<u>ELECTROACTIVE POLYMERS</u>

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ABSTRACT

Electroactive polymers have always intrigued the minds of many scientists and common people. This class of material can bear large strains up to 300% in response to an electric field and therefore has been an area of research. Due to such properties, these materials stand out as a substitute where all the other materials fail.

INTRODUCTION

The word Polymer has been derived from the Greek term poly-many and mer-parts. A polymer is a macromolecule or a large molecule consisting of several repeated sub-units. In simple terms, it can also be thought of as a problem that has got a recursive solution. There are two types of polymers mainly natural and synthetic. Both play a vital role in our lives due to their varied properties. Polymers are formed from the process of polymerization. Polymers can be found everywhere in your surroundings from plastic bottles to big containers. A small change in its structure can lead to a whole new range of properties.
Among these comes one more class of polymers which are the electroactive polymers. Electroactive Polymers(EAPs) change their shape, size, or volume in response to a strong electric field. These materials stand out in front of other materials mainly because of their high response speed, low density, improved resilience, etc. They are inexpensive, fracture tolerant, and compliant.
Muscles have been important for all life forms. It is because of muscles that we can convert the energy present in the body to generate motion. Due to this ability of muscles, they are also known as actuators, i.e. which transform energy from one type to another. There’s a lot of research and study going on muscles mainly because it is present in our body, surroundings, and they provide the optimum stability and controlled mechanical motion to the species. Different species have a little variation in their muscle structure but the main role is to provide stability. This functionality of muscle is a result of millions of years of evolution. This is the reason why scientists have been working on emulating these muscles.

The first-ever experiment was carried on a frog when it was observed that the frog muscles contracted when the nerves received an electric shock. This led to the conclusion that what moves our muscles are basically electric signals sent by the nerve cells.
All these series of experiments made scientists realise the importance of electrical simulation and the need to emulate the human muscles and so came in the idea of Electroactive Polymers(EAPs).

THEORY

Electroactive Polymers(EAPs) change their size in response to strong electric fields. The most desirable property of EAPs is the large response to a small input. The idea of EAPs was first demonstrated by Wilhelm Roentgen in 1880 by an experiment in which he took a rubber band with one end fixed and the other attached to a mass. When electric charges were sprayed on the rubber band, it changed its shape. EAPs have powerful actuation potential and many other properties of polymers like the ability to be formed into various shapes, improved resilience, etc.

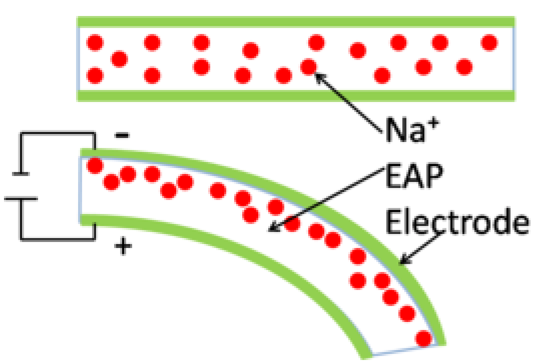
According to their working principle, they can be split into two categories :

1) Ionic EAPs
2) Electronic EAPs

Fig.1

IONIC ELECTROACTIVE POLYMERS

Fig.2



Ionic EAPs work when there's a displacement of ions which leads to a change in shape or its size. Since it involves the movement of ions only, voltage as low as 1-2V can be used to stimulate it but it needs to maintain its wetness throughout otherwise that will be an obstruction to the flow of ions. They've got strong bending capabilities and so are used as bending actuators. They have a slow response speed. Due to the situations which it demands for its working, they are not commercially viable and so are not produced in the market much. When the electric field is applied, it pulls the ions or pushes them into the region of the material which causes contraction. Although the voltage required is low but the resulting energy is very high because of the small spacing between the ions which results in greater potential energy.

ELECTRONIC ELECTROACTIVE POLYMERS

Electronic electroactive polymers(EAPs) are mainly driven by strong electric fields. Due to the strong electric fields, the electrostatic forces lead up to an electromechanical change in the EAPs. They are mostly used as planar actuators because of their large in-plane deformations.
In contrast to Ionic EAPs, these require voltage in the range of several kilovolts and have high activation voltage. Their response is pretty fast as compared to the Ionic EAPs.

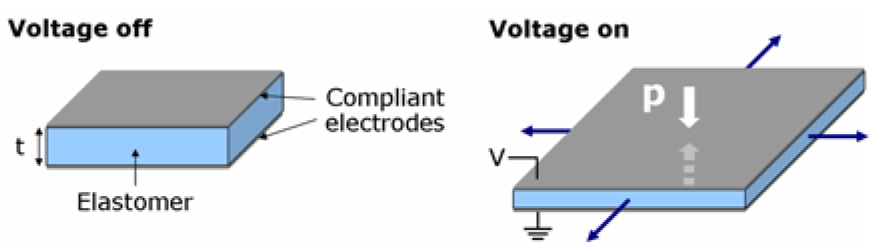


Fig.3

Among the electronic EAPs, soft dielectric EAPs or the direct elastomers(DE) are widely used and are also known as artificial muscles because of their strain bearing capacity of around 380%. They're readily available, thin, flexible, lightweight, etc.

When the two electrodes are set at different potentials, there develops a potential difference between them which leads to the movement of opposite charges from the electrodes towards each other in the direction of its thickness which squeezes the plane perpendicular to the plane of DE. Since the material is close to incompressible, it leads to a planar expansion. When the voltage is turned off the material gets back to its original shape. The main reason for such observations is because of the interaction of electric charges of the electrodes.

Usually, the expanding actuators perform work against the external pressure in the planar directions and these actuators are embraced by mechanical support as well. So when the actuator relaxes, i.e not performing work, then the mechanical support is removed which gives us the desired shape we want. Therefore, the shape of the mechanical support determines the final shape of the material when brought under the influence of an electric field.

APPLICATIONS

1) Biomimetic Robots: The purpose of studying this field is to improve prosthetics. Artificial limbs are being used everywhere. EAPs serve as the best material for the development of artificial limbs.
Artificial hand consists of a dielectric elastomer which executes both linear and bending movements simultaneously. Linear movement helps and moving the hand and bending movement helps the fingers to move and grab an object.

2) Linear Actuators: Spring roll is a type of linear actuator in which prestrained laminated elastomeric sheets are wrapped around a helical spring. When voltage is applied the elastomer sheets squeeze in the direction of thickness which then relaxes in length and extends the material. These rolls are used in automation because they’re able to produce large force while remaining small in size.

3)Push-Pull Actuators: These are basically spring rolls that are configured to work against each other. Transfer of voltage from one device to another can shift the position from back to forth. These resemble the functioning of a bicep and a tricep. Therefore, a potential application of these push-pull actuators is in the manufacturing of prosthetics.

4)Loudspeakers: Dielectric elastomers find a good place in the sound industry as well. These films can be stretched and placed over a frame. Electrical simulations can produce contraction and relaxation thereby producing bass and creating sound. These are light, inexpensive, and easily available.

5)Sensors: The change in the shape of these elastomeric films leads to a change in the capacitance of the material. If calibrated, this change in capacitance can be used to develop frame sensors. When the seatbelt is stretched and buckled, the stretching causes a change in the capacitance of the material thereby indicating the driver has put on the seat belt.

FUTURE APPLICATIONS

As inspired by the muscles, it is believed that artificial muscles developed from EAPs will replace their biological predecessors. It is also believed that they will be used to develop exoskeleton which provides support and protection to humans. Due to its lightweight and not involving any bulky materials such as motors, it would be an asset in the coming future especially for the elderly to provide them support and a good posture.

Another interesting application will be in the military. EAPs can be used to produce exoskeletons which can be used to create super soldiers. Due to high strain bearing capacity, these soldiers will be capable of running fast, carrying heavy ammunition, etc.

It is also believed that EAPs will be used to produce artificial limbs for handicapped people and they'll be able to control their limbs in a realistic manner.

EAPs can also be used in space applications. It was found that ionic EAPs will not be affected by the conditions present in the space and so are in use. EAPs which have been used for application in space are robotic arms, miniature rake, etc.

REFERENCES

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