TINY ROBOTS INSPIRED BY INSECTS

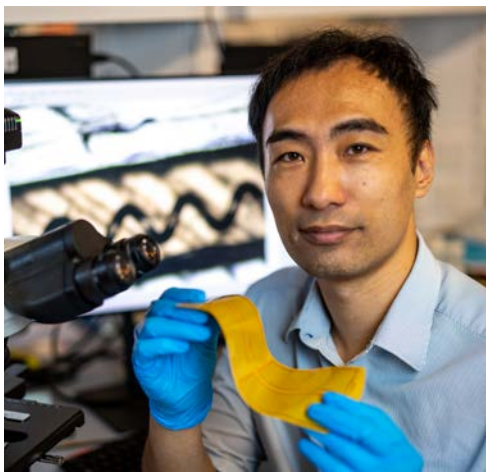
MINIATURE ELECTROSTATIC ACTUATORS — based on the muscles of insects — are robust and compact, and can offer the smallest of robots great agility to work in tight spaces.

Microscopic electromechanical devices inspired by the structure of insect muscles are transforming tiny robots, improving their power, precision, flexibility and size.

Miniature robots range from several millimetres to a few micrometres in size, and have a wide range of applications from search-and-rescue operations in natural disasters, to medical tools for imaging and performing surgery.

However, one of the major challenges in miniaturizing robots has been the problem of shrinking conventional electromagnetic actuators, which transform electrical energy into mechanical energy and movement.

Researchers led by Hongqiang Wang — an associate professor in the Department of Mechanical and Energy Engineering at Southern University of Science and Technology in Shenzhen, China — has been studying electrostatic actuators as a promising alternative for so-called soft robots, which have flexible bodies.



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▲ **The compact, yet powerful, limb muscles of insects including grasshoppers (left), have inspired the work of researchers such as Hongqiang Wang (right), pictured here with a sheet of electrostatic actuators.**

NATURAL INSPIRATION

"We are inspired by the nature of animal muscles to generate motion," says Wang, who explains that insect muscles have relative high strength, robustness to stress, and great precision. His team was inspired by these attributes to design electrostatic actuators which are flexible, controllable, powerful and scalable. These use the electrostatic force between two oppositely charged electrodes to move a membrane.

The researchers are testing millimetre-scale electrostatic actuators, inspired by the spatial arrangement of insect muscles, to stand in for conventional electromagnetic actuators in soft robots. Similar to biological muscles, these actuators have a hierarchical structure made up of microscale electrodes, electrode arrays and millimetre stacked layers.

Because these are fully adjustable like real insect muscles, they can be designed for a wide range of manipulation and locomotion tasks, and are already finding uses in prototype, ultra-thin and flexible, climbing robots — such as an earthworm-like, micro-crawling robots, and peristalsis (gut movement)-inspired, micro-medical robots[1].

The earthworm-like robot can be used to capture images during search-and-rescue operations under buildings that have collapsed in natural disasters. It is thin and flexible enough to navigate narrow pipes just 5mm in diameter and is robust enough to avoid being damaged or crushed.

Surgical robots require compact actuators to allow them to be small enough to move around within the human body. Inspired by the smooth muscles of the intestine, the thin and flexible actuator attached to the distal end of a robotic endoscope can hold scalpels or syringes, for use in minimally invasive surgery.

ENHANCING PERFORMANCE

These prototype robots demonstrate the many potential applications of millimetre-sized electrostatic film actuators and pave the way for even more compact, lightweight, powerful and agile miniature robots.

Wang says his research is highly dependent on support from colleagues in other disciplines, such as physics and materials science. For example, to design flexible actuators on the millimetre scale, the team had to develop new, softer materials with properties resembling natural muscle tissue.

Looking ahead, Wang hopes that the electrostatic actuators will have as many potential applications as electromagnetic actuators, which are already widely used. Finding improvements in materials, design and controllability of electrostatic actuators will be key, he says. ■

REFERENCE

1. Wang, H., York, P., Chen, Y. et al. *Int. J. Robot. Res.* **40**, 895–922 (2021)

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