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Artificial muscles powered by microbes

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Abstract

The potential to make complete soft artificial organisms that digest organic matter and move under their own power will open up a wide range of previously improbable applications. These include self-sustaining robots that find and digest waste, devices that monitor the environment and implantable medical devices such as pumps and valves that require no external power source. An artificial organism requires an artificial stomach to convert raw chemical energy into some useable intermediate form and an artificial muscle actuated by this energy. Previously an artificial stomach has been developed in the form of a microbial fuel cell (MFC). In contrast to traditional chemical fuel cells which generate electrical energy from the combination of pure chemicals, the MFC contains a culture of live microbes that act as the biocatalyst which generates electricity through the process of digestion. This paper presents research on embodying the microbial fuel cell. That is, we attempt to merge the MFC with a soft active body. The first stage of this process is to identify potential artificial muscle technologies and characterize them with respect to the requirements and output of the MFC. The major limitation in this context is the speed of energy conversion at the microbe level and the consequent low power output of the fuel cell. Two contrasting artificial muscle technologies are investigated: high-voltage dielectric elastomer actuators (DEA) actuators and low voltage ionic polymer metal composites (IPMCs). We show how both of these technologies can be driven by the low power of the MFC and how each has its own advantages and disadvantages in this context. We study the ability of the fuel cell to generate useful actuation and consider appropriate configurations to maximally exploit both of these artificial muscle technologies. We examine the energy requirements of these electroactive polymers, the size of the actuators and discuss how useful energy may be scavenged during relaxation. A prototype artificial sphincter is implemented using a dielectric elastomer actuator and a cilia-like propulsion and fluid mixing mechanism is investigated using ionic polymer metal composite actuators. Actuation and fluid-flow results are presented. To the best of the authors' knowledge this is the first report on work to power artificial muscles using microbial fuel cells.