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Effect of Magnetic Exclusion by Ferrofluids on Mesh-Electrode Water Electrolysis

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In space, water is essential for life support and, through water electrolysis ($2H_2O \longrightarrow 2H_2 + O_2$), as a source of hydrogen and oxygen for propellant and breathable oxygen. Under low gravity, buoyancy-driven bubble detachment is suppressed, causing bubbles to accumulate on electrode surfaces and decrease electrochemical efficiency. Space electrolysis systems also face severe mass and volume constraints, requiring miniaturization. We propose active bubble control using a ferrofluid electrolyte and permanent magnets. In a ferrofluid, the liquid phase is attracted toward a magnet, whereas bubbles are repelled owing to their much lower magnetic susceptibility (Fig. 1a). This produces magnetic buoyancy, i.e., magnetic exclusion, promoting bubble removal and improving reaction efficiency. Because this method requires no moving components and is driven only by permanent magnets, system simplification is expected 1. Porous metallic electrodes are promising for water electrolysis because of their large surface area. As a model system, mesh electrodes with controlled structural parameters were used to investigate the influence of mesh specifications on magnetic exclusion. Although decreasing the open area (OA) increases surface area, it also makes bubble detachment more difficult. The evaluated electrodes were Mesh 16 (SUS304, OA 56%), Mesh 50 (SUS304, OA 32.4%), and Mesh 180 (SUS316, OA 40.8%). Applying a magnetic field in the ferrofluid improved electrolysis performance under all conditions. At 5 V, the current, reflecting the reaction rate, increased by at least twofold compared with the condition without ferromagnetic particles. For Mesh 50, which had a small open area and was prone to bubble retention, the current increased by nearly threefold (Fig. 1b). The pronounced improvement for Mesh 50 indicates that magnetic exclusion becomes more effective as bubble retention becomes more severe. Although the experiments were conducted under terrestrial gravity, magnetic field analysis showed that, in the present magnet configuration, the magnetic buoyancy acting on the ferrofluid corresponds to approximately 100–1000 times Earth's gravity. This suggests that bubble removal could be maintained under microgravity. Therefore, this method is promising for compact, efficient water electrolysis cells.

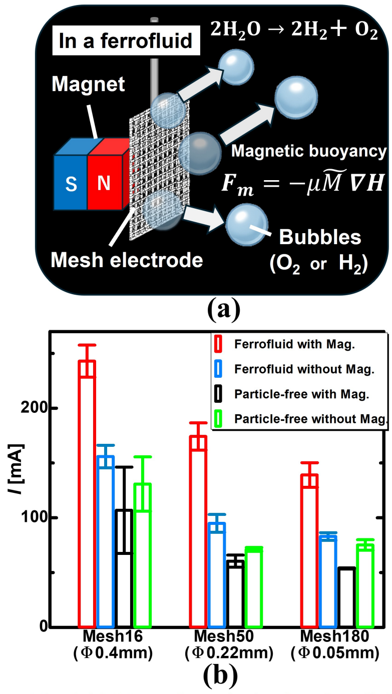

Fig. 1 (a) Magnetic exclusion in a ferrofluid.
(b) Current comparison at 5 V.

References
1 R. Somiya et al., “Self-driving characteristics of a pumpless water electrolyzer using water-based ferrofluid,”Magnetohydrodynamics 61, 25–32 (2025).

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