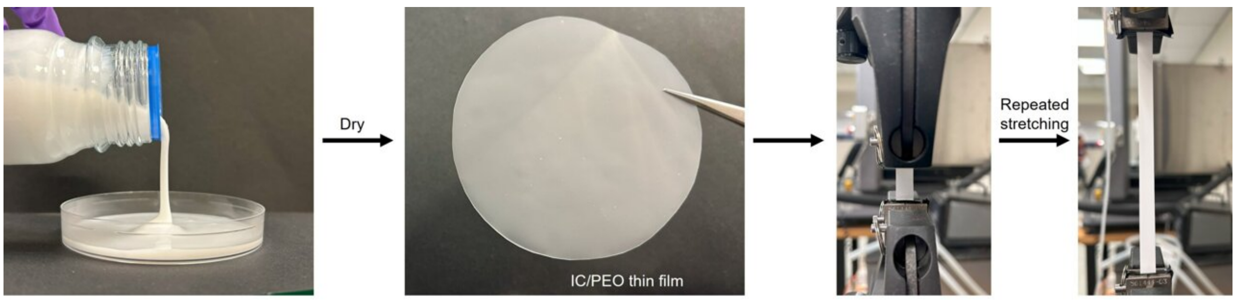
Medical Xpress

Spider-silk inspired electrode offers new possibilities for the next generation of biomedical devices

January 30 2024



Making the contractile material: The mixture is poured and dried to form a film. Then, the film is stretched repeatedly. Credit: NTU Singapore

An international team of scientists has developed a flexible electrode that wraps around muscles, nerves and hearts to deliver electrical stimulation to tissues or record electrical activity. Inspired by spider silk, the electrode contracts to conform to biological tissues, is non-toxic and performs better than conventional stretchable electrodes.

The innovation could open the door to biomedical devices for monitoring irregular heartbeat, nerve repair, wound closure and scar reduction.

The study was published in *Nature* in December and led by Prof. Chen

Xiaodong of NTU's School of Materials Science and Engineering; Prof. Gao Huajian of NTU's School of Mechanical and Aerospace Engineering; Prof. Liu Zhiyuan from the Chinese Academy of Sciences; and Prof. Hu Benhui from Nanjing Medical University.

Learning how to contract from nature

The electrode is made from a flexible material that contracts when wet to fit securely around tissues and organs.

Drawing inspiration from the structure of spider silk that enables it to contract when wet, 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 then 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, stabilizing the material in a stretched state when the film is dry.

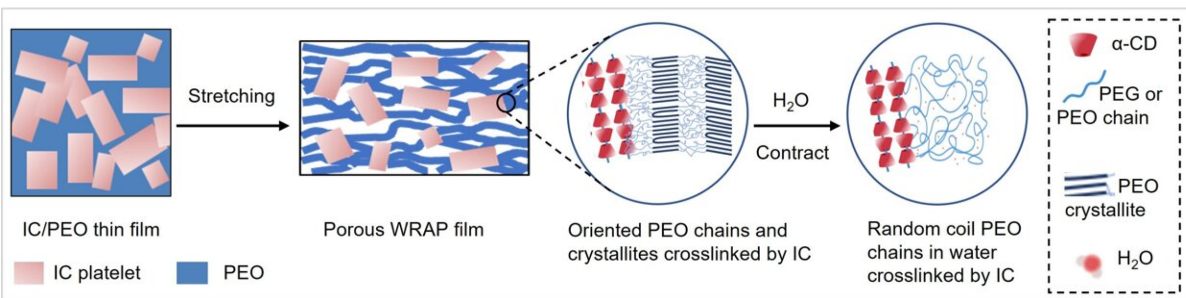
When the dry film comes into contact with water, the water breaks and dissolves the PEO structures, causing it to instantly contract to fit around tissues and organs seamlessly, like shrink wrap.

Experiments using cell cultures showed that the material was not toxic to cells.

Demonstrating the capabilities of the electrode

To create the flexible electrode, the researchers deposited gold, which is electrically conductive, onto the dry and stiff film before it was wetted.

In rat experiments, the team 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 PEO crystalline structures in the material break on contact with water, causing the film to become soft and contract. Credit: NTU Singapore

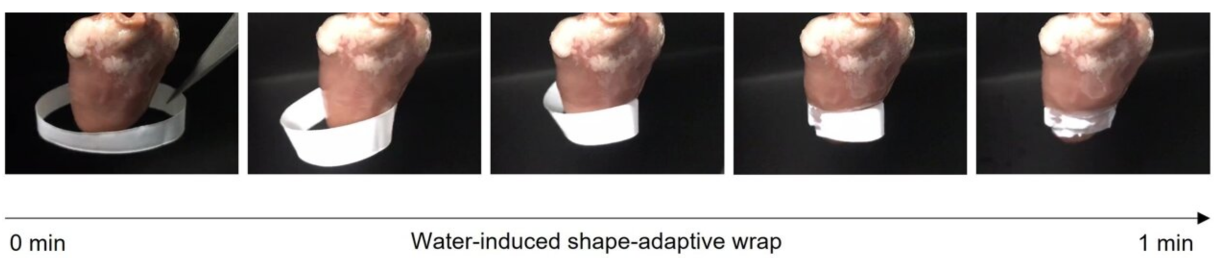
The scientists also showed that the electrode could detect electrical activity from the stimulation of a muscle graft by a nerve—a procedure commonly used to control prosthetic limbs or treat phantom pain after limb amputation.

"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 Dr. Yi Junqi, research fellow from NTU's School of Materials Science and Engineering and NTU's Institute for Digital Molecular Analytics and Science, and the first author of the study.

The scientists demonstrated that the electrode could be wrapped around the rat heart to detect electrical signals resulting from abnormal heart rhythms without customizing 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.

According to the researchers, the electrode can be installed temporarily or permanently, depending on its applications. For example, the electrode can be easily removed when it is no longer required. The device can be left in place if long-term monitoring or electrical stimulation is necessary.



A demonstration, using a chicken heart, of how the film contracts in contact with water. Credit: NTU Singapore

"Being minimally invasive, our innovation could make device implantation procedures safer and simpler," said Prof Chen.

"We envision that such materials that contract rapidly on demand will pave the way for biomedical applications of the future," said Prof. Gao Huajian.

"With the ability to measure the delicate and precise activities of living tissues, the flexible electrode opens the door to great possibilities for elucidating the mechanisms of brain disorders as well as treating neurodegenerative diseases that are difficult to overcome," said Prof. Tsuyoshi Sekitani, an expert in flexible electronic devices from the Institute of Scientific and Industrial Research at Osaka University, who was not involved in the research.

The scientists are currently working on enhancing the long-term stability of the electrode and optimizing its performance. In the future, they plan to conduct clinical trials to ensure the safe use of the electrode.

More information: Junqi Yi et al, Water-responsive supercontractile polymer films for bioelectronic interfaces, *Nature* (2023). DOI: 10.1038/s41586-023-06732-y

Provided by Nanyang Technological University