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Unraveling the cohesive and interfacial adhesive strengths of electrodes for automotive fuel cells

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HIGHLIGHTS

- Cohesive/adhesive strength of the electrode is quantified by using SAICAS method.
- Component and composition within the electrode layer of MEAs are confirmed.
- Relation between assembly temperature and interfacial adhesion is analyzed.
- Intermolecular diffusion by ionomer content can be analyzed using SAICAS method.

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ABSTRACT

Despite the pressing need to develop highly durable electrodes for electric vehicles powered by polymer electrolyte membrane fuel cells (PEMFCs), evaluating the mechanical robustness of the electrodes in membrane electrode assemblies (MEAs) has proven challenging because the electrodes are intrinsically porous and brittle. Herein, we propose a novel technique for effectively quantifying the mechanical robustness of the electrodes using a surface and interfacial cutting analysis system (SAICAS). The SAICAS enables the separate quantification of cohesion and adhesion of PEMFC electrodes. We find that the adhesion at the interface is higher than the cohesion in the bulk owing to a larger intermolecular diffusion at the interface than in the bulk. Also, the SAICAS could reliably quantify the cohesion and adhesion of PEMFC electrodes having different ionomer contents and assembly temperatures. Our findings are intriguing and will be useful for the efficient and effective design and development of robust electrodes and MEAs.

1. Introduction

Over the last decade, the world has undergone a massive shift away from its dependence on fossil fuels towards cleaner and more eco-friendly energy sources [1,2]. One promising candidate for eco-friendly energy is hydrogen, which can be used in a wide range of applications such as transportation, chemicals, and metal-refining industries [3–5]. Polymer electrolyte membrane fuel cells (PEMFCs) powered by hydrogen have gained much attention in recent years as promising candidates for eco-friendly vehicles, i.e., fuel cell electric vehicles (FCEVs). This is because they have high power density, high efficiency, and produce no harmful emissions [6–8]. In particular, the FCEV automotive industry has been growing significantly in terms of both passenger vehicles and medium- and heavy-duty vehicles such as buses and trucks. Such commercial vehicles require much higher durability than passenger vehicles, i.e., 5,000 h for passenger vehicles vs. 25, 000 h for heavy-duty vehicles [5,9–12]. However, for FCEVs to become commercially more competitive with conventional internal combustion

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