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Development of Biobattery-Driven Transdermal Osmotic Flow Patch

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Abstract

In recent years, iontophoresis has been used for transdermal drug delivery. The current flow through the negatively charged skin tissue generates electroosmotic flow that assist the penetration of drugs only from the anode side. In this study, a polyelectrolyte-fixed urethane sponges were mounted in a transdermal current-carrying bio battery patch to generate electroosmotic flow for efficient dose of drugs from both anode and cathode sides.

1. Introduction

Transdermal drug delivery is a method of drug administration that enable to absorb the drugs into a body through the skin. Transdermal drug delivery has various advantages such as minimal invasiveness and avoidance of drug degradation by digestive fluids and metabolic enzymes in the body since the drug directly enters the bloodstream through the capillaries of the skin[1]. Iontophoresis has attracted a great deal of attention as a technique for efficient transdermal drug delivery. Iontophoresis is a method of delivering drugs to the skin by electrophoresis and electroosmotic flow generated by percutaneous electric current. This method is currently widely used but requires an external power source. Conventional external power source is hard, thick and heavy, so we developed a compact and high-power density bio-battery patch (Fig. 1). Since output of the patch could decrease by evaporation of water from O_2 supply hole, in this study, Polydimethylsiloxane (PDMS) which reduces evaporation of water but oxygen permeable was used to cover the hole. Furthermore, in order to improve the dose flux, the urethane sponges, which has been used as a drug tank were modified by charged hydrogels to generate electroosmotic flow. This work will demonstrate the stable performance of the patch with PDMS cover and the efficient dose from both anode and cathode.

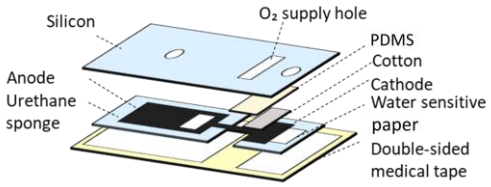

Fig. 1 Schematic of a bio-battery patch.

2. Experimental procedures

Fig.1 shows a schematic of the patch. The biobattery patch consists of silicone, PDMS film, anode for glucose oxidation, cathode for O_2 reduction, urethane sponges for reserving drugs, and can produce appropriate current to generate iontophoresis without an external power supply. PDMS film (500 μm thick) was put on the cathode to close the O_2 supply hole. The urethan sponges for cathode and anode were modified by hydrogels with positive and negative charges by using (3-acrylamidpropyl) trimethylammonium and 2-acrylamido-2-methyl-1-propanesulfonic acid as monomers, respectively.

The output current of the patch with and without PDMS film were measured and compared on a pig skin for 3 h. In order to evaluate the electroosmotic flow performance, the hydrogel-modified urethane sponges were sandwiched between the Franz cells and applied an electric current to generate electroosmotic flow (Fig. 2).

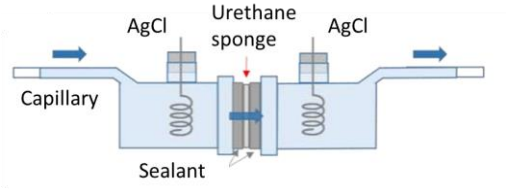

Fig. 2 Electroosmotic flow experimental system.

3.Results and discussion

The patch with PDMS cover retained stable current around 25 µA for more than 3 h, while the patch w/o PDMS lost the activity during 2 h operation due to the evaporation of inner water through the O_2 supply hole (Fig. 3). It was also demonstrated that the O_2 permeability of the PDMS film (500 µm thick) ensure enough O_2 supply for cathode reaction. It was confirmed that electroosmotic flow was produced in proportion to current density, indicating that the hydrogel-filled urethane sponges promote water flows to opposite direction (Fig. 4). The experiment of the dual dose from both anode and cathode is in progress by using the patch composed of the positive/negative hydrogels sponges.

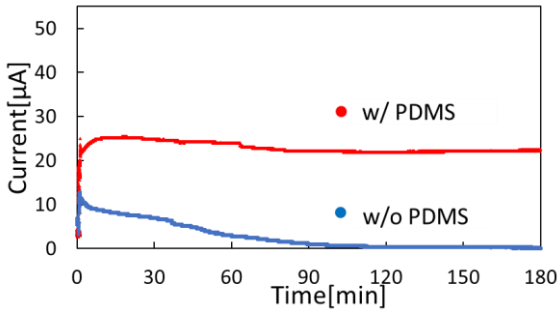

Fig. 3 Typical chronoamperometry on pig skin.

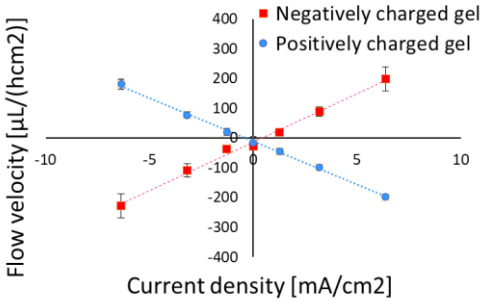

Fig. 4 Flow velocity of electroosmosis through positively charged gel and negatively charged gel.

4. Conclusions

We have successfully retained stable output current of the patch for more than 3 h by PDMS film and promoted water flows to opposite direction in proportion to current density by the hydrogel-filled urethane sponges. We are planning to apply this hydrogel-filled urethane sponges to the patch for the dual dose from both anode and cathode sides.

References

1). Kusama. S. *et al*, Transdermal electroosmotic flow generated by a porous microneedle array patch. *Nat. Commun.* **12**, 1–11 (2021).