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Actuation and Sensing properties of Electroactive Polymer Whiskers

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Abstract

In a world of unknown, touch modality is a key avenue for environments exploration. Implementation of such modality in mobile robot has been a major challenge for many research teams. Recently, several artificial whisker systems have been studied as promising tactile sensor. One key to the whisker's functionality is its sensor system. Our laboratory recently synthesized new electroactive polymer (EAP) actuator/sensor based on interpenetrated polymer networks (IPN) as host matrix and electrically conducting polymer. The first results of such actuator/sensor devices and their integration in a whisker prototype will be presented.

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Keywords: EAP actuator; Tactile sensor; Whisker; Conducting polymer; PEDOT; Interpenetrating Polymer network

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1. Introduction

Over the past years a lot of effort has been devoted to the implementation of touch modality in robot. One promising technology is the use of artificial whisker [1]. Recently, whiskers based on several sensor technologies have been used for texture discrimination [2–4]. As an example, the rat robot Psikharpax was able to discriminate texture by using a passive whisker with a sensor based on a simple elastomer tactile device [5]. Designing new active whisker (i.e. able to move) that can solve inherent limitations of conventional devices has been a major academic and economical challenge. The use of electronic conducting polymers (ECP) has interested numerous research teams all over the world since they represent a promising active material to elaborate biomimetic actuators and sensors, i.e. realizing motions and sensing similar to those of living systems [6]. Because they are lightweight, able to actuate without noise, and can theoretically develop high output strength, a lot of effort has been devoted to their integration in robotic devices. ECP dimensional and electrical changes are generated by the ion expulsion/inclusion motions during oxido-reduction or external mechanical stress processes [7–10]. Therefore, actuators and sensors working in air are usually built in a configuration where the internal layer is a solid polymer electrolyte (SPE) containing ions sandwiched between two ECP layers (ECP//SPE//ECP). Interpenetrating polymer networks (IPNs) represent an interesting material as solid polymer electrolytes (SPEs) in practical electrochemical devices [11,12] since they can provide improved physical properties such as mechanical strength and elasticity. Previously, we have presented the integration of such actuator in a biomimetic vision system [13]. In the present work, first investigations on actuator and sensor performances as well

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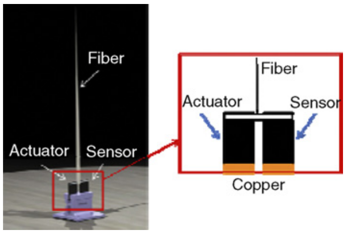

Fig. 1. Conducting IPN whisker representation.

as their integration in an artificial whisker will be described. Finally a first prototype of simple designed active whisker will be presented.

2. Experimental

The synthesis of actuator has been described elsewhere [13]. Conducting IPNs (CIPNs) actuators (7 mm × 3 mm × 0.3 mm) were maintained horizontal with steel clamps. Displacement was obtained by applying a sinusoidal shaped voltage between ±2 V. The relative displacements of the film were measured using a laser displacements sensor (IDL 1401–5 Micro-epsilon) and corresponding strain values were calculated [14].

CIPNs sensor were maintained horizontal with steel clamps. Displacements were applied using a Muscle Lever Arm 300 C from Aurora Scientific. A strain is applied to the CIPN and the resulting potential difference between the two faces is recorded as function of the time on a potentiostat (VMP Bio-Logic.).

CIPNs are able to move and to collect mechanical deformation. The whisker has a simple and light design: a support or grip with copper electrodes, a fiber and two separate Conducting IPNs. The first one as actuating material and the second one as sensor are linked with a Teflon film. Polymer fiber -generally used as optical fiber- has been chosen (Fig. 1). For the actuator control we used a low voltage motor controller from Pololu with a LPC2141 as micro-controller. The sensor signal is amplifying before being used by the LPC2141 and transmitted to the computer.

3. Results and discussion

3.1. Actuator and sensor performances

First the actuator performances are evaluated. In Fig. 2a, actuator strain is plotted versus frequency upon application of sinusoidal shaped voltage of ±2 V for a frequency range between 0,01 Hz and 50 Hz. As observed, for low frequencies the maximum strain value is 1%. Resulting Bode magnitude plot shows two gain asymptote lines with respectively a slope of −10 dB/decade between 0.1 Hz-1 Hz and −20 dB/decade between 1 Hz-10 Hz (Fig. 2b). The actuator strain response to an electrical stimulus corresponds to a second order low pass filter with two corner frequencies of 0.5 Hz and 1 Hz.

Fig. 3a shows the sensing properties of the CIPNs (no electrical stimulus is applied). A sinusoidal mechanical stimulus (i.e. strain of 2%) is applied to the CIPN and the resulting voltage difference between the two faces is plotted.

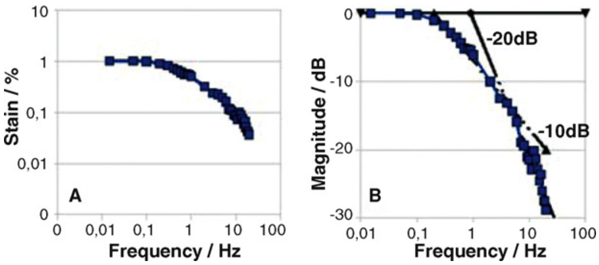

Fig. 2. Strain of CIPN actuator under ±2 V.

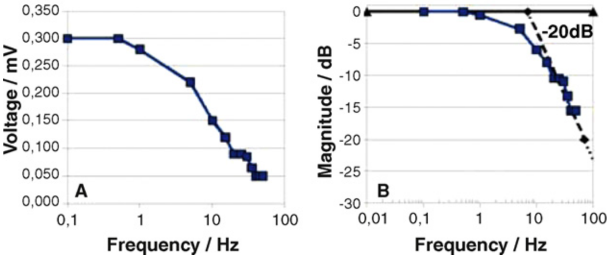

Fig. 3. Voltage sensing response of CIPN under a strain of 2%.

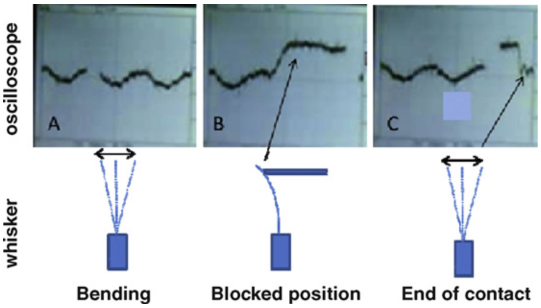

Fig. 4. Whisker testing. (A) Bending, (B) blocked position, (C) end of contact.

For low frequencies a maximum output voltage value of 0.3 mV is observed. Voltage sensing response amplitude is decreasing to the baseline value at 50 Hz. Resulting bode magnitude plot shows a gain line asymptote with a slope of −20 dB/decade (Fig. 3b). This result is in correlation with a low pass filter with a corner frequency of 10 Hz.

3.2. Whisker testing

Fig. 4 shows a first electroactive polymer whisker system based on CIPN tested in motion and with an applied simple contact perturbation. A sinusoidal wave potential of ±2 V with a frequency of 0.2 Hz is applied to the whisker and stain sensing responses after amplification are directly read on an oscilloscope. Fig. 5 clearly shows that the whisker is able to move and collects strain sensing responses due to actuation (Pictures A) and contact perturbation (Pictures B-C).

4. Conclusion

This paper presents CIPN actuator/sensor performances and design allowing their integration in an artificial whisker. For an applied sinusoidal wave potential of +/−2 V, the actuator shows a maximum strain value of 1% for frequency under 1 Hz. Sensor performances were also measured for a sinusoidal wave mechanical stimulus (strain of 2%) between 0.01 Hz and 50 Hz. The CIPN as sensor shows a maximum voltage response of 0.3 mV for frequency under 10 Hz.

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