Design of 3D Graphite Anode for Electrochemical Methanol Production from Lignin

Z. Xiong[1] , T. Hibino[1] , K. Kobayashi[1] , A. Miyawaki[2] , S. Teranishi[2] , Y. Sawada[1]
[1]Nagoya University,
[2] Soken Inc.
xiong.zichun.v6@s.mail.nagoya-u.ac.jp; hibino@urban.env.nagoya-u.ac.jp

Introduction

Lignin, as a major component of non-food biomass, contains abundant methoxy groups that can serve as a sustainable carbon source. Conventional thermochemical or catalytic methods for methanol production from lignin require harsh conditions, limiting their feasibility.[1-4] Our group has recently demonstrated that electrochemical demethylation of lignin enables methanol extraction under mild conditions. However, platinum anodes used previously suffered from methanol overoxidation and limited lignin utilization, resulting in low methanol yield.[5,6] In this study, we developed a three-dimensional (3D) graphite sponge anode to overcome these challenges and to establish a dual production system of methanol and hydrogen.

Experimental Procedures

Electrochemical cell was constructed with a 3D graphite (Gr) sponge anode, a $Sn_{0.9}In_{0.1}P_2O_7$–PTFE electrolyte, and a Pt/C cathode.[7] Lignosulfonate was used as the feedstock. The graphite electrode morphology was analyzed by microscopy and XPS, while radical formation was verified by UV–vis spectroscopy. Electrochemical performance was examined at 75 °C under potentiostatic control at +0.57 V vs. Au reference electrode. Products were quantified by gas chromatography and ^{1}H NMR, and efficiencies were calculated using Faraday's law.

Results and Discussion

The 3D graphite sponge electrode exhibited high capacity and surface functional groups favorable for •OH radicals' formation, while suppressing methanol overoxidation compared to Pt electrode. Continuous electrolysis of lignosulfonate revealed that methanol yield reached 69.3%, nearly 30% higher than the value obtained with Pt electrode. Faradaic efficiency for methanol production peaked at approximately 90%. ^{1}H NMR confirmed almost complete consumption of methoxy groups after electrolysis. Importantly, hydrogen was simultaneously produced at the cathode with a maximum faradaic efficiency of 68%, at a low cell voltage of approximately 1.0 V, much lower than conventional water electrolysis. This demonstrates the feasibility of an energy-saving simultaneous production of methanol and hydrogen from lignin.

Acknowledgement

This research was the result of using research equipment shared in a MEXT Project for promoting public utilization of advanced research infrastructure (Program for supporting construction of core facilities) Grant Number JPMXS04411023.

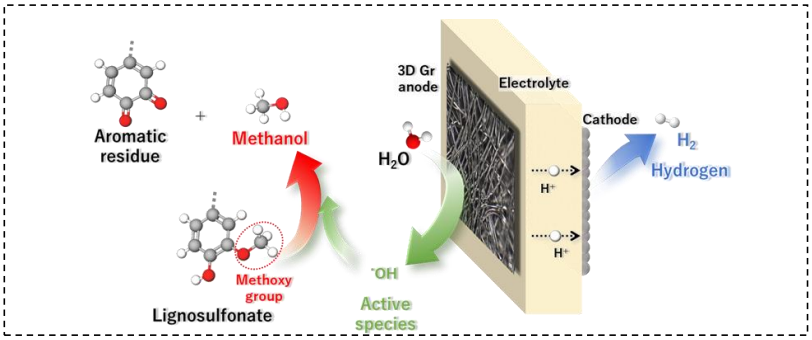

Figure 1 Graphical schematic of electrochemical cell

References

[1] N.-E. E. Mansouri, J. Salvadó, Ind. Crops Prod. 2006, 24, 8–16.
[2] X. Jiang, D. Savithri, X. Du, S. N. Pawar, H. Jameel, H. Chang, X. Zhou, ACS Sustainable Chem. Eng. 2017, 5, 835–842.
[3] H. Ma, T. Li, S. Wu, X. Zhang, Fuel 2021, 286, 119394.
[4] Q. Mei, H. Liu, X. Shen, Q. Meng, H. Liu, J. Xiang, B. Han, Angew. Chem., Int. Ed. 2017, 56, 14868–14872.
[5] T. Hibino, K. Kobayashi, D. Zhou, S. Chen, A. Zinchenko, S. Teranishi, A. Miyawaki, Y. Sawada, Appl. Catal. B-Environ. 2024, 341, 123328.
[6] X. Qi, W. Song, J. Shi, PLoS ONE 2017, 12, e0173864.
[7] B. Lee, Y. Sakamoto, D. Hirabayashi, K. Suzuki, T. Hibino, J. Catal. 2010, 271, 195–200.