# Benefits and Applications of Electroactive Polymer Actuators

By Colm O'Regan Jan 26 2017

*Image credit: Shutterstock / Unconventional*

**A polymer is a large molecule made up of repeating units (called monomers), linked together by a long chain. Due to their interesting properties, polymers are used in various applications, such as construction materials, automotive parts, plastics, and clothing.**

Electroactive polymers (EAPs) are a type of flexible, elastic polymer (elastomer) that change size or shape when stimulated by an electric field [1-2]. In other words, apply a voltage and they bend, contract or expand.

Generally speaking, EAPs are categorized by their mode of activation: electronic or ionic. Electronic EAPs include electrostrictive elastomers and dielectric electroactive polymers (DEAPs), while an example of an ionic EAP is the ionic polymer metal composite (IPMC).

In electronic EAPs, the electric field applies coulomb attractive forces to the electrodes. This causes the change in size and shape due to compressive forces. With ionic EAPs, the mobility and diffusion of ions changes the shape [3].

EAP materials are especially suitable in actuators – components used to move or control mechanisms. For instance, one exciting type of ionic EAP is the ionic polymer metal composite (IPMC) [3]. These are promising because low voltages can be used to get large bending strains. An electric field is applied to one side of the polymer membrane, forcing ions over to this side. The membrane swells on this side only, causing the actuator to bend.

As an example, these actuators could then be used to move the aileron of an aircraft's wing, causing it to turn [4].


*EAP actuators could be used to replace heavy parts in aircraft wings. Image credit: Shutterstock / GuoZhongHua*

## Materials and Construction of Electroactive Polymers

Unlike the electroactive polymers of the past, the examples today are strong, robust and efficient. This is thanks to the materials used to develop them, and the breakthroughs in manufacturing methods. For instance, the aforementioned IPMCs can generate significant forces at low voltages.

Early versions were slow however, and could only survive a few voltage cycles because chemical reactions broke down the polymer [5]. Advances in the field mean scientists and engineers can now make IPMCs with highly stable and conductive ionic liquid electrolytes, allowing ions to flow rapidly into robust fibers threaded through a hollow tube [5].

The materials and methods used to construct EAP actuators depend on the type of EAP in question. For IPMCs, two types of base polymer are generally used: Nafion®, such as that used by *Grau et al.*[4], and Flemion®. The polymer membrane is plated on both sides with either Pt or Au electrodes. These noble metals provide the best electrical conductivity and electrochemical stability [6], and so are ideal for many applications. The membrane contains water as the solvent, and $Na^+$ or $Li^+$ cations balanced by fixed anionic groups in the polymer [3].

Grau *et al.* also used shadow masks purchased from Ossilla and organic thin film transistor materials (lisicon®SP400 and lisicon®M001) from EMD Performance Materials Group. They used 1-Butyl-3-methylimidazolium tetrafluoroborate (BMI-BF4) as their ionic liquid. A complete description of their method can be seen in reference [4] below. A general method for fabricating EAP membranes is given in reference [7].

In contrast, a typical dielectric electroactive polymer (DEAP) – a type of electronic EAP - consists of a dielectric elastomer membrane placed between two electrodes. When an electric field is applied, the membrane compresses and stretches, causing the material to change shape [8].

## Benefits and Applications of EAPs

The benefits of IPMCs in particular are the large electromechanical bending at low voltages [9], and their soft, flexible structures. This allows them to mimic the motion of biological muscles, and be used in aqueous environments [10,11].

Typical benefits of DEAPs include low elastic stiffness and high dielectric constant, large deformations, large energy convention efficiencies, light weight and low noise [8].

Benefits can also vary depending on the materials and methods used, as well as the vendor. For instance, Parker Hannifin says their EAP technology offers several advantages when compared with traditional technology [12]. They quote ultralow power consumption, 10X additional battery life, silent operation and a stretchable polymer with up to 20% working strain for actuators.

On the other hand, Arkema develop specialty fluorinated EAPs (terpolymers), which have the ability to store large amounts of energy and boast larger changes in size or shape [13]. Various companies manufacture EAPs [1], so be sure to do your research before selecting a vendor.

The applications of EAP actuators are numerous. They've received considerable attention as soft biomimetic actuators in bioengineering applications like artificial muscles and active catheters.

Due to the stability of their electrodes (using the noble metals Pt or Au), they're also useful for underwater robotic applications and aquatic propulsors, where corrosion resistance and fast actuator response are important [3].

DEAP actuators have potential in acoustic applications such as sound generation, and noise and vibration control in loudspeakers [8].

## References

1. Electroactive Polymer Actuators and Sensors – Types, Applications, New Developments, Industry Structure and Global Markets, *Innovative Research and Products, Inc.* **2013**

2. Electroactive Polymers as Artificial Muscles – Reality and Challenges (2001), *Proceedings of the 42nd AIAA Structures, Structures Dynamics and Materials Conferences (SDM),* Gossamer Spacecraft Forum (GSF), held in Seattle WA, April 16-19

3. Nanothorn Electrodes for Ionic Polymer-Metal Composite Artificial Muscles, Palmre et al, *Scientific Reports,* **2014**, DOI:10.1038/srep06176

4. Printed Unmanned Aerial Vehicles Using Paper-Based Electroactive Polymer Actuators and Organic Ion Gel Transistors, Grau et al, *Microsystems & Nanoengineering*, **2016**, DOI:10.1038/micronano.2016.32

5. Electroactive Polymers: Artificial Muscles Made of Electroactive Polymers Impart Lifelike Movements to Biomedical and Robotic Devices, Gregory T. Huang, *MIT Technology Review*, **2002**

6. The State of Understanding of Ionic Polymer Metal Composite Architecture: A Review, Tiwari et al, *Smart Mater. Struct.* **2011**, DOI:10.1088/0964-1726/20/8/083001

7. Prep Procedure: Ion-Exchange Polymer Metal Composites (IPMC) Membranes, Keisuke Oguro, *Worldwide Electroactive Polymer (EAP) Webhub*

8. An Application Review of Dielectric Electroactive Polymer Actuators in Acoustics and Vibration Control, Zhao et al, *Journal of Physics*, **2016**, DOI:10.1088/1742-6596/744/1/012162

9. Recent Advances in Ionic Polymer–Metal Composite Actuators and Their Modeling and Applications, Jo et al, *Prog. Polym. Sci.* **2013**, DOI:10.1016/j.progpolymsci.2013.04.003

10. Biomimetics Using Electroactive Polymers (EAP) as Artificial Muscles - A Review, Bar-Cohen et al, *Adv. Mater.* **2006**, DOI:10.1007/978-90-481-9751-4_268

11. Biomimetic Jellyfish Robot Based on Ionic Polymer Metal Composite Actuators, Yeom et al, *Smart Mater. Struct.* **2009**, DOI:10.1088/0964-1726/18/8/085002

12. Electroactive Polymer (EAP) Technology: Energy Efficient, Lightweight, Quiet and Flexible, Parker Hannifin [PDF]

13. Arkema acquires the PIEZOTECH startup company and speeds up its development in the fluorinated materials of the future - Arkema News, **2010**