3D-Printable Artificial Muscles for UUV propulsion

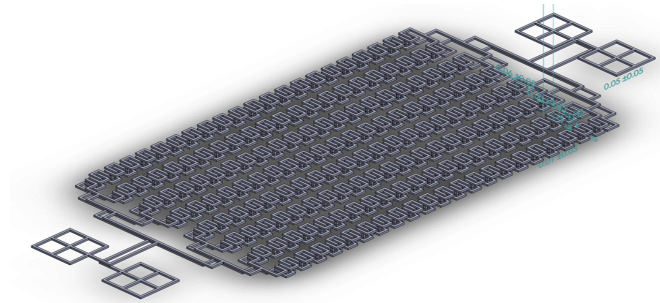
CRUSER Consortium for Robotics and Unmanned Systems Education and Research

Microfluidic Artificial Muscles. *(Left) A single fiber consists of a stack of micro-capacitors defined by microfluidic channels inside a polymer. The polymer serves as the dielectric (orange), while the electrodes are channels filled with conducting fluid or gel (blue and red). Applying voltage to the two electrodes would generate force contracting the fiber. Fibers would be arrayed in the two lateral directions to form a muscle fiber bundle that adds force. (Right) Geometry controls the direction of the generated force. Shown here is one geometry for a sphincter-like muscle, e.g. for peristaltic propulsion of UUVs.*

Background/Motivation. Traditional robotic actuation typically uses hydraulics or electrical motors. Hydraulics provide large forces but are bulky and difficult/expensive to maintain. Electrical motors are miniaturizable but provide little force when the scale shrinks. Neither are ideal for a plethora of applications, e.g. prosthetics, walking robots, and wearable exoskeletons. Artificial muscles offer a big promise for these applications. Furthermore, unmanned underwater vehicles demand acoustic stealth, which is difficult to achieve with propeller-based locomotion, as its cavitation gives the vehicle away. In contrast, a UUV traveling like a pelagic fish would avoid cavitation and thus be more difficult to detect. However, even then, the presence of electrical motors and other metal parts would produce a mechanical impedance mismatch, resulting in detection. Artificial muscles made of polymer with density close to that of water would produce significantly less reflected energy and ought to be acoustically translucent.

Deliverables:

- Proof of principle for the artificial muscles and microfluidic capacitor stack technique.
- Proof of feasibility through measurements of generated force as a function of voltage.



Approach and Methodology.

- Build microfluidic devices in PDMS (polydimethyl siloxane) using above design. It contains a bundle of 8 muscle fibers, each of which is a double helix of capacitor plates and microchannels. Fill channels with electrolyte and apply voltage. Observe deformation to calculate strain, stress, and output force. That would prove principle.
- Design and 3D-print devices in flexible resin, with 3D-arrayed bundles. Measure output force with a force gauge, as a function of voltage. That would prove practical feasibility for propulsion actuation.

Operational Impact. The development of the proposed artificial muscles would enable/improve critical applications:

- **Unmanned underwater vehicles** – stealthier, more efficient, lighter, faster
- **Unmanned walking vehicles** – lighter, more efficient, more agile, stealthier
- **Wearable exoskeletons** – lighter, more intuitive, more flexible
- **Armored exoskeletons** – more strength and protection, retain comparable agility, avoid physiological fatigue
- **Human prosthetics** – light, more intuitive, strong, more flexible, biomimetic

FY19 Call for Proposals

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