学 位 論 文 内 容 の 要 旨
DISSERTATION ABSTRACT

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学 位 論 文 題 名
Title of dissertation submitted for the degree

Domestic wastewater treatment and electricity recovery by a PVDF-based air-cathode MFC coupled with a low voltage booster multiplier
(低電圧昇圧増倍器を搭載した PVDF-based air-cathode MFC による都市下水処理および電力回収)

Microbial fuel cell (MFC) has emerged as a promising technology during these two-decade due to its ability to simultaneously treat domestic wastewater and to directly produce renewable bioelectricity. However, the high capital cost, low voltage output, and low effluent quality are major obstacles of the practical application of MFCs in wastewater treatment. Therefore, the present study aims to develop a cost-effective and energy-saving MFC system for domestic wastewater treatment. The current status and issues of MFC technology for its practical application are summarized in Chapter 1. This chapter also provides the objectives and outline of this dissertation. Chapter 2 provides literature reviews about MFC technology applied for domestic wastewater treatment with an emphasis on MFC architecture, operating conditions and, cost-effective anode and cathode materials. This chapter also reviews the existing power management system (PMS) technology used to boost the low voltage output of MFC which is usually ranging from 3 to 12 V. Furthermore, the principle of microbial electrolysis cell (MEC), operating conditions, and current applications are described in this chapter.

In Chapter 3, PVDF-based air-cathode MFCs (MFC-PVDF/ACs) were constructed and operated for about 6 months. The performances in terms of COD removal and power production of the MFC-PVDF/ACs were compared with those equipped with platinum-catalyzed air-cathode MFCs (MFC-Pts). Interestingly, MFC-PVDF/ACs achieved higher COD and SS removal and generated higher power densities than the MFC-Pts. In addition, the PVDF-based air-cathode is more durable than Pt cathode. These results suggest that the expensive platinum-based air-cathode is not always necessary for domestic wastewater treatment, and the low-cost PVDF-based air cathode could be used for large-scale MFCs. Although the MFC-PVDF/AC achieved excellent COD and an SS removal, two major issues still remain; the low output voltage and removal of ammonium nitrogen in the treated effluent.

Chapter 4 focuses on the development of the new low voltage booster (LVB) designed specifically for the low voltage output of the MFC (< 0.5 V). Unfortunately, most of the commercially available PMSs require a startup voltage > 0.7 V which is higher than the working voltages of typical MFCs. In this chapter, a transistor-based LVB system was proposed to harvest electrical energy during the domestic wastewater treatment (ie. COD oxidation) and boosts up the low voltage of the MFC to a usable level (4 - 5.2 V).

In Chapter 5, a low voltage booster multiplier (LVBM) was developed to further increase the low voltage output of MFC. In the LVBM electronic system, the low MFC-PVDF output voltage is firstly

boosted by a transistor-based DC/AC self-oscillating LVB circuit, and the boosted voltage was further multiplied by a multistage single-phase Cockroft-Walton voltage multiplier circuit. A LVB with a 20-stage AC/DC multiplier circuit could amplify the MFC voltage (ca. 0.4 V) up to 89 V, which was the highest boosted voltage that has been ever reported, for several days without voltage reversal. The feasibility of LVBM application in MFC technology is discussed.

The MFC-PVDF/AC was successfully used to remove COD from domestic wastewater in Chapter 3. However, ammonium nitrogen must be removed from the MFC treated effluent. The conventional nitrification-denitrification systems require the high-energy demanding aeration and effluent recycling. The ammonium is expected to be removed from a bioelectrochemical system when the COD/N ratio is sufficiently low. Therefore, the MFC-PVDF/AC is used as a primary treatment to remove COD and a power source of MEC which is used in a downstream to remove ammonium nitrogen via the microbe-assisted anodic ammonium oxidation process. As a result, the MEC achieved an ammonium oxidation rate of and a nitrogen removal rate of 0.173 kg NH_4-N/m^3/d and 0.095 kg TN/m^3/d without aeration. This result suggests that ammonium nitrogen can be removed bioelectrochemically without aeration by an integrated MFC and MEC system.

In Chapter 7, the conclusions of individual chapters are summarized, and the outlook and remaining issues for a large-scale practical application of MFC technology are discussed. The present study demonstrates that the integration of MFC-PVDF/AC, LVBM and MEC is a promising approach to develop a cost-effective and energy-saving domestic wastewater treatment system with simultaneous renewable energy.