Electroactive polymer composites and applications

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1 Introduction

In recent decades, polymers have emerged as one of the most remarkable materials in biomedical applications because of their high biocompatibility and degradation. An alternative specific feature of polymers is their flexibility and functionalities, allowing their growth from bioactive hydrogels to recyclable polymers. It also includes a wide range of manufacturing techniques, such as electro-spinning, 3D printing, extrusion, casting, and microfluidity. By reinforcing nanoparticles into a polymer matrix, novel nanocomposites can be developed to extend their functionalities and range of properties of polymers.

Due to that, polymer composites are studied widely today for applications such as drug delivery, tissue engineering, and wound healing. In this background, electroactive smart polymer materials are developed due to their ability to transfer electrons under a specific electric field leads to offer more applications in various engineering fields such as sensors and robots. The merits of using electric field as an external stimulus, compared to others, which allow to precise control in terms of the duration of electric pulses, the current magnitude, and intervals between pulses. However, compared to other smart polymer systems, electroactive smart polymers have been less studied for aerospace, biomedical, space, and automotive applications.

Recently, investigators have attracted due to the electro mechanical properties of electroactive polymers. Since, the merits of this type of actuators are not only utilized for actuation, lightweight, and easy fabrication, but some dielectric polymers could offer larger rate of strain. This strain rate is particularly used for medical applications like micro values and pumps.

Fig. 8.1 shows the plot of maximum strain rate for the respective maximum applied electric field. The reducing and convergence of the strain rate could be demonstrated clearly.

Fig. 8.2 shows the biomedical applications of the potential electroactive polymer. This acts as a new development of smart systems capable to respond to the electric

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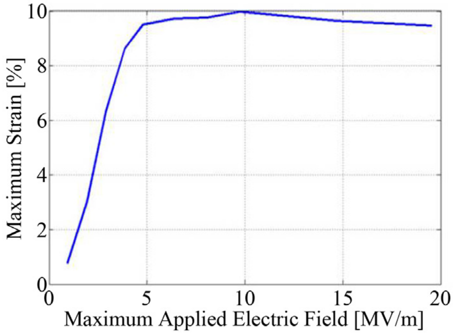

Figure 8.1 Maximum strain rate versus maximum applied electric field [1].

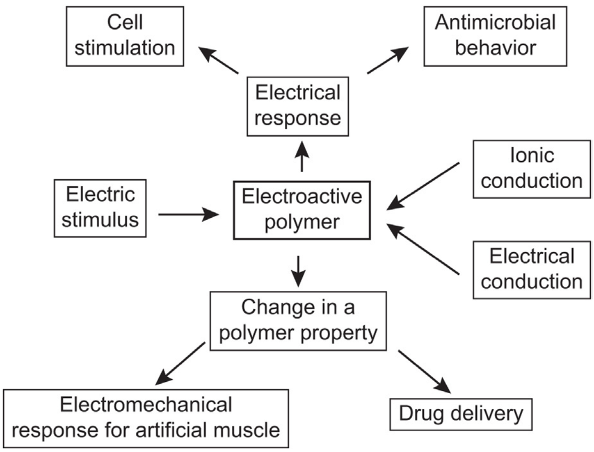

Figure 8.2 General overview of electroactive polymer [2].

field specifically in the field of biomedical. It ranges from polymers delivering an electrical signal in order to altering some required properties under an electric stimulus.

2 Mechanism

Several active polymers are available along with different properties due to the different activation mechanism [3,4]. Depending upon the fabrication of smart materials, both one-way as well as reversible activation are perceived [5–8]. To develop the smart materials, the selection of materials is based on the ability of shape control and self-sensing characteristics [9].

The different mechanisms are available to create an actuation in electric active polymers. They are: (1) polarization, (2) molecular shape and phase change, and (3) mass/ion transportation [10,11]. Polarization mechanism is used to produce actuation by dielectric elastomers and piezoelectric polymers. Molecular phase change mechanism is followed by shape memory polymer and liquid crystal elastomers to produce activation. Basically mass/ion transportation mechanism is used in the materials such as gel and conducting polymer to generate activation. Different stimuli sources such as electrical, light, and magnetic are used in electroactive polymers for manufacturing various smart materials according to the required applications. In that most significant and available source is electrical simulation and also it can be controlled by advanced control systems [12]. More research work is being reported on the manufacturing of electroactive polymers based on electrical simulation; however, other stimulation source has their own applications. Therefore various electric active polymers have different mechanism for activation based on the stimuli and response [13].

Classification of electroactive polymers based on activation mechanism is divided into different types. They are: (1) ionic electroactive polymers which includes ionic polymer–metal composites and conducting polymer actuators, (2) field activated electroactive polymers which includes dielectric elastomers, and ferroelectric polymers [14]. The migration of ions is activated by the resultant force from the electric field in the ionic electroactive polymers [15,16]. This method need low voltage (10 V) for activation operation; however, it suffered from the low frequency and energy efficiency [17]. Second activation mechanism of field initiated electroactive polymers has larger electromechanical coupling efficiency, which specifically uses electric power. Hence it gives good response to the every strain leads to short response time duration. But it required higher voltage to activate the material [18].

3 Applications of electroactive polymers

3.1 Used in aerospace applications

Due to the actuation capability of electroactive polymers, investigators have given due consideration to this field of interest. Generally, this type of polymer has the electromechanical properties, which endow the capacity to function as both sensors and actuators [19–21]. Electric current induced the electroactive polymer to deform in required size and shape, which leads to attain the strain rate up to 300 % [22]. The advantages of electroactive polymer when it used as an actuator are low weight, flexible, lower electric power consumption, quick response, and low actuation voltage [23,24].

Nowadays, Nafion- and Flemion-based electroactive polymers are developed from this research area, and these materials have greater attention to as an actuator and sensor purpose [25–27]. Wang et al. [27] reported the flexible tactile sensors, and it was developed based on Flemion ionic polymer material to produce composites. The actuators made with this material for getting the performance of large strain and low voltage, which is used for the applications of smart materials and microelectromechanical systems [28–30]. Recently, research work in electroactive polymers is enhanced to produce improved actuation properties for advanced applications. The beneficial properties such as damping of vibration and shock, aesthetics, and flexible actuator designs are could be provided by visco-elastic based electroactive polymer materials [31].

3.2 Used in biomedical applications

Recent development in polymer science is the innovation of creating smart materials with the behavior of stimulus response. The usage of electroactive polymers is very high, as it has a capacity of transfer ions under a condition of specific electric field which has multiple applications such as sensors and soft robots [32,33]. This electroactive polymer can be used as biomaterials to achieve proliferation and adhesion of human cells [34–37].

Wu et al. [38] manufactured the optimal electroactive polymer for a medical endoscope application. For modeling of medical endoscopes, the port Hamiltonian framework is suitable. Fig. 8.3 shows the actuators being coated outside of the medical endoscope. A compliant endoscope applicable for medical examination is shown in Fig. 8.4. The flexible structure of the inner tube of the endoscope can be represented by a Timoshenko beam. The left end of the beam is fixed and right end is free. The electroactive polymer actuators and beam are linked through the power conjugated variables. In their study, they were proposed a Hamiltonian model of the medical endoscope.

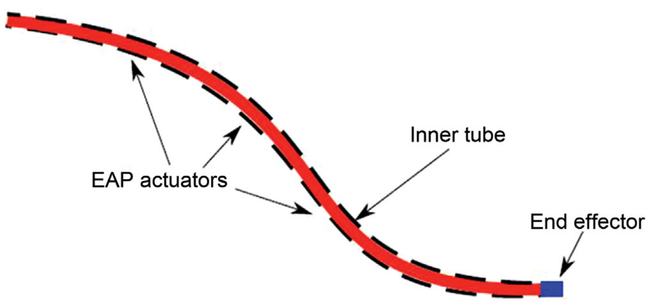

Figure 8.3 Electroactive polymer actuated endoscope [38].

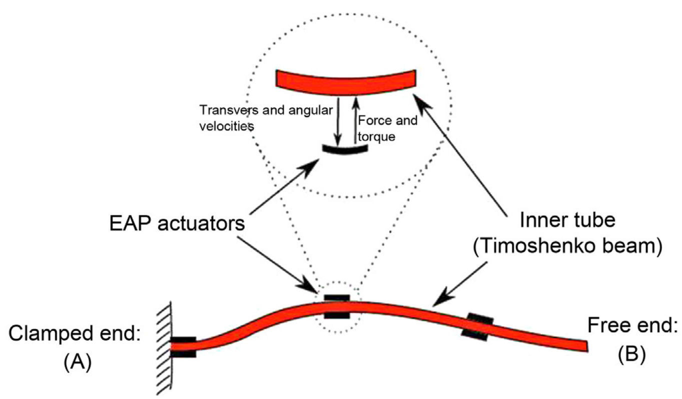

Figure 8.4 Simplified actuators endoscope [38].

3.3 Used in space applications

Various robotic systems and tests are developed by many researchers for space operations. The main requirement for space applications is that it should be controllable and deployable without any serious issues. Bulk shape and size materials are limits the capability of space mission system in which use low weight and high strength, compact materials to achieve the more time in space [39–41]. The superior quality of electroactive polymers such as dielectric and ionic are recommended in space-affiliated industry. The ionic-based electroactive polymer material is most suitable material for attaining all the requirements [42–44].

3.4 Used in automotive applications

The electroactive polymer material is widely used in automotive industry to develop the haptic technology. This technology is utilized to induce the mechanical feedback for getting the information keeping focus on the driving of automobile in road [45]. The vibration sensation can be generated by the unimorph effect, which permits an out-off plane displacement. The piezoelectric actuator material as electroactive polymer is used for producing this effect. Poncet et al. [46] developed the haptic circular buttons to provide the sensations of vibration while touching it by the person.

The electroactive actuators manufactured with polycarbonate substrates as shown in Fig. 8.5. This polymer stack is built by screen printing technology. After manufacturing, the stack is annealed at a temperature of 60°C for the durations of 3 minutes and then allows it to dry at a temperature of 120°C for 5 minutes. Fig. 8.6 shows the printed polymer actuators for haptic feedback applications. Also they developed

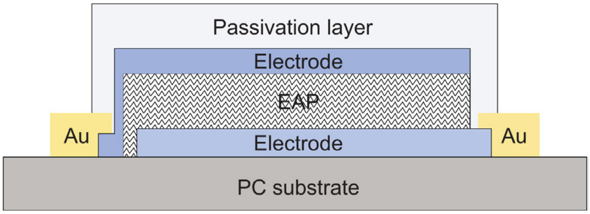

Figure 8.5 Schematic diagram of the piezoelectric electroactive polymer stack [46].

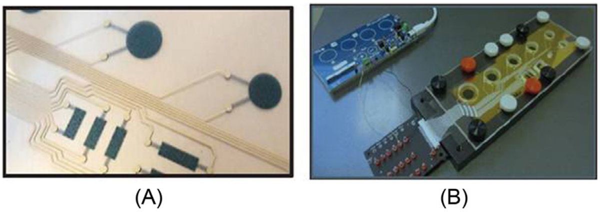

Figure 8.6 (A) Photograph of developed electroactive actuator and (B) clamped foil for characterization [46].

the finite element model for this application to forecast the frequency and amplitude at resonant modes during activation of electroactive polymer. This study proved the simulation result as well as analytical model result both is in good agreement to determine the haptic effect.

4 Conclusions

Electroactive polymer materials belong to a new class of materials that can be effectively used to attain innovative smart materials which is highly dominant research areas in the manufacturing of such materials. It plays a major role in the manufacturing of aircraft products in which enhancing the actuation proficiency in different systems. The flexibility of electroactive polymer is to make possibility of the development for aircraft and biomedical applications.

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