Energy

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Solar Energy: Charged For The Future

Once regarded as costly and impractical, solar technology is now poised to play a larger role in the future, thanks to new developments that could result in lower costs and improved efficiency. Potential applications include cell phones, computers, automobiles, homes and office buildings. The American Chemical Society will address the progress and challenge of this technology during a first of its kind symposium, "Science and Technology of Next Generation Photovoltaics" this September. Here are a few highlights of research toward improving the efficiency of solar cells:

"Plastic" solar cells show gains in performance -- Nobel Prize winner Alan J. Heeger, Ph.D., and colleagues at the University of California, Santa Barbara, say that new developments in "plastic" solar cells, particularly chemical modifications to titanium oxide layers, could provide efficiencies of up to 15 percent in the future. He already has developed plastic solar cells with efficiencies between 5 percent and 6 percent, considered among the highest to date for this type of solar cell. These developments could pave the way for wider use of plastic solar cells, a type of conducting polymer, which are increasingly seen as a low cost, efficient and long-lasting source of solar energy. Heeger, a professor at the University, shared the 2000 Nobel Prize in Chemistry for his contributions toward the discovery of plastics that conduct electricity. His presentation will be delivered by study co-author and University colleague Kwanghee Lee, Ph.D.

Ultrathin, dye-sensitized solar cells called most efficient to date -- Researchers in Switzerland have developed dye-sensitized solar cells that have reached the highest efficiencies to date among a new generation of thin film photovoltaic devices that show promise as a low-cost energy source. The new cells, composed of an ultrathin film of nano-sized semiconductor crystals such as titanium dioxide, have been shown in laboratory studies to produce efficiencies of 11 percent, whereas most new solar cells have efficiencies between 4 percent and 5 percent, according to Michael Graetzel, Ph.D., a chemist at the Swiss Federal Institute of Technology, Lausanne. These cells, which can be engineered into inexpensive, flexible sheets, could be used as coatings on glass windows to supply electric power to homes and businesses or as coatings on tents to supply power for soldiers in the field. The cells could be used in consumer applications within two to three years, the researcher says.

Carbon nanotubes could boost efficiency of solar cells -- Researchers at the University of Notre Dame in Indiana say they have found a new and promising way to boost the efficiency of solar cells. In preliminary studies, carbon nanotubes that were engineered into the architecture of semiconductor solar cells (composed of cadmium sulfide, zinc oxide and titanium dioxide) resulted in a doubling of the cells' photoconversion efficiencies (converting light into energy). In some cases, the efficiency of solar cells jumped from 5 percent to 10 percent in the presence of carbon nanotubes, according to Prashant Kamat, Ph.D., a professor of chemistry at the University. Carbon nanotubes also could be added to other types of solar cells, such as dye-sensitized solar cells and organic solar cells based on conducting polymers, to create similar or even stronger efficiency boosts, he says.

Re-inventing nature for cheaper solar power

A research team in Sydney has created molecules that mimic those in plants which harvest light and power life on Earth.
“A leaf is an amazingly cheap and efficient solar cell,” says Dr Deanna D’Alessandro, at the University of Sydney. “The best leaves can harvest 30 to 40 percent of the light falling on them. The best solar cells we can build are between 15 and 20 percent efficient, and expensive to make. We’ve recreated some of the key systems that plants use in photosynthesis,”

Bacteria and green plants use photosynthesis to convert light energy into usable chemical energy. Wheel-shaped arrays of molecules called porphyrins collect light and transfer it to the hub where chemical reactions use the light energy to convert carbon dioxide into energy-rich sugar and oxygen. “This process, which occurs in about 40 trillionths of a second is fundamental to photosynthesis and is at the base of the food chain for almost all life on Earth,” says Deanna.“We have been able to construct synthetic porphyrins. More than 100 of them can be assembled around a tree-like core called a dendrimer to mimic the wheel-shaped arrangement in natural photosynthetic systems.” These molecules designed by the team are about 1 trillionth the size of a soccer ball. But the large number of porphyrins in a single molecule means that a significant amount of light can be captured and converted to electrical energy – just like in nature. “Since they are so efficient at storing energy, we think they could also be used as batteries – replacing the metal-based batteries that our high technology devices depend on today,” Deanna says.“Our preliminary results are very promising. We are still in the early stages of building practical solar energy devices using our molecules.The challenge is immense, but is crucial to providing alternative energy solutions for Australia and the world.”

Now they’ve made the molecules, the team along with their Japanese collaborators at Osaka University are working to combine them in the equivalent of a plant cell. Then, over the next five years they will attempt to scale up the technology to commercial scale solar panels.

Latest Fuel Cell Material Advance Overcomes Low Humidity Conductivity Problem

Fuel cells have been a workable technology for decades -- but expensive and lacking in infrastructure. In recent years, researchers have addressed durability, manufacturability, and conductivity challenges in alternative proton exchange membrane (PEM) materials for fuel cells -- bringing the hydrogen-based energy source closer to reality. James McGrath, at Virginia Tech, will announce his research group's latest development, a PEM material that retains conductivity during low humidity, during the Hydrogen Economy symposium at the National Meeting of the American Chemical Society this September.

Fuel cells convert chemical energy, usually from hydrogen, to electrical energy. In a PEM fuel cell, the critical exchange takes place through a thin water-swollen copolymer film that contains sulfonic acid (SO3H) groups. Electrons are peeled off by oxidation of the hydrogen atoms and hydrated protons pass through the film to combine with oxygen on the other side to form water as a byproduct. The efficiency of the exchange process depends upon water, so efficiency -- measured as proton conductivity -- goes down as humidity goes down. "Up to now, a lot of water has been needed to assist the proton transfer process," said McGrath. McGrath and colleagues have demonstrated a method for creating a material with improved conductivity even at lower humidity. The U.S. Department of Energy awarded the group $1.5 million over five years to advance the research.
Instead of stirring two kinds of reactive monomers, or small molecules, together to form a new random copolymer, the new material links blocks of two different short polymers in sequences. For example, he would link polymer W (loves water) and polymer d (dry but strong) into a chain this way: WWWWWddddddWWWWWddddddd. The researchers can link a 10- to 50-unit block of a polymer containing acidic groups (SO3H) that like water (hydrophilic) to an equally long block of a polymer that has mechanical strength, thermal stability, and endurance, but hates water (hydrophobic). The chains self-assemble into flexible thin films. Under an atomic force microscope, the film's swirling surface looks like a fingerprint, with light ridges and dark channels. It turns out that the soft hydrophilic polymer forms the dark channels where water is easily absorbed so that the entire film -- or proton exchange membrane (PEM) -- has an affinity for water transport that is two to three times higher than the present commercially available PEM.

In addition to making PEM materials with better qualities, another goal of the research is to make PEM materials that can be easily manufactured. The self-assembling nature of the block copolymer material into a nanocomposite film is an important attribute. In addition, the researchers are working on processing the film from powders using a reverse roll coater, equipment commonly available in the coatings industry but not yet being used to produce PEM material.

Micro fuel cells for portable energy

Since their conception, micro fuel cells have been heralded by scientists as a renewable, long-lasting and environmentally friendly alternative to lithium ion (Li-Ion) batteries for powering mobile devices. But they have not yet become widespread because they are manufactured from hundreds of tiny parts using different materials, making them complicated to develop and expensive to produce. Now, researchers are using a readily available material and existing machinery to make cost-effective, single-piece ceramic fuels cells. Dr Michael Stelter and his colleagues at the Fraunhofer Institute for Ceramic Technologies and Systems (IKTS) are making the cells from a ceramic film called LTCC (Low Temperature Co-Fired Ceramic), which comes in rolls of plastic-like tape with the consistency of leather. The cells are machined while the film is 'green', or unfired. LTCC is commonly used as a substrate to produce a multi-layered printed circuit board. Being ceramic, it can withstand higher temperatures, enabling it to be used in difficult environments such as car engines and for military applications. It is reliable and stable — millions of LTCC components are produced daily for electronic engine control.

'Because it is so widely used, there are many machines available on the market for working with LTCC, making ceramic fuel cells cost-effective to develop,' said Stelter.

Fuel cells produce electricity from an external supply of fuel and oxygen, which can be replenished. In hydrogen cells, a catalyst at the anode separates the electrons from the protons and allows the protons to pass through a membrane to the cathode. The electrons take a longer route round a circuit, generating a current. The protons and electrons combine with oxygen at the cathodes to produce water. 'The tools that create geometrically structured machined channels and buried tubes can also conduct liquid and gas in micro fuel cells,' said Stelter. 'We use stamping, punching, embossing and laser structuring techniques.' Individual layers are machined and up to five layers are stacked up. The cells are then laminated like circuit boards while still in the flexible green state, and then fired. The fuel cells are currently hand-assembled, but using the same machines as used in automated mass production.

The power produced by the ceramic micro fuel cells is directly comparable with traditional ones as the method for power production is unchanged. The four-cell unit shown produces 500 milliwatts for a 6cm x 6cm, 6mm-deep block using hydrogen as a fuel.

According to Stelter, the time to market for ceramic fuel cells depends on the level of integration the customer wants. 'We could have a product in two years based on today's state-of-the-art hydrogen technology,' he said. 'If, instead, we went for direct methanol fuel, it would take five years or so. We don't have all the system components such as a micro pump yet.' The next step is to demonstrate industry applications for ceramic fuel cells. The cell can produce a power range of 30-50 microwatts up to 3W, the upper limit restricted only by production price. For lower wattages, Stelter says it is better to use alternative micro technologies such as structured silicon.

One immediate application will be as a power source for portable electronics where there is no mains plug to power a device or recharge a battery.

Stelter and his team are now working on how to integrate micro actuators, such as micro pumps and micro valves, with the cells. LLTC components are already used in pressure sensors, including industrial sensors such as those used in chemical process control and food processing. Another IKTS department is working on piezoelectric components. 'We want to see a motherboard integrating electronics, gas power and micro actuators into a micro-integrated fuel cell system,' said Stelter. 'It could do everything in a single, flat device. It would be cheaper and more reliable for a fuel cell to carry its own electronics on the stack.' He sees the integrated systems being used in portable wireless applications and personal medical devices,

Cooking up a transport solution

Fuel cell cars could one day run on hydrogen made from cooking oil now research into a novel way of producing hydrogen is to take a step forward. If the process is proved to have commercial potential, other sources of the gas could include scrap tyres and waste industrial oil. A team at the Leeds University is perfecting the making of liquid fuels by reforming unmixed steam. Put simply, fuel is reacted with steam to release hydrogen from both. The process was invented 10 years ago in the US but not made public until 1999. Now researchers around the world are trying to make it commercially viable so that it can play a significant role in the much-touted 'hydrogen economy'. It claims to be a convenient way to distribute fuel for hydrogen production, which is difficult and expensive to store and transport.

Speciality chemicals company Johnson Matthey and scrap tyre recycler Tyrolysis of Wales, are supporting the work at Leeds. The idea is that fuel can be distributed in liquid or compressed gas form to filling stations, where it is reformed into hydrogen. General Electric has a large demonstrator in place but it uses methane and pulverised coal. The Yorkshire team is, instead, investigating the basic science for the process so that other fuels, particularly those from biomass and the waste stream, can also be used. The science is not well understood in detail,' said Dr Valerie Dupont, principal author 'In the last three years we have looked at the chemistry of the process and there is still more to do to make sure that it is optimised and reliable.'

In laboratory experiments, up to 76% of the available hydrogen has been produced from the methane fuel and steam combined, and 44%from sunflower cooking oil and steam combined. Higher efficiencies could be achieved with improved steam conversion, which is now the main limiting factor.The laboratory reformer has a total capacity of 80cc and contains a granulated nickel/alumina catalyst, which is fed first with air. Oxygen from the air binds with the nickel in an exothermic reaction that generates heat for the process. Then some vaporised fuel is fed into the reformer to help complete reduction of the nickel. Finally, with the reformer now running at about 800ºC, a mix of vaporised fuel and steam are fed in so that dolomite can absorb the carbon dioxide, effectively separating out the hydrogen. The process is repeated and is regenerative. Sulphur in the fuel is claimed to also undergo oxidation under the airflow rather than irreversibly poisoning the reforming catalyst.The nickel material and the dolomite are sometimes described as catalysts for the process but Dupont also refers to them as 'mass transfer materials' because they facilitate the movement of atoms and do not largely accelerate the reaction themselves. The process goes under different guises and is known as 'chemical looping combustion' when used in a different type of reactor. Whatever its name, it clearly works well with methane although there are many questions to be answered, particularly if it is to be used with other fuels.

'One question we want to answer is what are the optimum periods for the air feed, fuel feed and fuel/steam feed,' said Dupont. During the next three years the Leeds team will also investigate what happens when waste cooking oil, waste tyre pyrolysis oils, pine wood forestry material and industrial waste oil are used.

Fuel companies dream that tankers may one day collect old cooking oil from local factories, instead of petrol or diesel from the middle east, and transport it to filling stations to be reformed on demand into hydrogen for fuel cell cars. This is decades away from reality but the work at Leeds is bringing it closer.

Spugne a idrogeno nelle auto del futuro

Una sperimentazione con una matrice porosa apre una nuova strada allo stoccaggio dell'idrogeno in vista della costruzione di vetture non inquinanti

Un gruppo di scienziati è riuscito a trovare una prima soluzione al problema della conservazione dell'idrogeno, in vista di un suo impiego come combustibile per mezzi di trasporto. Lo studio è stato svolto da ricercatori dell'Università di Nottingham, Regno Unito coordinati da Martin Schröder ed è stato pubblicato sulla rivista "Angewandte Chemie". Gli scienziati hanno utilizzato una matrice porosa in cui hanno inserito quanto più idrogeno era possibile. Ma, e questa è stata la sorpresa della ricerca, successive prove con matrici con pori più grandi non hanno portato allo stoccaggio di maggiori quantità di idrogeno.
La matrice porosa in questione, che assorbe l'idrogeno come una spugna, si chiama metal organic framework (MOF) e ha una struttura molecolare che ricorda una impalcatura piena di fori di forma cilindrica. In questi fori viene iniettato l'idrogeno in forma gassosa. Inizialmente, gli scienziati avevano immaginato che aumentando il volume dei pori sarebbe aumentata anche la quantità di idrogeno immagazzinabile. Per verificare questa ipotesi, è stata calcolata la quantità esatta di combustibile che poteva essere contenuto in un certo volume. Il calcolo si è però rivelato più complicato del previsto, e solo dopo molti sforzi si è arrivati a un dato definitivo, che costituisce il principale risultato della ricerca.
L'idrogeno è stato pompato in tre MFO dello stesso materiale ma con pori di differente taglia, rispettivamente di 6,5, 7,3 e 8,3 angstrom di diametro (un angstrom è un decimiliardesimo di metro). I pori di taglia intermedia sono stati quelli che alla fine hanno offerto la più alta densità d'idrogeno: 43,6 grammi di idrogeno per litro, 4,7 grammi per litro in più dei buchi più piccoli e 2,5 in più di quelli più grandi. I ricercatori hanno inoltre concluso che la misura ottimale del diametro dei pori di MOF varia a seconda del materiale di cui è composto.

Superconductivity Is Key To Conserving Energy

Dr. Fatih Dogan, at the University of Missouri-Rolla, is working with superconducting materials that might eventually revolutionize the way energy is conserved. He is author of a new article about the possible mechanisms of superconductivity at high temperatures published on the current issue of Nature Physics.
“If we understand the mechanisms of high-temperature superconductivity, we could discover new materials that could be superconducting. Computers would work extremely fast without heating up and power lines could transport electricity on thin lines without losing energy” Dogan says

Dogan is working with a mixture containing versions of four elements: yttrium, barium, copper and oxygen. In a UMR lab, high-quality crystals of the mixture are grown. The crystals are used by physicists around the world for neutron scattering measurements. Powder from the four elements is heated, melted, and then allowed to cool in a disc shape about the size of a silver dollar. The trick to getting the material in the disc to form as a single high-quality crystal, according to Dogan, is to place a seed crystal that melts at higher temperatures in the center of the mixture. Under precisely controlled conditions during the cooling process, the seed crystal colonizes the surrounding material.

Life Sciences

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Tumour survey unearths wealth of mutants

Cataloguing cancer genes may pay dividends.

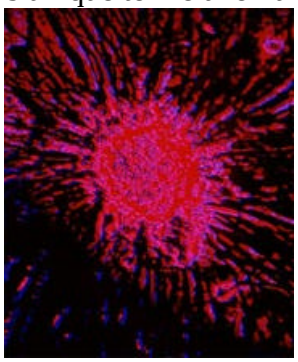
A hunt through thousands of human genes has turned up nearly 200 that are altered in breast and colon cancer. These genes might be useful for diagnosing cancer or as new targets for drugs.
The findings suggest that a US$1.5-billion initiative funded by the US government to decode the 'cancer genome' could throw up useful leads — and goes some way towards appeasing the project's critics.
Cancer arises when cells rack up mutations in a number of their genes, and begin to divide uncontrollably. Researchers have already identified some of the genes involved in this process by cherry-picking promising candidates — but there are thought to be many, many more. In the latest study, researchers searched for culprits by determining the genetic sequence of some 13,000 genes found in 11 breast tumours and 11 colorectal tumours that had been preserved for study. They then looked for differences in the genes between cancerous and normal tissues, and cross-checked the result with an additional bank of tumours from 24 breast or colorectal cancers. The trawl unearthed a total of 189 genes that were mutated in the tumours and are suspected to be a cause of cancer; the majority of these had not been implicated in cancer before.The study confirms that cancer is a fiendishly fickle enemy. The team found that breast and colon tumours harbour almost completely different mutations — in fact, only two mutated genes were shared between them. Cancers in other tissues might also be driven by a different spectrum of mutations. In addition, the team found that no two tumours are exactly alike. All in all, the researchers estimate that a typical breast tumour carries mutations in more than 100 genes. Some 20 of these might be involved in causing the cancer, they say. Less than half of these are likely to be found in another breast tumour. The study is published in the current issue of Science.

The results add weight to the idea that battling cancer is going to be a long and difficult task, as each person might need a different, tailored combination of drugs to combat the wayward cancer genes that are fuelling their disease. But there is some hope. One of the lead authors on the study, Victor Velculescu of the Sidney Kimmel Comprehensive Cancer Center in Baltimore points out that many of the mutated genes fall into groups with a common function, such as sending signals within a cell. So it is possible that drugs that interfere with these processes might work on many different cancers. "Simpler themes emerge within the complexity," he says.

The study serves as a forerunner of the Cancer Genome Atlas, a vast project that aims to find all the genetic changes that occur in cancers. A $100-million pilot project, funded by the US National Human Genome Research Institute and the National Cancer Institute, is just starting up; but some scientists have been critical of the whole approach, saying that it might not unearth mutations that occur in a significant number of cancers, and so might be of little use. The new study, done independently of the atlas, allays some of those concerns because it shows that at least some such mutations do occur in a significant number of cancers, even if they are not found in all cancers.

Therapy breakthrough against skin cancer

Immune cells removed from melanoma sufferers and genetically engineered to better recognise cancer can fight the disease when reintroduced into the patients. In a preliminary study, two of 17 participants with advanced melanoma were declared clinically free of the disease one year after receiving this experimental form of treatment.If not treated early, skin cancer can spread through the body and develop into advanced melanoma. Patients with this stage of the disease may undergo surgery or chemotherapy. But some people with the illness fail to respond to these conventional treatments and die. The approach taken by Steven Rosenberg, at the US National Cancer Institute in Bethesda and colleagues aims to give such patients a final chance to beat the disease.
Developing the new treatment involved first investigating the chemical markers on the outside of cancer cells that the body's natural immune system recognises.
The team honed in on chemical markers unique to melanoma cells, such as one called "MART-1".



When the body successfully detects this type of cancer, immune cells produce receptor proteins on their surface that pick up on the presence of MART-1 in order to destroy the melanoma. So researchers engineered a harmless retrovirus to carry the gene responsible for the production of these proteins. They then removed immune cells from 17 melanoma patients and exposed the cells to the engineered virus. The virus integrated itself into the DNA of such cells so that they, too, began expressing the surface protein that recognises melanoma, signals such as MART-1.
Rosenberg's team then infused the engineered immune cells back into the patients, all of whom had failed to respond to conventional therapies and were likely to die from the disease within three to six months. While most of the patients subsequently lost their battle against melanoma, two of them responded to the treatment. In fact, both were declared clinically free of the illness and have remained so for 18 months so far.

Experts acknowledge that further trials are necessary, in particular to determine whether the success rate of the treatment can be improved. They also point out that past trials using gene therapy to alter cells have produced unanticipated side effects. In a 2002 French trial, boys being treated with gene therapy for X-SCID – or "bubble boy" syndrome – unexpectedly developed leukaemia.
However, cancer experts say the chances of such a side effect developing with the melanoma treatment are slim. This is because it involves inserting genes into mature immune cells, which are less likely to multiply uncontrollably than the stem cells that were genetically altered in the French trial. The researchers are now working on improving their technique. The group hopes to gain FDA approval in the next month to test these. The team are also working on receptor proteins for other tumours, such as breast and prostate cancers.

Journal reference: Science

New technique will help search for new cancer drugs and antibiotics

A team of John Innes Centre (JIC) scientists led by Prof Tony Maxwell have developed a new technique that will help search for new anti-cancer and anti-bacterial drugs more quickly and accurately. The researchers found a new way of measuring the activity of a group of enzymes called DNA topoisomerases that help package DNA, the molecule that stores genetic information, into cells. Chemicals that block these enzymes could be developed into new anti-cancer and anti-bacterial drugs.

The previous method used for measuring the activity of topoisomerases is time consuming and labour-intensive; this new technique is faster, more accurate and could be automated with robotics to screen thousands of chemicals and identify those with the potential to be made into drugs.

“This development is really exciting because it will speed up the whole discovery process for this type of drug. A quicker and more accurate screen will allow more potential drugs to be assessed and therefore aid the search for urgently needed new anti-cancer and antibacterial drugs” says Tony Maxwell. “A patent for the technique has been granted and we already have several pharmaceutical companies that are interested in licensing the technology”.

Study Suggests A Second Dimension To Alzheimer's Disease

The genes responsible for an inherited form of Alzheimer's disease play a direct role within cells that has largely been overlooked, according to a report in the September 8, 2006 issue of the journal Cell, published by Cell Press. The findings suggest that there may be an additional dimension to the irreversible neurodegenerative disorder, which potentially suggests a new avenue for the pursuit of therapies, the researchers said.

The researchers found that two genes mutated in familial Alzheimer's disease known as presenilins may control the balance of calcium within cells by acting as a calcium channel. Calcium is an important signaling molecule, with effects on the nervous system that include functions relevant to learning and memory, the researchers said. The research team also discovered that the mutant forms of presenilin--which have been linked to about 40 percent of familial Alzheimer's disease cases--lose the ability to serve this function. Presenilins are primarily known for their role as an enzyme that cleaves amyloid precursor protein (APP) to form amyloid ß-peptide, the principal constituent of the plaques that riddle the brains of Alzheimer's patients. "Clearly it makes sense that presenilin's role in cleaving APP would affect Alzheimer's disease," said Ilya Bezprozvanny of UT Southwestern Medical Center at Dallas. "But our findings suggest a totally different angle, raising the possibility that presenilin's effect on the disease may be two-fold." Bezprozvanny cautioned, however, that further work is required to determine whether or not the genes' other role in calcium regulation has a causal connection to the symptoms of Alzheimer's disease.

Alzheimer's disease affects nearly 2% of the population in industrialized countries. Most cases of the disease are of unexplained origin and are characterized by late onset in people over the age of 60. A small fraction of cases are characterized by an earlier onset and genetic inheritance. The two forms of the disease otherwise share many common characteristics, Bezprozvanny said, and it is generally assumed that study of familial Alzheimer's can lead to new insights into general mechanisms underlying the disease. Earlier studies had linked mutations in the presenilin gene to abnormal calcium signaling and suggested that calcium might have some relevance to Alzhiemer's disease. However, the mechanistic basis for presenilin's apparent effects on calcium remained unclear, leaving a question as to whether the proteins played a direct role.

The researchers now report from studies in mice that presenilins can form ion channels. The effects of presenilin could account for about 80% of the calcium leaked from a membrane bound cellular compartment called the endoplasmic reticulum, they found. Cells with the mutant presenilin become "overloaded" with calcium, Bezprozvanny explained, which heightens the strength of the calcium signal. Moreover, the heightened calcium signal was reversed in mutant cells in which the scientists restored normal presenilin. They further showed presenilin's role in calcium signaling to be independent of its role in the production of amyloid ß.
The findings suggest that drugs that restore normal calcium levels might be useful for treating Alzheimer's disease, Bezprozvanny said. Indeed, he added, a drug called memantine, which is already in use against Alzheimer's, acts on receptors that are a component of the calcium pathway. The development of Alzheimer's drugs has almost exclusively focused on amyloid plaques, he said. The current findings begin to suggest the possibility that a combination therapy targeting both amyloid and calcium signaling might be a "best case scenario," Bezprozvanny speculated.

Aberrant calcium signaling might also be a common link among multiple neurodegenerative diseases, he added. For example, he noted that his group earlier found evidence for a direct effect of abnormal calcium signaling in Huntington's disease.

MIT proton treatment could replace x-ray use in radiation therapy

Scientists at MIT, collaborating with an industrial team, are creating a proton-shooting system that could revolutionize radiation therapy for cancer. The goal is to get the system installed at major hospitals to supplement, or even replace, the conventional radiation therapy now based on x-rays. The fundamental idea is to harness the cell-killing power of protons -- the naked nuclei of hydrogen atoms -- to knock off cancer cells before the cells kill the patient. Worldwide, the use of radiation treatment now depends mostly on beams of x-rays, which do kill cancer cells but can also harm many normal cells that are in the way.

What the researchers envision -- and what they're now creating -- is a room-size atomic accelerator costing far less than the existing proton-beam accelerators that shoot subatomic particles into tumors, while minimizing damage to surrounding normal tissues. They expect to have their first hospital system up and running in late 2007. Physicist Timothy Antaya of MIT's Plasma Science and Fusion Center argues it "could change the primary method of radiation treatment" as the new machines are put in place.

The beauty of protons is that they are quite energetic, but their energy can be controlled so they do less collateral damage to normal tissues, compared to powerful x-ray beams. Protons enter the body through skin and tissue, hit the tumor and stop there, minimizing other damage. Protons are far more massive than the photons in x-rays, and the x-rays tend to pass directly through tissues and can harm living cells along the entire path. The side effects often include skin burns and other forms of tissue damage. The new machines, in fact, should allow radiation specialists to deposit a far bigger dose of killing power inside the tumor, but spare more of the surrounding normal tissues. This is expected to increase tumor control rates while minimizing side effects.
Because of their high energy and controllability, protons have been used as anti-cancer bullets in the past, with promising results. But medical centers can't easily come up with the $100 million or more needed to build a proton machine dedicated to this medical use. That's because protons are produced inside the huge, expensive atomic accelerators that are usually employed at major atomic research centers, including national laboratories.

Now, Antaya and his colleagues at MIT and at Still River Systems Inc. think they can provide the new machine for far less money, have it occupy just one moderate-size hospital treatment room, and achieve better results than x-ray therapy. MIT is licensing the technology to Still River Systems.Industry is already showing acute interest in the new technology because more than half of all cancer patients are now treated with radiation, meaning there are two million radiation patients worldwide. That offers a huge market for an effective new radiation system, and the directors of major cancer research and treatment centers are already enthusiastic, Antaya said.

In his own research experience, Antaya had worked with new types of cyclotrons -- they were called "atom smashers" years ago -- using new "superconducting" coils to generate the necessary magnetic fields. As a result, he could see a "nexus between all the required technologies and how we could pick a reasonable set of properties, with a good chance of being successful," he said. Building it is quite a challenge, however. "This is an accelerator that's going to be in the room with the patient, so it's quite a difficult design exercise" just in terms of safety issues, Antaya said. But he and his colleagues are betting it will work as expected.

Ultrasound Delivers Therapeutic Molecules Into Living Cells

Researchers have shown how ultrasound energy can briefly “open a door” in the protective outer membranes of living cells to allow entry of drugs and other therapeutic molecules – and how the cells themselves can then quickly close the door. Understanding this mechanism could advance the use of ultrasound for delivering gene therapies, targeting chemotherapy and administering large-molecule drugs that cannot readily move through cell membranes.

Using five different microscopy techniques, the researchers showed that the violent collapse of bubbles – an effect caused by the ultrasound – creates enough force to open holes in the membranes of cells suspended in a liquid medium. The holes, which are closed by the cells in a matter of minutes, allow entry of therapeutic molecules as large as 50 nm in diameter – larger than most proteins and similar in size to the DNA used for gene therapy. “The holes are made by mechanical interaction with the collapsing bubbles,” said Mark Prausnitz, at the Georgia Institute of Technology. “The bubbles oscillate in the ultrasound field and collapse, causing a shock wave to be released. Fluid movement associated with the resulting shock wave opens holes in the cell membranes, which allow molecules from the outside to enter. The cells then respond to the creation of the holes by mobilizing intracellular vesicles to patch the holes within minutes.”

Ultrasound drug delivery could be particularly attractive for gene therapy, which has successfully used viruses to insert genetic material into cells – but with side effects. It could also be used for more targeted delivery of chemotherapy agents. “One of the great benefits of ultrasound is that it is noninvasive,” Prausnitz said. “You could give a chemotherapeutic drug locally or throughout the body, then focus the ultrasound only on areas where tumors exist. That would increase the cell permeability and drug uptake only in the targeted cells and avoid affecting healthy cells elsewhere.”

Researchers have only recently found that the application of ultrasound can help move drugs into cells by increasing the permeability of cell membranes. It had been hypothesized, but not definitively shown, that the ultrasound increased the permeability by opening holes in cell membranes.

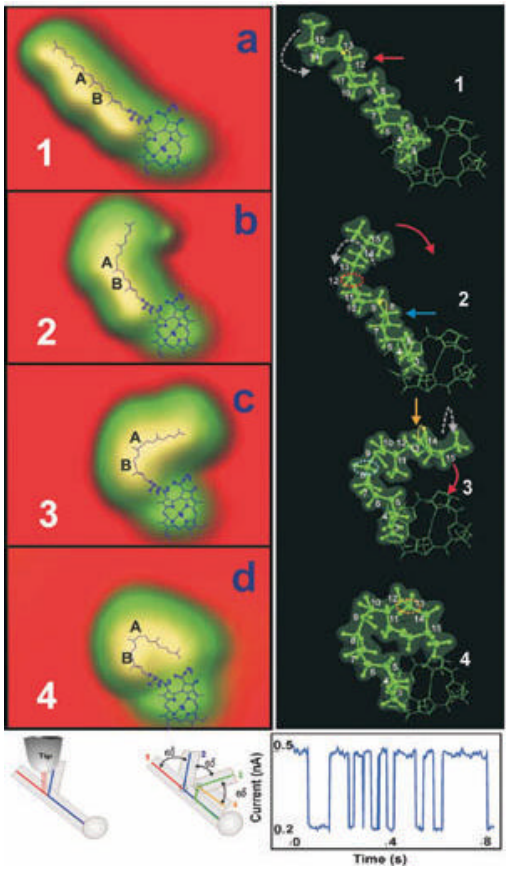
Prausnitz and collaborators used scanning and transmission electron microscopy of fixed cells and two types of optical microscopy of living cells to assess ultrasound effects and cell responses. Beyond demonstrating that ultrasound punched holes in cell membranes, the researchers also studied the mechanism by which cells repair the holes. After the ultrasound exposure, they introduced into the cell medium a chemical not normally taken up by the cells. By varying when the chemical was introduced, they were able to determine that most of the cells had repaired their membranes within minutes. Though the researchers used prostate cancer cells in the study reported in the journal, they have also studied other types of cells and believe ultrasound offers a general way to briefly create openings in many classes of cells.

Researchers face a number of challenges, including FDA approval, before ultrasound can be used to deliver drugs in humans. For example, the effects of the ultrasound were not consistent across the entire volume of cells, with only about a third affected. Researchers will also have to address safety concerns and optimize the creation of collapsing bubbles – a phenomenon known as cavitation – within bodily tissues. “Before we can use ultrasound for therapy in the body, we will have to learn how to control the exposure,” Prausnitz noted. “If we can properly design the impact that ultrasound makes on a cell, we can generate an impact that the cell can deal with. We want just enough impact to allow transport into the cell, but not so much of an impact that the cell would be stressed beyond its ability to repair the injury.” Researchers don’t yet know if the membrane holes cause long-term harm to the affected cells. General assays show that cells survive after resealing the membrane holes, but detailed studies of cell behavior are still needed. Evidence from other researchers suggests that cell membranes are frequently damaged and repaired inside the body – without long-term ill effects. That suggests cells may similarly tolerate ultrasound’s effects.

Reference: Journal of Ultrasound in Medicine and Biology (Vol. 32, No. 6).

Nanoscientists Create Biological Switch From Spinach Molecule

Nanoscientists have transformed a molecule of chlorophyll-a from spinach into a complex biological switch that has possible future applications for green energy, technology and medicine.



Scientists used a scanning tunneling microscope to manipulate chlorophyll-a into four positions.

The study offers the first detailed image of chloropyhll-a – the main ingredient in the photosynthesis process – and shows how scientists can use new technology to manipulate the configuration of the spinach molecule in different arrangements, report Saw-Wai Hla from Ohio University in the journal Proceedings of the National Academy of Sciences.

The scientists used a scanning tunneling microscope to image chlorophyll-a and then injected it with a single electron to manipulate the molecule into four positions, ranging from straight to curved, at varying speeds. Though others have created two-step molecule switches using scanning tunneling microscope manipulation in the past, the new experiment yields a more complex multi-step switch on the largest organic molecule to date.

The work has immediate implications for basic science research, as the configuration of molecules and proteins impacts biological functions. The study also suggests a novel route for creating nanoscale logic circuits or mechanical switches for future medical, computer technology or green energy applications, said Hla, an associate professor of physics.

“It’s important to understand something about the chlorophyll-a molecule for origin of life and solar energy conversion issues,” he said.