ROBOTICS

Motile microelectronics with wireless power

A tetherless microelectronic system can be controlled by wireless power to direct locomotion and perform grasp and release tasks.

Changhao Xu and Wei Gao

Robots are often designed and built for tasks that are monotonous or even dangerous for people, including routine manufacturing and space exploration. They are also of particular interest in precision surgery. Medical robots such as the da Vinci surgical system have opened up new capabilities in minimally invasive surgery, but existing systems are limited by their cost and demanding training procedures. They also struggle with hard-to-reach tissues[1]. Recently, micro- and nanorobots have been introduced to access deep tissues non-invasively and treat diseases at the cellular level[2–6]. Many of these microrobots have demonstrated potential for drug delivery and biosensing, but precise motion control and functional medical tasks demand on-board electronics for signal analysis, autonomous diagnosis and wireless communication, and integrating such capabilities remains challenging[7]. Writing in *Nature Electronics*, Feng Zhu, Oliver Schmidt and colleagues now report a microelectronic system with twin micro-engines that can achieve precise locomotion and actuation control assisted by on-board wireless energy[8].

The researchers — who are based at the Chemnitz University of Technology, Liebniz IFW Dresden and the Changchun Institute of Applied Chemistry — developed their autonomous microrobotic system by using shapeable polymeric nanomembranes as a platform to integrate the twin micro-tubular jet engines, as well as electronic units and robotic arms (Fig. 1a). The polymeric frame is mechanically robust yet deformable, and can recover its original geometry after severe mechanical deformations. The complete microrobotic system (which consists of a hydrogel layer, a polyimide layer, titanium heaters and platinum catalysts) is formed on a sacrificial layer. When released into an acidic solution, the sacrificial layer is selectively etched and the system is released from the substrate. The hydrogel layer swells and the strain mismatch between hydrogel and polyimide layers guides the curling of the platform and results in two tubular structures at the edges of overlapping

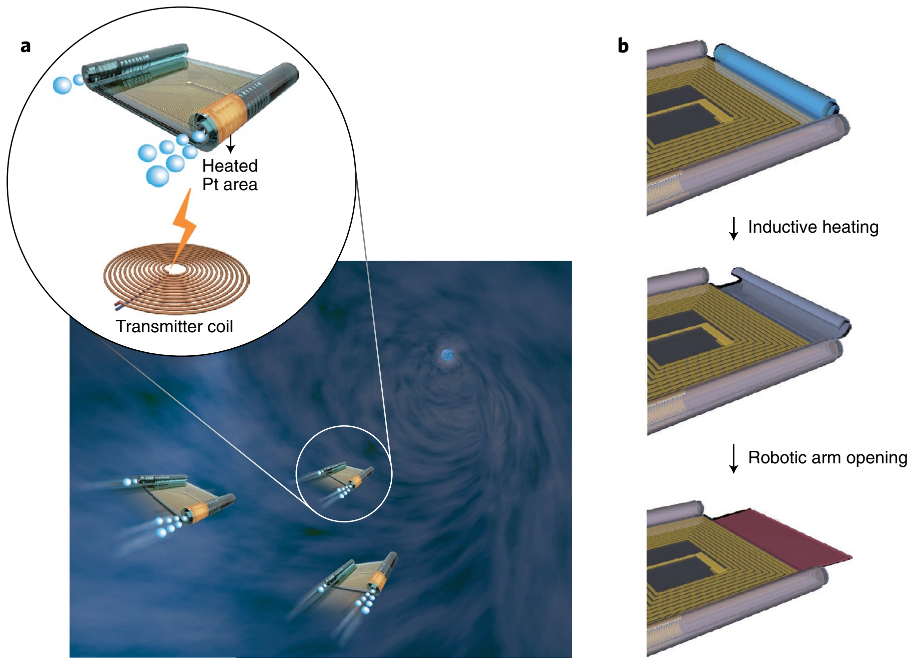

Fig. 1 | A motile microelectronic system with wireless power for locomotion and robotics control. **a**, The microelectronic system, which consists of twin tubular micro-engines, can achieve precise locomotion driven by wireless energy. **b**, A microrobotic arm composed of a thermoresponsive polymer layer that can swell and shrink depending on the local temperature and is controlled by inductive heating. Figure adapted with permission from ref. [8], Springer Nature Ltd.

planar layers. By patterning numerous microelectronic systems in parallel following the nanofabrication process, mass production can be obtained with a yield of 80% to 95%.

The propulsion of micro and nanoscale objects in low Reynolds number fluids (such as bacteria swimming in water) is challenging due to the dominance of viscous forces. Zhu, Schmidt and colleagues overcome this issue with their two catalytic tubular jet micro-engines, which are formed from the tubular structures of the system and are designed with thin catalytic platinum layers. When placed in a hydrogen peroxide (H_2O_2) fuel solution, the platinum catalyses the decomposition of H_2O_2 into water and oxygen, and jet propulsion of oxygen bubbles drives the microsystem forward. Compared with a single-tube configuration, the twin-engine microsystem provides adequate space to integrate more functional units and generates more stable and powerful propulsion.

In order to control the propulsion, heating wires and a receiving coil are integrated into one of the twin micro-catalytic engines. By inductive coupling and harvesting electromagnetic fields from surrounding transmitters, energy can be wirelessly transferred to heat up the resistive wires. Higher temperatures at the platinum catalytic reaction sites will lead to a faster decomposition rate of H_2O_2 and increased production of oxygen in one engine, so the microsystem can be made to change its direction of motion. Full bi-directional rotation can also be achieved by designing asymmetric micro-engines with varying platinum catalytic areas. In this case, the microsystem rotates into one direction in the absence of external power; when wireless power is applied, trajectories including moving straight and rotating in the opposite direction can be achieved.

The wireless energy transfer can also be used to power on-board electronic units. To illustrate the capabilities of this approach, Zhu, Schmidt and colleagues integrate an infrared light-emitting diode (LED) or a biodegradable polymeric robotic arm into this system. The LED can be wirelessly controlled by switching the remote power on and off. The thermoresponsive polymer component in the micro-arm has a similar tubular structure to the micro-engine, except that it can swell and shrink depending on the local temperature controlled by inductive heating (Fig. 1b). When the external magnetic field is switched on, the polymer layer shrinks and the robotic micro-arm opens. Shutting down the external transmitter will roll up the micro-arm back to the tubular shape. As an example of performing grasp and release tasks, a gold wire is captured and delivered by the micro-arm.

The demonstration of such a complex motile microelectronic system is impressive, but in order to deliver medical microrobotic systems various challenges will need to be addressed. The approach will, for example, need to be designed with enhanced wireless power density and integrated with additional functional electronic units for biosensing, imaging and actuation. To enter clinical trials, future biomedical microrobots will require efficient propulsion and precise motion control in the complex fluids in vivo, and to achieve practical biomedical applications, alternative propulsion mechanisms based on biofluids or external power sources, which can provide a substitute for the H_2O_2 fuel, will be key[6,9]. ❐

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