Building better bioelectronics

Conducting polymers could help probe the secrets of cell biology

Materials science happens at the surfaces and interfaces of materials, and at the interface between disciplines. For MacDiarmid Institute Principal Investigator, Professor Jadranka Travas-Sejdic, that interface is also where some of the biggest challenges – and most exciting research opportunities – can be found. Professor Travas-Sejdic's work at the University of Auckland focuses on what she calls the “fascinating interplay between biology and human-made electronics”. Although her research encompasses a range of topics, one unifying theme is the use of conducting polymers. “These polymers have a remarkable combination of properties – they're electrically conductive, biocompatible, and flexible,” explains Professor Travas-Sejdic. “They're very promising for a number of health and bioelectronics applications. And we've shown that it's possible to add other functions to them, through chemical synthesis.”

Alleviating mechanical mismatch

The functionalisation of conductive polymers is the subject of Professor Travas-Sejdic's Marsden project, carried out in collaboration with her colleague at both the University of Auckland and the MacDiarmid Institute, Professor David Barker. “One big challenge with conducting polymers is that in general, they're brittle and hard to process,” says Professor Travas-Sejdic. “So David and I have taken a biomimetic approach, using ‘side-chain engineering’. This allows us to alleviate the issues of mechanical mismatch, as well as tuning the other properties of the polymers.” As a result, they've managed to create electrically-conductive materials that can bend, stretch and self-heal, making them suitable for use in a host of sensors and other biocompatible devices.

The same synthetic platform, which Professor Travas-Sejdic describes as looking “a bit like a bottle brush”, goes beyond bioelectronics, and has been used to produce everything from photoluminescent plastics to stretchable strain sensors, Professor Travas-Sejdic is also looking to extend the work, in collaboration with MacDiarmid Institute Associate investigator Dr Viji Sarojini. “Viji has expertise in synthesising antimicrobial peptides,” she says, “so we're hoping to develop antimicrobial conductive hydrogels that could help in wound healing, or even neuron repair.”

Simpler, faster molecular diagnostics

Another use of the platform has been to create conductive substrates that encourage cell adhesion, “...biointerfaces that can be switched on and off in response to external changes.” This complements another area of research that Professor Travas-Sejdic had previously undertaken. Working with research groups in UCLA, Harvard and South Korea, she developed electrospun porous substrates that act as a test-bed for electrically-responsive cells, such as those found in the heart and nervous system. “We realised that if we could functionalise those substrates by adding biological recognition probes, we could produce a filter to selectively capture biological targets,” she says. So in 2017, Professor Travas-Sejdic and Professor Barker, together with Auckland biologist Dr Clive Evans and MacDiarmid Institute Emeritus Investigator, Professor David Williams, successfully applied for funding from the MBIE Endeavour programme.

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“Our goal is to develop a simpler, cheaper and faster way to carry out molecular diagnostics, so we've been working closely with colleagues in the School of Medicine,” explains Professor Travas-Sejdic. “The substrate that we've now made can rapidly pick out specific target molecules, and because it is conductive, we can use electrochemistry to extract those molecules for analysis.” In principle, the ‘capture’ stage could be as simple as pouring complex fluids through the filter. The ‘release’ step would involve adding the filter to a clean buffer and applying a voltage. “It could be just as easily applied in the field as in the lab”, says Professor Travas-Sejdic. She is keen to develop this idea further, and is in discussion with patenting experts at the University of Auckland. She says, “We have demonstrated the proof-of-principle, so we know it works. The next stage will be to extend it to other targets, and to test how it performs with complex samples like blood or plasma.”

Probing cells in 3D, literally adding another dimension to our understanding of the cell environment

Electrically stimulating the growth of neural stem cells

For Professor Travas-Sejdic, developing novel materials is only part of the challenge, “I'm also really interested in new, effective fabrication techniques”. Over the course of several years, Professor Travas-Sejdic and MacDiarmid Institute-funded PhD students Peikai Zhang and Cosmin Laslau developed one such system – a micro-extrusion printer that can create arrays of 3D pillars, made from her conducting polymers (CP). She explains “The printing principle is simple – we extrude CP ink from a micro-pipette to form these high aspect ratio microelectrodes. But altogether, it's very complex, so our lab is the only one that does it that way.” Professor Travas-Sejdic's arrays offer a potential route to probing cells in 3D, literally adding another dimension to our understanding of the cell environment. One application of this platform is in electrically stimulating neural stem cells, a project that Professor Travas-Sejdic is working on in collaboration with the University of Wollongong. “Jeremy (Crook) and Eva (Tomaskovic-Crook) used their facilities for cell culturing to grow stem cells onto our microelectrode arrays, and to test how they responded to drug compounds,” says Professor Travas-Sejdic. “We're now in conversation with Professor Michael Dragunow from Auckland Medical School and Brain Research NZ. We'd like to see if our platform could also be useful in the study of mature human neurons that come from patients.”

In 2019, Professor Travas-Sejdic became only the fifth woman to be awarded the prestigious Hector Medal, an award previously won by the great Ernest Rutherford

The scope of Professor Travas-Sejdic's research, and its remarkable, world-leading impact was recently recognised by the Royal Society Te Apārangi. In 2019, she became only the fifth woman to be awarded the prestigious Hector Medal, an award previously won by the great Ernest Rutherford.