Continuous monitoring of lactate in sweat using a self-powered biosensor screen-printed on paper substrate

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Abstract
Wearable sensors that monitor lactate levels during exercise from athletes' sweat are expected to be useful for their training. In this study, we fabricated an electrode for an enzymatic biofuel cell that generates electricity from lactate. We also fabricated a self-powered lactate sensor that measures the concentration of lactate from changes in the amount of electricity generated by the electrode. These sensors were tested in a laboratory environment and field-tested on an exercising test volunteer.

1. Introduction

In recent years, the use of lactate sensors for long-term monitoring of lactate levels in sweat has been attracting attention.[1)] In particular, self-powered sensors that do not use batteries are considered useful because of their safety. We have investigated the covalent immobilization of mediators and enzymes onto grafted MgO-templated carbons (GMgOC) with polymethacrylate glycidyl groups (GMA) to improve the long-term stability of the anodes of glucose biofuel cells[2)]. In this study, we investigated suitable cross-linkers for anodes to further improve the performance of lactate biofuel cells based on this method. In addition, a self-powered lactate biosensor combining the biofuel cell and a wireless transmitter was tested for evaluation on the body during an exercise.

2. Experiment

The electrode of the lactate biofuel cell was fabricated by printing five layers of carbon ink as the lead part on water-repellent Japanese paper, and two layers of GMgOC ink on top of the carbon ink. The anodes were treated by UV irradiation of the electrodes, followed by a drop of the mediator thionine (10 μL) and a drop of a mixture of the enzyme LOx (40 U) and the cross-linking agent PEG-DGE (Poly(Ethylene Glycol) DiGlycidyl Ether). LOx is lactate oxidase.

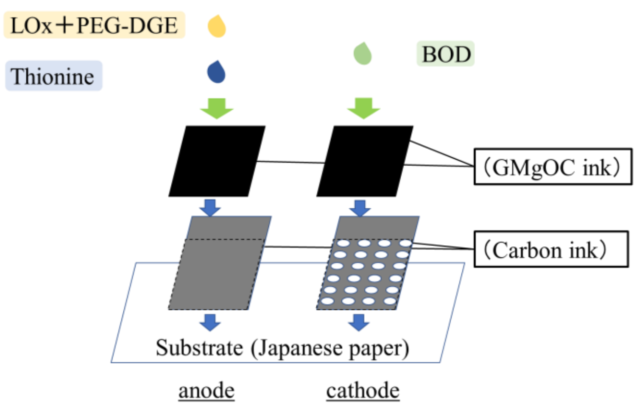

Fig. 1 Lactate biofuel cell

The cathode was prepared by dropping the enzyme BOD (2.0 U) onto the electrode after UV irradiation (Fig. 1). BOD is bilirubin oxidase. Biofuel cells fabricated from these anodes and cathodes were combined with a wireless transmitter. The transmission interval of the radio transmitter depends on the amount of electricity generated by the biofuel cell. The field test utilized this to estimate the concentration of lactate in sweat based on the radio transmission interval when the transmitter was attached to an exercising person.

3. Results and discussion

Figure 2 shows the temporal changes in sweat lactate concentration and blood lactate concentration during exercise in the field test. Sweat lactate concentration follows changes in blood lactate concentration due to exercise. This showed a good relationship between sweat lactate concentration and blood lactate concentration. This suggests that this self-driven biosensor can be used to measure lactate concentration in sweat.

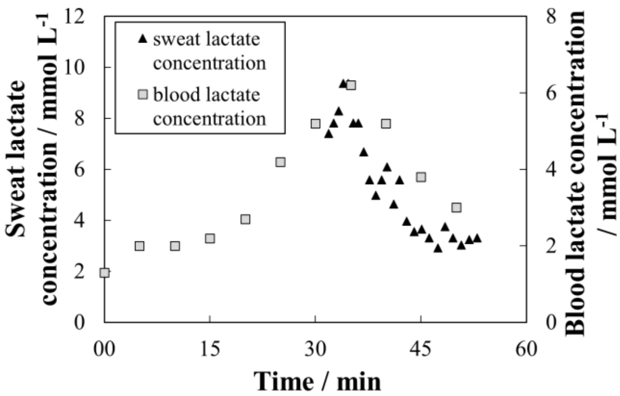

Fig. 2 Relationship between sweat lactate concentration and blood lactate concentration in on-body test

4. Conclusions

A self-powered lactate sensor that generates electricity from lactate in sweat was fabricated to measure lactate concentration in sweat in real time without batteries. The sensor was worn and measured in a field test on test volunteers. From the results obtained, a correlation was confirmed between blood lactate concentration and sweat lactate concentration measured by a self-powered sensor. This indicates that the lactate concentration in sweat of the user during exercise can be successfully monitored noninvasively.

References

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