CARDIAC CATHETER WITH VARIABLE HEAD CURVATURE ACTUATED BY IPMC (IONIC POLYMER-METAL COMPOSITE)

M.-S. Ju[1], P.-K. Fung[1], C.-C. K. Lin[2], Y.-Z. Hong[1], C.-K. Chung[1], T.-C. Wu[3]
[1]Department of Mechanical Engineering, National Cheng Kung University
[2]Department of Neurology, National Cheng Kung University
[3]Electronics Research & Service Organization, Industrial Technology Research Institute

INTRODUCTION

The technically difficult part in a catheter surgery is to push a catheter (~ϕ2mm below) through the crotched vessels by using guide wires with different curvatures. The above-mentioned process takes a lot of time and also raises the risk of surgery due to numbers of guide-wire changes.

IPMC (Ionic Polymer-Metal Composite) consists of an electrical active polymer layer sandwiched by metal electrode layers. When a driving voltage is provided, the IPMC membrane bends toward anode direction because the hydrophilic positive ions move toward cathode direction [1-3]. During the design of an IPMC actuator, there are four technical problems to be overcome: (1) how to glue electrode layers on the polymer membrane; (2) how to drive under a wet condition; (3) how to prevent electrolysis when higher driving voltage (>1.23V) is to be applied and (4) how to increase the force output of the actuator (mN order).

The purpose of this study is to develop an active guide-wire by using IPMC membrane and to overcome above technical problems.

METHODS

According to the actuation principle of IPMC, a two segment IPMC actuator is designed. Two pairs of electrodes are joined to the polymer membrane and form a two-segment actuator. While two different phase voltages are applied on the two pairs of electrodes respectively, the actuator can perform a variable S-shape deformation. This design will offer an opportunity to solve the problem that a traditional catheter with a single fixed curvature can not overcome.

The size of the IPMC actuator is decided based on the constraint of the catheter and the length is 20 mm, the width is 1 mm and the thickness is 0.2 mm. The diameter of the whole active guide-wire is constrained to less than 1 mm.

The nafion® is one kind of ion exchange polymers, and a 20% nafion solution is used to make a membrane in this study. In order to attach the electrode layers to the membrane, we mix the nano silver powder with a 5% nafion solution and spread on a glass slide. After drying the solution, a membrane is formed (the electrode layer, ~30μm), and a 20% nafion solution is spread on it and cured to form a film. The film was cut into two halves and glued together by using nafion solution. The electroless silver plating process was applied at the final step and nickel layer was electroplated on two spots as the contacts for electric conduction.

To demonstrate the feasibility of the IPMC actuator, a performance test system was set up and a prototype of IPMC actuator is fabricated and tested. Finally, the IPMC actuator was assembled to form the head of a guide-wire.

RESULTS AND DISCUSSION

The IPMC (length of 20mm, width of 5 mm & thickness of 0.3 mm) driven by 2.8V could perform an approximately 90 degree bending (Fig. 1) and the force was about 0.25gf. The sheet resistances are 0.12 ohm/mm and 0.15 ohm/mm. The elasticity of the IPMC is 3.5GPa (Dry) or 1.16GPa (Wet). According to the test results, the deformation and force output were proportional to the driving voltage, and we found that the oxidations on IPMC surface electrodes made the resistance too high, so its performance was deteriorated under long-term actuation (Fig. 2).

CONCLUSIONS

The active guide wire with the IPMC actuator could change the head curvature according to the magnitude of the applied voltage. Reducing the surface resistance and maintaining the humidity of IPMC can further improve the performance of the active head, and to accurately control the tip position of the IPMC actuator is an on-going work.

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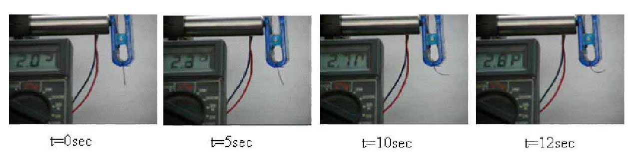

Figure 1: Actuating result of IPMC driven by dc voltage

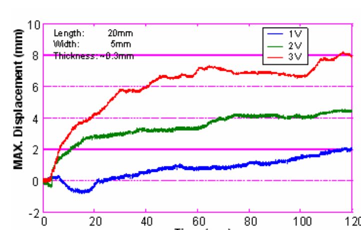

Figure 2: Displacement Response