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Additive Manufacturing of Triply Periodic Minimal Surface Structures as Electrodes for Redox Flow Batteries

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Porous electrodes are performance- and cost-defining components of redox flow batteries (RFBs) as they provide the available surface area for electrochemical reactions, the porous structure for electrolyte transport, and facilitate mass, charge, and heat transport [1]. Therefore, enhancing the electrode performance is a promising strategy to increase power density and reduce system costs. Conventional carbon-fiber-based porous electrodes are repurposed from fuel cell gas diffusion electrodes and have not been tailored to sustain the requirements of liquid-phase electrochemistry. Consequently, new manufacturing techniques offering high control over the electrode microstructure and resulting properties need to be developed [2]. Additive manufacturing techniques are uniquely suited to design controlled architectures, which can, in turn, help understand geometry-performance relationships, as well as manufacture high-performance electrodes providing enhanced electrochemical performance and reduced hydraulic resistance [3,4].

I will present our latest progress on the additive manufacturing of advanced electrode geometries for RFBs, illustrating the versatility of this manufacturing approach to fabricate electrode microstructures for electrochemical applications. In this presentation, I will discuss our work on utilizing triply periodic minimal surface (TPMS) structures as RFB electrodes. TPMS structures are found in natural systems such as butterfly wings, leaves, and sea urchin skeletons and have periodic surface structures with large surface areas, which are presumed beneficial for RFB electrodes. In our previous work [4], we found that the electrode pillar shape influences mass transfer rates, motivating the investigation of various TPMS forms, including gyroid, diamond, and IWP. In this work, the TPMS electrodes were fabricated by additive manufacturing using a commercial desktop digital light processing printer followed by carbonization. We assessed their potential in organic redox flow cells and found that TPMS electrodes feature higher internal surface area and enhanced mass transport compared to cubic periodic structures, boosting the reactor performance. Especially the diamond TPMS outperforms the regular cubic structure, featuring the lowest overpotential and highest current density and mass transfer coefficient. Our work shows the potential of additive manufacturing to fabricate customized porous electrodes that enable multiscale structures with increased electrochemical performance and low hydraulic resistance.

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