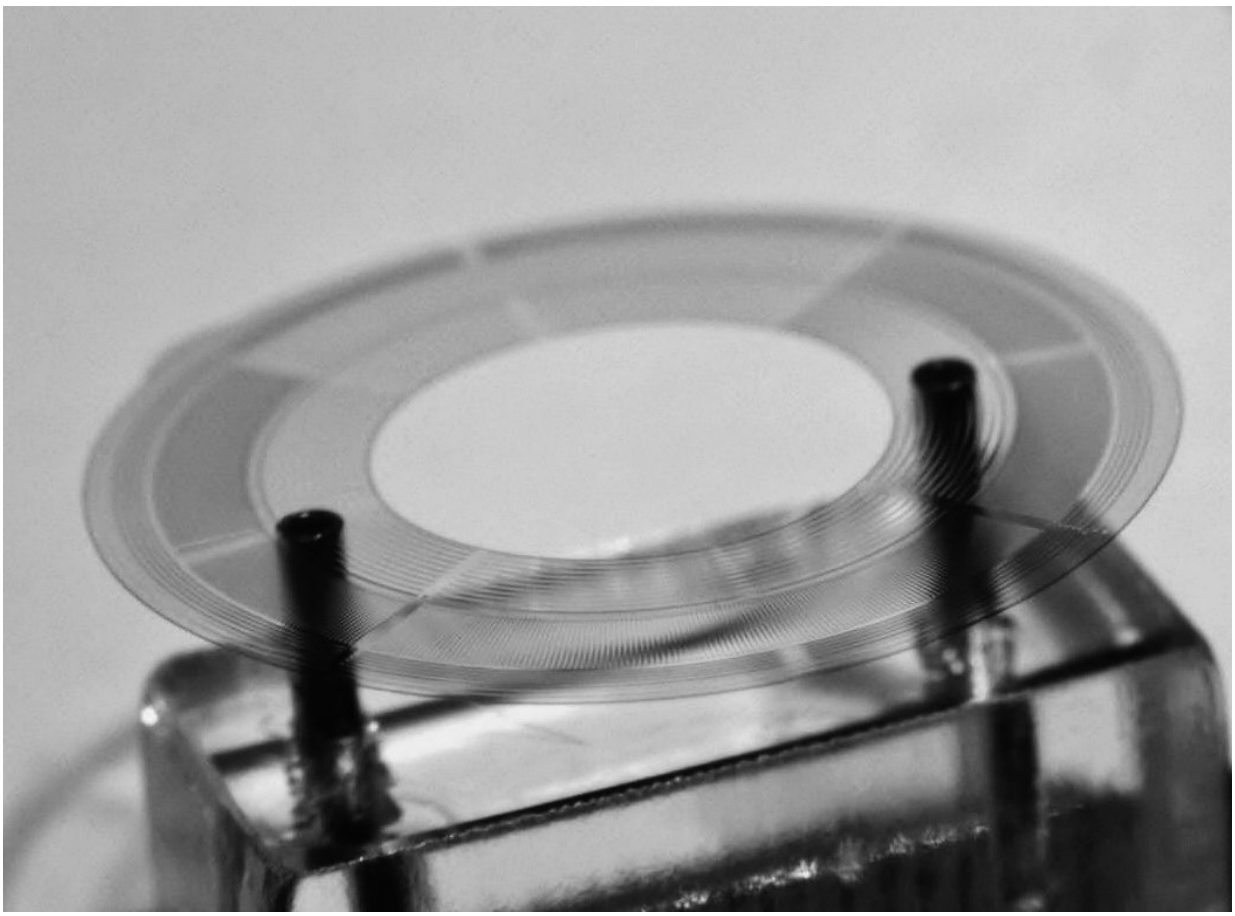
Evaluating linear and rotational microhydraulic actuators driven by electrowetting

October 2 2018, by Ingrid Fadelli



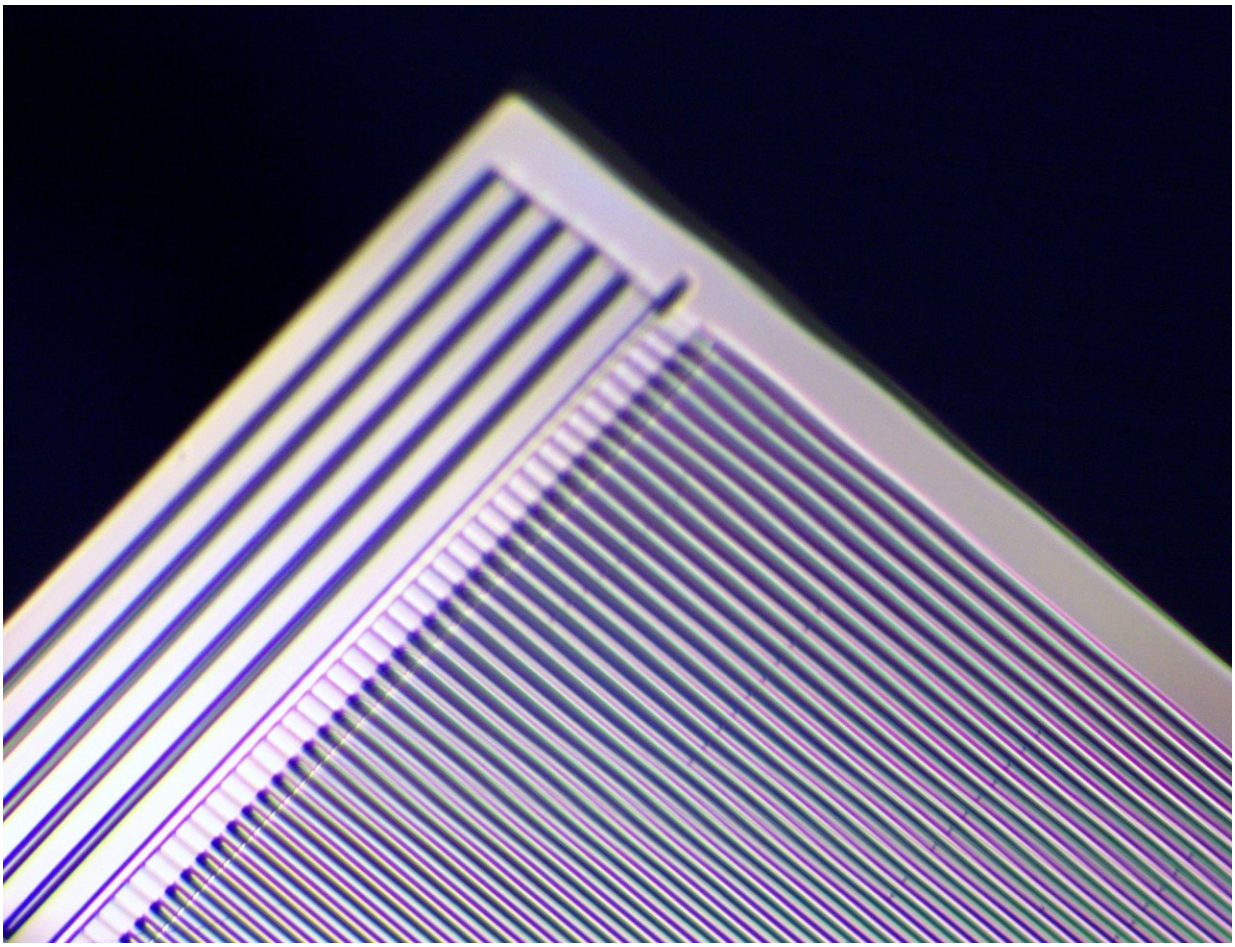
Credit: Jakub Kedzierski

Microhydraulic actuators are designed to convert electrical power into mechanical power on a microscale with more power density and higher efficiency. Essentially, these new actuators work by combining the surface tension force derived from a large number of droplets that are distorted by electrowetting electrodes.

In a study published in *Science Robotics*, two researchers at MIT have recently investigated the performance of microgram-scale linear and rotational microhydraulic actuators driven by electrowetting. This work is an evolution of their previous efforts, which explored new ways of converting electrical power to hydraulic power.

"We have been working on the electrowetting effect for a number of years, and were intrigued by the possibility of generating physical motion by designing a solid and fluid hybrid device based on electrowetting," Jakub Kedzierski, one of the researchers who carried out the study, told TechXplore. "After working through some different design iterations, we settled on this design."

The design of the microhydraulic actuators devised by Kedzierski and his colleague Eric Holihan is partly inspired by the structure of human muscle. In muscle fibers, small forces between actin and myosin molecules are added along long filaments to produce a large total force. "In a similar way, our actuators add relatively small surface tension forces produced by many electrowetting drops along a long sheet of polyimide to produce a much larger force," Kedzierski explained. "We call the actuators microhydraulic because, like in hydraulics, the force is initially produced in the fluid, and is then transferred to a solid component that can do work."



Credit: Jakub Kedzierski

The microhydraulic actuator consists of three main components: the electrode array, the fluidic layer of water droplets in oil and the solid droplet array. Drops are attached to the droplet array using etched hydrophilic regions. Through the process of electrowetting, these drops are pulled by electrodes into the electrode array.

Therefore, when the electrodes are cycled in sequence, the drops and droplet array move along with the traveling voltage waveform. The small individual force of each drop is thus amplified, as the hundreds of drops

in each droplet array contribute to a larger total force.

"Two layers are separated by a few microns of fluidic drops. These drops are attached to one layer and can be electrically pulled by electrodes on the other layer," Kedzierski explained. "This produces motion between the two layers, and as a bonus, provides permanent lubrication between them. The small surface tension force of each drop is amplified by having a large number of drops working in tandem."

The researchers evaluated the actuator by measuring the mechanical work it could perform and the electrical power required. They found that its maximum output power density was of 0.93 kilowatt/kilogram, which is similar to that of some of the best electric motors on the market. At maximum power, their actuator was 60 percent efficient, yet it reached efficiencies as high as 83 percent when the power was lower.

"There are a few reasons this technology is revolutionary," Kedzierski said. "First, it has the power density of motors, and a high energy conversion efficiency. Second, it works on a very small scale and improves as components are shrunk, while classical motors degrade quickly when shrunk below centimeter dimensions. Finally, it provides precise digital motion in a way that is similar to a stepper motor, a workhorse for many technological applications, including robotics."

More information: Jakub Kedzierski et al. Linear and rotational microhydraulic actuators driven by electrowetting, *Science Robotics* (2018). DOI: 10.1126/scirobotics.aat5643

Jakub Kedzierski et al. Microhydraulic Electrowetting Actuators, *Journal of Microelectromechanical Systems* (2016). DOI: 10.1109/JMEMS.2016.2521439