Gravity-beating ultrasonic tweezers provide a sound route to bio-engineering

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Sound engineering: complex sonotweezers can manipulate and arrange many small particles simultaneously. Credit: Professor Bruce Drinkwater, Bristol University

Pioneering 'tweezers' that use ultrasound beams to grip and manipulate tiny clusters of cells under electronic, push-button control could lead to life-changing medical advances, such as better cartilage implants that reduce the need for knee replacement operations.

Using the crafted sound fields, cartilage cells taken from a patient's knee can be levitated for weeks in a nutrient-rich fluid. This means the nutrients can reach every part of the culture's surface and, combined with the stimulation provided by the ultrasound, enables the cells to grow and to form better implant tissue than when cultured on a glass petri dish.

By holding the cells in the required position firmly but gently, the tweezers can also mould the growing tissue into exactly the right form so that the implant is truly fit-for-purpose when inserted into the patient's knee. Over 75,000 knee replacements are carried out each year in the UK; many could be avoided if cartilage implants could be improved.

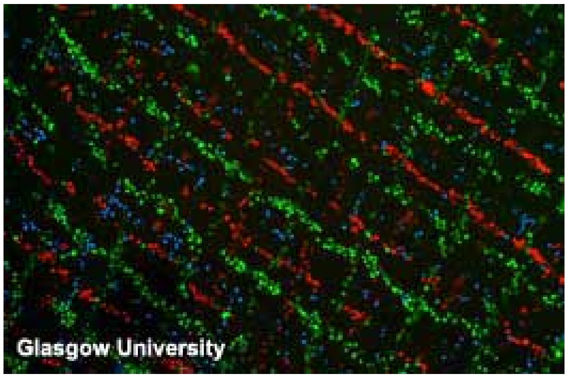
This is just one potential application of ultrasonic tweezers developed with Engineering and Physical Sciences Research Council (EPSRC) funding by a closely integrated team harnessing and combining expertise at four UK universities. The team comprises researchers from the Universities of Bristol, Dundee, Glasgow and Southampton, as well as a range of industrial partners; their extremely close and highly productive collaboration, supported by the four-year EPSRC grant, has established the UK as a world leader in this fast-growing technology.

Sound engineering: complex sonotweezers can manipulate and arrange many small particles simultaneously. Credit: Professor Bruce Drinkwater, Bristol University

Professor Bruce Drinkwater of Bristol University, who co-ordinated the programme, says: "Ultrasonic tweezers have all kinds of possible uses in bioscience, nanotechnology and more widely across industry. They offer big advantages over optical tweezers that rely on light waves and also over electromagnetic methods of cell manipulation; for example, they have a complete absence of moving parts and can manipulate not just one or two cells (or other objects) at a time but clusters of several centimetres across – a scale that makes them very suitable for applications like tissue engineering."

The tweezers developed with EPSRC funding involve multiple, tiny beams of ultrasonic waves that, in a typical device, point into a 10 mm-diameter chamber from all around. With the aid of a powerful microscope to monitor the procedure, the forces generated by the waves can then be manipulated so that they nudge cells into the required position, turn them around, or hold them firmly in place.

Professor Martyn Hill from the University of Southampton, who led the cartilage tissue engineering work in collaboration with Dr Rahul Tare and Professor Richard Oreffo, says: "Ultrasonic tweezers can provide what is, in effect, a zero-gravity environment perfect for optimising cell growth. As well as levitating cells, the tweezers can make sure that the cell agglomerates maintain a flat shape ideal for nutrient absorption. They can even gently massage the agglomerates in a way that encourages cartilage tissue formation."



Living micro-tartan: cells stained with red, green and blue fluorescent dye show that acoustic fields can manipulate and line up tissue growing in culture. Credit: Professor David Cumming

The research programme has also shown that ultrasonic tweezers can be used to build up cell tissue layer by layer and, as an example, the team has produced a microscopic tartan tissue. They anticipate that the tweezers could, for instance, help to reconstruct nerve tissue after severe trauma such as limb amputation. Professor David Cumming from the University of Glasgow says: "It could ultimately be possible to develop a wearable device that produces a kind of acoustic scaffold to help guide a patient's nerve cells as they regenerate."

The team has made a range of innovative tweezing devices, such as a real-life Sonic Screwdriver and a microscopic acoustic Tractor Beam that have turned the science fiction fantasies of Dr Who and Star Trek into reality. Professor Sandy Cochran of the University of Dundee says: "Our partnership with industry has been vital to developing devices and capabilities that are delivering unprecedented sophistication in the field of ultrasound."

His colleague Dr Mike MacDonald adds: "This has enabled us to undertake cutting-edge physics experiments that could lead to big advances in the application of ultrasound-based techniques in sectors such as healthcare. Looking at the programme overall, close collaboration across the multi-university team has been critical to its success, with the interaction between researchers making a particularly significant contribution."

Together, the team has built a platform of understanding that will enable ultrasonic tweezer technology to be refined and miniaturised and specific uses to be explored and developed in the next few years. The first real-world applications, in sectors such as bioscience and electronics, could potentially come on-stream within around 5 years.

Provided by Engineering and Physical Sciences Research Council

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