

BROWSING THE RESEARCH POSTERS at a scientific conference in 2002, Paul Stoddart was taken aback. Before him was an electron micrograph of a cicada wing that showed line after line of microscopic pillars arrayed on the wing's surface, a pattern that resembled just the nanostructure Dr Stoddart was looking for to improve the sensitivity of a spectroscopy technique he was using.

That chance sighting led Dr Stoddart, a research fellow at Swinburne University of Technology, to spend many days searching suburban scrub for cicadas, removing their wings and coating them with silver. This was no amateur nature experiment; it was a means of refining an optical fibre sensor that would allow the continuous monitoring of blood glucose levels in humans.

"When I saw these patterns of structure on the cicada wings I thought they could be of some interest to the sensor application. So I coated a wing with silver and found it produced excellent results," Dr Stoddart says.

"The wings have an anti-reflection coating to prevent them reflecting sunlight and enhancing their camouflage. It turns out that this type of anti-reflective coating is exactly the kind of nanostructure suitable for the spectroscopy technique – Surface Enhanced Raman Scattering – that we use.

"The wing surface provides a scale of roughness that is ideally suited to our needs. When laser light illuminates the roughened surface, which has been coated in silver or gold, the light interacts with the surface electrons in such a way that the Raman scattering (the scattering of light photons) is increased by a factor of a million ... in other words there is an amplification effect."

Further, the particular ordered, pillar-pattern of the cicada wings adds a regularity that allows the results to be replicated more accurately.

Dr Stoddart and colleagues at Swinburne's Centre for Atom Optics and Ultrafast Spectroscopy are using Surface Enhanced Raman Scattering in the development of a device that will constantly monitor blood glucose levels in people with diabetes.

The research team has developed and patented an optical fibre probe that could

DIABETES HOPE ON THE WINGS OF SILVER CICADAS

The wings of a familiar noisy insect, the cicada, were the starting point for a device that will be able to continuously monitor blood glucose levels **BY PENNY FANNIN**

be used to monitor people's blood glucose levels in real time, instead of the periodic tests diabetics must self-administer through the course of each day. The probe fits inside a small-gauge needle and Dr Stoddart envisages both would be incorporated into a wristwatch-style device. "The watch would contain the laser and the optics and the needle, with its fibre sensor, would be plugged in." With one end of the needle plugged in to the device the other would penetrate the skin.

Crucial to the success of such a device is finding a way for the glucose in the blood to interact with the sensor, Dr Stoddart says.

"These optical fibres are the diameter of a hair and at the top of the hair we are building this sensor device," he says. "For the sensing technique to work the optical fibre needs to have a nanostructured metal surface, preferably gold or silver, on its tip," he says. "The metal surface interacts

with the light passing through the optical fibre and amplifies the signal returned from the glucose by Surface Enhanced Raman Scattering." The signal is then translated into a blood glucose reading through a spectrum analyser that is built in to the device.

"The fact that it's an optical fibre sensor is important because it removes the difficulty of otherwise aligning a focused laser beam with the sensor surface," Dr Stoddart says.

"The passive end of the fibre light guide can be rigidly mounted for accurate alignment with the laser, while the sensing end can remain flexible to make contact with the sample. In this way the sensor can be packaged into a thin, flexible needle and inserted beneath the skin with minimal discomfort."

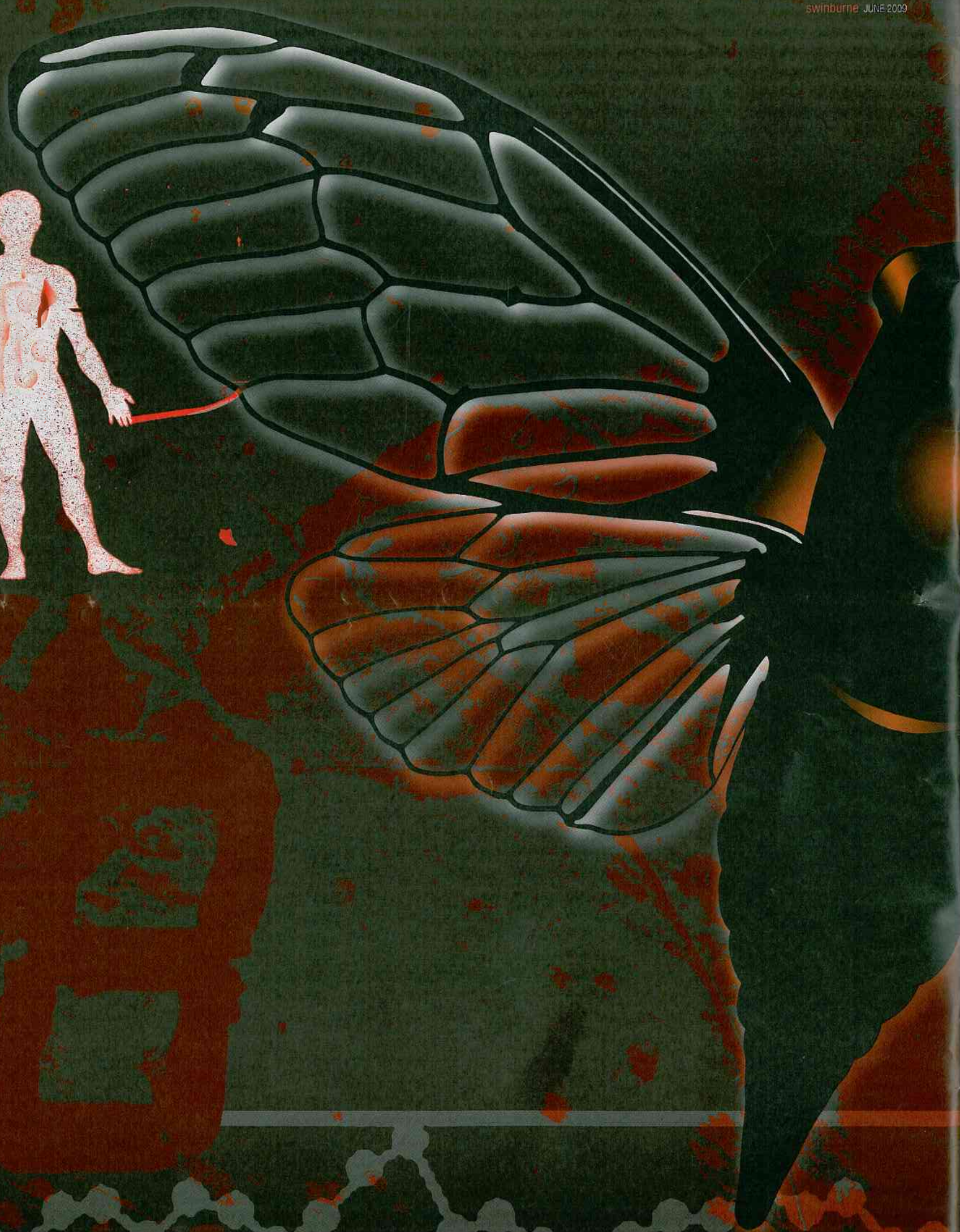
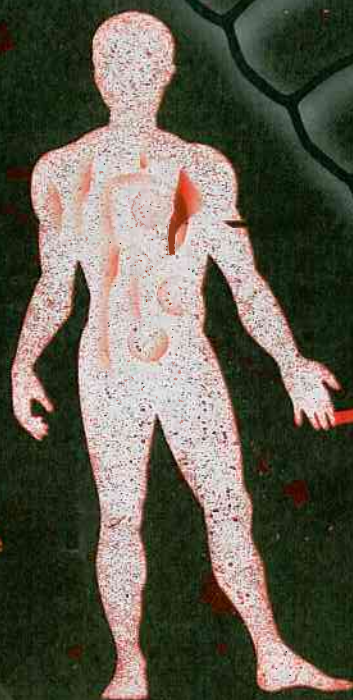
Traditionally, optical fibre sensors have been used for industrial applications such as monitoring temperatures in oil wells,

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ILLUSTRATION: NUSHT GARNSWORTHY

NEW TECHNOLOGIES

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Optical fibres help hearing surgeons 'see'

Cochlear implants, or bionic ears, have dramatically improved the hearing of more than 150,000 people worldwide. However, in a small number of cases, the process of implanting the device can damage the delicate structures inside the cochlea (the snail-shaped structure in the inner ear that contains the organ of hearing).

At a trade show in 2007 Dr Paul Stoddart, a research fellow at Swinburne's Centre for Atom Optics and Ultrafast Spectroscopy, met representatives from Australian cochlear implant manufacturer Cochlear Ltd and began discussing the potential for optical fibre sensing devices to prevent potential tissue damage during cochlear implantation.

"There might be some residual hearing left, so it would be better if the surgeons could tell, during implantation, if they were pushing up against the fine internal cochlea structures," Dr Stoddart says.

Cochlear's head of implant design and development Edmond Capcelea says it is important to minimise any potential trauma to the internal cochlea structures during implantation.

"Minimising trauma at insertion is really worthwhile," he says. "Right now this procedure is done without direct feedback in terms of insertion of the electrode array into the cochlea. Direct, instant feedback during insertion is preferable to lagging feedback, such as from patient performance.

"This development we're running with Swinburne University of Technology is part of our drive to develop smarter or superior electrode arrays whereby the surgeons can get clues on whether they are touching the delicate internal cochlea tissue during insertion of the electrode array."

In collaboration with Cochlear, Dr Stoddart is investigating putting optical fibre Bragg gratings into the electrode array of cochlear implants where they could be used to guide the insertion of the array by the surgeon.

"Optical fibre Bragg gratings were first used in the telecommunications industry to make optical fibre components, but the fibres can also be used for sensing," Dr Stoddart says.

Fibre Bragg gratings can be constructed in an optical fibre where they reflect particular wavelengths of light and transmit others. "If you stretch the fibre it can reflect longer wavelengths and if you compress it you can reflect shorter wavelengths so it is a good strain sensor," Dr Stoddart says.

"This is a very neat way of making an optical fibre filter without using discrete elements; everything can be done in the optical fibre."

Dr Stoddart says the research aims to put an optical fibre Bragg grating in the electrode array of cochlear implants where it can detect any pressure on the internal structures of the ear by monitoring a shift in the wavelength.

"In due time we want to be trialling the first of these sensors in an implant. It will be a very significant development if we can get these fibres routinely used in implants."

— Penny Fannin

sensing strain in bridges or in optical fibre gyroscopes in aeroplanes. Their use in medical devices is only now being widely explored.

Dr Stoddart hopes the optical fibre sensor would be used as an alternative to the existing finger-prick test for measuring blood glucose levels. In this test a small lancet is used to puncture the fingertip and the resulting drop of blood is placed on a testing strip. The strip is then put in a blood glucose monitor that reads the blood sugar level.

"The problem with the finger-prick test is you get snapshots of your glucose level; there might be five or six measurements per day, but you don't know what's



happening in between those measurements," Dr Stoddart says.

"Our approach provides minimally invasive, continuous monitoring. If you want a controlled system you need to have continuous monitoring."

Dr Barry Dixon, the head of clinical research in the Intensive Care Unit (ICU) of Melbourne's St Vincent's Hospital, says there is a clinical need for continuous glucose monitoring that is less invasive and more efficient than current methods.

Critically ill patients in the ICU are medically unstable and have problems with glucose control so their glucose levels are regularly monitored, Dr Dixon says.

"At the moment in the ICU we take four-hourly blood glucose measurements and then work out how much insulin we should give," Dr Dixon says. "Our ICU is a 12-bed ICU so with 12 patients we would be doing that pretty much all the time. That adds up to a lot of blood tests and a lot of time spent measuring insulin needs."

"Long-term, I hope we can set up a continuous glucose measurement where the device goes into the skin a small distance and that, as the technology improves, the measurements will become non-invasive and can be made just with a light source."

Such a novel application for optical fibre sensors started with the Diabetes Australia Research Trust providing seed funding for Swinburne's research. Further funding over the past five years from the National Health and Medical Research Council (NHMRC) and ASX-listed company BioPharmica Ltd (BPH) has seen the research program make significant achievements.

At the moment Dr Stoddart's device is about the size of a lunch box. Although some of the components will need to be smaller, the research focus now is on improving the stability of the sensor.

He says for the glucose in the blood to absorb onto the sensor the metal surface needs to be treated with a chemical. "You need this intimate connection between the sensor and the glucose to take the measurement," he says.

Commercially available chemicals have been trialled and the research team has

identified a treatment that allows detection of glucose at the lowest physiological levels in which they occur in humans.

"At this stage the surface treatment only lasts for some minutes, we need to improve that to several days," Dr Stoddart says there are well-established methods of doing that but they need to be worked through.

He envisages the wristwatch device would need to have its sensor replaced every few days. For this to happen the sensors need to be produced quickly and in high numbers. That's where the cicada wings become important.

Dr Stoddart, in collaboration with Associate Professor Arnan Mitchell's group at RMIT University, has been using a technique called nanoimprint lithography to make copies of the cicada wing patterns at a nano scale. The technique involves making a mould of the wing surface and pressing it into a layer of heated plastic on the tip of an optical fibre. This creates an accurate imprinted copy of the nanoscopic pattern found on each wing. The imprinted tip can then be coated with gold or silver to make the sensor.

Dr Stoddart says that when his team first used nanoimprint lithography to make the moulds about one tip an hour was being produced. "Funding from the NHMRC has allowed us to increase that by a factor of 100 and at that rate the process can be commercially viable. Because the sensors are disposable we need to be able to do that." At current rates of progress he estimates the device would be available for trials in five years.

"By developing medical applications for optical fibre sensors we can find a way to make a difference to people's lives," he says. "Whenever I talk about this diabetes work I ask for a show of hands from people with a family member or friend with diabetes; it's amazing how many people put their hands up. You don't get that when you're working with oil wells." ■

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