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Full Length Article

Waste pig blood-derived 2D Fe single-atom porous carbon as an efficient electrocatalyst for zinc–air batteries and AEMFCs

Hee Soo Kim [a,b,1], Jiho Lee [c,1], Jue-Hyuk Jang [a], Haneul Jin [a], Vinod K. Paidi [d], Soo-Hyoung Lee [c], Kug-Seung Lee [d], Pil Kim [c,*], Sung Jong Yoo [a,e,f,*]

[a] Center for Hydrogen-Fuel Cell Research, Korea Institute of Science and Technology (KIST), Seoul 02792, Republic of Korea
[b] KEPCO Research Institute, Korea Electric Power Corporation, 105 Munji-ro Yuseong-gu, Daejeon 34056, Republic of Korea
[c] School of Chemical Engineering, Jeonbuk National University, 567 Baekje-dearo, Deokjin-gu, Jeonju, 54896, Jeonbuk University, Republic of Korea
[d] Pohang Accelerator Laboratory, 80 Jigokro-123-beongil, Nam-gu, Pohang, Gyeongbuk 37673, Republic of Korea
[e] KHU-KIST Department of Converging Science and Technology, Kyung Hee University, Seoul 02447, Republic of Korea
[f] Division of Energy & Environment Technology, KIST School, University of Science and Technology (UST), Seoul 02792, Republic of Korea

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ABSTRACT

Biomass is a useful precursor for manufacturing electrocatalysts because it is highly abundant, eco-friendly, and is composed of organic materials that include Fe and nitrogen precursors. Among the numerous waste biomass types, slaughtered pig blood contains a high concentration of Fe-porphyrin inside the hemoglobin, and this characteristic makes it an ideal precursor for fabricating a bio-inspired Fe-N-C oxygen reduction reaction (ORR) catalyst. Here, Zinc (Zn)-hydrolysates are obtained from purified waste pig blood was used as a porous carbon source for two-dimensional (2D) sheet-like porous single-atom electrocatalysts. In addition, pig blood provides Fe single-atom catalytic sites derived from hemoglobin in (Zn)-hydrolysates and shows excellent ORR activity by retaining excellent mass transfer due to the presence of mesopores generated by Zn activation under NH_3 pyrolysis Furthermore, one of the catalytic materials is a Zn-incorporated Fe single-atom porous carbon catalyst (designated Zn/Fe_{SA}-PC)/950/NH_3, was successfully integrated as an Anion Exchange Membrane Fuel Cells (AEMFCs) and Zn-Air Batteries (ZABs) where it supported maximum power densities of 352 and 220 mW/cm^2, respectively. This study demonstrates the new designs and preparation procedures for high-performance electrocatalysts that can be manufactured at low cost from abundant and renewable blood biomass.

1. Introduction

The depletion of fossil fuels and the increase in environmental pollution, such as greenhouse gases and fine dust particles, have spurred the development of clean and sustainable energy technologies in recent years [1,2]. As a result, various clean energy conversion techniques such as fuel cells and metal-air battery systems have emerged as promising alternatives to traditional fossil fuels [3,4]. In both technologies, the most important component is the oxygen reduction reaction (ORR) on the cathode side, but this reaction is slow and requires an efficient catalyst [5,6]. Currently, the most effective cathode catalysts incorporate platinum (Pt), but this element has high costs, limited global reserves, poor durability, and toxicity that severely restrict commercial development [2–5]. Thus, considerable efforts have been made to develop multifunctional electrocatalysts that are free of precious metals and non-precious metals [7–9]. As a result, transitional metal (Fe, Co, and Ni)-based alloys, carbides, oxides, and heteroatom (e.g. N, S, and P)-doped carbon electrode materials have attracted much attention due to their excellent electrocatalytic activities [9–12].

M-N-C (Metal-Nitrogen-Carbon) catalysts are promising materials to replace platinum catalysts. Non-precious transition metals are highly abundant, low in cost, and support high catalytic performances and durability. Such M-N-C catalysts have been studied extensively [13–16]. Most M-N-C catalysts are manufactured by forming an M-N_x moiety, which is achieved by using a metal precursor and carbon support doped with nitrogen with high-temperature heat treatment [17–19]. In this step, the drawback is that particles can aggregate to block the pores and the active site of the M-N_x can collapse. Moreover, this process generally

* Corresponding authors at: Center for Hydrogen-Fuel Cell Research, Korea Institute of Science and Technology (KIST), Seoul 02792, Republic of Korea (S.J. Yoo).
E-mail addresses: kimpil1@jbnu.ac.kr (P. Kim), ysj@kist.re.kr (S.J. Yoo).
[1] H.S.K and J. L contributed equally.

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