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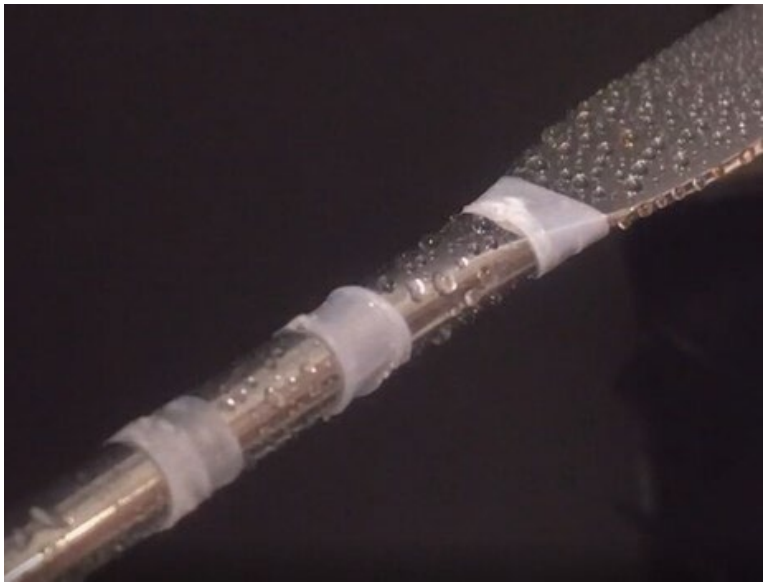
Spider silk-inspired electrode wraps around tissues and organs



Scientists from Singapore and China have created a flexible electrode that wraps around muscles, nerves and hearts to deliver electrical stimulation to tissues or record electrical activity.

Described in the journal Nature, the electrode contracts to conform to biological tissues and performs better than conventional stretchable electrodes. It is made from a flexible material which, like spider silk, contracts when wet, enabling it to fit securely around tissues and organs.

The scientists created the material by mixing a compound called semicrystalline poly(ethylene oxide) (PEO) with another compound, poly(ethylene glycol)-α-cyclodextrin inclusion complex (IC). IC connects the PEO semicrystalline structures and holds them together.

The material was repeatedly stretched to form a thin film; the stretching causes the semicrystalline PEO to create bridges and pores. At the same time, the semicrystalline PEO re-forms into crystals, stabilising the material in a stretched state when the film is dry.

When the dry film comes into contact with water, the water breaks and dissolves the PEO structures, causing it to instantly contract to fit around tissues and organs seamlessly, like shrink wrap. Experiments using cell cultures showed that the material was not toxic to cells.

To create the electrode, the researchers deposited gold, which is electrically conductive, onto the dry and stiff film before it was wetted. In rat experiments, the researchers demonstrated that the electrode created using the film could deliver electrical impulses effectively to nerves.

The electrode can also record electrical signals from muscles, nerves and the heart, with higher sensitivity than conventional stretchable gold electrodes, thanks to the seal between the electrode and the tissue. The scientists showed that the electrode could detect electrical activity from the

stimulation of a muscle graft by a nerve — a procedure commonly used to control prosthetic limbs or treat phantom pain after limb amputation.

The scientists demonstrated that the electrode could be wrapped around the rat heart to detect electrical signals resulting from abnormal heart rhythms without customising its size or shape. To install the electrode around the heart, it is first delivered into the chest via a small incision guided by a camera. The electrode then unfolds to surround the heart for easy installation. When the electrode comes into contact with water in the chest cavity, it contracts to wrap around the heart.

The researchers said the electrode can be installed temporarily or permanently, depending on the application, so it can be easily removed when it is no longer required or left in place if long-term monitoring or electrical stimulation is necessary. Professor Chen Xiaodong, from NTU Singapore, noted, “Being minimally invasive, our innovation could make device implantation procedures safer and simpler.”

The scientists are currently working on enhancing the long-term stability of the electrode and optimising its performance, with the aim to conduct clinical trials to ensure its safe use. They envision that their rapidly contracting material will pave the way for the biomedical devices of the future, suitable for monitoring irregular heartbeat, nerve repair, wound closure, scar reduction and more.

“Our water-responsive material may play an important role in shaping the next generation of biomedical applications at the interface between electronics and the human body,” said first author Dr Yi Junqi, a research fellow at NTU Singapore.

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