

Feature

Science and Technology

Conductive Polymers Taking Charge

POLYMERS are discarding their traditional roles as electric insulators to literally take charge as conductors with a range of novel applications.

Until recently, metals were the old reliables for conduction of electric charge while organic polymers such as plastics, rubbers and synthetic fibres were used as insulating sheaths, and others like polyesteramides and polyimides served as insulating enamel for copper or aluminium cables.

It is easy for a metal to conduct electricity because of the special nature of the metallic bonds that hold metal atoms together in a crystal lattice like arrangement. The metal cations are held together in the crystalline arrangement, while the free electrons move through the interstices of the lattice. These free electrons conduct the electric charge.

Common organic polymers generally consist of many carbon atoms that are covalently bonded to each other to form long chains that resist the flow of electric charge.

Unlike organic polymers, metallic conductors cannot be shaped according to the need,

a limitation which scientists have sought to overcome by trying to make the polymers themselves conducting.

Scientists have now achieved considerable success in chemically modifying this long chain to allow electricity to pass through. With this, they are predicting a range of exciting applications — replacing copper wires in airplanes, powering tiny watches as well as massive automobiles, optical computing and even drug delivery.

The development of conducting polymers can be divided into three periods. The first generation products were made conductive by incorporating conductive fillers and/or additives into the desired organic polymer.

The second generation conducting polymers themselves conduct electric current without any additives. Here a delocalised electron cloud and/or non-bonding electrons conduct the electricity, just as the free electrons do in the

crystal lattice that holds metal atoms together. The third generation conducting polymers are basically insulators or poor conductors, which are made conducting by a process called "doping". Dopants are either strong oxidising or reducing agents which create positive or negative charge carriers in the polymers.

Dopants are of two types: ionic dopants and neutral dopants. Neutral dopants are basically neutral molecules which are transformed during doping into positively or negatively charged groups with or without modifications.

Ionic dopants are salt systems which dissociate into negative and positive ions, either of which takes part in the doping process.

Conductive polymers are already finding a wide range of applications in several countries, according to a report in the journal "Science".

Batteries with conductive polymer electrodes are being sold in Japan and Europe.

Toyota is testing a windshield made with a heat-reflecting coating of conductive polymer.

A conductive polymer temperature sensor developed by Allied-Signal Research and Technology Corporation in New Jersey indicates when frozen food has thawed.

The US Defence Department is testing conductive polymer latexes as electromagnetic shields that can thwart spies' efforts to eavesdrop on conversations and electronic signals.

And scientists predict that the day is not far off when surgeons and nurses in an operating theatre may be wearing conductive polymer fibres in the form of antistatic clothing.

One of most exciting applications foreseen is the use of conducting polymers to deliver or release controlled amounts of drugs directly into a patient's skin over weeks or months. The polymers can be designed in such a way that they release the drug ions when an electric current passes through them. The sys-

tem, needless to say, requires two electrodes to pass the electric current and drive the drug through the skin into the blood.

What scientists at the University of Minnesota in Minneapolis envisage is a system having a drug-loaded polymer which serves as one of the electrodes of the battery. Turning of the current between the electrodes would both release the drug when needed and drive it through the skin into the blood stream.

A less exotic, but far larger application, according to "Science", is the use of conductive polymers as antistatic agents and in electromagnetic shields, the market for which is expected to grow by over 25 per cent in the next decade.

Antistatic clothing is needed by operating personnel to eliminate static discharges that can confuse sensitive electrical monitors or even stun the heart during open heart surgery.

Such clothing also reduces the number of computer chips

and circuit boards ruined by static discharge in the computer industry.

Some firms in the US have already developed methods to impregnate nylons and polyesters with a number of stable conductive polymers, while others have made fibres of only conductive polymers which can be woven in to fabrics or blended with more conventional fibres.

Another novel application of these conductive polymers is in aircraft to protect against lightning bolts that release large amounts of electric charge. When lightning strikes a metal aircraft, the charge distributes itself over the entire metal surface from which it gradually leaks into the atmosphere. Unless they are protected in some way, the lightning can burn right through an aircraft's skin. Some airplanes now are being made of non-metallic composite materials that cannot dissipate the electrical charge of a lightning bolt.

Other intriguing possibilities include painting anything from computer cabinets to walls or buildings with a conductive latex paint to keep electromagnetic radiation from leaking into the atmosphere.

Some of the more unusual optical properties of conducting polymers are being put to use in thermal windows that could either keep the heat out or let it in, "Science" says.

Allied-Signal has developed some polymers, which are bluish in their original non-conductive state and turn transparent in the conductive state to absorb infra-red radiation.

Windows coated with such polymers can have tremendous commercial advantages in hot countries where they can considerably reduce the air-conditioning bills by keeping out the heat.

In cold climates, the material could serve two purposes through a built-in, light-controlled electrical circuit which changes the polymer from a non-conductive to a conductive state and vice versa.

During daytime in cold climates, the circuit would make the polymer coating on the window conductive, letting the heat in to warm the room. When the sun is not shining, the circuit allows the polymer to become non-conducting again which prevents the heat from leaking out of the building.

The unusual optical properties of conductive polymers may find use in optical computing, where scientists are attempting to replace microchips that operate with electricity with optical devices that would operate with pure light and 100 times quicker.

Scientists are also working on conductive polymers as optical switches, using polydiacetylene to create a device that allows pulse switching on a picosecond time scale.

The exceptionally high optical non-linearity of this material, which changes the speed of light according to the light intensity, allows switching to be done with cheap but low-intensity dye lasers. Most optical switches manufactured currently require more intense light to function properly.

—PTI

Earthquake Forecasting : Deciphering Subterranean Forces

by G. S. Mudur

THE 45-second earthquake that rocked northern Uttar Pradesh last month could be regarded as the unleashing of a colossal amount of energy that was building up as continental stresses accumulated many kilometres underground.

To forecast such an earthquake, scientists would have to identify the point where the stress was building up, determine the breaking point of crustal rocks, and then predict in what direction the energy released underground would move towards the surface.

With no direct way of doing this, scientists are relying on indirect approaches to earthquake forecasting. But despite several decades of work, and a few successes on the way, seismic science is yet to make the breakthroughs that will make an earthquake forecast as routine as the weather forecast.

Most seismically active zones on earth lie along areas where different continental plates collide with each other. Parts of northern India fall in an earthquake belt that extends from the Hindu Kush region to Himachal Pradesh and from the Indo-Nepal border in

Uttar Pradesh to Assam in the northeast.

This earthquake zone is the boundary where the Indian subcontinental plate is constantly pushing against the Eurasian plate, moving at a rate of five centimetres per year. This interplate collision gave rise to the Himalayas that are still rising and has made the zone seismically active.

As the Indian plate pushes and goes under the Eurasian plate, a process called subduction, stresses gradually accumulate at various points within the crust. At some points, the stresses bend sections of the crustal rocks, taking them to their elastic limit — their breaking point — and the rocks fracture, triggering off seismic waves that produce the earthquake.

The depth of focus of an earthquake lies around such a fracture in the crust. "A major problem with forecasting is that we have no direct access to the underground geological environment," says Dr. V P Kamble, deputy director general of the seismology division at the Indian Meteorological Department (IMD) in New Delhi.

The approach to long-term earthquake forecasting uses

past data to try and identify zones where earthquakes are overdue. Studies of historic seismicity provide clues about where earthquakes are most likely to occur since earthquakes tend to recur in the same area over long periods of time.

In this technique, scientists try to identify regions around plate boundaries where earthquakes have not occurred for a long time. The search for such "seismic gaps" is based on the belief that stress is gradually building up in the region, making it a potential zone for a future earthquake.

Past data has helped seismologists delineate India into five earthquake zones on the basis of their vulnerability. Most damaging earthquakes occur in zone four and zone five. The epicentre of the October 20, 1991 earthquake in Uttar Pradesh fell in zone five.

Scientists at the IMD's seismology division area now preparing a database on past earthquakes along the Indian-Eurasian plate interface. "Statistical studies are also aimed at determining return times for earthquakes in a vulnerable zone," said Kamble. Among the most promising

areas of earthquake forecasting research is the search for precursors that could help seismologists make useful predictions well in advance about the time, the location and the magnitude of the earthquake.

Precursors for earthquakes could be foreshocks, the accumulation of stress, strain changes and their effects on crustal rocks ground-water levels and gas emissions.

Foreshocks are clusters of smaller earthquakes that precede a larger earthquake. They are believed to be caused by the gradual build-up of stress that will ultimately be released in the form of an earthquake of larger magnitude.

The first forecast that led to live-saving action was made by Chinese scientists when they successfully predicted the February 4 1975 earthquake in Hainan in northeastern China. The success of the Chinese was based on the use of long-term, medium-term and short-term precursors.

Crustal movements were detected in 1974 and a few months before the earthquake, water levels in wells began to change. The imminent forecast however was based on the recognition of a swarm of smaller earthquakes as a se-

quence of foreshocks. The bending of the crust as gigantic stresses gradually build up deep underground can be monitored by strainmeters which can detect uplift or subsidence of areas of hundreds of square kilometres by only a few centimetres.

Such changes in the strain will be reflected in the form of changes in the electrical conductivity of the rocks and soil before the earthquake.

Radon is a radioactive gas that constantly seeps out of underground rocks. Studies by Japanese scientists suggest that measurement of radon concentrations in groundwater in carefully chosen wells could help determine the chances of earthquakes.

Some scientists believe animal behaviour might be an intriguing precursor. This follows several reports about abnormal behaviour of animals just before earthquakes. Dogs are said to bark and howl and snakes come out of their burrows.

Abnormal animal behaviour was also reported just before the Hainan earthquake. Researchers believe the high sensitivity of some animals to ultrasonic noise and vibrations that precede an earthquake might be responsible for the queer behaviour.

Joining the Indian Meteorological Department and the Geological Survey of India, the past three decades have seen other Indian laboratories initiating work on earthquake forecasting.

Helicopters with Nozzles in the Rotor Blades

MORE than 50 years have passed since the test pilot Hanna Reitsch hovered in Berlin with one of the first helicopters.

Despite all assets, they still retain the disadvantages that they are noisy and require large amounts of energy for relatively low payloads and, due to their complicated engineering, also involve high maintenance costs. However, this could take a turn for the better thanks to a new helicopter development, for which the entrepreneur Alex Fallier was awarded a 1991 Philip Morris Research Prize.

Since the birth of helicopter technology, the propulsion concept has basically remained the same: via transmission an engine drives the rotor, which provides lift and propulsion. A tail propeller must compensate for the torque of this drive system because otherwise the helicopter would rotate constantly around its vertical axis in the opposite direction to the rotor. Fallier, the head of the machine tool company Fallier Maschinenbau in Ergoldsbach near Landshut in Bavaria, who over the years has developed almost twenty remote controlled model heli-

copters as a hobby, picked up on the "reaction propulsion" principle for his new concept and adapted it for use in helicopters.

The innovation here is that there is an engine in the rotor head, which drives an "impeller". This sucks the air from above and compresses it after it has been used "as a side benefit" to cool the engine. Afterwards the compressed air and the exhaust fumes are blown through the hollow rotor blades, from whose ends it then escapes towards the rear. The recoil effect drives the rotor blades forward; a simple shield ensures that the rear-most blade is not supplied with compressed air.

Such a helicopter does not need a transmission, clutch, cooling fan or tail rotor. The low torque of the impeller can be compensated for by a vertical rudder. Although this alone results in huge weight decrease, the suction of the impeller reduces it further by approximately five per cent. This means that greater payloads can be transported and the fuel consumption decreases by approximately 40 per cent.

However, these are not the only advantages of reaction propulsion. The already low noise emission of this system is emitted upwards and fades away through the air intake. The "whispering" is enhanced further by means of specially designed rotor blade tips, which lower the "slapping" noise made by the rotor blades. Furthermore, due to the relatively low rotor speeds, the tips of the rotor blades do not rotate in the supersonic region, thus avoiding the typical "booming" noise made by helicopters.

Since only the engine and rotor bearings require maintenance, the costs are reduced accordingly. In Fallier's opinion, the new aircraft, at a cost of approximately 100,000 DM in series production, would be appreciably cheaper than conventional helicopters.

Although his invention only exists in model form, the jury of the Philip-Morris Stiftung (Philip Morris Foundation) in Munich, who in 1991 awarded this prize for remarkable achievements in the field of high technology for the fifth time, are convinced that the "Fallier helicopter" will pave its own way.

—M.S.

SAFER PESTICIDE SPRAYING

In a joint project with an Australian company, researchers at the Imperial College in London are testing a prototype of a new manual crop sprayer that avoids operator contamination by possibly toxic pesticides, reports London Press Service.

The sprayer uses a process called Down Fluid Injection (DFI), in which fluids are introduced and mixed with each other at a controlled rate at the sprayer nozzle. As the tank is filled with water only, it does not become contaminated, enabling the knapsack to be used for all types of pesticides. In addition, the operator does not come into contact with the pesticides when the product container is opened to transfer the formulated active ingredient to the sprayer, and he is not required to handle and mix the chemical concentrates.

The problem of operator contamination is particularly acute in developing countries. The World Health Organisation estimates that over one million people world wide are seriously affected by exposure to pesticides with up to two per cent of these cases proving fatal.

The environment in general can also gain protection with the new system, as its constant dilution and flow rates eliminate the need for accurate quantity mixing calculations by the operator, mistakes in which can result in the dumping of unwanted, potentially toxic solutions in nearby water sources, due to mixing excessive quantities.

Dr Graham Matthews of Imperial College's International Pesticide Research Centre (IPARC) says the DFI method is likely to represent a major step forward in pesticide application technology. According to him, there have been several developments of closed transfer systems for mechanised sprayers, but there has not been a satisfactory system for manually

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carried knapsack sprayers until now.

In the new equipment, a disposable concentrate dispenser is mounted on the spray lance handle. Water pumped to the nozzle surrounds a flexible bag of concentrate in the dispenser, and a small pressure differential maintains a steady upwards flow of liquid concentrate into the bulk flow in the lance. This system has the added advantage that feed rate is not dependent on the level of the fluid, as with gravity-fed systems.

PAC's involvement in the sprayer project is part of the programme of collaboration with the Natural Resources Institute, an agency of the British Overseas Development Agency aimed at developing equipment for smallholder farmers of developing countries.

CHEAPER SOLAR CELLS

Silicon solar cells that are as efficient (about 10 per cent) as conventional ones in converting sunlight to electricity, but are expected to sell for around 2 dollars per watt, against 8-12 dollars per watt for commercial products, are now being made in prototype quantities by Texas Instruments Inc. based in Dallas, Texas, reports the journal Chemical Engineering.

The development is a joint effort between TI and Southern California Edison Co. based in Rosemead, California, which is interested in photovoltaics for load leveling, says Nick Patapoff, Jr., a senior engineer in Edison's research center at Irwindale, California.

Conventional solar cells are more expensive because they are made from semiconductor-grade silicon (about \$50-70/kg) that is refined from inexpensive metallurgical grades

(\$1-3/kg). The purification involves reacting metallurgical silicon with hydrogen chloride to form trichlorosilane, which is then reduced to high purity polycrystalline silicon; finally, an ingot is pulled from a molten bath of this material and sliced into 4-in-dia wafers.

In contrast, the new cells are made from metallurgical-grade material itself, by partial melting at a carefully controlled temperature on a planar surface, forming silicon spheres of roughly 30-mil dia. The melting is done on a crucible to keep the spheres from agglomerating. Next, the spheres are embedded in a thin aluminium foil as 4-in-square cells, each containing some 17,000 spheres.

CHEMICAL SWEETENS SOUR NATURAL GAS

An American company, Quaker Chemical Corp. has developed an environmentally safe alkanolamine for removing hydrogen sulfides and organic sulfides from sour natural gas, reports the journal Chemical Engineering.

The resulting gas product will meet pipeline specifications of less than 4 ppm hydrogen sulfide says Edward Dillon, a Quaker researcher.

Normally, alkanolamines are not selective for hydrogen sulfide, absorbing carbon dioxide as well, according to Dillon. But Sulfa-Scrub — as the hexahydro triazine is tradenamed — instantaneously reacts with carbon dioxide, but does not react at all with hydrogen sulfide.

One mole of triazine can react with four moles of hydrogen sulfide. Consumption of Sulfa-Scrub is less than 0.1 gal/ppm hydrogen sulfide million std. cubic feet of gas.

Dillon says a big advantage of Sulfa-Scrub is that because the reaction product is a liquid, no hard-to-dissolve solids are formed, as is the case with other solvents. In addition, the reaction product is said to be an excellent water-soluble corrosion inhibitor.

COME Diwali and the neighbourhood is full of noise made by crackers and light displays from dazzling firework shops which produce a fountain of white sparks. Rockets go up in the sky producing trails of yellow-orange, blue-green, red, white and gold sparks.

Pyrotechnics has an obscure history. It is the science of fire and embraces not only fireworks used in dazzling displays at Diwali and other festivals but also a whole range of devices that use similar materials including hazard flares, safety matches and even the solid fuel rocket boosters of the space shuttle.

One of the oldest pyrotechnic compositions is "black powder" or "gunpowder" which serves both as a propellant and explosive charge in modern fire-works. Black powder is believed to have originated either in China or India.

It is said that the Chinese developed black-powder more than 1,000 years ago for use in crude rockets and fire crackers. The knowledge of black powder (a mixture of potassium chlorate — salt petre, charcoal powder and sulphur) travelled west during the middle ages. The English monk Roger Bacon published his formula for this explosive mixture in 1242 as a part of his defence against accusations of witchcraft.

But according to some historians black powder was invented in India long before the Chinese invented it independently. Dr Gustav Oppert, sometime Curator of the Government Oriental Manuscripts Library at Madras wrote in late 19th century that no Chinese work on black powder compares in antiquity with Sukramiti which prescribes guns and projectile weapons as the standard weapons for a king's war chariot.

Sukramiti is a work considered contemporary to Manusmriti assigned by many scholars to the second century BC. Dr Oppert cites the even more ancient Nitishastra as describing smoke balls containing blackpowder among weapons to be hurled against the enemy. Nitishastra was written by Valishmpayana who is also credited with the authorship of Yajurveda believed to have been composed be-

Pyrotechnics — The Science of Crackers and Fireworks

by G V Joshi

tween 1000 BC and 800 BC. The German scholar Dr Oppert finds a stanza in Atharvana Rahasya as a clear proof that Indians were familiar with "agnichurna", combination of charcoal sulphur and other material providing the fire power.

According to Dr Johann Beckmann, another German scholar, black powder invented in India was brought to Europe from Africa by a Saracen (nomadic Syrian Arabs) and that Europeans improved its preparation and found different ways of using it in small arms and canons.

Whoever invented it, Chinese or Indians, it certainly

was not called gun powder for guns were invented in the 14th century and were not known in India or China until the Portuguese came in the early 16th century.

A French chemist Jean Appier suggested (in 1630) an addition of copper sulphate to the basic mixture to produce a green flame, but the brilliant colour effects common today were not developed until the 19th century. Claude-fortue Ruggieri in 1901 was the first to describe the use of metal compounds for colour effects.

The spectacular splashes of light produced by fireworks is

the most famous pyrotechnic phenomenon. White light flares contain a metal such as magnesium as a fuel. A mixture of potassium perchlorate and fine aluminium or magnesium powder produces a powerful explosion along with a burst of white light. Charcoal and iron particles produce dimmer, gold coloured sparks. A few metallic compounds are responsible for nearly all the colours in fireworks. Compounds of strontium produce the reds, barium creates greens. The best blue emitter is copper chloride, while purple and violet colours are emitted by a mixture of strontium chloride and copper chloride.

A common form of crackers is a sparkler held in hand and started by heating in a flame. They derive their colour from the combination of strontium carbonate which emits red light, and aluminium granules which provide the sparks. These ingredients are mixed with fuel, binders and an oxidiser to create a slurry and allowed to harden on a piece of wire to create sparklers.

Most of the crackers and fireworks used in India up to 1940s were imported from China. But now they are made in India. Sivkasi, a town in Tamil Nadu, known for calendars and matchboxes, is one of the leading manufacturing centres.

One of the simplest pyrotechnic products in daily use is a match. A reaction between potassium chlorate (oxidiser) in the match stick and red phosphorus in the striker surface produces a flame that ignites the mixture of potassium chlorate and a blue-like fuel in the match head. All the pyrotechnic effects — heat, smoke, light, gas and sound — are present though in a mild and safe form.

Pyrotechnics has many other applications. Calcium silicide fuel mixed with iron oxide generates a moderate amount of heat but no gas. During World War II, small pyrotechnic devices containing this composition and fuse were built into can of rations so that they could be warmed in the absence of a stove. Canned noodles which warm up using similar devices are common in Japan, where noodles are very popular.

Flares used by a ship to indicate its position in case of an emergency are another form of pyrotechnic product.



On board a DC8 specially equipped by NASA as a flying laboratory, a scientist monitors levels of ozone over the Antarctic