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Electroactive Polymer

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ABSTRACT

Few types of polymers can be excited by electric, chemical, pneumatic, optical, or magnetic field to change their shape or size. For convenience and practical actuation, using electrical excitation is the most attractive stimulation method and the related materials are known as electroactive polymers (EAP) and artificial muscles. One of the attractive applications that are considered for EAP materials is biologically inspired capabilities, i.e., biomimetics, and successes have been reported that previously were considered science fiction concepts. EAP materials exhibit the reverse effect of converting mechanical strain to electrical signal allowing using them as sensors and energy harvesters.

Keywords: Electroactive Polymer (EAP), Electrical excitation, energy harvesters, dielectric elastomers, sensing.

1.TYPES OF EAPS:

1.1. IONIC ELECTROACTIVE POLYMER:

1.1.1 Introduction to EAP:

The Ionic EAPs usually work at low voltage (less than 5 V for actuation). These EAPs are suitable for application in biological environment. When compared with other types of actuator technologies, the EAP actuators generate higher strain than electroactive ceramics and react faster than shape memory alloys [11]. Besides, EAPs are economically priced and can be fabricated into multiple shapes and are lightweight. with these features, EAPs find application in several applications. EAPs are also used to develop" artificial muscles" [14].

1.1.2 **Range of Application:**

I. Sensors based on Conducting Polymers:

The CPs or intrinsically conducting polymers (ICP) are organic polymers that are electronically conductive with comparatively high and reversible ion bank. The mechanism of both mechanical sensing and actuation are identical and mostly based on the insertion and expulsion of ions into and from the polymer structure—the structure being ionically as well as electronically better conductive. Basis external stimuli and the related output, this type of material can be used as actuator or sensor flawlessly.

In this process the mechanically induced charge is converted proportionately to electrical energy which is proportional to the intensity of the applied load and the dimensional change of the film. The efficiency of this conversion was estimated as less than 0.01%, and the induced voltage at few microvolts. CPs' ability to measure relatively high strains and their low mechanical impedance (Young's modulus) makes this kind of sensor potentially very useful for various applications such as instrumentation to detect strain and force and tensile strain can be measured by a free-standing film of CP [6].

Elasticity, high thermos resistivity and piezo resistivity of the PPy conducting polymer have attracted some researchers to use it in usable e-textiles in biomedicine and usable electronics. Examples includes deposition of a thin layer of PPy on a Lycra/cotton fabric to make a sensitive glove, and coating elastomeric fabric to make smart knee sleeve to provide feedback on knee flexion angle [9].

Gas or chemical sensors are also interesting application for CPs, as the absorption of gas molecules leads to a change of electrical conductivity in the polymer matrix.

II Sensors based on Ionic Polymer–Metal Composites:

IPMC is established in a trilayer fashion with the metallic electrode attached at the top and bottom of an ionic polymer layer. Ionic polymers are considered as polyelectrolytes, formed by a fixed, covalently bounded network of immobile ionic repeated charge units (hydrophilic). These are covalently bounded to these repeated units which are grafted onto a network of a non-ionic polymer (hydrophobic). The hydrophilic, microstructure network creates porosity, improving the charge transport of oppositely charged mobile counter-ions when swollen in the presence of diluent acidity, or the ion exchange capacity (IEC), of which the ionic polymer membrane shows the capacity for the counter-ions storage, the ion conductivity of the ionic polymer indicates ion mobility across membrane. IEC and ionic conductivity are the major characteristics of ionic polymers as sensors and actuators. Both depend on the structure of the membrane. Metals that have been used successfully as electrodes are platinum, copper, silver, palladium and gold [13].

III Sensors based on Carbon Nanotubes:

Application of voltage to carbon nanotube electrodes immersed in an electrolyte result in charge to the electrodes which is balanced by the counter-ions from the electrolyte. Insertion/expulsion of ions from the carbon nanotubes can generate positive and negative strain which enables carbon nanotube electrodes to work as an actuator. Doping carbon nanotubes with some molecules produces a potential difference or change in the electrical conductivity. So, charged CNTs in the form of yarns can generate voltage when tensile stress of up to several hundred megapascals is applied [8].

2.2. Electronic Electroactive Polymer:

2.2.1 **Introduction:**

Unlike other ionic EAPs, electronic EAPs are free from any electrolyte medium. Ion migration is not required for the electromechanical coupling. Therefore, electronic EAPs require a shorter period for response or relaxation than ionic EAPs: this can be less than 1 ms making electronic EAPs work at higher frequencies than ionic EAPs for dynamic sensing.

2.2.2 **Categories:**

I. Sensors based on Dielectric Elastomer:

Dielectric elastomer (DE) sensor is type of strain sensor that detects the change in capacitance .DE sensors are based on a system with two compliant electrodes with an intermediate dielectric layer (formed using a long chain polymer with suitable electric permittivity and film thickness). Among the electric EAP materials, the dielectric elastomer (DE) is one of the most promising and with outstanding properties.

II. Sensors based on Liquid-Crystal Polymers:

Liquid-crystal (LC) 'phases' are intermediate phases between the crystalline state (in which the molecules are spatially fixed into very ordered arrangement) and the liquid state. Molecules that form LC phases are usually long, rigid rods with anisotropy present at molecular level gives LC phases their unusual behavior. While the LC material is partially disordered so it retains the ability to flow, it can also display crystal-like optical properties for example birefringence.

III Sensors based on Piezoelectric Polymers:

The atomic structure of piezoelectric polymer material is the most significant factor in understanding the sensing mechanism of piezoelectric polymer tactile sensors. Most of the well-known piezoelectric materials are inorganic due to their high piezoelectric strain constant. Example of piezoelectric polymer is polyvinylidene fluoride-trifluoroethylene (P(VDF-TrFE)).

2.3. Various Application are as follows:

Miniature robotic arms, android heads that could mimic facial expression is one of the industrial applications.
Robotic swimming fish: This remotely controlled stealthy, noiseless, biomimetic swimming robotic fish made with IPMC's can be used for naval application [7].
Artificial smooth muscles actuator: by arranging IPMC material segments, we can provide skeletal joint mobility [10].
It can also be used for correction of refractive errors of the human eyes and bionic eyes and vision.

Surgical tool- The IPMC actuator can be adopted for use as a guide wire or a micro-catheter in biomedical application for intra-cavity endoscopic surgery [

3.1 Properties of Ionic Electroactive Polymer:

Table 1: Properties of Ionic Electroactive Polymer [1]-[15].

Types of EAPs	Typical stimuli sense	Typical sensing range	Typical working frequency or response time	Typical signal readout	Notes
Conducting Polymers	Forced or displacement	Up to few percent strain	0.1-100 HZ	-1MPa stress produces 20-60 µv and 200-600 Cm^{-3} for 1% strain ->100 Mv change in conductance-a few microampere-0.180 Mv (3% strain)	Potential drift due to environment changes. CPs are used in both free standing and trilayer configuration.
	Gas molecules	<10 ppm	Few seconds		
Ionic Polymer metal composite	Displacement (strain)	Upto 10% in strain	Microsecond to seconds or up to hundreds of Hertz	Approximately 100 mV (200 N load)	Potential drift due to environment Changes
Carbon nanotubes	Force	Up to several hundred MPa	Milliseconds	~ 75 nA (200 Mpa load)	Generally, displays sharp current peaks
	Gas molecules	~0.01 ppm	2-10 s	Few microsecond (NH3 detection)	Generally, displays high Sensitivity

3.2 Properties of Electronic Electroactive Polymer:

Table 2: Properties of Electronic Electroactive Polymer [1]-[15].

Types of EAPs	Typical stimuli sensed	Typical sensing range	Typical working frequency/ response time	Typical signal readout	Notes
Dielectric Elastomers	Strain	Strain: 300%	<50 Hz (Potential higher sensing frequency than the current value)	0-300 Nf 10-40 mV	Used mainly for sensing mechanical strain, commercially established. Only a few studies have been reported so far.
	compression	Compression strain >0.6	~ 10 Hz		
Liquid Crystal Elastomers	Bending	Displacement of a few millimeter	0.3-9 Hz	-1 ~ 50nC m	
Piezoelectric Polymers	Pressure	<150 MPa	9 Hz 0.001-10	-1 ~0.013 V N	Signal attenuated when measuring static force
	Heat	20-180 C	n. a	~ 8V/^{O}K	n. a

4. CONCLUSION:

Using EAP materials as actuators of manipulation, mobility, robotic devices which involves multidisciplinary efforts for latest materials, chemistry, computers, electromechanics and electronics. Although the actuation force of the existing materials requires further improvement, there has already been success in the development of mechanisms that are driven by EAP actuators. However, looking at EAP getting replaced by existing actuators in commercial devices and engineering mechanisms, requires identifying applications where EAP materials would not need to compete with existing technologies. We find it encouraging to see the growing number of researchers and engineers who are pursuing career in EAP-related careers. Certainly, the growth in the research and development activity will lead to making these materials becoming the actuators of choice.

5. Scope in Future:

EAPs will face some challenges to all before wide-scale deployment becomes a possibility:

EAPs have the potential to be produced in various forms ranging from fibres, to films, to fabrics and strips. EAPs also find development in the field of MEM technology. For sensory applications, the continued implantation of sensor devices based on EAPs can improvise ease of manufacture, mechanical flexibility, and quality of signal output. The sensors for practical use must reach operational parameters reliably to make it successful. Standards for both research purpose and mass- production are yet to be achieved: this is probably due to the diversity of EAPs. There are many variables to consider, such as geometries, chemical compositions of materials, fabrication procedures and electromechanical coupling properties.

Maintaining the sensor specifications with appropriate packaging methods and materials is a major challenge (particularly for ionic EAPs, as most of them need to work in moist conditions). Prospective approaches for packaging or sealing the EAPs to prevent or retard degeneration are still in development and have yet to meet industrial needs.

Methods for transportation of sensory information from sensors to other recipients are yet to be developed, particularly for biomedical applications. Recent attempts are being made to develop EAPs that are compatible with neuron interfaces. There is expectation that the neuron system can be used for communicating sensory information from EAP-based sensors.

Nonetheless, EAPs are attractive materials that will play a dominant role in sensor-related technologies in the future. It is doubtless that inspiring stories about research and commercialization related to EAP sensors will persist.

REFERENCES:

1)Yoseph Bar-Cohen; A. Anderson , *Electroactive polymer (EAP) actuators—background review*,2019.
2)Chengyun Ning Zhengnan Zhou; Guoxin Tan; Ye Zhu; Chuanbin Mao, *Electroactive polymers for tissue regeneration: Developments and perspectives* , 2018, 81, 144-162.
3)Komal Powar; Prasad Vengurlekar, application of electroactive polymer in electronics and mechatronics,2018,9,31-35
4)Mahmood Jabareen , *On the modeling of electromechanical coupling in electroactive polymers using the mixed finite element formulation*, 2015, 12, 105-115.
5)Yousef Bahramzadeh; Mohsen Shahinpoor , *A Review of Ionic Polymeric Soft Actuators and Sensors: Yousef Bahramzadeh*, 2014, 1, 39-50.
6)Aaron David Price; Hani E Naguib; Foued Ben Amara, *Electroactive polymer actuators for active optical components*, 2014, 18, 2556–2564.
7)C Jean-Mistral; S Basrour; J-J Chaillout, *Comparison of electroactive polymers for energy scavenging applications*, 2010, 19,1-14.
8)Kannan Balasubramanian; Marko Burghard . *Biosensors based on carbon nanotubes* , 2006, 385, 452-468.
9)Federico Carpi; Danilo De Rossi , *Electroactive Polymer-Based Devices for e-Textiles in Biomedicine*, 2005, 9, 295-305.
10)Andres Punning; Mart Anto; Maarja Kruusmaa; Alvo Aabloo, *A Biologically Inspired Ray-like Underwater Robot with Electroactive Polymer Pectoral Fins*,2004.
11)Y. BarCohen; S. Lea, M. Shahinpoor; j Haffison ; J. Smith, *Electro-Active Polymer (EAP) actuators for planetary applications* , 1999, 3669,57-62.
12)K.G. Neoh; K.K. Tan; P.L. Goh; S.W. Huang; E.T. Kang; K.L. Tan, *Electroactive polymer– SiO2 nanocomposites for metal uptake* , 1999, 887-893.
13)Amid Keshavarzi; Mohsen Shahinpoor; Kwang J. Kim; Jeffrey Lantz , *Blood pressure, pulse rate, and rhythm measurement using ionic polymer-metal composites sensors* , 1999, 3669, 369-378.
14)R.H. Baughman , *Conducting polymer artificial muscles*, 1996, 78, 339-353.
15)P.J.RILEY; G.G.WALLACE , *Intelligent Chemical Systems Based on Conductive Electroactive Polymers* ,1991, 2,228-238.