

Objectives:

My goal with this grant is to design, build and test a DE actuator to test its capabilities in terms of strength, repeatability, extreme temperatures, and humidity. Research will also include testing the range of electrical response of the actuator. A list of capabilities for the DE material has been provided by the University of British Columbia. Testing of this actuator will compare the values to see if a design can be made to test the limits and capabilities of the material.

A dielectric elastomer (DE) is a ribbon-like material that reacts to a voltage by compressing itself (See Figure 1). DE consists of three layers; a rubber-like material called an elastomer, sandwiched by two layers that are conductive or sensitive to voltage. When the conductive layers are provided a voltage the conductive layers become opposite in electric charge and become attracted to each other. This attraction causes the conductive layers to move closer to each other and compress the elastomer between them causing it to become thinner. When the DE is stacked multiple times and supplied a voltage, the stack contracts in an accordion-like fashion. When subjected to a pulling force perpendicular to the face of the stack, the attraction between the multiple conductive layers can be strong enough to resist the pulling force. This behavior of converting this force into motion makes the part an actuator like a muscle in a human arm.

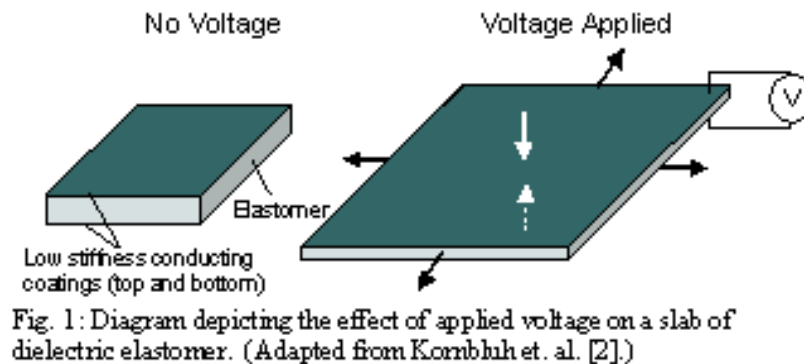
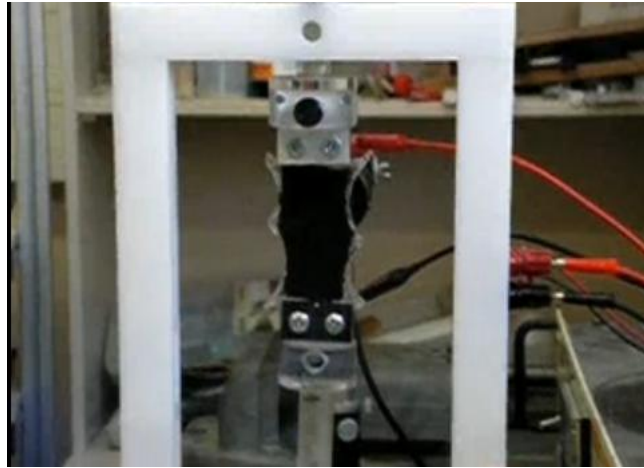


Figure 1: Image taken from University of British Columbia Department of Computer and Electrical engineering page.

An actuator of this nature has already been made. Professor Gal DeBotton has made such an actuator that is available to demonstration on his faculty webpage and Youtube (See Figure 2). The design of the actuator will follow his example because it will be the simplest and most efficient method of testing the actuator's strength when supplied a weight.

The tests are conducted to explore and experiment with the capabilities of this material. Understanding its limits is paramount for future research and manufacturing or designing with this material. The nature of each test will be thoroughly explained in the following section.



Importance:

This material gives robots the opportunity to evolve from rickety, brittle, cumbersome machines into dexterous, graceful, and more durable robots. Older robots suffer from a rigid shell that compromises mobility, spasmodic movements, and brittle materials that made a single crack dent compromising to the design. Having flexible parts allows the parts to rebound from impacts and adjust to given tasks given their flexibility. Right now at the Italian Institute of Technology, scientists are developing a robot designed after an octopus made completely out of DE actuators (Harmon). Harvard is also producing a flexible robot of a similar design that can also camouflage and walk over aggressive terrain (Harmon). NASA has a challenge to make a robot arm with flexible actuators to beat a human arm in arm wrestling to test the material's strength(NASA).This technology allows the robot to be flexible and have the range of motion of a real live octopus. This technology also allows robots to have an advantage in mobility that vertebrates in nature share. A hard frame with muscle-like DE actuators allows it to move gracefully and with greater dexterity and with the strength of having a solid structure.

This material has potential to replace pneumatic actuators in current robotics. Pneumatic actuators commonly seen in the form of pistons, hydraulics, or gas powered tools are complex in design with moving parts and considerable maintenance which create enormous opportunities for malfunction and failure. This DE actuator has no moving parts and is essentially a single flexible part. This material also poses a unique characteristic of being able to sustain force while being deformed. This material would ideally serve as an artificial muscle in prosthetics especially because it can be grafted into the required shape for the muscle needed. This would

also be very useful in creating flexible robots. Having flexible manipulators would allow robots to grip a wide variety of objects regardless of shape or orientation with a wide range of motion.

This research holds the potential of bringing the university into a particular league of universities that are researching cutting edge robotics. This technology and research would further engrave the university's reputation as a leading campus in reputable areas of research with other well-established universities. Funding for this research would make the University of Idaho a hotspot for extraordinary advances in technology and historical discoveries in what is possible for robotics.

This research will also allow me to pursue my long term goal to create a functioning octopus arm. An octopus arm has a wide range of motion and incredible dexterity. This research will help me begin to design the initial prototype for the arms and design a fiscally viable design as well as a shrewd and sturdy design. This research will help me continue to make the robot which will have a flexible shape allowing it to explore small areas and maneuver with ease in unorganized environments. This prototype would be ideal for the purpose of deep sea search and rescue as well as exploration. If the material is robust in terms of temperature tolerance, the prototype might be sturdy enough for space exploration where maneuverability is key to discovering new worlds.

This research would also make way for making prosthetic limbs with DE actuators for muscles. Future funding could also research if the electrical signals present in human nerve could actuate the DE parts. This research would be a historical in providing veterans of war with reasonable and useful prosthetic limbs that seemed only accessible through science fiction.

Methods:

The design will mimic a human bicep muscle as well as Professor De Botton's design. The actuator will consist of the DE material stacked to increase the range of contraction. The material chosen will be the amount of DE stacked will depend on the funding since the material must be purchased by quote and not off the shelf. Typical dimensions for the DE material are 100 mm in width which can be cut short accordingly to any design modifications. The actuator will have clamps on either end allowing it to hold onto a solid surface and carry a weight when testing its strength and other tests. The clamps will be designed from the machine shop in Gauss-Johnson so that the parts can be custom made to the design.

The mechanism's construction is elegantly simple and are capable of a large range of strain ranging from 10%-100% of its original length, some prototypes can stretch as far as 380%(Madden). The elastomer material chosen is 3M VHB 4910 acrylic which can be purchased for commercial use. The conductive layers are most usually a powder or thick resin which is

essential because thick conductive layers would limit the contraction range of the actuator. The best source of conductor layers would be magnesium power (Madden).

The first tests will be to examine the design's strength and electrical response. The typical voltage supplied to the actuator is around 10kV which produces a minimal current. A weight will be attached to the lower clamp of the actuator. The actuator will be allowed to stretch due to the weight and then the voltage will be turned on. Measurements will then be taken to determine the change in length or width of the actuator as it stretched or contracted. This set of tests will help establish the material's Modulus of Elasticity which explains how far the material will stretch with a certain amount of force.

The next set of tests for the research is to test repeatability. A material can be strong enough to use but if it breaks after 5 actuations or lifting a weight, and then clearly the material isn't very sturdy. What the next set of tests will do is repeatedly contract and release with a weight and observe if the actuator fatigues or breaks. How many trials it takes to fatigue or permanently deform from being pulled by the weight will help establish how strong the material is.

The next set of tests will be to determine its sensitivity to heat and cold. Now, according to the information provided by the University of British Columbia, the range of temperature for this material are between -10°C and 90°C (14°F - 194°F). The next set of tests will examine the integrity of the material after spending duration in an oven or freezer to analyze the material's response to extreme temperatures. Sensitivity to temperature will help determine the range of uses for this material because if it fractures in cold quickly but only slightly deforms to extreme heat, then this material would not be used for robots venturing in Antarctica.

The last set of tests will determine the material's reaction to humidity. The humidity tests will include performing strength tests in a controlled environment and changing the humidity over time to see if the voltage is disrupted due to the conductive properties of water and its likelihood to disrupt electrical equipment.

After all tests are conducted, the data gathered will be compared to the data shared by the University of British Columbia to see if the design created was stronger or weaker or if the data was comparable. Once data is gathered, findings on the material's strengths and weaknesses will make way for determining the capabilities of manufacturing this material for commercial use and for future research.

Timeline:

Jan-9-Feb1 Design Prototype

Feb 2-Feb 6 Build prototype

Feb 7-March 19 Conduct strength tests and gather data

March 20-April 3 Conduct temperature sensitivity tests and gather data

April 4-April 30 Gather data for final analysis

May 1-May 10; Engineering Expo

Publicize Design: Design will be shared at engineering expo to help attract potential sponsors and interest in the material and experiments. Hopefully, with more funding, more experiments can be conducted and more complex and sophisticated designs constructed to make more advanced robotic actuators.

Bibliography

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