NTU Singapore unveils 5-in-1 magnetic surgical robot

News

Scientists in Singapore have developed a tiny robot that can navigate across soft and uneven surfaces to perform five surgical functions wirelessly.

Close-up of the 4.4 mm 5-in-1 soft surgical robot on a simulated soft tissue environment - *NTU Singapore*

In use, the 4.4mm long mobile robot is controlled by weak magnetic fields, can cut biological tissues, release drugs, grip and store tissue samples, or generate heat remotely at any one time. The team at NTU Singapore said it takes under a second to switch between these functions.

The work, led by Associate Professor Lum Guo Zhan at Nanyang Technological University, Singapore, is detailed in *Advanced Materials*.

Using magnetic coils in the laboratory to remotely control the robot, the team was able to make the robot deploy different tools and perform different functions, such as activating a blade to cut through tissue, or emitting heat to a targeted area, which could be relevant for approaches being studied that use heat for cancer treatment.

“Most magnetic robots like this can perform only one or two functions. Our latest invention can now do five, and our long-term goal is for doctors to use these mini robots in the body, navigate them to a targeted location, and use them to perform treatments,” Assoc Prof Lum said in a statement.

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Mini robots are being studied worldwide as a possible way to make minimally invasive surgical and medical procedures safer, less painful and more precise. Such devices could one day allow doctors to carry out targeted surgeries deep inside the body without large cuts or bulky surgical instruments.

The robot is made from soft magnetic materials, including PDMS and Ecoflex, which are silicone-based materials commonly used in soft robotics. These materials are embedded with magnetic microparticles measuring five micrometres each, allowing different parts of the robot to respond to magnetic fields.

At the centre of the device is a magnetic module that can be magnetised, demagnetised and remagnetised in different directions. Each magnetic orientation activates a different function of the robot, allowing the same mobile robot to perform five different functions.

The researchers engineered specific regions of the robot to respond independently to the same magnetic field, allowing one section to change shape and activate a function while the rest remains unchanged. At small scales, magnetic fields often affect the entire device at once, causing it to behave like a single magnet, with all parts reacting to a magnetic field, thereby limiting how precisely it can move or activate different tools.

Most miniature magnetic robots are also limited to five degrees of freedom, moving along three axes and rotating in two directions. The NTU robot can roll, which allows it to spin around its own long axis and provide finer control over how it can be positioned.

The NTU team tested the robot’s surgical functions using biological tissue models, including chicken liver, as well as gelatin-based materials that simulate soft tissue.

In laboratory tests, the robot cut through biological tissues, dispensing particles simulating drug particles, gripped and stored tissue samples, and generated localised heat after being induced by magnetic fields.

To produce heat, the researchers exposed the robot to a high-frequency alternating magnetic field. This caused magnetic materials inside the device to generate heat remotely, in an approach relevant to magnetic hyperthermia methods being explored in cancer treatment.

The team also evaluated the biocompatibility of the robot’s materials by exposing them to human skin cells under laboratory conditions. More than 99 per cent of the cells remained viable after exposure to the robot’s materials, similar to the control group, suggesting that the materials were largely non-toxic.

The team is now exploring how future versions could be combined with imaging technologies, sensing systems and clinically realistic artificial organ models that better mimic the physical behaviour of human tissues. Assoc Prof Lum is also working with surgeons to understand how mini robotic systems could eventually fit into real clinical workflows.