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World's first microscale 'transformer' robot

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Microrobots could perform medical procedures and serve as a non-invasive form of medical treatment. However, this would require an ability to change form-and-function to fit the need. Using shape transforming microbricks, we developed 'Transformer' Robots capable of morphing from racecar to humanoid robot.

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The live-action Transformers film series features Autobots, mechanical, modular robotic lifeforms that could change their bodies into various alternative modes such as weapons, vehicles or machinery, and help save our planet from alien threats. Inspired by this fantasy, scientists and engineers have been developing technologies to construct cell-sized, shape-changeable microtransformers for minimally invasive medicine.

These microrobots are expected to move through complex biological microenvironments, then transform into therapeutic modes when necessary. The ability to switch between different modes of functionality as needed allows a single robot to serve for multiple tasks such as targeted drug delivery, controllable drug loading and release, and localized blood clot removal. To effectively employ such tiny machines, we need to be able to control their 3D-to-3D shape transformations, which required sensors, actuators, mechanics, control algorithms and wireless communications to be embedded into their bodies. Currently, microrobots have the ability to fold up into different 3D shapes from the 2D Origami sheet, but are incapable of 3D-to-3D shape transformations.

Direct Laser Writing is a technique developed to print nearly any 3D shapes of microstructures. However, Direct Laser Writing only uses a single material to generate 3D structures, which are incapable of active shape transformation. To address this, we developed a 4D Direct Laser Writing technique, in which the intensity of the laser pulse can be changed. This allows us to print structures with different material properties, so we can manipulate the extent of shape transformation possible in different parts of the microrobots.

Our aim is to allow researchers to be able to create microbots to fit specific needs. For this purpose, this technique should offer maximum shape-transformation while minimizing the design complexity. To answer this need, the system is split into building blocks that are the smallest units capable of 3D-to-3D shape transformation in response to external stimuli. By assembling these tiny replicated building blocks, large and complex shape transformations can be constructed.

To demonstrate the capabilities of this new technique, we created to microscale 'transformer' microbot. Our microbot has a basic humanoid shape: neck, shoulder, arms, backbone, and legs, that are made up of hundreds of micro-building blocks with distinct design parameters. When sensing a change of pH value, the microtransformer changes its structure from humanoid-state to racecar-state. This change of shape can be used to "turn on" the microbot depending on its location in the body.

Our design method for 4D micro-printing technique will pave the way to create mircobots with different functions that can be activated in a precise manner. These intelligent micromachines will be considered for use in various biomedical applications.