Energy

FONDAZIONE SILVIO TRONCHETTI PROVERA

FTP

More Efficient Solar Cells

A semiconductor material with three energy bands uses more sunlight, by trapping low-energy photons.

Researchers at Lawrence Berkeley National Laboratory (LBNL) have created a new type of semiconductor material designed to improve the efficiency of solar cells by capturing low-energy photons.

Traditional solar cells respond only to a narrow spectrum of sunlight, making them highly inefficient. In the language of physicists, solar cells convert light with wavelengths corresponding to the energy it takes for electrons to jump from the valence band to the conduction band. Photons with lower energy pass right through the material.

The new semiconductor material can capture these low-energy photons for electricity, which could make solar cells with efficiencies of around 45%, compared with 25% for conventional cells that use a single semiconductor and 39% for cells with layers of mixed semiconductors.

The new semiconductors have three energy bands instead of the usual two (valence and conduction). The third band lies below the conduction band, effectively splitting the gap between the valence and conduction bands into two smaller parts. "This helps low-energy photons to participate in the process because they can excite [electrons] to the [intermediate] band and then up. It's like a stepping stone," says Wladek Walukiewicz of LBNL, lead author of the work.

The researchers found that introducing a few atoms of oxygen into a zinc-manganese-tellurium (ZnMnTe) alloy splits the compound semiconductor's conduction band into two parts. Similarly, adding nitrogen to a semiconductor such as gallium arsenide phosphide will also give a multi-band semiconductor.

LBNL has licensed the technology to RoseStreet Labs, a startup in Phoenix, AZ, which plans to commercialize solar cells made from these multi-band semiconductors. Because it's an entirely new technology, though, it's hard to say when such a solar cell will be available, Walukiewicz says.

Existing solar cells with the best efficiencies--those as high as 39%--convert light into electricity by using different semiconductor materials with different band gaps, which are stacked on top of each other to capture a broader spectrum of light wavelengths. But these solar cells are expensive, limiting their application to uses in satellites. A device made from a single, multi-band semiconductor would likely be cheaper and easier to make, says Walukiewicz.

Nonetheless, adding oxygen to the ZnMnTe alloy is hard, because oxygen does not mix readily with tellurium. To make the new materials, then, the researchers have developed a method that implants highly energetic oxygen atoms into the alloy using an ion beam. Then they use "a very short pulse of laser to melt the material and rapidly regrow it so that the oxygen is all trapped inside,"

Making a solar cell from gallium arsenide phosphide should be easier, the researchers say, because gallium arsenide compounds can be grown layer by layer.

To reach 40% efficiency, though, the semiconductor material and solar cell will have to meet some fundamental requirements of physics. For instance, efficiency goes down if the material has defects or if electrons and "holes" combine in the solar cell and create photons. But if the LBNL researchers are able to overcome these challenges, "this would represent a breakthrough."

Organic nanowires for smaller solar cells

Irish researchers have measured photoconductivity in a single polymer nanowire, a finding that could lead to inexpensive miniaturised solar cells and photo detectors.
Both devices work by converting light into electricity, and building smaller versions of the devices will rely on nanostructured materials with good photoconducting properties. The properties of inorganic photoconducting nanowires, such as ZnO or Si, have been measured, but relatively little is known about the properties of organic nanowires. Organic nanowires could be both chemically tunable and relatively inexpensive to integrate into electronic circuits.

Gareth Redmond's group at the Tyndall National Institute in Cork, Ireland has succeeded in measuring photoconductivity in a single polymer nanowire. The researchers fabricated the 200nm wide, 15μm long polymer wires using a simple template wetting technique. Metal contacts were made on either end of a single wire to measure the photo-induced current over several on–off cycles of a near-ultraviolet laser.
The wires' quantum efficiency, or the number of current-carrying electrons produced per photon hitting the wire, is about 0.1 per cent, which is comparable with several inorganic nanowires. As in many polymer-based electronic devices, the limiting factors may be the non-crystalline structure and poor electrical contact with the metal leads.

Life Sciences

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Immune response vital in cancer fight

Activity of body's defences predicts outcome better than tumour spread.

It has long been known that the immune system can home in on cancerous cells and that immune cells can take up residence within tumours. But it hasn't been clear whether such cells have much of an impact on the progress of the disease.

A study by Jérôme Galon, Franck Pagés, and a team of researchers at INSERM in Paris has brought the significance of these immune-system invaders to light. The team studied tumours taken from over 400 patients with colon or rectal cancer and measured the type, location, number and gene expression of immune cells found in the tumours, among other things. They then compared how well this information matched up with what happened to the patients.

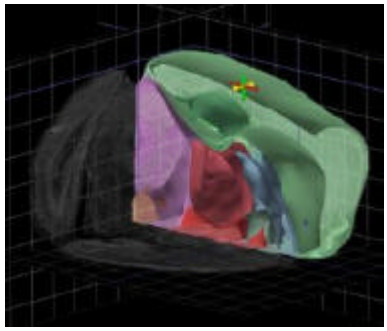
Most tumours are classified into stages based on their size and the extent to which they have spread throughout the body. A person with a stage 0 tumour — the lowest stage — has an early cancer that has yet to spread, whereas a person with a stage 4 tumour —the highest stage — has advanced cancer that has spread to another organ. It seems only logical that the higher the stage, the worse the prognosis for the patient. In general, that is the case. But Galon and his co-workers found that a better indicator of patient outcome was the degree to which immune cells had infiltrated the colon or rectal tumour. "We found that there is an importance of natural anti-tumour immunity against human cancer," says Galon. Whether a cancer recurs or not after treatment, he adds, may have more to do with the immune system than with the tumour itself. Even patients with small tumours that have not spread, says Galon, will have a bad prognosis if they have a weak immune response to the cancer. The results of his study will be presented in this week's Science.

Galon's study is the most rigorous analysis thus far in humans. A previous study with ovarian cancer also showed hints that the immune system affects cancer, though in that case the presence of a particular type of immune cell in the tumours actually suppressed immunity and led to poorer patient outcomes. Galon and colleagues have only evaluated colon and rectal tumours so far, but Galon says they will be testing the same phenomenon in other tumour types, such as prostate and breast cancers.

The results bode well for the development of therapies that modulate the immune system, such as vaccines against cancer.

3-D Brain Atlas To Help Unlock Mysteries Of Neurological Disorders

The completion of the Allen Institute for Brain Science's inaugural project signals a remarkable leap forward in one of the last frontiers of medical science -- the brain.



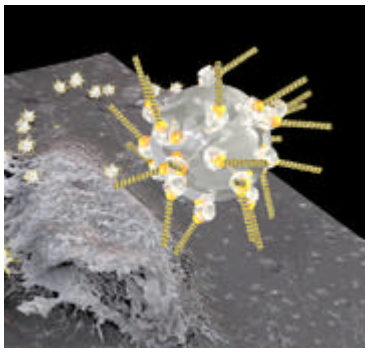
A computationally reconstructed 3D rendering of mouse brain anatomy

The Allen Brain Atlas is a Web- based, 3-dimensional map of gene expression in the mouse brain. Detailing more than 21,000 genes at the cellular level, the Atlas provides scientists with a level of data previously not available. Since humans share more than 90 % of their genes with mice, the Atlas offers profound opportunity to further understanding of human disorders and diseases such as Alzheimer's, Parkinson's, epilepsy, schizophrenia, autism and addiction.
"This project is an unprecedented union of neuroscience and genomics," said philanthropist and Microsoft co-founder Paul G. Allen, who provided $100 million in seed money to launch the Allen Institute for Brain Science's first project, the Allen Brain Atlas, in 2003. "The comprehensive information provided by the Atlas will help lead scientists to new insights and propel the field of neuroscience forward dramatically." Publicly available at no cost online at http://www.brain-map.org. the map shows which genes are active -- or "expressed" -- within the brain and which regions and cells they are expressed in, thereby linking them to particular brain functions. "This is a multidisciplinary project of unprecedented scale. It combines the scientific disciplines of math, physics, neuroscience, and genomics to define where those 21,000 genes are expressed and activated in the brain. There's no other information set like this."

The project has already led to several significant new findings about the brain. It reveals that 80 % of genes are turned on in the brain, much higher than the 60 to 70 % scientists previously believed. It indicates that very few genes are turned on in only one region of the brain -- paving the way for additional insight about the benefits and potential side effects of drug treatments. And it shows the location of genes associated with specific functions, providing scientists with valuable information about regional brain activity.Many of the discrete regions of the brain perform similar functions in all mammals, and greater than 90 % of all mouse genes have a direct counterpart in humans. By establishing this baseline of the normal mouse brain, the Atlas allows researchers to compare the brain with others altered to mimic neurological and psychiatric diseases found in humans. Previous atlases have contained anatomic maps showing the location of various regions of the brain, but little or no information about the gene activity within them. Others have contained gene information but none have been nearly as comprehensive as the Atlas, which includes data for every major structure in the brain for nearly all the genes in the genome. Even before its announced completion, the Atlas was receiving more than 4 million hits monthly and being accessed by approximately 250 scientists on any given work day. Users are not required to provide information about their work, but anecdotal evidence indicates that the Atlas is already assisting research projects.
Going forward, the Institute will shift its focus to human research in order to answer critical questions about human brain disorders and diseases. With the view of becoming a self-sustaining entity, the Institute will be pursuing grants and partnerships with funding agencies and foundations to advance neurological health issues.

Cell-Like Nano Particles for Attacking Disease

Researchers are developing smart "nanocarriers" for drug delivery and diagnostics.



In this idealized image, engineered nanocarriers find and attack specific diseased cells. The stick-like objects allow the nanocarriers to bind to particular cells.

Using parts of living cells in a smart nanotechnology-based drug delivery system, researchers in Switzerland have demonstrated a "nanocarrier" that can target specific types of cells and light up in response to conditions in their immediate environment. The work is part of a growing effort by scientists worldwide to develop nano devices that can circulate in the bloodstream, slip stealthily past the body's immune system, attach to cancer or inflammatory cells and deliver a deadly drug payload.

Already, early versions of such nano-based treatments have been approved for breast cancer. But Patrick Hunziker, at University Hospital Basel, and Wolfgang Meier, at the University of Basel, are attempting to trigger the release of the drugs at more precise locations and at release rates adjusted to have the most effect on a particular disease. One promising approach to achieving this goal is to develop nanocarriers that can respond to cues in their immediate environment, similar to how living cells can open and shut membrane pores. Hunziker and Meier have just reported in the journal Nano Letters on a system that incorporates bacterial proteins that form such pores.

The researchers first developed a type of polymer that self-assembles to form hollow spheres about 200 nm across. During the assembly process, they introduce the pore proteins, which form channels in the polymer spheres. As in bacteria, where the pores can close to protect cells from acidic environments, these channels also open and close in response to changes in pH. The researchers then demonstrated that the resulting nanocarrier could control the location and duration of a fluorescent signal--an ability that could be useful in lab diagnostics. To do this, they added another biological molecule to the mix, encapsulating within the spheres an enzyme that breaks down certain compounds, causing them to glow. They then added the nanocarriers to a solution containing these compounds. In experiments in which the researchers add the enzymes directly to the solution, without using the nanocarriers, the compounds glow diffusely and for only a few minutes. When using nanocarriers, though, the light is concentrated within the spheres, where the enzymes are sequestered, and the signal lasts many times longer--about three hours. Combined with the ability (demonstrated in an earlier paper) to make the nanocarriers latch onto specific cells, the system could be used to highlight the location of these cells in lab tests. Their current work also demonstrates the possibility of a switchable system that responds to local conditions. In the experiments, the spheres glowed only when the solution had the same acidity as structures called lysosomes located within cells. This is due in part to the pH sensitivity of the enzyme they used; but it is also, Hunziker says, because the pores are open at this level of acidity. This sensitivity could theoretically ensure that the fluorescent signal only switches on inside a cell.

The Swiss researchers are now testing the toxicity of the nanocarriers in animals and working on developing a system that could deliver an appropriate drug to targeted cells, perhaps by using synthetic channels, rather than the current bacterial proteins, which would open to deliver the drug once inside target cells.

Two-dimensional disease detection

Purdue University researchers have created the first two-dimensional images of biological samples using a new mass spectrometry technique that furthers the technology's potential applications for the detection of diseases like cancer. The technology, desorption electrospray ionization (DESI), measures characteristic chemical markers that distinguish diseased from non-diseased regions of tissue samples within a few seconds and has eliminated the need for samples to be treated with chemicals and then be specially contained.

This tool has a wide range of applications and could be used in the future to address many medical issues, said Graham Cooks, lead author of the work.‘This technology could be used to aid surgeons in precisely and completely removing cancerous tissue,’ he said. ‘With these images, we can see the exact location of tumour masses and can detect cancerous sites that are indistinguishable to the naked eye.’Current surgical methods rely on the trained eye of a pathologist who views stained tissue slices under a microscope to assess what tissue must be removed.
This study was the first to take the graphical data presented by DESI mass spectrometry and turn it into a two-dimensional image of the tissue. ‘The ability to produce an image is a great advance,’ he said. ‘It is much more practical to have an image that can quickly and easily be interpreted. It brings the technology much closer to being ready for the clinical setting.’Several technical papers have been published about DESI experiments since the method was announced two years ago as an alternative to traditional mass spectrometry techniques.Conventional mass spectrometry requires chemical separations, manipulations of samples and containment in a vacuum chamber for assessment. DESI researchers modified a mass spectrometer, which is commonly used in biological sciences, to speed and simplify the time-consuming and labour-intensive analytical process.
Mass spectrometry works by first turning molecules into ions so they have mass and can be detected and analyzed. The DESI procedure does this by positively charging water molecules by spraying a stream of water in the presence of an electric field. These charged molecules contain an extra proton and are called ions. When the charged water droplets hit the surface of the sample being tested, they transfer their extra proton to molecules in the sample, turning them into ions. The ionized molecules are then vacuumed into the mass spectrometer, where the masses of the ions are measured and the material analyzed.
‘Through analysis of the abundance of certain ions and mass ratios, the contents of the sample can be identified,’ Cooks said. ‘This information can be used to precisely determine the location of cancerous tissue and borders of tumours.’In this study, researchers mapped the distribution of fatty substances called lipids in a rat brain. The team was able to create a high-resolution image with a spatial resolution of less than 500 micrometers, meaning the image distinguishes small details separated by less than 1/100th of an inch. The researchers evaluated the sample by spraying small sections of it with the charged water droplets, obtaining data for each section and then combining the data sets to create an analysis of the sample as a whole. Software was used to map the information and create a two-dimensional image showing the distribution and intensity of selected ions.

The team is now working on the technique to improve the image resolution and has placed an instrument in the Indiana University School of Medicine, Cooks said.
Cooks' research team has also designed and built a portable mass spectrometer using the DESI technology. It is roughly the size of a shoebox and weighs about 40 pounds, compared to around 600 pounds for a conventional mass spectrometer. The portable instrument runs on batteries and can be carried anywhere, allowing the technology to more easily be used for field applications like explosives detection.

A paper on the research is published on Angewandte Chemie

Gene therapy synchronization studied

Singaporean scientists say a combination of drug and genetic cancer therapies produces enhanced effects of individual treatments.
Yi-Yan Yang and colleagues at the Institute of Bioengineering and Nanotechnology say such synchronization not only improves the promise of a more effective cure but also means the dosage of anticancer treatments can be reduced.

The researchers used biodegradable nanoparticles made from a polymer that has both a water-loving side and an oil-loving side. When placed into a water solution the polymer spontaneously forms nanoparticles in which the oil-loving part hides in the core and the water-loving part lines the outside shell. If an oil-loving drug is present in the solution, it will be incorporated in the core, which, in contrast, the shell can be used to bind DNA or RNA.
The researchers say they loaded the nanoparticles with a potent anticancer drug and therapeutic gene, and injected them into mouse tumors and observed a significantly slower growth rate in the tumor.

The research is detailed in the October issue of the journal Nature Materials.