ARTIFICIAL MUSCLES : ELECTRICAL CURRENT INFLUENCE ON BILAYER MOVEMENT.

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SUMMARY

A bilayer structure polypyrrole-flexible and inactive polymer has been constructed to transform molecular strain in macroscopic movement during electrochemical oxidation/reduction process of polypyrrole film. With the aim of optimizing bilayer movement, the rate (rad.s^{-1}) of those electrochemomechanical movements for a same described angle (90°), the consumed electrical charge (mC) and electrical energy (mJ) under different electrical conditions and with different bilayer dimensions has been studied. The obtained results shown an increasing of both movement rate and consumed electrical energy per mass unit at increasing applied current per mass unit (mA.mg^{-1}). Hower the electrical charge consumed remain constant. Also the bilayer dimensions has not influence on movement rate and on consumed electrical charge or energy per mass unit. However for a constant consumed electrical charge per mass unit the angle travelled remain constant varying bilayer dimensions.

Keywords: conducting polymer, polypyrrole, artificial muscle, electrochemomechanical device.

INTRODUCTION

The transport of charge-compensating ions that accompanies electrochemical switching of polypyrrole between the conductive (oxidized) and semiconducting (reduced) states has elicited much attention in recent years [1-3]. A variation of volume between reduced and oxidized states of polymer has been observed during electrochemical oxidation/reduction process. This variation of volume promote molecular strains into the polymer [4-5].

These facts have been known since the beginning of eighties and such polymers were applied as actuators able to change in a few micrometers its length to close or open an electrical circuit [6].

A bilayer structure polypyrrole-flexible and inactive polymer has been constructed to transform molecular strain in macroscopic movements [7-11]. Electrical currents trigger oxidation or reduction (chemical) processes developing a mechanical movement. An electrochemomechanical device has been constructed.There are a similarity between this

electrochemomechanical device and a muscle: an electrical pulse comes from the brain through the nervous system and triggers a chemical process in a muscle. The chemical energy stored in organic molecules is transformed by chemical reactions into mechanical energy; during this transformation a change of volume takes place.

In this work, with the aim of optimizing bilayer movement, the rate of those electrochemomechanical movements for a same described angle (90°), the consumed electrical charge (mC) and energy (mJ) under different electrical conditions and with different bilayer dimensions has been studied.

EXPERIMENTAL

Polypyrrole films were electrogenerated from 0.1M $LiClO_4$ organic solutions. All the films presented in this work were electrogenerated from acetonitrile having a 2% water content, needed to provide films having a high ability to store charge. Pyrrole and $LiClO_4$ were from Janssen. Acetonitrile was from Lab.Scan. Ultrapure water was obtained from a Milli Q Reagent System fed by a Milli Q Water purification system.

The working electrode and two counterelectrodes were AISI 304 stainless steel sheets, having a surface area of 3.5 cm^2.

Polypyrrole was electrogenerated by square waves of potential between -300mV (2s) and 850mV (8s) in order to control the morphology of the film , its adherence to the metal and its ability to grow and store charge. All the films were obtained under an inert atmosphere of argon.

The polypyrrole films obtained, one from each side of the steel electrode, were stuck to a commercially available tape having 0.1mm of thickness. The bilayer polypyrrole adherent film was peeled from the stainless steel. A bilayer film having a surface area of 3cm^2 was obtained.

The bilayer was put in a 1M $LiClO_4$ aqueous solution. It was held at the top with a metallic clamp to allow electrical contact. As counterelectrode two platinum sheets were used and the calomel electrode was employed as reference electrode.

RESULTS

The movement rate of polypyrrole/ flexible and inactive polymer with different dimensions has been compared with the aim of determining the polymer dimension or mass influence on the relation between movement rate of bilayer and current applied (Fig.1). There is a direct ratio between the movement rate and the applied electrical current per mass unit ($mA.mg^{-1}$). The movement rate increases when the applied electrical current per mass unit rises. However the movement rate under a same electrical current per mass unit remain constant when polymer film dimension varies.

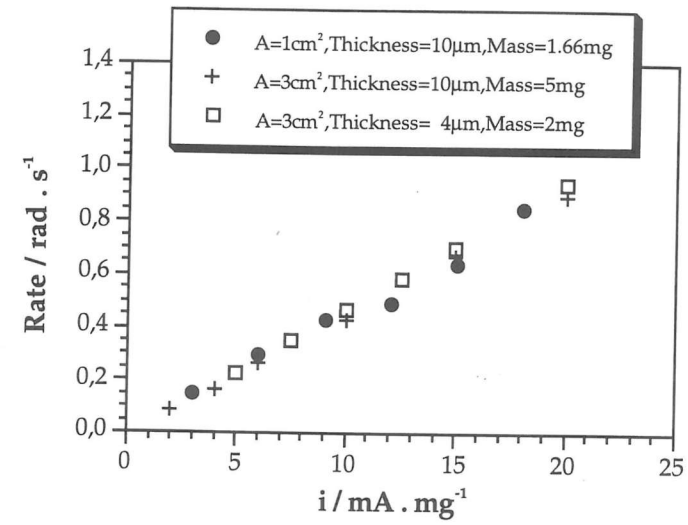

Fig. 1 : *Movement rate of bilayer devices with different dimensions versus applied electrical current per mass unit ($mA.mg^{-1}$) for a same described angle (90 °).*

Also, the obtained results show a same consumed electrical charge per mass unit of conducting polymer ($mC.mg^{-1}$) for a same described angle, not depending either on applied current or on conducting polymer dimensions (Table 1).

	Q(mC .mg^{-1})		
I (mA)	Area=1cm^2 Thickness=10µm Mass=1.66mg	Area=3cm^2 Thickness=10µm Mass=5mg	Area=3cm^2 Thickness=4µm Mass=2mg
5	33	35	32
10	32	36	35
15	33	36	34
20	38	37	34
25	40	34	34
30	36	35	34

Table 1 : *Evolution of the consumed electrical charge with the applied electrical current for different bilayer devices for a same described angle (90 °).*

On the other hand, consumed electrical energy per mass unit ($mJ.mg^{-1}$) increases linearly at increasing the applied electrical current per mass unit ($mA.mg^{-1}$). However

remain constant at a same applied electrical current per mass unit of conducting polymer ($mA.mg^{-1}$) not depending on bilayer dimensions (Fig.2)

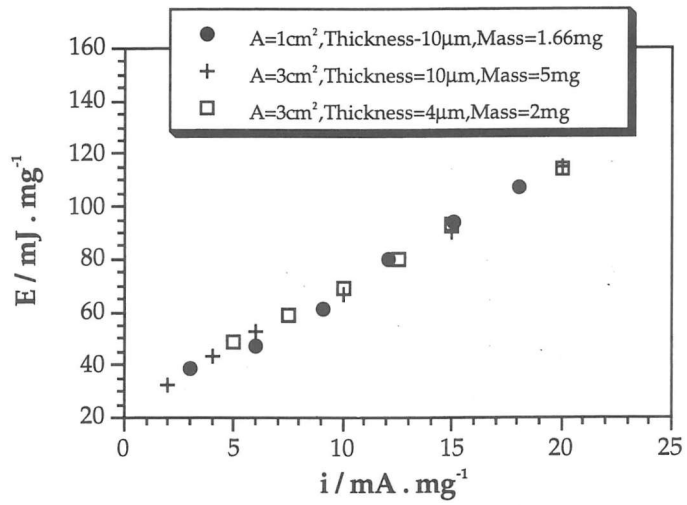

Fig. 2 :*Electrical energy per mass unit ($mJ.mg^{-1}$) consumed by bilayer devices with different dimensions versus applied electrical current per mass unit ($mA.mg^{-1}$) for a same described angle (90^{o}).*

CONCLUSIONS

- The movement rate ($rad \cdot s^{-1}$) increases linearly at increasing applied current per mass unit ($mA.mg^{-1}$), not depending on the conducting polymer dimensions.

- The consumed electrical charge per mass unit of conducting polymer ($mC.mg^{-1}$) to cross over the same described angle, not depends either on applied current or on bilayer dimensions.

- The consumed electrical energy per mass unit of conducting polymer ($mJ.mg^{-1}$) increases linearly at increasing applied currents per mass unit of conducting polymer ($mA.mg^{-1}$), not depending on conducting polymer dimensions.

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