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Towards multiphase transport layers - Binary pore size distributions with hydrogen bubble assisted electrodeposition

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In electrochemical devices, porous transport layers (PTLs) bridge the gap between flow fields and catalyst layers. They provide pathways for liquids and gases to be distributed over and removed from the catalyst layer, provide mechanical support as well has thermal and electrical conductivity. As the electrical current drawn from such devices is directly linked to the flow of reactants, the mass transport capabilities of the PTLs become especially critical at high current density operation. State of the art PTLs are primarily fiber-based (e.g. carbon, titanium) as they satisfy the complex requirements posed by their operating environment. However, in two phase counter flow operation, undesirable liquid accumulations and subsequent blockage of gas transport pathways can occur. Excessive accumulations of reaction products or a lack of fresh reagents stall out the electrochemical conversion, limiting the achievable power density. To overcome these limitations, alterations and improvements to the base material have been investigated to guide liquids and gases into dedicated pathways within the porous structure[1–4]. While they show varying degrees of success, they require additional processing steps, adding cost, and are still limited by both phases having to compete for the same pore network.

We explore the synthesis of hierarchical PTLs containing dedicated pathways for the transport of liquid and gas, realized by a difference in pore sizes on two distinct length scales. While 3D printing is positioned as a promising manufacturing route, currently this method lacks the production speed and resolution. Therefore our approach is focused on an alternative synthesis route whereby the porous material is generated by co-depositing a metal and a gas from a solution containing the metal salt and a source of protons to form hydrogen gas. The hydrogen acts as dynamic template which, together with the deposition kinetics of metal at high overpotentials, forms a structure containing macroscopic and microscopic pores (Figure 1a). This type of structure has in the past been used successfully to improve boiling heat transfer[5], and has been postulated to find application in other electrochemical devices such as batteries or fuel cells[6].

In this talk, I will discuss the necessary development steps to adapt this material for the use in electrochemical systems. At the core of the synthesis route we conceptualized an approach to manufacture self-standing PTLs from this material while preserving its hierarchical microstructure. This enables its use as transport layer and allowed for the application of a wide range of characterization methods to link the synthesis parameters to the resulting material microstructure. Structural information (Figure 1b) obtained through X-ray tomographic microscopy was used to perform transport simulations and ascertain the potential of the material as PTL. The simulations showed increased diffusive transport in dry and liquid filled state compared to state-of-the-art materials. Through careful tuning of synthesis parameters and post treatment steps, the mechanical stability was improved substantially to the point where the integration in electrochemical systems is possible. If successful, this could open the door to a new class of PTLs tailored to the transport requirements of a given system.

Participation

In-Person

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