* mother ship orbiting overhead. A mass-spectroscopy instrument on the lander analysed the material in the icy dust of the comet and detected a signal for polyoxymethylene, a long-chain molecule or polymer made up of repeating units of formaldehyde, one of the simplest organic molecules.

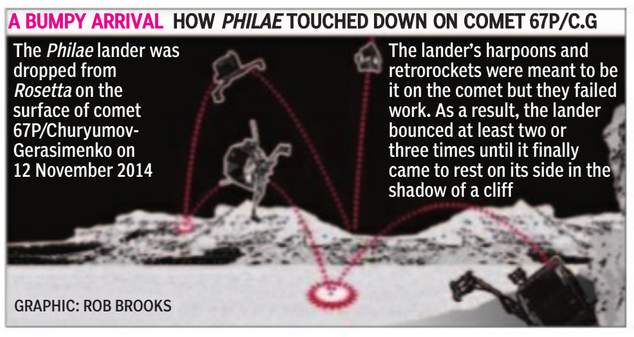
"The ratio of carbon, hydrogen and oxygen in this compound is the same as in many important compounds used in living organism, such as ribose sugar which is used to make biological molecules such as DNA and RNA," Dr Wright said.

Philae was the first man-made object to make a soft landing on a comet, and although previous comet encounters, such as the 1986 flyby of Halley's Comet by the *Giotto* spacecraft, have suggested the presence of organic polymers, none had actually made a direct detection from the surface. "This is the first faltering steps towards getting to grips with what is actually there," Dr Wright said.

Philae was designed to collect data over many months using a range of instruments but it bounced several times from its original landing site, finally coming to an uneven rest in the shadow of a rock or cliff-face. Its solar panels were unable to charge the onboard batteries, which ran out of power after three days. However, as the comet continued to edge closer to the sun, *Philae* re-emerged from its hibernation briefly on 13 June after a partial recharge of its batteries. It subsequently made contact with the *Rosetta* spacecraft six more times over 10 days, but it has not been heard of since its last transmission on 9 July.

The plan was to analyse samples of the comet deep under the surface but both of the lander's drills failed to deploy. However, Dr Wright believes the landing disturbed the comet surface enough for the mass spectrometer to analyse material beneath the outmost layer of dust. Six other studies, published in the journal *Science*, from the instruments on board *Philae* have produced the first detailed account of a comet from such a close range.

An experiment using radio waves, for instance, found that between 75 and 85 per cent of the comet's interior was nothing but a void of space, suggesting that the "icy dust" that makes up the comet is loosely packed. Measurements show that the surface of a comet is composed of granular particles about 25cm thick with a harder layer below. Daytime surface temperatures of the comet range from minus 143° Celsius to minus 183° Celsius.



THE INDEPENDENT

PLUS POINTS

Spiders & malaria

Mosquito-eating spiders from East Africa and Malaysia could become a new weapon in fighting malaria, researchers have said. A species found only around Lake Victoria in East Africa, called *Evarcha culicivora*, is adapted to hunt female *Anopheles* mosquitoes that transmit malaria parasites.

"This is unique. There's no other animal that targets its prey based on what that prey has eaten," says Fiona Cross, an arachnologist at the International Centre of Insect Physiology and Ecology in Kenya, who co-authored a study on the spiders. She says these spiders "love" feeding on human blood as it gives them an odour that renders them sexually attractive to potential mates.

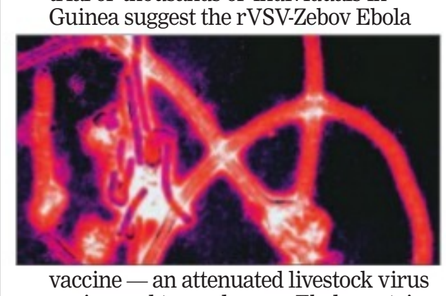
But the spiders pose no danger to humans, the researchers say, because they lack specialised mouth parts to pierce people's skin. Instead, to get the nutritious blood meal, the spiders feed on the female mosquitoes that carry blood they suck from humans.

The study, published in the current issue of *Journal of Arachnology*, says the spiders identify female *Anopheles* mosquitoes through their uptilted abdomens — a resting posture they adopt after feeding on human blood.

SCI DEV.NET

Ebola vax success

Interim results from a Phase 3 clinical trial of thousands of individuals in Guinea suggest the rVSV-Zebov Ebola vaccine — an attenuated livestock virus engineered to produce an Ebola protein — is safe and highly effective, according to a report published on 31 July in *The Lancet*. None of the 2,014 individuals who were vaccinated at the start of the trial contracted Ebola after a 10-day window to account for a pre-existing infection, while only 16 of the 2,380 people who received the vaccine 21 days later became infected. The data indicate that the vaccine, which was developed by the Public Health Agency of Canada and then licensed to NewLink Genetics and Merck, could provide protection as high as 100 per cent.



"We believe the world is on the verge of an efficacious Ebola vaccine," Marie-Paule Kieny, the World Health Organisation's assistant director-general for health systems and innovation, said during a press conference in Geneva, Switzerland, according to *Nature*.

JEFF AKST/THE SCIENTIST

5 Water Socks

Jaspreet Singh, a 23-year-old Indian-origin law student at Wayne State University in Detroit has developed water-resistant socks and launched a successful kickstarter campaign that blew past its business goal within two days, according to a media report. He came up with the idea during a public speaking class at the University of Michigan where he was supposed to pitch a business idea, *The Detroit News* reported.

After a year and a half, Singh created the 5 Water Socks brand after much research, testing and development. He got a working prototype for hydrophobic athletic socks and launched a successful kickstarter campaign that sought to raise $10,000, but brought in more than $21,300 within two days.

Kickstarter is a US-based global crowdfunding platform. The first of the socks will be produced in a North Carolina facility in August and September and should be shipped out by October, the report said.

The socks are breathable and feel like any regular pair of athletic socks, but when they come into contact with liquids, the fibres that have been fused with water-resistant particles cause the liquid to bead up and run off. When submerged, they will get wet, but not as quickly, and they will dry faster, said Singh.

"There are socks that are completely waterproof, but it's a different market," he said. "They aren't breathable, they don't feel soft. These are for everyday use." The name, 5 Water Socks, is inspired by Punjab as well as Detroit, where he was born. Five for the Great Lakes and also because Punjab is referred as "the land of five rivers".