Transducer powered by electrochemical reactions for operating fluid pumps in soft robots

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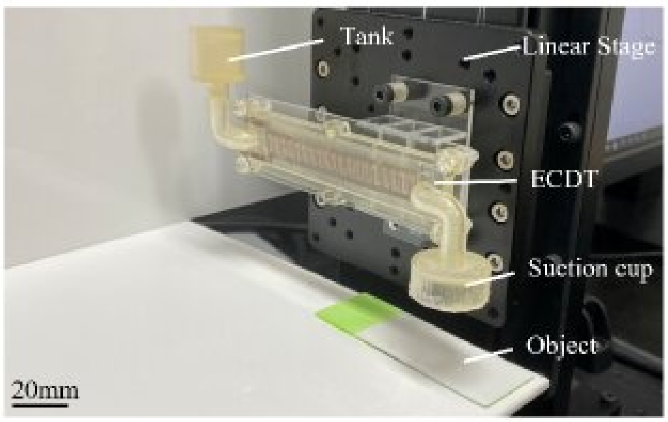

Researchers from SIT, Japan, have recently developed an electrochemical reaction-based transducer that allows smooth control of fluidic systems in soft robots, enabling self-sensing actuation without complexity and opening doors to miniaturized soft robotic technology. Credit: Shingo Maeda from Shibaura Institute of Technology, Japan

The word robot may conjure images of hard, metallic bodies that are invulnerable to attacks. In modern day-to-day life, however, robots are hardly needed for defending against enemy attacks. Instead, they are required to perform more mundane tasks such as handling delicate objects and interacting with humans. Unfortunately, conventional robots perform poorly at such seemingly simple tasks. Moreover, they're heavy and often noisy.

This is where "soft" robots have the upper hand. Made of materials called elastomers (materials with high viscosity and elasticity), soft robots absorb shocks better, can adapt better to their environments, and are safer compared to conventional robots. This has allowed for a broad range of applications, including medicine and surgery, manipulation, and wearable technology. However, many of these soft robots rely on fluidic systems, which still use pumps operated by mechanical parts (motors and bearings). As a result, they are still heavy and noisy.

One way around this problem is to use chemical reactions to drive pumps. But while such systems are definitely lightweight and quiet, they don't perform as well as conventional pumps. Is there a way to beat this trade-off? Turns out, the answer is yes. A team of researchers from Shibaura Institute of Technology (SIT), Japan, led by Prof. Shingo Maeda, introduced an electrohydrodynamic (EHD) pump that uses electrochemical reactions to drive pumps. The EHD pumps have all the advantages of pumps driven by chemical reactions and none of their issues.

In a recent study, the team, including Prof. Maeda, Yu Kawajima, Dr. Yuhei Yamada (all from the Department of Engineering Science and Mechanics, SIT), and Associate Professor Hiroki Shigemune (Department of Electrical Engineering, SIT) has gone one step further, designing a self-sensing EHD pump that uses an electrochemical dual transducer (ECDT) to sense the fluid flow, which, in turn, activates electrochemical reactions and increases current.

"Self-sensing technology has attracted much attention recently for compactifying soft robots. Incorporating sensors in soft robots enhances their multifunctionality, but often makes for complex wiring and bloating. Self-sensing actuation technology can help solve this issue and allow for miniaturization of soft robots," explains Prof. Maeda. This paper was made available online on 7 January 2022 and was published in the journal *ACS Applied Materials & Interfaces* on 19 January 2022.

The team based the ECDT design on the EHD pump they had previously designed. The pump consisted of a symmetrical arrangement of planar electrodes, which allowed an easy control of the flow direction by simply changing the voltage. Moreover, the arrangement enabled an obstruction-free flow and in the same amount in each direction owing to same strength of the electric field on either side.

The team evaluated sensing performance in terms of range of detectable flow, rate, sensitivity, response, and relaxation times, and also used mathematical modeling to understand the sensing mechanism. "The ECDT can easily be integrated into a fluidic system without bloating or complexity," says Yu Kuwajima, doctoral student at the Smart Materials Laboratory (SIT) and the first author of the study. Additionally, the researchers tested its performance by using it to drive a suction cup to detect, grab, and release objects.

"The advantages of the ECDT are that it does not require any special equipment or complex processing for its fabrication. Moreover, it is small, lightweight, and demonstrates a wide range of sensitivity," says Prof. Maeda.

More information: Yu Kuwajima et al, Electrochemical Dual Transducer for Fluidic Self-Sensing Actuation, *ACS Applied Materials & Interfaces* (2022). DOI: 10.1021/acsami.1c21076

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