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Ceramics International

Available online 10 April 2024

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Study on surface morphology and properties of biological type Ag-IPMC and its application on butterfly soft robot

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https://doi.org/10.1016/j.ceramint.2024.04.114

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Abstract

Ionic Polymer Metal Composite (IPMC) is a new type of artificial muscle material. It has unique advantages such as low driving voltage, good flexibility and rapid response that make it suitable for driving soft robots. However, the high preparation cost limited its widely application. The focus of this paper is to study a low-cost and high-performance Ag-IPMC and explores its application in driving bionic butterfly robots. In addition, based on the flexible characteristic of IPMC, a bionic butterfly soft robot is designed and manufactured, and its related performance is also studied. This manuscript also has provided a reference value for the extensive diversified application of the biological IPMC.

Introduction

Living creatures have sophisticated body structures and superb survival skills under the rule of “natural selection, survival of the fittest". With the development of science and

technology, people increasingly want to produce bionic robots that are consistent with the structure and function of organisms, and bionics is the bridge connecting biology and technology. In recent years, researchers have proposed a soft robot based on the prototype of mollusks which can change their bodies shape to perform efficient movement. Ian D Walker and others studied the soft robot supported by pneumatic muscle structure and changing the air pressure inside the robot [1,2]. Chen developed a single segment continuous robot made of silicone rubber using pneumatic drive [3]. Harvard University also has developed a multi gait soft robot driven by gas to realize quadruped walking of the robot [4].

Electro Active Polymer (EAP) is one of the commonly driver materials for soft robots, including Dielectric Elastomers (DE), Carbon Nanotube (CNT) and Ionic Polymer Metal Composite (IPMC) and so on, which have broad application prospects in the field of medical and engineering applications. IPMC has been used in biomedical, biomimetic machinery, MEMS and other frontier scientific fields as the good biological compatibility, strong shape plasticity and good adaptability to the liquid environment [[5], [6], [7], [8], [9],24,25]. Texas A&M University developed a hexapod walking robot driven by IPMC, which can walk in water [10]. Joel J Hubbard and others used it to drive the pectoral and caudal fins of the bionic robot fish [11]. Yang Liang provides a new idea for analyzing the internal mechanism of IPMC using the W-M model from the fractal theory [12].

The electrode of IPMC is generally used metals (Pt, Au, Ag, Cu, etc.) on the surface of ion exchange membrane by electroless plating [[26], [27], [28]]. Gold (Au) and platinum (Pt) have good conductivity, strong stability and bonding with the substrate film, but their cost is high. Copper (Cu) and graphene oxide composite also have their advantage, but the braking performance of Cu-IPMC material is poor [13,14]. This paper selected Ag as the electrode to prepare Ag-IPMC, which can reduce the cost and ensure its good actuation. At the same time, the biological type butterfly actuator was prepared, which also laid a foundation for the development of the bionic soft robot field.

Section snippets

Experimental mechanism

Silver has very small resistivity value of Ag (1.6×10^{-8}) < Au (2.4×10^{-8}) < Pt (1.0×10^{-7}) (Ω•m), at room temperature. Using metallic silver as the electrode can reduce the cost and the surface impedance of IPMC. Many reducing agents can conduct silver mirror reaction as the high electric potential of Ag^{+}, such as sugars, acids, phenol and so on. Among them, non-

toxic glucose as a reducing agent has low requirements for experimental conditions [15]. The principle reaction equation is as follows:…

Analysis of Ag-IPMC SEM

Fig. 3 shows the surface morphology of Ag-IPMC prepared for different cycle number of secondary electroless plating. It can be seen from Fig. 3 (a) that the roughed traces on the surface of the basement membrane are faintly visible, and most of the silver particles are unevenly distributed in the roughed gullies. With the increase of the cycle number (Fig. 3 (b)), the traces roughed gradually disappear, and silver particles becomes dense and slowly filling the grooves covering. It can be seen…

Butterfly type Ag-IPMC

Combining the flight characteristics and rules of natural butterflies, a butterfly type Ag-IPMC is prepared to drive the bionic butterfly robot. The bending deformation characteristics under different voltages are studied to find the most suitable voltage value that can best simulate the characteristics of biological butterfly, which lays the foundation for expanding the application of IPMC.

Fig. 7 (a) and Fig. 7 (b) show the natural butterfly and the size of it, which is composed of front and…

Conclusion

In this paper, based on the idea of saving experimental cost and diversifying the application of IPMC, Ag-IPMC were prepared with different cycle number of the secondary electroless plating, and researching its micro morphology and driving performance. The results showed that when the number of electroless plating was two, the coating electrode was the most flat and the metal particles were evenly distributed. The butterfly type Ag-IPMC was prepared according to the body structure and flight…

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.…

CRediT authorship contribution statement

Liping Zhang: Supervision, Writing – review & editing, Funding acquisition. **Jinfei Ren:** Data curation. **Aifen Tian:** Conceptualization, Writing – original draft, Writing – review & editing. **Jiahua Li:** Writing – original draft. **Qilong Chen:** Data curation, Writing – review & editing. **Yaping Wang:** Writing – review & editing. **Huiling Du:** Funding acquisition.…

Acknowledgements

This work was supported by the financial assistance from the Key Laboratory Project of Expressway Construction Machinery of Shaanxi Province, China (300102259510) and the National Natural Science Foundation of China under Grant Number (52172099).…

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