Biomimetic and TPMS-inspired flow field designs for advancing PEMFC performance

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This study explores the performance impacts of biomimetic leaf-vein-inspired distributor combined with flow fields based on triply periodic minimal surfaces (TPMS). I-type and G-type porous flow fields were evaluated against a conventional parallel channel-rib flow field (CPFF) to assess their influence on mass transport and electrochemical behavior. The results demonstrate that the I-type flow field enhances current density by up to 15% in the ohmic region, while the G-type design ensures stable operation at current densities as high as 2 A/cm^2 by promoting efficient reactant access and water removal. Additionally, the analysis highlights that reducing the solid volume fraction V_f to 30% significantly improves gas penetration, especially under mass transport-limited conditions. Investigations into relative humidity (RH) effects further reveal a delicate balance between membrane hydration and water accumulation, underscoring the importance of RH optimization. Integrating a hierarchical leaf-inspired distributor leads to further performance gains, boosting current density by up to 4% compared to conventional distributors and achieving a 32% increase in power density relative to CPFF. These findings highlight the promise of TPMS-based porous structures and nature-inspired designs in advancing the efficiency of next-generation PEMFCs.

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