Bio Focus

3D printer builds synthetic tissues

Three-dimensional printing is revolutionizing art, manufacturing, and now biomaterials. Researchers have automated the printing of smart, programmable networks of lipid-bound droplets that may be the future in creating synthetic, tissue-like biomedical materials. These soft tissues can conduct electrical signals like neurons and contract like muscle. Tens of thousands of aqueous droplets are judiciously ejected into oil to "print" a lattice of microcompartments bound by cell-like lipid bilayers. While most engineered-cell mimics, such as liposomes, fail to work together to exhibit teamwork-dependent functionality, these printed droplet networks display cooperative tissue-like emergent properties.

We want to "do something where the sum is greater than the individual parts," said chemist Hagan Bayley, a professor of chemical biology at the University of Oxford. As reported in the April 5 issue of *Science* (DOI: 10.1126/science.1229495; p. 48), Bayley's group used a modified commercial printer to pattern picoliter lipid-coated droplets to form a soft, tissue-like material. The droplets are formed from phospholipid bound monolayers where the inside is an aqueous solution. Precise control over droplet deposition and definition of the composition of the droplet contents and supporting membrane then enables the engineering of structures exhibiting tissue-like cooperative properties.

This assembly technique affords biotechnologists the ability to create a wide variety of materials. Through control of the position and properties of each individual droplet in the assembly, Bayley's group can "confer upon simple materials the properties of complex biological tissues." For example, by outfitting only certain droplets with an ionically conductive pore membrane protein (αHL), a pathway can be created within the material that allows for nearly instantaneous conduction of current. This controlled conduction process mimics the activity of nerve axons by allowing long-distance electrical communication.

"Cooperative action" can also enable macroscopic conformational change, allowing researchers to design complex shapes through folding. By patterning high and low osmolarity droplets within the structure, folding can be programmed through osmosis. As an aqueous medium flows up the salt gradient, droplets respectively swell and shrink; small volume change at the cellular level evolves to macroscopic folding. Such an emergent property could allow design of nonprintable structures or muscle-like flexing activity.

We want to "build materials that behave like biological tissues," Bayley said when asked to define his group's aspirations. He sees a tremendous future in this approach, starting, for example, by modulating the mechanical properties of these structures by inserting hydrogels or polymers into the microcompartments. This system could also be used for advanced drug delivery and as a highly engineered three-dimensional scaffold for tissue engineering.

Michael J. Cohen

Nano Focus

Efficiency of organic semiconductors enhanced

Organic semiconductors have traditionally not been considered candidate thermoelectric materials because they have been inefficient in carrying out the essential heat-to-electricity conversion process. Now, a team of researchers from the University of Michigan has improved upon the state of the art in organic semiconductors by nearly 70%, achieving a figure of merit of 0.42 in the PEDOT:PSS compound.

"That's about half as efficient as current inorganic semiconductors," said project leader Kevin Pipe, an associate professor of mechanical engineering as well as electrical engineering and computer science at Michigan.

PEDOT:PSS—or poly(3,4-ethylenedioxythiophene) poly(styrene sulfonate)—has previously been used as a transparent electrode in devices such as organic light-emitting diodes and solar cells, and as an antistatic agent for materials such as photographic film. In PEDOT doped by PSS, only a small fraction of the PSS molecules actually bond to the host PEDOT; the rest of the PSS molecules do not become ionized and are inactive. The researchers report in the May 5 online edition of *Nature Materials* (DOI: 10.1038/NMAT3635) that these excess PSS molecules dramatically inhibit both the electrical conductivity and thermoelectric performance of the material.

"The trouble is that the inactive PSS molecules push the PEDOT molecules apart, making it harder for electrons to jump between PEDOT molecules," Pipe said. "While ionized PSS molecules improve electrical conductivity, non-ionized PSS molecules reduce it."

To improve its thermoelectric efficiency, the researchers restructured the material at the nanoscale. Pipe and his team used solvents to remove some of these non-ionized PSS dopant molecules from the mixture, leading to large increases in both the electrical conductivity and the thermoelectric energy-conversion efficiency. □

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