# Controlled Surface Nanostructures for Performance-Analysis on Solid Support Fuel Cells

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One performance-determining parameter in fuel cells is the geometry of the triple phase boundary (TPB), the active zone where fuel, catalyst, and ionomer coincide and the chemical reaction occurs. Thus the geometry of this zone distinctively alters the performance of a fuel cell [1]. In this paper, we present a way to systematically alter this geometry and thus to investigate experimentally the influence of structure dimension on fuel cell efficiency.

We designed a fuel cell with a solid support electrode patterned by high resolution lithography techniques. A nanopattern was transferred by reactive ion etching into the highly doped silicon substrate forming tapered nanopillars with well defined diameter. Figure 1 presents the fabrication scheme and Figure 2 a processed sample with etched nanopillars. Subsequently these posts were coated with catalyst and then brought into contact with the ionomer, forming the membrane electrode assembly (MEA). Since the contact between catalyst-coated pillars and ionomer determines the triple phase boundary, we were able to deliberately adjust the TPB length by varying the post diameter. Using electron-beam lithography for pattern creation, we predefined and varied the TPB length by several orders of magnitude within a single attempt and studied its influence on fuel-cell efficiency. To pattern a sufficiently large active area by electron-beam lithography, we developed a way to expose a large number of dots with varying diameter in a reasonable time. For that purpose, the beam was deliberately defocused, leading to single pixel exposures with adjustable diameter.

As alternative method of mask preparation, we optimized thermal dewetting of thin metal films. Lee et al. already demonstrated the use of dewetted metal films as etch masks [2]. To achieve smaller dimensions, we optimized the dewetting processing parameters by systematic investigation and obtained structure dimensions with a mean diameter of 9 nm. Next, the dewetting pattern was successfully used as an etch mask for nanopillar fabrication. Figure 3 shows a sample, where a platinum thin film was used to create 150 nm tall posts. This alternative method of fabrication demonstrates that once the optimal dimension is determined by the above-described technique, an appropriate mask can be fabricated in an efficient way by thermal dewetting.

[1] R. O'Hayre, D.M. Barnett, and F.B. Prinz, ECS **152**(2), A439-A444 (2005)
[2] J. Lee, and B. Kim, MSE A **449-451**, 769-773 (2007)

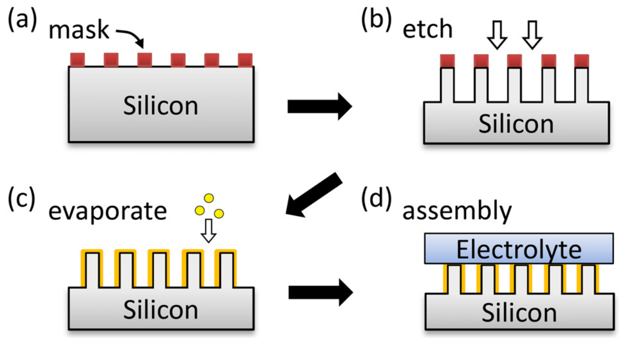


Figure 1: Schematic diagram showing: (a) creating a mask on top of a highly doped silicon substrate; (b) pattern transfer by anisotropic reactive-ion etching forming an array of posts; (c) evaporation of catalyst on post surface; (d) membrane electrode assembly.

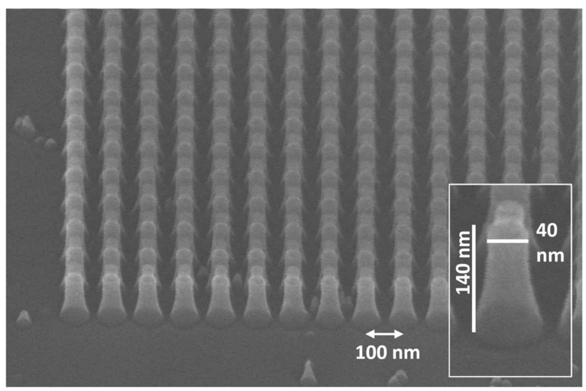


Figure 2: Scanning electron micrograph of a tilted sample. A mask created by electron-beam lithography was transferred into the substrate by reactive-ion etching, creating tapered nanopillars of controlled diameter.

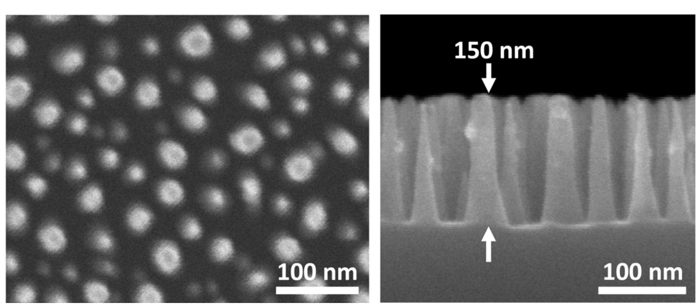


Figure 3: Scanning-electron micrograph of a sample (left: top view and right: cross section) with a 3 nm platinum film, thermally dewetted at 800°C for 240 s and subsequently etched with HBr at 2 mTorr, 40 W for 15 minutes. Thereby 150 nm tall tapered nanopillars were created.