Bio Focus

Stretchable silver nanowire microelectrodes show promise for studying cell functions

Stretchable electronics have opened the door to exciting possibilities in biomedical treatment and research, with applications that go beyond wearable diagnostic and therapeutic devices. Someday, they could play a key role in stimulating wound healing and bringing therapeutic drugs to market faster.

As reported in *Advanced Healthcare Materials* (doi:10.1002/adhm.201670083), researchers at ETH Zürich have recently fabricated miniaturized stretchable electrodes using silver nanowires. The electrodes are biocompatible and can be used to study complicated biological processes. The size of the electrodes enables precise spatial control of electrical fields and the fabrication method is user-friendly and inexpensive.

The key to their success is a simple, benchtop technique for patterning nanowires onto a stretchable membrane. After spreading a silver nanowire suspension over a photomask and letting it dry, the mask is flipped upside down and placed on a liquid prepolymer. As the exposed prepolymer is cured with UV light, it becomes cross-linked and the nanowires are trapped inside. The polymer is then lifted off and discarded, leaving only the silver nanowires within the masked areas. These nanowires are transferred onto an elastic silicone membrane by pressure and curing in an oven.

Using this method, it is possible to envision an electrode design, print out the photomask, and pattern the nanowires all in one day, according to Vahid Hosseini, a doctoral candidate who led the research under the direction of Viola Vogel at ETH Zürich. In addition, it requires little specialized training or equipment.

Characterization tests showed that the stretchy electrodes were well suited for studying the mechanical and electrical co-stimulation of cells and tissues. This co-stimulation occurs regularly in the body, but is difficult to study *in vivo* with existing tools. The ability to explore this in the laboratory could lead to new insights on cell and tissue functions, leading to models that better predict the effectiveness of medical interventions.

"Combined stimulations are important to better simulate the native microenvironments of various tissue and organs, and might thus expand on the tool box utilized by a rapidly growing community that is developing human organ-on-a-chip platforms," according to Vogel. "The vision of these chips is that they might one day replace (at least in part) some animal and human clinical studies and thereby reduce the cost and speed of bringing new drugs to the clinics."

In a proof-of-concept study, the researchers integrated the microelectrodes into a stimulation device. The membrane was placed on top of a microfluidic channel through which fluid could be pumped at various speeds and loads. The researchers could stretch the membrane and mechanically stimulate cells grown *in vitro* above the membrane. Combined with the microelectrodes, the device facilitated the electrical, mechanical, and electromechanical stimulation of cells.

After pretreating the device to ensure that cells were not exposed to potentially harmful solvents, the researchers coated the surface with fibronectin, a protein important in wound healing. A few days later the cells were exposed to electrical, mechanical, and electromechanical stimulation in amounts that promote the healing of skin wounds. The results demonstrated both the reliability and possibilities of this method for studying the effects of complex environmental stimuli that many cells experience.

"The scientists used an elegant approach to micropattern silver nanowires on elastic membranes," says Gulden Camci-Unal, a researcher at the University of Massachusetts Lowell who specializes in engineering biomaterial platforms to improve human health. "The results can be used to design new devices that have diagnostic and therapeutic capabilities."

Stretchable microelectronics have enormous potential in biomedicine, but there have been some challenges, according to Camci-Unal. As in this work, priorities for the future should include a focus on inexpensive fabrication methods, durable electronic components, and biocompatible coatings, she says.

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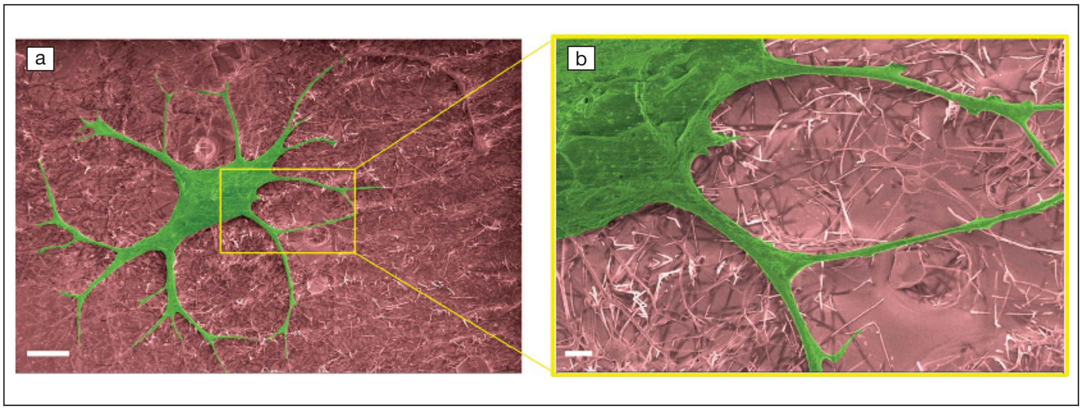

False color scanning electron microscope images of a fibroblast (green) on top of a silver nanowire/polymer (PDMS) carpet at different magnifications. Scale bars are (a) 10 μm and (b) 2 μm. Credit: Vahid Hosseini.