Living Tissue and Technology Are Now Closer Thanks to Innovative Bioelectronic Gel

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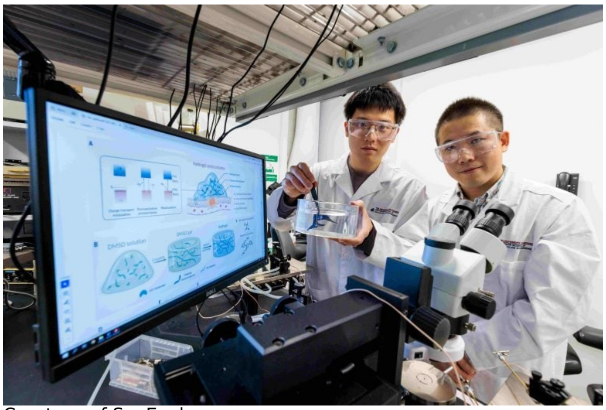
Courtesy of SynEvol
Credit: UChicago Pritzker School of Molecular Engineering

Hydrogels are the ideal material for connecting electronics to living tissue because they are pliable, soft, and as tolerant of water as the tissue itself. On the other hand, semiconductors—the essential components of bioelectronics like pacemakers, biosensors, and drug delivery systems—are hydrophobic, brittle, and hard, which prevents them from dissolving in the manner that hydrogels have historically been constructed.

Scientists from the Pritzker School of Molecular Engineering at the University of Chicago have broken through this long-standing obstacle by developing a novel method for creating hydrogels in order to construct a potent semiconductor in hydrogel form, according to a recent article published in Science. Under the direction of Asst. Prof. Sihong Wang's research team, the end product is a bluish gel that resembles a jellyfish and wiggles in water while retaining the enormous semiconductive capacity needed to transfer data between electronic devices and biological tissue.



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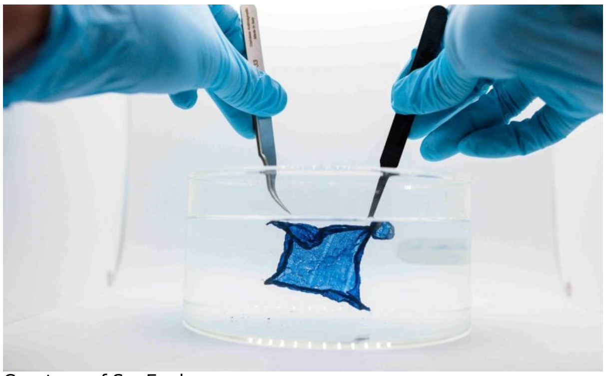
The material showed charge-carrier mobility up to 1.4 cm2 V-1 s-1, stretchability of 150% strain, and tissue-level moduli as soft as 81 kPa. This indicates that their material satisfies every need for the perfect bioelectronic interface because it is simultaneously hydrogel and semiconductor.

"Creating a device with tissue-like mechanical properties is a challenge that must be addressed when creating implantable bioelectronic devices," stated Yahao Dai, the new paper's first author. "In this manner, they can both deform together and create a very intimate bio-interface when it is directly interfaced with the tissue."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According to Dai, the material offers numerous potential non-surgical uses, such as better skin readings or better wound care, even though the article primarily concentrated on the difficulties faced by implanted medical equipment like pacemakers and biochemical sensors.

According to UChicago PME Asst. Prof. Sihong Wang, "it has very soft mechanical properties and a large degree of hydration similar to living tissue." Due to its high porosity, hydrogen facilitates the effective diffusion transfer of many substances and nutrients. Because of all these characteristics, hydrogel is most likely the best material for medication delivery and tissue creation.

Making a hydrogel usually involves dissolving a substance in water, then adding the gelation agents to transform the liquid into a gel. While some materials dissolve easily in water, others need to be altered chemically by researchers, the basic idea remains the same: Without water, hydrogel cannot form.

However, semiconductors often do not dissolve in water. The UChicago PME team reconsidered the question instead of trying to drive the process through new, time-consuming methods.

"We thought, 'Well, let's take a different approach,' and we developed a solvent exchange procedure," Dai stated.

They used an organic solvent that is miscible with water to dissolve the semiconductors rather than water. The dissolved semiconductors and hydrogel precursors were then used to create a gel. At first, their gel was an organogel rather than a hydrogel.

"We then submerged the entire material system in water to allow the organic solvent to dissolve out and allow the water to enter in order to ultimately transform it into a hydrogel," Dai explained.

The wide application of such a solvent-exchange-based approach to many polymer semiconductor types with various functions is a significant advantage.

The team's patented hydrogel semiconductor, which is being marketed by UChicago's Polsky Center for Entrepreneurship and Innovation, is not a semiconductor-hydrogel hybrid. It is a single substance that possesses both hydrogel and semiconductor properties.

“It’s just one piece that has both semiconducting properties and hydrogel design, meaning that this whole piece is just like any other hydrogel,” Wang said.

Unlike any other hydrogel, however, the new material actually improved biological functions in two areas, creating better results than either hydrogel or semiconductor could accomplish on their own.

First, having a very soft material bond directly with tissue reduces the immune responses and inflammation typically triggered when a medical device is implanted.

Second, the new material allows for stronger photo-modulation effects and an increased biosensing response due to the high porosity of hydrogels. Increased sensitivity results from proteins' ability to diffuse into the film and form volumetric interactions, which greatly expands the interaction sites for biomarkers-under-detection. In addition to sensing, the more effective transport of redox-active molecules at tissue surfaces significantly enhanced reactions to light for therapeutic purposes. This helps with devices like light-operated pacemakers and wound dressings that may be heated more effectively with a quick flash of light to hasten the healing process.

Wang jokingly said, "It's a 'one plus one is greater than two' kind of combination."