Chapter 19
Biochemical Pump with Enzymatic Reaction

- Organic Device with an Active Transportation System -

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Abstract  A biochemo-mechanical pump was constructed with funnel type glass tubes and an enzyme membrane, immobilized catalase onto single-side of dialysis membrane. By applying hydrogen peroxide (H₂O₂) solution into non-enzyme immobilized side tube, the pressure in another tube increased rapidly. Namely, an active transportation of H₂O₂ by the asymmetric enzyme membrane from the funnel area to the tube induced the increase in the tube pressure (max.: 5000 Pa), thus resulting in buffer discharge with non-pulsating and low flow rate. The output pressure was linearly related to the concentration of hydrogen peroxide over a range of 11.8 to 123.6 mmol/l, with good reproducibility.

19.1 Introduction

Many type of Micro-machining devices and MEMS (Micro Electro Mechanical System) with micro-fabrication techniques have been investigated [1]. Particularly, micro-actuator devices such as motor, pump, etc. were required in the medical and analysis fields. The existing devices, however, obtain the mechanical force from electric or heat energy, thus resulting lower energy conversion efficiency and complicate system for energy transfer [2]. In living organism, protein molecule such as muscle molecule actin/myosin and ATP synthetase, functioned directly as the devices for energy conversion and transfer with high efficiency [3]. Since some biocatalyst could be catalyze chemical reaction with volume change at room

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temperature and pressure, mechanical force would be expected to be provided directly from chemical energy [4,5].

In this paper, an active transportation system was achieved using asymmetric catalase immobilized membrane with hydrogen peroxide as substrate. A biochemical pump was also fabricated with the enzyme membrane and glass tubes.

**19.2 Experimental Section**

**19.2.1 Construction of Biochemical Pump**

Figure 19.1 illustrates the biochemical pump with catalase immobilized enzyme and glass tubes. The chemical pump consisted of a funnel type glass tube (narrow i.d.: 7 mm) and a catalase immobilized membrane.

Catalase (EC 1.11.1.6, activity: 65000U·mg-1, Roche Pharmaceuticals, NJ, USA) was used for constructing the biochemical pump. The enzyme catalyzes specificity for hydrogen peroxide, thus resulting oxygen molecule as one of enzyme products.

For enzyme immobilization, catalase was mixed with PVA-SbQ monomer solution (photocrosslinkable polyvinyl alcohol containing stilbazoie quaternized; Type: SPP(styryl pyridinium polymer)-H-13(Bio), Tokyo Gosei Kogyo Co., Tokyo, Japan) and phosphate buffer solution (pH7.0, 50mmol/l) in a weight ratio of 1 : 50: 25, [6-8] to a dialysis membrane (thickness: 15 μm, Part No.157-0144-02., thickness 15μm, Technicon Chemicals Co., S.A., Oceq, Belgium) spread on a glass plate, and then irradiated with a fluorescent lamp for 2 hour in order to photocrosslink the monomer solution and immobilize the enzyme onto single side of the dialysis membrane.

The catalase immobilized membrane was removed from the glass plate and immersed in phosphate buffer. In order to prevent enzyme deactivation when not in use, the membrane was stored in buffer below 10 °C.

The chemical pump was fabricated by sealing the opening mouth of the funnel-type glass tube with phosphate buffer solution, by the asymmetric enzyme membrane, in which the enzyme immobilized side was faced to the inside of the tube (see the enlargement of Figure 19.1). Then, the membrane sealed side of the tube was immersed into a funnel area (filled with buffer solution).