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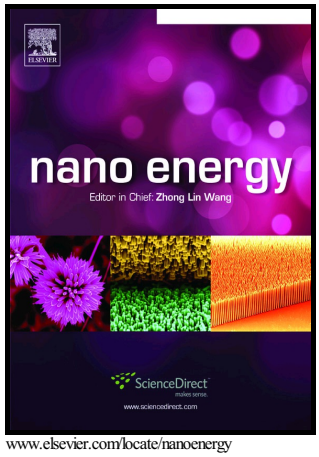

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Abstract

Proton exchange membrane electrolyzer cells (PEMECs) have received great attention for hydrogen/oxygen production due to their high efficiencies even at low-temperature operation. Because of the high cost of noble platinum-group metal (PGM) catalysts (Ir, Ru, Pt, etc.) that are widely used in water splitting, a PEMEC with low catalyst loadings and high catalyst utilizations is strongly desired for its wide commercialization. In this study, the ultrafast and multiscale hydrogen evolution reaction (HER) phenomena in an operating PEMEC is *in-situ* observed for the first time. The visualization results reveal that the HER and hydrogen bubble nucleation mainly occur on catalyst layers at the rim of the pores of the thin/tunable liquid/gas diffusion layers (TT-LGDLs). This indicates that the catalyst material of the conventional catalyst-coated membrane (CCM) that is located in the middle area of the LGDL pore is underutilized/inactive.