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ELECTROACTIVE POLYMERS AS ARTIFICIAL MUSCLE IN BIOMEDICAL ENGINEERING: A REVIEW

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ABSTRACT

In the past few decades, with the paced technological advancement, a number of smart polymers have been developed. These polymers have replaced the conventional materials such as metals and alloys. An electroactive polymer is a polymer that exhibit change in shape or size by application of electrical stimulation. This EAP polymer emerged as a new class of actuation material. These polymers offer advantages over traditional polymers due to some specific properties such as large strain, low density, light weight, high power to weight ratio, easy to process, and mechanical flexibility. Due to these inherent properties, EAP polymers have wide areas of applications in sensors and actuators. The behavior and the properties of these polymers resembles to the natural muscles, so these polymers are also known as Artificial Muscles. An Artificial muscle is a materials or device that exhibits a change in shape and size within a component or device and behaves like a biological muscle. In recent years, EAP polymers are frequently being used as artificial muscles in biorobotic and biomedical field. The aims of this paper to provide a comprehensive review of EAP polymers as artificial muscle in biomedical engineering that can be useful in treatment and surgery in future due to increasing demand of technology and advancement. This paper presents a detailed review of EAP polymers in the biomedical engineering.

Keywords: An Artificial Muscle, Biomedical Engineering, EAP Polymer, Natural (Biological) Muscle, Sensors and Actuators

I INTRODUCTION

An artificial muscle technology is the new technology. In the past few years, this technology attracted more attention of scientists and engineers in the fields of biomedical and biorobotic. There are some new smart materials such as Electroactive polymer are emerged as artificial muscle due to some inherent properties and behavior like to biological muscle. The beginning of EAP is remarkable since 1990, a new series of EAP polymers are developed that can produce a large strain leading to great change in view of these materials [1]. EAP polymers provide the largest displacement among the all types of polymers such as chemically activated, magnetically activated, thermally activated polymers, Inflatable structures and Light activated polymers. EAP polymers are the class of electrically activated polymers [2]. There are many problem are face by a human in daily life to live longer such as health. Due to some accidental reasons or disease,there is a need of availability of organs transplant but in shortage of donations,one alternative to solve this problem is the development of artificially. Growing technology of EAP polymer can be useful to solve this problem that can improve the human life better again [3].Additional to these EAP polymers can also be used in biomedical engineering for surgical instruments and apparatus due to, these can be designed in various shapes and sizes.

II CLASSIFICATIONS OF EAP POLYMERS

There are many types of EAP polymers. They are classified according to their actuation mechanism.

2.1 Electronic EAP

The electronic EAP is actuated by an electric field. This class of EAP is able to generatehuge displacement and hold its displacement when actuated under DC electric field.These electronic EAPs have high electromagnetic coupling coefficients and are capableof high work densities 100 times that of natural muscle [4].However, high electric field is needed for actuation,approximately 10 MV/m, so high voltage had to be used, generally >1kV.Theelectronic EAP also known as field activated. They produce linear relationship between electric field and generated strain [5]. The primary advantage of electronic EAPs is the possibility of achieving highactuation strains and stresses, fast response and long lifetime. A potential drawback is that electronic actuators currently require high driving electric fields (up to the order of 100 V mm^{-1}) due to the electrostatic nature of their activation mechanisms [6].

2.2 Ionic EAP

The mechanism of activation of these materials involves transport or diffusion of ions.These materials consist of two electrodes and electrolyte. The primary advantage of ionic EAPs is represented by their inherent responsiveness to extremely low driving voltages. However, their disadvantages are the need to maintain electrolytes wetness, having a relatively low efficiency in the range of ~1%, and they have difficulty sustaining constant displacement under activation of a DC voltage (except for conductive polymers). The diffusion or macroscopic motion of ions is responsible for the actuation slow speed of these materials that is the range of tens to a fraction of a second [5]

These Electronic and Ionic EAP polymers are further classified as shown in Table 1.

Table1. Different types of EAP Polymers [7].

Electronic EAP Polymers	Ionic EAP Polymers
Ferroelectric Polymers	Ionic Polymer Gels (IPG)
Dielectric EAP	Ionic Polymer-Metal Composite (IPMC)
Electrostrictive Graft polymers	Conducting Polymers
Electrostrictive Paper	Carbon Nanotube (CNT)
Electro viscoelastic Elastomers	
Liquid Crystal Elastomers	

III COMPARISON OF EAP POLYMERS WITH NATURAL (BIOLOGICAL) MUSCLE

Nature has developed a number of types of actuators. One of the first and smallest is arotary actuator probably developed about 3,500 million years (Myr) ago which provides some bacteria with a rotating flagellum to enable them to propel themselves about in liquid environments. Natural Muscles generally made of proteins [8]. Natural muscles have self-repair capability providing billions of work cycles with more than 20% of contractions, contraction speed of 50% per second, stresses of ~0.35 MPa, and adjustable strength and stiffness [9]. Although natural muscle and artificial muscle are same in design but significant differences in their performances such as force, rest time and contraction velocity. Here a table is provided for comparison between natural muscle and EAP polymers.

Table 2. Comparison between natural muscle and EAP polymer [10].

Properties	Natural muscle	EAP Polymer
Actuation Strain [%]	20% max (40%)	>300%
Force [Mpa]	0.1	25
Reaction Speed	Msec	µsec to min
Density [kg/m^3]	1037	960-1100
Power to Mass [W/kg]	50 max(200)	Up to 3500
Drive Voltage		Ionic EAP 1-7V Electronic EAP 10-150V/µm
Consumed Power		milli Watts
Fracture Toughness	High and can self-repair	Resilient, Elastic

IV EAP POLYMERS AS ARTIFICIAL MUSCLE IN BIOMEDICAL ENGINEERING

Using EAP materials as artificial muscles of artificial organs and limbs is involved with significantchallenges such as functional compatibility, rejection avoidance, and ability to meet the stringent requirements that are associated with the use of these materials on or in humans. However, it fulfills the all the requirements of human which is suffer from abnormality. It will help to get the better human life by improving the performance of human. Here some applications are presented of EAP polymers as artificial muscles in biomedical engineering that can change the view of EAP polymers in biomedical fields and advances in EAP polymers can change a better life to human in future.

4.1 Braille Display

Braille is a read and writes mechanism for vision-impaired people by touching raiseddots with fingers. Vision-impaired peopletend to have more difficulties in recent years with the prevailing introduction ofliquid-crystal displays for touch panels. AIST (National Institute of Advanced Industrial Science and Technology),Tokyo Univ. and Keio Univ. [2009-2010] developed a ultra-thin, ultra-light Braille display for vision-impairedpeople by using ionic EAP actuators with Nano-carbon electrodes, which have thin,light and low-voltage properties. A brail display structure is shown in Fig. 1. [11].

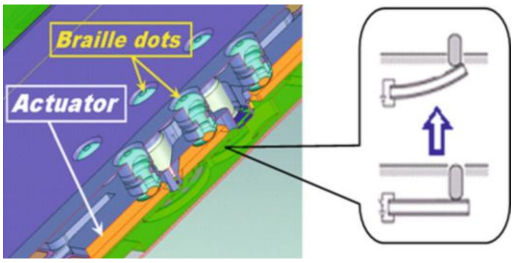

Fig.1. Brail display structure and its motion [11].

4.2 Cardiac-Assist Device

An EAP polymer based artificial ventricular assist type or cardiac assist muscle as shown in Fig. 2. has been developed for patients with heart abnormalities associated cardiac muscle functions. It is a compression device that can be implanted external to the heart without interfere the internal blood circulation. This device provides soft compression of the left ventricular of a weak heart to produce more internal pressure and to pump more blood from one or more sides in synchrony with natural systolic contraction of the ventricle. It also provides arrhythmia control of the beating heart [12].

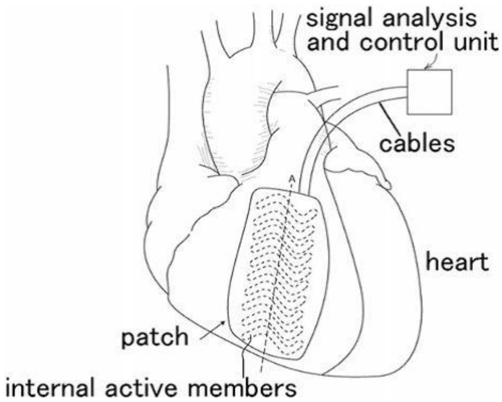

Fig. 2 Electroactive polymer based patches for cardiac assist device[12].

4.3. Correction of Refractive Error of the Human eye

An IPMC polymer based artificial muscle as shown in Fig. 3 has been developed for dynamic and static surgical corrections of the refractive error in the eye. This muscle equipped with scleral band which iscontrol by a computer. The scleral band is an encircling band around the middle of the eye globe and provides relief of intraretinal traction forces in cases of detachment or buckle surgery. It can also induce myopia. Depending upon, how much tension is placed on the buckle by increasing the length of the eye globe in the direction of optical axis and changing the corneal curvature [12].

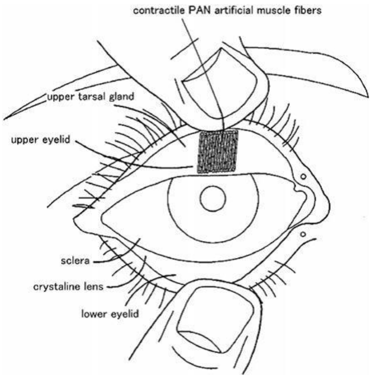

Fig. 3 Refractive error correction of an eye [12].

4.4. Cochlear Implants

The use of conjugate polymers muscle in cochlear implants is being studied by intelligent polymer research institute. The cochlear implants device is a multi-channelarray of electrodes that is brought into contact with hearing nerves and electrically stimulates. These nerves restore hearing in deaf people [13].

4.5 Surgical Tool

An ionic EAP polymer can be adopted as a guide wire or a micro catheter for endoscopic surgery and diagnostics [12].

4.6 Artificial sphincter

Boston Scientific Scimed, Inc. had developed an electroactive polymer based artificial sphincters and artificial muscle patches as shown in Fig. 4. The artificial urethral sphincter treats patients with incontinence that arises from malfunctionof the patient's urethral sphincter or anal canal. The artificial sphincter comprises a cuff that comprises one or more electroactive polymer actuators and placedaround a body lumen, and a control unit that expand or contract the cuff [14].

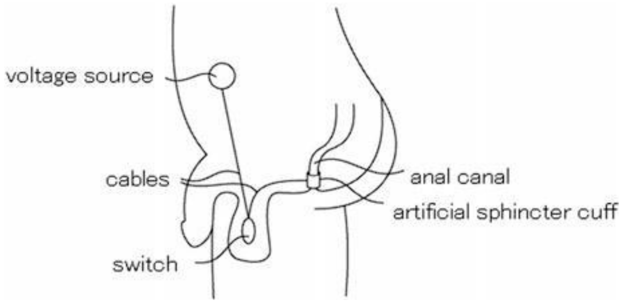

Fig. 4 Electroactive Polymer Based Artificial Sphincters [14].

4.7 Catheter device

One of the earliest medical applications of polymer actuators is a catheter driving ion polymer metal compound (IPMC). National Institute of Advanced Industrial and Science and Technology (AIST) has developed a catheter bending mechanism by attaching a pair of IPMC membrane muscles onto a catheter enabling 4 directional bending motions by applying voltage on the membranes. Conventionally, catheters are directed by a twisting motion at the hand of a doctor to place it at a precise location guiding it to the correct branching blood vessels under fluoroscopy. By using IPMC actuator, quick and precise operations can be achieved by bending them to a desired direction [14].

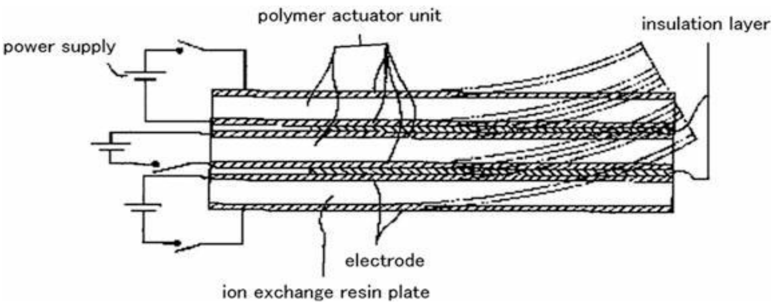

Fig. 5 Catheter device that changes the bending direction arbitrarily by IPMC[14].

V CONCLUSION

In the past several years, we have witnessed significant advances in stimulus-activepolymers. They can change their shapes (configuration or dimension) or produce mechanical power in response to heat, light, electricity, magnetic field, and water/solvent. In the recent years these materials are used as artificial muscle. EAP polymers based artificial muscle giving new innovations in the field of biorobotic and biomedical. Due to increasing demand of technology these materials are widely using in these fields due to their inherent properties resembles to natural muscle. Thus new development in the EAP polymer can change the view of these materials in biomedical field and will give better and live longer human life in future.

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