stantially reacted to form epoxy resin as they were deposited, either as alternating single layers or as alternating stacks of five layers each. A single printed layer of 5% solution results in a film thickness of about 25 μm, which becomes a liquid-epoxy film of ~1 μm once the water is lost.

As the researchers pointed out, the self-assembly approach can be applied to combinations of ceramic powders, modified with ionic dispersants, and ionic polymers.

Current ink-jet printing offers a lateral resolution of about 25 μm and a thickness of about 1 μm.

SHIMING WU

Fabricated Joint Cartilage Mimics Structure and Function of Tissue

Bioengineers at the University of California—San Diego (UCSD), in a collaboration with scientists at Rush Medical College in Chicago, have fabricated cartilage tissue that mimics certain features of the multilayered structure and cellular functions of natural articular cartilage. "We've designed a tissue made up of different types of cartilage cells with the notion that this type of tissue could be implanted into a patient and be grown to conform to the specific geometry of the individual's joint," said Robert Sah, professor of bioengineering at the UCSD Jacobs School of Engineering, referring to the research conducted with Koichi Masuda and Eugene Thonar at Rush.

In previous work, the research team found that cartilage is soft at the surface, but 25 times stiffer in the deep regions, and that the cells in the surface region make a key protein called superficial zone protein, which is a major lubricant of joints. Using this data, the bioengineers developed a strategy to organize different types of chondrocytes in a cartilage construct, mimicking the stratified nature of normal cartilage tissue. As graduate student Travis Klein described at the Biomedical Engineering Society's annual meeting in October, the research team fabricated this construct using a method in which the cells are suspended in a gel until they surround themselves with normal cartilage-matrix components. The gel is then removed, leaving an entirely biological tissue.

In laboratory tests, the researchers found that the cells at the surface of their engineered tissue effectively secreted superficial zone protein. In addition, the cells used to form the cartilage surface made tissue that was soft and had a less dense matrix than that formed by cells in the deeper regions.

The researchers described the engineered tissue as "immature cartilage," such as that found during fetal development, in which the cartilage cells are organized in a stratified fashion and densely packed, and the matrix is loosely knit. The researchers expect this will give the implant an advantage because as it continues to mature, it is likely to integrate well and conform to fit with the surrounding cartilage and joint tissue.

Palladium Mesowire Array Sensor Detects Hydrogen Gas

Chemists at the University of California—Irvine (UCI) have built a nanoscale hydrogen sensor that can be used to detect dangerous levels of the explosive gas in devices such as fuel cells and internal-combustion engines. The sensors were found to respond faster and be more selective for hydrogen than conventional sensors, while needing significantly less power for operation. In building this sensor, Reginald M. Penner, UCI professor of chemistry, and his team created nanowires using a method called step-edge decoration. In this method, palladium ions

https://doi.org/10.1557/mrs2001.273 Published online by Cambridge University Press

are electrochemically transformed into atoms of palladium metal on a piece of graphite. Rudimentary wires begin to grow when these palladium atoms collect at step edges, which are defects of nanometer height on the graphite surface.

As reported in the September 21 issue of *Science*, the sensor consists of up to 100 mesoscopic palladium wires, 100–500 μm long arrayed in parallel and contacted at each end by strips of silver. In tests, Penner's group applied a small voltage to the sensor and then exposed it to hydrogen gas. When exposed to the gas, the wires swelled by as much as 3%. When the gas was removed, the wires shrank to their regular size, but in doing this, atomic breaks formed in the wires, making them nonconductive.

After these breaks had formed, the sensor was again exposed to air containing hydrogen gas. As the wires swelled, breaks in individual wires began to seal, making those wires conductive. At lower concentrations of hydrogen, a few wires became conductive, but when the chemists increased the concentration of hydrogen, an increasing number of wires became conductive, and more electricity flowed through the device. Because of this, the researchers found that they could measure the percentage of hydrogen in the ambient air through the amount of electricity being used by the sensor—the greater the current, the higher the concentration of hydrogen.

The sensor functioned when the ambient air contained as much as a 10% concentration of hydrogen, at which point the breaks in all the palladium wires sealed. This operating capacity is crucial, Penner said, because concentrations of hydrogen above 4% are explosive. In addition, the researchers found that when compared with conventional sensors, their nanowire-array-based sensor responded faster, required much less power (<100 nW), and was less sensitive to other gases such as oxygen, carbon monoxide, and methane.

Penner said, "Hydrogen is a clean energy source, but before hydrogen can replace hydrocarbons as a fuel, we need better ways to store it and to control its use in motors and fuel cells. Reliable, cheap, compact, and safe hydrogen sensors are needed for monitoring ambient air for leaked gas. This nanowire-based sensor meets these needs." □