

# Mega strength in nano materials

### THERE IS MORE GRIT TO THE GRAM IN MINERALS FOUND IN NATURE, SAYS S ANANTHANARAYAN

icroscopic organisms found in the sea build themselves lightweight, mineral frameworks that support the bulk of the organism. *Radiolarians* are single-cell creatures, less than a fifth of a millimetre across, found in zoo-plankton, and they have an intricate mineral skeleton. *Diatoms* are microscopic, some-times single-cell creatures that have a shell made of silica, or the material of sand, Sponges are multi-cell animals that consist of a porous network of the material of fibrous tis-

The common feature of these organisms is that their supporting framework displays remarkable strength, considering the materi-al of which the framework is made. In a paper published in the journal, *Nature Materials*, Dongchan Jang, Lucas R Meza, Frank Greer and Julia R Greer, at the California Institute of Technology and the Jet Propulsion Lab, Pasadena, report their work on creating mimics, using the principles of natural struct-ures, and finding that the lookalikes show the same strength-to-weight ratio as the real thing

#### Strength and dimensions

One element in efficient framework structures is that all parts of the cross section of a support are not equally important. When a beam is bent, for instance, it is the inner or





the outer parts of the length of the beam that

are compressed or stretched. Hence, a beam can be equally strong even if material in the middle is removed — which leads to the "I" cross section of beams used in engineering. In animal bones, too, the bone is hol-Ing. in animal bones, too, the bone is not-low, the load-bearing, hard material being on the outside. This apart, when objects become small-er, the cross section of supports can shrink faster than the dimensions of the

object, because the weight to be support-ed depends on the cube of the dimensions while the strength of the supports dep-ends only on the square. This is the reason that an ant has narrow legs, compared to its body, but not so the elephant. But in the case of natural skeletons of

micro-organisms, it is found that the ra-tio of mechanical strength to weight, of the support, is better that what it should be, simply based on the dimensions and the bulk properties of the materials. One Images of synthetic lattice made from TiN explanation could be that materials become stronger when they are in small dimensions, and forces of crystal structure are important. rather than how well the many crystals hold together. In biological structures, the different segments have evolved to come together so that the component sizes are chosen according to the size-dependent properties leading to the best overall strength, stiffness and fracture resistance.

### **Copying nature**

In their study, the California scientists used this idea, by first finding out the dimen-sions at which different materials began to show improved properties. Then, they creat-ed three-dimension structures, using members of the materials, of the appropriate sizes. Doing this required three conditions to be satisfied - first, that the material grow stronger at some smaller dimensions. This property is found in metallic glass and in ceramics, which escape sudden collapse under load when they are the nano-scale, and also in metals in the



Both images are the same size. The legs of the fly are proportionately thinner



form of single crystals; second, there should be a technique to fabricate the components at these reduced sizes: and, third, it should be

beside to create a larger structure out of these smaller modules. The team was able to do all this with the ceramic material titanium nitride (TiN). The team first digitally created a three-dimensional structure similar to that of the diatom shell. The structure was then built up of TiN, using twin methods, called *Two Photon Lithography* and *Atomic Layer Deposition*. The first method is similar to drawing miniature patterns for etching printed circuits on copper sheets. For making printed circuits, a full sized drawing is optically reduced and shone on a photo-sensi-tive layer on the copper sheet. The portion where light did not fall can then be etched away, leaving miniature patterns of copper connec-tors. In TPL, a laser beam is focused to create three-dimensional chemical changes in a pho-tosensitive material, to leave a polymer scaffold

with the required structure TiN is then deposited, using ALD, which is a chemical vapour deposition technique where atom level layer control is possible. Etching out the polymer material then leaves a lattice of thin and hollow nanotubes. The struts in the lattice can be about seven microns long, of tubes with wall thickness 75 nanometres, which is 0.075 microns. Testing the structure that was created

with a varying load showed that the mate-rial displayed good stiffness and uniform bending till about 80 per cent of its maximum strength and then became non-uni-form and failed at a load of about 150 micro Newtons. This corresponds to stretch-ing stress of 1.76 Giga Pascals (this is about 17 million times the atmospheric pres sure). This strength is an order of magnitude higher that of most similar ceramics, whose values are measured only in Mega Pascals.

The size of the structure created is a one-millimetre cube. The test results suggest that the fabrication technique developed could be used to build lightweight, robust components and devices

"With this approach, we can really start thinking about designing materials backward," says Julia R Greer, professor at Caltech. "I can start with a property and say that I want some-thing that has this strength or this thermal con-ductivity, for example. Then I can design the optimal architecture with the optimal material at the relevant size and end up with the material I wanted... We are now able to design exactly the structure that we want to replicate and then process it in such a way that it's made out of almost any material class we'd like — for example, metals, ceramics, or semiconductors — at the right dimensions."

THE WRITER CAN BE CONTACTED AT simplescience@gmail.com

### PLUS POINTS

### 'Mangrove management is a necessity'

The prevailing idea that sea-level rise will inevitably wipe out mangrove forests — fragile ecosystems that protect nearby communities from natural hazards such as floods and storms — is challenged by a recent "Response of mangrove soil surface elevation to sea level rise" report. It says mangroves in some areas will be able to survive climate changeinduced sea-level rise as they can slowly increase the level of soil in which they thrive, but only if they are managed and protected. Activities such as building dams

on rivers and converting mangrove areas into shrimp farms may have a stronger impact on the health of these eco-systems than sea-level rise it adds. Once weakened by such

changes, mangroves will be less able to adapt to sea levels. "A lot of the rivers (that feed mangrove areas) are being dammed, and by doing that we reduce the freshwater and sediment flow to mangroves. Both can be very deleterious," said Anna McIvor, lead author of the report and a researcher at the University of



Cambridge, UK. "Once mangroves are degraded, they are much less likely to keep up with sea-level rise," she said.

Alfredo Quarto, executive director of the Mangrove Action Project, a US conservation NGO, said the report's main benefits were that it highlighted the need for further study and the need to act. "One of the problems with such studies," h said. "is that (though) they highlight things that are important, how does one take those bits of information and put them into practice to conserve the mangroves? So I hope the report stimulates action by governments and that they see the value of mangroves in protecting (communities)." scidev.ne

## Wireless innovations

**Sniffing danger** 

An "artificial nose" that could save lives by swiftly sniffing out bloodpoisoning bacteria has been developed by scientists. The device can test for the bugs in just 24 hours instead of the usual 72 and researchers hope it can be used to prevent sepsis, a potentially fatal condition. In some cases it can



Researchers hope that the artificial nose will be used to prevent sepsis which kills an estimated 20 to 35 per cent of sufferers

rapidly lead to septic shock, organ failure and death. An estimated 20 to 35 per cent of victims die.

The new device consists of a small plastic bottle with a chemical-sensing array or artificial nose attached to the inside. A blood sample is injected into the bottle, which is then shaken to agitate a nutrient solution and encourage

bacteria to grow.

**Iron Age massacre** Excavations in Somerset have revealed a gruesome glimpse of Iron Age Britain. Archaeologists have discovered evidence of a massacre involving hundreds, if not thousands of people, with some of the slaughtered bodies being stripped of their flesh or chopped up. Human remains unearthed from an ancient site near Yeovil have cut marks, often in multiple rows, and occurring at the ends of important joints. "It is as if they were trying to separate pieces of the body according to Dr Marcus Brittain, the Cambridge archaeologist and head of a major excavation of Britain's largest Iron-Age hill fort, Ham Hill. Defleshing signs had been found on other Iron-Age human remains, but the scale of the evidence at this site was particularly dramatic, he said. Ham Hill is so vast — the size of 123 football pitches surrounded by Iron-Age ramparts — that only a small part has so far been excavated. It is clear from the remains discovered that there are "hundreds, if not thousands of bodies" buried in the site, Brittain said. "It's unusual to find this number of bodies on any site. let alone from the Iron Age."



CANCER AND HOW IT SPREADS

volved. Given the vast number of activi-ties that need to be coordinated in every cell, it is not surprising that malfunctions occasionally arise. Cancer is a prominent example of a disease that arises from such abnormalities in cell function. If current trends continue, almost half the population of the USA will eventually develop can-cer, making it the second-leading cause of death after cardiovascular disease

Although our understanding of the mol-ecular and genetic defects that lead to cancer is not yet complete, enormous prog-ress has been made in recent years and there is reason to believe that our grow-ing understanding of this dreaded disease will eventually allow it to be brought under control.

The term cancer, which means "crab" in Latin, was coined by Hippocrates in the fifth century BC to describe diseases in which tissues grow and spread unrestrained throughout the body, eventually choking off life. Cancers can originate in type involved, they are grouped into several different categories. *Carcinomas*, which account for about 90 per cent of all cancers, arise from the epithelial cells that cover external and internal body surfaces. Lung, breast and col on cancer are the most frequent of this type. Sarcomas develop from the cells of sup porting tissues such as bone, cartilage, fat, connective tissue and muscle. Lymphomas and leukaemias arise from cells of blood and lymphatic origin, with the term leu*kaemia* being reserved for situations in which the cancer cells reside and proliferate mainly in the bloodstream rather than grow as solid masses of tissue. No matter where cancer arises, it is defined by a combination of two properties: the ability of cells to proliferate in an uncontrolled fashion and their ability to spread through the body. Although uncontrolled proliferation is a defining feature of cancer cells, it is not the property that makes the disease so dangerous. After all, the cells of benign tumors also proliferate in an uncontrolled fashion, but such tumors are rarely life-threatening because the cells remain in their original location and can usually be surgically removed. The hazards posed by cancer cells come from uncontrolled proliferation combined with the ability to spread throughout the body. For more than 100 years, scientists have known that tumors are supplied with a dense network of blood vessels. However,



Cancer cells (left) were injected into an isolated rabit thyroid gland that was kept alive by pumping a nutrient solution into its main blood vessel. The tumor cells fail to link up to the organ's blood vessels and the tumor mass stops growing when it reaches a diameter of roughly one-two millimetres. Cancer cells (right) were either injected into the liquid-filled anterior chamber of the rabit's eye, where there are no blood vessels, or they were placed directly on the iris. Tumor cells in the anterior chamber. nourished solubly by diffusion. remain alive but ston crowing chamber, nourished solely by diffusion, remain alive but ston growing before the tumor reaches a millimetre in diameter. In contrast, blood vessels quickly infiltrate the cancer cells implanted on the iris, allowing the tumors to grow to thousands of times their original mass.

most investigators initially believed these were either pre-existing vessels that had expanded in response to the tumor's presence or were part of an inflammatory response designed to defend the host against the tumor. In 1971, Judah Folkman proposed a new idea regarding the significance of blood vessels in tumor developsted that signaling molecules that triggered angiogenesis - growth of blood vessels - in the surrounding host tissues, and that these new vessels were required for tumors to grow beyond a tiny localised clump of cells This idea was initially based on obser vations involving cancer cells grown in isolated organs under artificial laborato ry conditions. In one experiment, a normal thyroid gland was removed from a rabbit and placed in a glass chamber, a small number of cancer cells were injected into the gland and a nutrient solution was pumped into the organ to keep it alive Under these conditions the cancer cells proliferated for a few days but suddenly stopped growing when the tumor reached a diameter of one-two millimetres. Virtually every tumor stopped growing at exactly the same size, suggesting that kind of limitation allowed them to grow onlv so far. When tumor cells were removed from the thyroid gland and injected back into animals, cell proliferation resumed and massive tumors developed. Why did the tumors stop growing at a tiny size in the isolated thyroid gland and yet grow in an unrestrained fashion in live animals? On closer examination, a possible explana-tion became apparent. The tiny tumors, alive but dormant in the isolated thyroid gland, had failed to link up with the or-gan's blood vessels; as a result, the tumors stopped growing when they reached a

diameter of one-two millimetres. When injected into live animals, the same tubecame infiltrated with blood vessels and grew

to an enormous size. To test the theory that blood vessels were needed to sustain tumor growth, Folkman implanted cancer cells in the anterior cham-ber of a rabbit's eye, where there is no blood supply. As cancer cells placed in this location survived and formed tiny tumors, blood ves-sels from the nearby iris could not reach the cells and the tumors quickly stopped growing.

When the same cells were implanted directly on the iris tissue, blood ves-sels from the iris quickly infiltrated the tumor cells and the mass of each tum-or grew to thousands of times its original size. Once again, it appeared the tumors needed a blood supply to grow

beyond a tiny mass. If tumors require blood vessels to sustain their growth, how do they ensure this need is met? The first hint came from studies in which cancer cells were placed inside a chamber surrounded by a filter possessing tiny pores through which cells lanted into animals, new capillaries proliferate in the surrounding host tissue. In contrast, normal cells placed in the same type of chamber do not stimulate blood vessel growth The most straightforward interpretation is that cancer cells produce molecules that diffuse through the tiny pores in the filter and activate angiogenesis in the surrounding host tissue. Subsequent investigations have revea led that the main angiogenesis-activating molecules are proteins called Vascular Endothelial Growth Factor and Fibroblast Growth Factor, both of which are produced by many kinds of cancer cells as also certain types of normal cells. When cancer cells release these proteins into the surrounding tissue, they bind to receptor proteins on the surface of the *endothelial cells* that form the lining of blood vessels. This binding activates a signalling pathway that causes the endothelial cells to divide and secrete protein-degrading enzymes called *Matrix Metallopro-Tein*ases

CHENDA KUN REPORTS ON HOW A GROUP OF CAMBODIAN STUDENTS HAS CREATED BLUETOOTH-CONTROLLED ROBOTS AND HOUSEHOLD **ELECTRONICS VIA SMARTPHONES** 

oxer Muhammad Ali once claimed he was so fast he could turn off a light switch in his hotel room and could jump into bed before the room was dark. That said, you could be even faster thanks to wireless technology created by a group of technology students in Cambodia. Their projects — Magic House and World-E, where electronic appliances are controlled by bluetooth on smartphones — may not seem like high-tech or breakthrough technology but imagine turning off a light switch from your phone while you're in bed before falling asleep. If that's not enough, ArrowDot Team, the group that has developed this technology, boasts one can even control robots from a bluetooth-

enabled smartphone. Comprising students and graduates from the Institute of Tech-nology of Cambodia, the team's aim is to design this technology in such a way so that it can be used by all and sundry.

"If you have an Android phone, you can control lighting appli-

Wall-E, sits happily on a high

shelf. Even though the group receives no funding for their projects, there's no doubt these unassuming youngsters are an avid lot. While most of the equipment

they used to make the robot was bought in Cambodia, some parts comprise household electronic items. Sophatra said World-E had been designed to pick up rubbish and she hadn't grown tired of making robots ever since she joined ArrowDot, despite her busy schedule. "We have put our own money, energy and time into making World-E," she said. To make it move, software called Mikrobasic Pro, routed through a peripheral interface controller, is used on a microchip and the bluetooth device is used to rece-ive and control the robot. The same technology applies to hou-sehold electrical appliances that are controlled by bluetooth. Apa-rt from a smartphone, the group said they could use a computer or radio frequency remotes to monitor appliances and the romembers, the prototypes are spe cial because though this technology may not be new in the rest of the world, it means a lot to a poor country like Cambodia. ArrowDot hopes to change that. "If our country has no technology, then it seems we live in an era where people know nothing. How can we catch up with others who have already been to the moon? With this technology, we can strengthen and raise the profile of our country," said Bunchhat, Asked how this technology would benefit consumers if investments were made in projects like Magic House, he said it would save money and time.

These break down components of the extracellular matrix, thereby permitting the endothelial cells to migrate into the surrounding tissues. the proliferating endothelial cells become organised into hollow tubes that evolve into new networks of blood vessels.

THE WRITER IS ASSOCIATE PROFESSOR AND HEAD, DEPART-MENT OF BOTANY, ANANDA MOHAN COLLEGE, KOLKATA AND CAN BE CONTACTED AT tapanmaitra59@yahoo.co.in

your house without spending too much time," said Tep Sophatra, a team member and fourth-year student at ITC.

"The reason why we came up with this is because phone tech nology has become advanced and everyone has access to it," said Yim Bunchhat, team leader. Due to the rapid growth in mod-ern technology, a variety of app-lications could be controlled by smartphones, thanks to bluetooth communication, he added. A quick peek into the adjoining om where the group was exhibiting their invention revealed everything: a robot called World-E, inspired by the film character



#### DALYA ALBERGE/THE INDEPENDENT







