Abstract

[Project Information]

Project Title :	Development of Catalyst Synthesis Technology for Highly Efficient Conversion of Cellulosic Waste by Using Low-temperature and Environment-friendly Plasma
Project Number :	JPMEERF20223R01
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Principal Investigator :	Takeuchi Nozomi
(PI ORCID) :	ORCID0000-0002-2115-6392
Principal Institution :	Institute of Science Tokyo Meguro-ku, Tokyo, JAPAN Tel: +81-3-5734-2566 E-mail: takeuchi@ee.eng.isct.ac.jp
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[Abstract]

Due to the urgent need to reduce CO_2 emissions and growing concerns over depletion of fossil fuels, biofuels—capable of achieving carbon neutrality—are gaining attention as a form of renewable energy. Cellulose, the most abundant organic material on Earth, is a key biomass resource. Expanding the use of biofuels derived from cellulose-based waste materials, such as agricultural residues, holds great promise for building a sustainable society. A typical conversion pathway from cellulose to biofuel involves two steps: (1) hydrolysis of cellulose into glucose and (2) hydrogenation of glucose into biofuel. This study aims to establish an innovative catalyst synthesis process that significantly enhances glucose yield during the hydrolysis reaction. Hydrolysis catalysts are primarily obtained via sulfonation, a process that modifies carbon materials with sulfonic acid groups. However, conventional sulfonation requires long processing times in concentrated sulfuric acid at temperatures above 200° C, making it impractical due to high costs and environmental burden.

The ultimate goal of this research is to develop a practical catalyst synthesis process by enabling rapid sulfonation of carbon materials under mild conditions—specifically, using dilute sulfuric acid at room temperature—through a low-impact gas–liquid interfacial plasma technique. To achieve this, the sulfonation mechanism was explored by combining radical measurements and catalyst synthesis experiments, along with the development of a reaction model involving radical generation and mass transfer across the gas–liquid interface. As a result, a novel sulfonation method using dielectric barrier discharge plasma was developed. Compared to conventional hydrothermal treatment, this method reduces energy consumption to less than 1/100 and sulfuric acid usage to approximately 1/100–1/3, while increasing the glucose yield from cellulose hydrolysis by over 72.3%.

[References]

P. Attri, K. Ishikawa, N. Takeuchi, T. Nozaki, et al., "Developments in low-temperature plasma applications in Asia", Reviews of Modern Plasma Physics, Vol. 9, 6 (2025). DOI:10.1007/s41614-025-00184-9

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