TINY DANCERS

SCIENTISTS WORKING IN THE EVER-EVOLVING FIELD OF NANOTECHNOLOGY PUSH AROUND MOLECULES, MAKE PARTICLES POWERED BY THE ENERGY RELEASED FROM BONE FRACTURES, AND CREATE MATERIALS THAT CAN'T BE SEEN WITH THE NAKED EYE. MICHAEL FRANCO TAKES A LOOK AT HOW THE SCIENCE OF THE MINUSCULE IS ANYTHING BUT SMALL-TIME

YOU MIGHT KNOW IN THEORY THAT A NANOMETRE IS ONE-BILLIONTH OF A METRE, BUT SEEING AN ARTIST'S IMPRESSION LIKE THIS, FEATURING A NANOROBOT PERCHED ON THE HEAD OF PIN, GIVES YOU A SENSE OF SCALE

IMAGE: SPL/CLICK PHOTOS

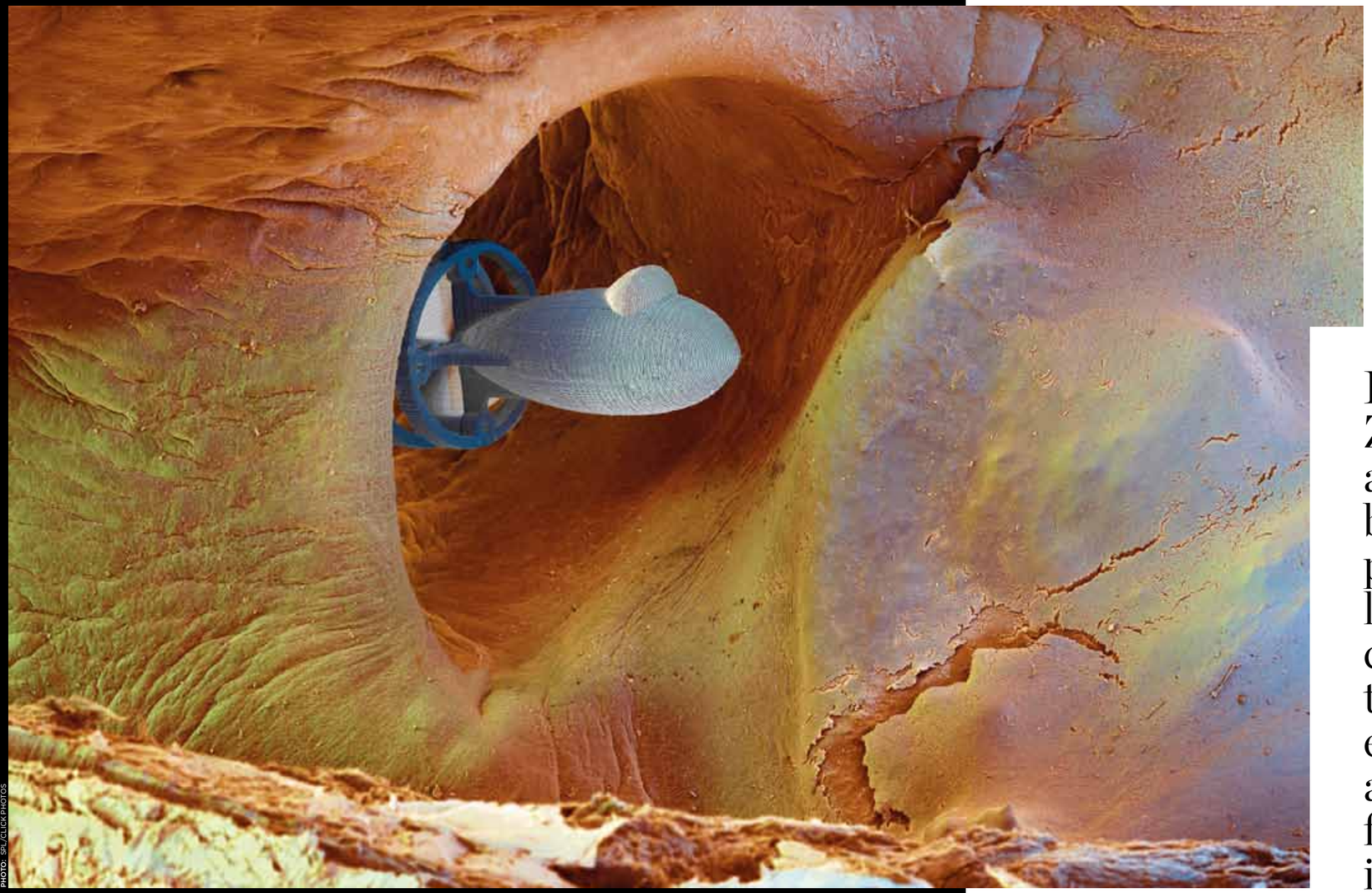


PHOTO: SRL/CLICK PHOTOS

ABOVE: THIS IS AN ACTUAL, UN-RETOUCHED IMAGE OF A MICRO-SCALE SUBMARINE MADE BY MICROTEC, A COMPANY THAT PRODUCES MICRO SYSTEMS AND COMPONENTS FOR INDUSTRIES SUCH AS BIOTECHNOLOGY AND MEDICAL ENGINEERING. THE SUBMARINE WAS POSITIONED IN AN ACTUAL HUMAN ARTERY FOR DEMONSTRATION PURPOSES

Eight metres below the ground in Zurich, Switzerland, researchers are using high-end electron-beam systems to understand the properties of particles at the nano level — tiny bits of matter that can be as small as single atoms. At this scale, the slightest vibrations, electromagnetic interference, air currents, or temperature fluctuations can have monumental impacts on the work.

The facility in which they carry out their research — a "noise-free" lab at IBM's Binnig and Rohrer Nanotechnology Center — is mounted on top of seismic blocks weighing 30 to 68 tonnes each, which are suspended on active air springs, decoupling the facility from ground vibrations. Each room is lined with nickel-iron alloy sheeting that functions as a force field against electromagnetic fields. To keep temperatures regulated, a ventilation system that generates minimal air flux keeps the climate steady to 0.1 degrees Celsius per hour. And because even the scientists' bodies generate roughly 100 watts of heat in addition to vibrations from movement (think about Gulliver stomping amongst the Lilliputians), they are kept out of the main experimentation room and work their equipment remotely.

According to lab designer Dr Emanuel Löertscher, "In the field of nanotechnology, an increasing number of fabrication and characterisation steps dealing with the sub-10-nanometre (sub-10nm) scale became very sensitive towards external disturbances, as they directly interfere with the experiments. The noise-free labs have opened up a new range of experiments that we can now conduct."

Let us get some perspective. Just how big is something at the sub-10nm scale? One nanometre is equal to one-billionth of a metre, so if you made a tiny brick that measured 10 nanometres high, you would need about 10,000 bricks to equal the thickness of a sheet of paper. Put another way, your fingernails grow approximately one nanometre every second. The sub-10nm

scale is important in nanotech research as it's considered the size transistors will need to be, in order to handle future computer requirements. Once manufactured, it will be possible to fit 10,000 of them across the width of a human hair.

While work at the nano level deals with the super-small, the impact of the research can be enormous. Already, nano

A NANOMETRE IS ONE-BILLIONTH OF A METRE, SO IF YOU MADE A TINY BRICK 10 NANOMETRES HIGH, YOU'D NEED 10,000 BRICKS TO EQUAL THE THICKNESS OF A SHEET OF PAPER

breakthroughs have improved everything from the medicines we ingest, to the windows we put in our homes, to the clothes we wear. Here's a look at how the ultra small has big effects across our world.

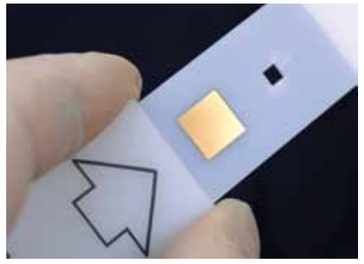
MEDICAL APPLICATIONS

Nanotech research has been applied to the fight against cancer for years. Among other examples, there is nano-"popcorn" which helps doctors detect as few as 50 malignant prostate cells; a nanotube forest that can trap cancerous cells in the blood; and nano-"volcanoes" that can be used to deliver deadly drugs to tumours.

One of the more popular applications of nanotech in fighting cancer is to deliver metals, such as gold, to cancerous cells and then use a laser or other light source to heat the metal up, destroying the problematic cells. But getting the temperature precisely right can be a challenge. Now, researchers at Harvard University in the United States have invented something that might help solve this problem — tiny thermometers made from nanodiamonds.

The diminutive diamonds are injected into cells using nanowires, and can read temperature fluctuations as small as 1.8 milliKelvin (0.0018 Kelvin, the equivalent of one-thousandth of a degree Celsius). Peter Maurer, a member of the research team, says, "Our nanoscaled temperature-sensing technique can be used to ensure that specific cancer cells are heated above a lethal temperature, while non-cancerous cells remain at uncritical temperatures."

Beyond little tech's ability to fight the "Big C", nanotechnology is being applied in other health fields as well, including the treatment of diabetes. A team of researchers from several different US institutes, including North Carolina State University, the Massachusetts Institute of Technology and Children's Hospital Boston, has created an injectable nano-network that releases insulin naturally in the body when blood sugar levels rise. The network is created using positively charged



TOP: SENSAPILL IS A DEVICE THAT CAN DETECT INTERNAL BLEEDING WITH AN INBUILT BIOSENSOR AND A WIRELESS TRANSMITTER. IT IS USED TO HELP DIAGNOSE A RANGE OF DISEASES ASSOCIATED WITH THE BOWEL
ABOVE: A SURFACE PLASMON RESONANCE SENSOR CHIP FEATURING A SQUARE OF GOLD FILM WITH MICROSCOPIC GROOVES ON ITS SURFACE. BIOMOLECULES SUCH AS PROTEINS CAN BIND TO THE FILM, CAUSING CHANGES IN THE WAY IT REFLECTS LIGHT. STUDYING CHANGES IN LIGHT REFLECTANCE CAN PROVIDE INFORMATION ABOUT THE BIOMOLECULE
RIGHT: THE LAYERED WALLS OF MULTI-WALLED CARBON NANOTUBES REDUCE THE CHANCE OF UNWANTED CHANGES IN THE TUBES' MECHANICAL OR ELECTRICAL PROPERTIES

DEATH TO MOZZIES

Research by scientists in India may hold the key to a new way to kill mosquitoes. To study zebrafish, the scientists treated mosquitoes with special water-soluble nanoparticles of carbon (which glow), then let the fish eat them. In the process however, they noticed that above certain concentrations, the nanoparticles blocked the life cycle of the mosquito, killing the larvae. Plus, they observed that the fish seemed fine even after eating these "infected" larvae. With more research, this method could perhaps be used in water bodies such as ornamental fish ponds.

PHOTOS: SPL/CLICK PHOTOS (MAIN, SENSAPILL, SENSOR CHIP, NANO WIRE)

MORE SMART USES OF NANOTECHNOLOGY

Nano Everywhere

Nanotechnology is science, engineering, and technology conducted at dimensions of 100 nanometres or less. Although we often think of nanotech as cutting-edge, it's been around for quite some time, in some unexpected places.

SWORDS

THE SECRET BEHIND **DAMASCUS STEEL SWORDS** — FAMED FOR THEIR STRENGTH, SHARPNESS AND FLEXIBILITY — LAY IN **CARBON NANOTUBES,** WHICH MINIMISED THE EFFECT OF IMPURITIES THAT WOULD WEAKEN THE METAL OR MAKE IT BRITTLE

ANCIENT ROMAN ARTISTRY

THE ROMANS MADE USE OF NANOPARTICLES WHEN THEY CRAFTED A GOBLET 1,600 YEARS AGO. KNOWN AS THE **LYCURGUS CUP,** IT LOOKS PEA-GREEN WHEN LIT FROM THE FRONT, AND BLOOD-RED WHEN LIT FROM BEHIND. **SHINY GOLD AND SILVER SLIVERS IN THE GLASS,** JUST 50 NANOMETRES IN DIAMETER, ARE BEHIND THE EFFECT

1960s MOVIES

THE 1966 FILM *FANTASTIC VOYAGE* SAW A TEAM OF PEOPLE SHRUNK TO ONE MICROMETRE IN SIZE (NO NANOMETRE, BUT CLOSE ENOUGH) BEFORE BEING DISPATCHED INTO A HUMAN BODY. THE TEAM HAD **AN HOUR TO REMOVE A BLOOD CLOT FROM A SCIENTIST'S BRAIN,** BEFORE REVERTING TO NORMAL SIZE

coatings made from chitosan (found in the shells of shrimp) and negatively charged coatings made of alginate, which is usually found in seaweed.

Nanotech has also been applied to help those suffering from osteoporosis, an often-painful condition that leads to small — and sometimes large — cracks in the body's bones. Researchers at Penn State University and Boston University, in the United States, have come up with a way to use these cracks to power nanoparticles that deliver bone-repairing drugs.

Yes, really. The nanoparticles are powered by tiny fractures inside the body. Dr Ayusman Sen, professor of chemistry at Penn State, explains how it works. "When a crack occurs in a bone, it disrupts the minerals in the bone, which leach out as charged particles — as ions — that create an electric field, which pulls the negatively charged nanoparticles toward the crack."

MILITARY APPS

You know those creepy warlocks in the TV series *Game of Thrones* who can project multiple versions of themselves? A scientist in Singapore has figured out how to do just that, using nanotechnology.

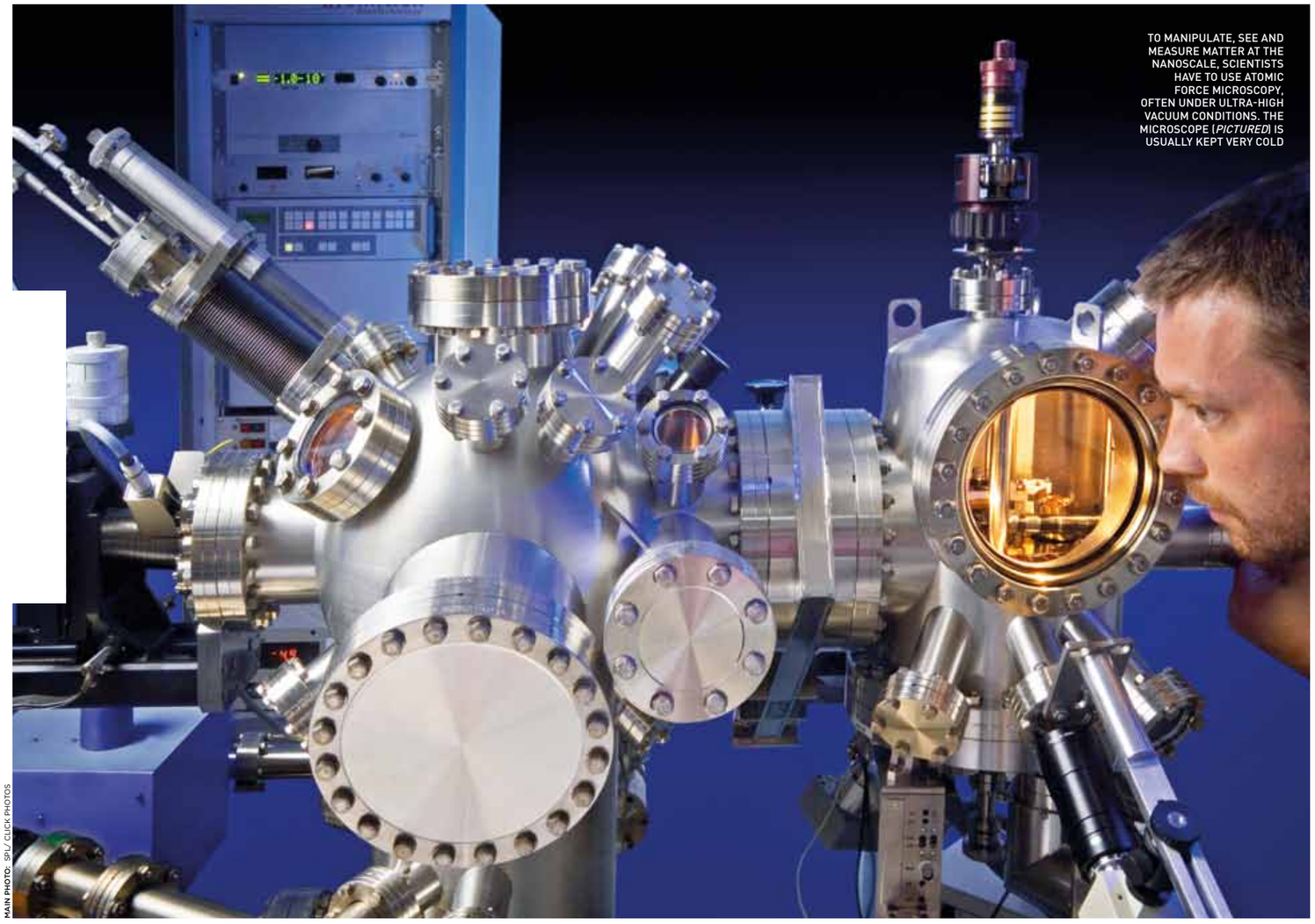
It might sound like pure wizardry, but it is actually solid science. Dr Cheng-Wei Qiu, a physicist at the National University of Singapore, has developed a device consisting of eight concentric rings of plastic circuit boards coated with copper measuring 35,000 nanometres thick, or about a third the width of a human hair. When an object was placed inside the circles and the device activated, radar scans showed that the object appeared to have tripled, with one appearing to either side of the original.

At the moment, the device only works in two dimensions and only with longer wavelengths like those emitted by radar equipment. But by using spheres instead of rings and shrinking the copper loops to 50 nanometres wide, Qiu believes the device could

AMERICAN RESEARCHERS HAVE COME UP WITH A WAY TO USE CRACKS IN THE BONE TO POWER NANOPARTICLES THAT CAN DELIVER BONE-REPAIRING DRUGS

cloak items in the visible light spectrum. This means that planes and ships could appear to be in multiple places at once, making it difficult for enemies to know which to attack.

He says it might even be possible for a soldier to pull off the warlocks' trick. "If we could scale the frequency up to infrared or near-infrared light, if someone puts on a specially designed coat, people will see the original person and several versions along with him," says Qiu. "Or you might imagine that when one guy puts on the coat,



TO MANIPULATE, SEE AND MEASURE MATTER AT THE NANOSCALE, SCIENTISTS HAVE TO USE ATOMIC FORCE MICROSCOPY, OFTEN UNDER ULTRA-HIGH VACUUM CONDITIONS. THE MICROSCOPE (*PICTURED*) IS USUALLY KEPT VERY COLD

MAIN PHOTO: SPL/ CLICK PHOTOS

QUANTUM JEWELLERY

December 2012 marked the debut of Gold Light, said to be the world's first gold-nanoparticle jewellery. According to an article in the *Guardian*, the spherical pendant essentially comprises a crystal shell holding nanoparticles of precious metals — mostly gold, with small, varying amounts of silver and platinum — suspended in two millimetres of water and detergent. The pendant changes colour when exposed to different types of light, and will display different hues if light is put in front (as compared to behind) it.

The *Guardian* article quoted designer Roberto Carrascosa as saying, "The idea of Gold Light appeared in an informal meeting in 2010, in which I was shown that classic precious metals took on unexpected colours when reduced to nanoparticles and put in a solution." Also at the meeting was scientist Victor Puntes, of the Catalan Institute of Nanotechnology. Along with other collaborators, the duo began work on a project which would eventually produce Gold Light.

MORE SMART USES OF NANOTECHNOLOGY

PREGNANCY TESTS

GOLD NANOPARTICLES IN SOME PREGNANCY TESTS WILL REACT WITH **COMPOUNDS IN A PREGNANT WOMAN'S URINE** AND PRESENT EITHER A RED (POSITIVE) OR BLUE (NEGATIVE) RESULT. A STORY ON THE INTERNET THAT WENT VIRAL TELLS A RELATED TALE: A WOMAN WAS CONFUSED WHEN HER PREGNANCY TEST PRODUCED NO RESULT. TURNS OUT SHE HAD URINATED ON AN IPOD NANO, NOT A PREGNANCY TEST

"TEABAGS"

FOR LESS THAN A PENNY, A TEABAG-LIKE MATERIAL CREATED BY STELLENBOSCH UNIVERSITY IN SOUTH AFRICA **PURIFIES DIRTY WATER.** USERS PLACE THE BAG IN THE NECK OF A BOTTLE AND LET THE WATER PASS THROUGH **NANOFIBRES AND AN ANTIMICROBIAL FILM**

SALTINESS

WHAT HAPPENS WHEN YOU SPLIT A GRAIN OF SALT INTO SEVERAL NANOMETRE-SIZED PARTICLES? YOU INCREASE THE SURFACE AREA, OFFERING YOUR TASTE BUDS **MUCH MORE FLAVOUR FOR MUCH LESS SALT.** RESEARCHERS THINK THIS COULD CUT DOWN ON SALT CONSUMPTION, AS WELL AS THE NEGATIVE SIDE EFFECTS OF A SODIUM-HEAVY DIET

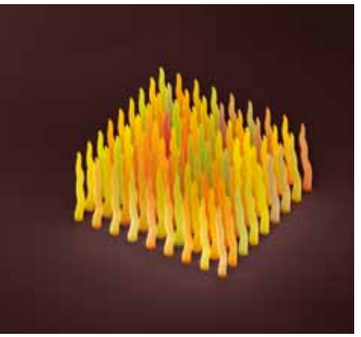
BOTTLES

BEER BREWER SABMILLER INFUSES ITS BOTTLES WITH **FLAKY NANOPARTICLES OF CLAY,** WHICH EFFECTIVELY FILL UP SPACE IN THE WALLS OF THE BOTTLE. THIS HELPS STOP OXYGEN FROM GETTING IN AND CARBON DIOXIDE FROM GOING OUT, KEEPING THE DRINK FRESH

he disappears but appears in two other positions — left and right, with a slightly distorted shape, for example."

While Qiu's device might make it difficult for enemies to strike soldiers in the field, the chance still exists that the warriors will take a hit. In that case, nanotechnology can still come to the rescue.

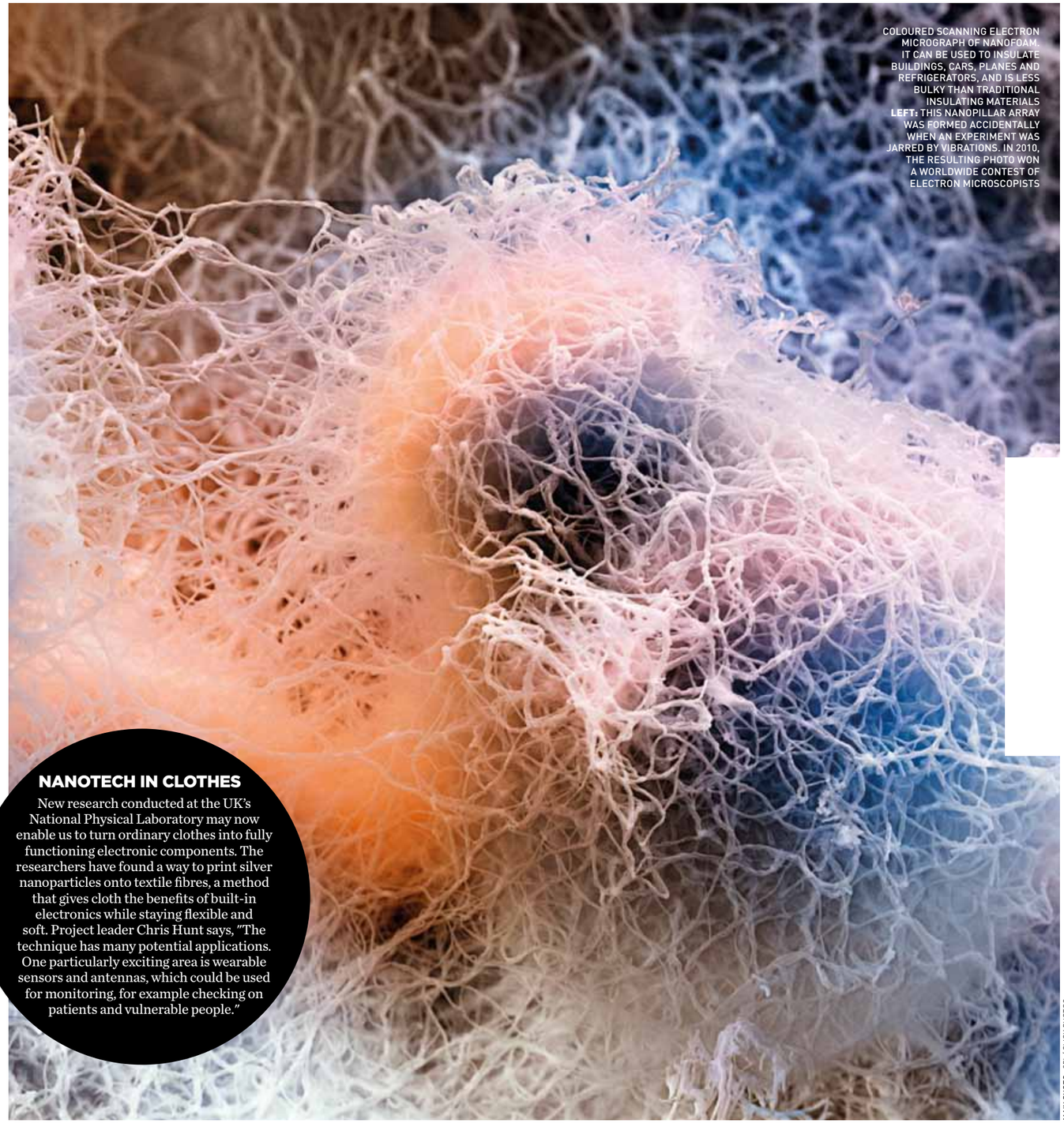
In the United States, Dr Yu Qiao, a professor of structural



engineering at the University of California, San Diego is working with funding from the US military to produce the world's first nanofoam armour. It is created at the molecular level by combining two materials, and then removing one using a process known as acid etching. This creates a honeycombed foam with microscopic channels. The nanofoam is unique because it disperses the force of an impact over a wider range than standard foam, so it could potentially be incorporated into helmets or vests to protect soldiers in future from brain trauma or lung injury.

The US Air Force is also getting in on the nano action. Its office of Scientific Research, along with the US Department of Defense, is working with Dr Zhenqiang Ma, of the University of Wisconsin-Madison, to improve the sight of both pilots and soldiers.

Ma, who is an electrical and computer engineer, has created curved night-vision goggles by employing nanomembranes of germanium, a metallic element that flexes better than the silicon normally used in such applications. He is also working on goggles that employ



COLOURED SCANNING ELECTRON MICROGRAPH OF NANOFOAM. IT CAN BE USED TO INSULATE BUILDINGS, CARS, PLANES AND REFRIGERATORS, AND IS LESS BULKY THAN TRADITIONAL INSULATING MATERIALS
LEFT: THIS NANOPILLAR ARRAY WAS FORMED ACCIDENTALLY WHEN AN EXPERIMENT WAS JARRED BY VIBRATIONS. IN 2010, THE RESULTING PHOTO WON A WORLDWIDE CONTEST OF ELECTRON MICROSCOPISTS

NANOTECH IN CLOTHES

New research conducted at the UK's National Physical Laboratory may now enable us to turn ordinary clothes into fully functioning electronic components. The researchers have found a way to print silver nanoparticles onto textile fibres, a method that gives cloth the benefits of built-in electronics while staying flexible and soft. Project leader Chris Hunt says, "The technique has many potential applications. One particularly exciting area is wearable sensors and antennas, which could be used for monitoring, for example checking on patients and vulnerable people."

MAIN PHOTO: SPL/ CLICK PHOTOS

a unique nanomembrane that will make it possible to simultaneously see visible and infrared light. If the wearer's field of vision is obscured by dust or smoke, they can still navigate the battlefield.

SPORTING FIELDS

In 2008, the vast majority of swimmers who won medals at sporting events worldwide — including the Summer Olympics in Beijing — did so while wearing Speedo's LZR Racer bodysuit, specialised swimwear coated with water-resistant nanoparticles. According to an article in the *Los Angeles Times*, after 105 records were broken that year, 79 of them by people wearing the LZR Racer, the international governing body of aquatic sports, Fédération Internationale de Natation (more commonly known as FINA), finally banned the suits in the midst of outcry against "technology doping".

While nanotech didn't go over so well then, that doesn't mean it hasn't greatly impacted the world of sports. Nanoparticles help make golf balls fly farther, skis more slippery, bicycle frames lighter, and tennis racquets more powerful. Roger Federer won one of his Wimbledon matches using a Wilson nCode racquet. This series of racquets has reportedly employed nano-sized silicon dioxide crystals that fill the gaps between the racquet's carbon fibres, helping to make the end product more powerful and durable.

NANOFOAM DISPERSES THE FORCE OF AN IMPACT OVER A WIDER RANGE THAN STANDARD FOAM, AND COULD ONE DAY BE USED IN HELMETS OR VESTS

Researcher Dr Joseph Wang says applying nanotechnology to sports isn't about better equipment — it's about a safer athlete. Wang and his team at the University of California, San Diego, in the United States, have designed an electrochemical biosensor in the form of a temporary tattoo that athletes can wear to monitor their lactate levels.

"Lactate is an important biomarker, especially for monitoring athlete's performance," says Wang. "But traditional lactate sensors rely on finger-stick blood (blood drawn by pricking a fingertip), which is intrusive and inconvenient during physical activity. This sensor conforms to the skin and can continuously assess lactate in perspiration through a non-invasive manner."

The tattoo-cum-measuring instrument works at the atomic level, explains Wang. "The sensor is modified with lactate oxidase, an enzyme that converts lactate into pyruvate while releasing two electrons. Carbon nanotubes with a large surface area facilitate the electron transfer and amplify the current. In this way, the dynamic change of lactate concentration can be easily observed."

Elevated lactate levels can indicate when an athlete has reached their threshold of exertion, or can show if he or she has any metabolic or physiological disorders.

SAFETY USAGE

In the 21st century, the biggest threats to our safety might come from the smallest places. Harmful biological agents can be slipped into public water supplies or released as gas on public transportation, and many sensors aren't strong enough to detect them. The work Dr Harald Plank is doing at the Graz University of Technology in Austria is set to change that.

Plank and his colleagues have developed a highly sensitive nano sensor through the use of focused electron beam induced deposition, or FEBID. Not familiar with that technique? He explains it in simpler terms: "Imagine a tube with water flowing through it and a small valve controlled by an operator. Now exchange the tube for nano grains of platinum measuring about two nanometres each, exchange the valve for carbon in between the platinum grains, and replace the operator with the gas molecules in the air."

The idea is that as certain gas molecules hit the sensor, they will create an electrical flow (the water in the above example), alerting the user to their presence.

So far the device has been used to measure levels of nitric oxide, nitric dioxide and carbon monoxide in the air, but it can be modified to detect other gases as well. Plank believes the device could also work in fluids. In fact he says, "We have worked with a group which used a similar concept and special transducer which reacted on cancer markers in human blood."

While this may sound amazing enough already, Plank says the real breakthrough is that the device can be made with "nanoscale dimensions in almost all shapes, on almost all surfaces". This means that the sensor could one day be incorporated into mobile devices — turning everyone with a smartphone into a toxic-chemical watchdog. ●