Research Title:

Affordable Fuel Cells for Zero-Emission Transportation Applications

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This report, as a research outcome summary in Year 3 and continuation of the initial phase (Year 1) and second phase (Year 2), presents the development of platinum-group-metal (PGM)-free catalysts for the oxygen reduction reaction (ORR) in anion-exchange membrane fuel cells (AEMFCs) toward affordable zero-emission transportation. Two complementary strategies were implemented: (a) electronic structure engineering via a bioinspired MnFe-porphyrrole dual-atom aerogel to break linear scaling relations, and (b) pore-architecture optimization of Fe-porphyrin aerogels to improve mass transport.

The MnFe catalyst demonstrated enhanced intrinsic ORR activity (E_onset = 0.99 V vs. RHE) and delivered 0.27 W cm-2 in AEMFC tests. Density functional theory analysis confirmed that Mn–Fe charge transfer weakens OH adsorption on Fe sites, improving catalytic performance. In parallel, tuning the linker length in Fe-porphyrin aerogels revealed that hierarchical porosity, rather than surface area alone, governs fuel cell performance. The optimally structured catalyst achieved peak power densities of 591 mW cm-2 (H2–O2) and 242 mW cm-2 (H2–air) with stable operation.

These results demonstrate that combining dual-atom electronic modulation with controlled pore engineering provides a viable pathway toward high-performance, durable, and cost-effective PGM-free AEMFC cathodes.