Optimization of Fuel Cell Catalytic Layer for Deep-Sea Carbon Sink Monitoring

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Abstract

The long-term continuous operation capability of deep-sea carbon sink monitoring equipment is fundamentally constrained by the technical bottlenecks of insufficient endurance and low energy conversion efficiency of its power supply system, which severely hinders the high-precision observation and mechanism elucidation of deep-sea carbon sink processes. This study proposes a technical solution based on proton exchange membrane fuel cells (PEMFCs), leveraging their inherent advantages of sustainable power generation and stable operation, with a focus on performance enhancement and adaptive optimization of the catalytic layer, the core component of PEMFCs. Using non-precious metal M-N-C catalysts (M=Fe, Co, Ni) as the core active materials, we regulate the interfacial interaction between the catalysts and ionomer side chains to optimize charge transport efficiency and reaction kinetics in fluid electrochemical processes, achieving a synergistic improvement in the fuel cell's energy density, deep-sea environmental adaptability, and long-term durability. Combined with in-situ electrochemical tests, molecular dynamics simulations, and advanced material characterization techniques, this study systematically reveals the intrinsic operation mechanism of the catalytic layer for efficient and stable performance under extreme deep-sea conditions. This work provides core technical support for the construction of a long-term stable energy supply system for deep-sea carbon sink monitoring equipment. This technical breakthrough can effectively enable multi-month continuous observation of carbon sink monitoring devices, accurately capture the spatiotemporal dynamic characteristics of key carbon sink parameters, and further provide critical technical underpinnings for marine resource development practices, including carbon sink assessment in deep-sea oil and gas development zones and blue carbon ecosystem conservation.

Keywords

Carbon Sink Monitoring, Energy Supply, PEMFC, Electrochemistry