

Bio-Nanopore Models using Hybrid Photolithographic-Electrochemical Fabrication

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A new hybrid lithographic-electrochemical fabrication approach in which micrometer sized openings etched in silicon are filled in with electroplated metal has been used to construct solid-state nanopores. Although several examples of solid-state nanopore fabrication are reported in the literature all have difficulties in terms of complex fabrication, lack of diameter control, or problems creating only a single pore.¹⁻⁴ The new approach overcomes the size limitations of traditional microfabrication while making use of lithography for placement of a single pore in a substrate. Metal nanopores have a proven advantage in that gating of positive or negative ions is possible, depending on the applied potential.⁴ The technique lends itself to electrochemical or optical feedback control of restriction size. Further, surface chemistry modification of the metal plated opening is possible.

Biological nanopores are complex protein assemblies that span cell membranes and control ion and polymer transport across an otherwise impermeable lipid bilayer. These nanopores perform a wide range of cellular functions including maintaining cell homeostasis and killing other cells.⁵⁻⁷ It was recently shown that some bio-nanopores facilitate the transport of relatively long molecules of single-stranded DNA, thus forming the basis for a DNA detector.⁸⁻¹² This system has been suggested for potential applications including analyte detection¹⁰ and ultra-rapid DNA sequencing.⁸ Because lipid membranes are fragile, the practical realization of these applications might require the use of an anthropogenic nanoscale pore. A stable, robust solid-state mimic might facilitate understanding of bio-nanopores and transport of large molecules through highly confined spaces by allowing control of the location, dimension, and composition of the pore. The challenge is to create one and only one hole, nanometer scale in all dimensions, in a defined location on a given substrate.

In the fabrication approach discussed here, a micropore is etched with tetramethylammonium hydroxide solution through a photolithographically patterned silicon substrate. A thin layer of silver is subsequently evaporated into the pore to provide electrical conduction for subsequent processing. Finally, additional silver is electroplated at the edges of the micropore. The latter process restricts the size of the opening. An example of the structure thus produced is shown in Figure 1. In one sample (not shown), the pore area was $10^3 \mu\text{m}^2$ after the silicon etch. After silver electroplating the pore was reduced to less than $1 \mu\text{m}^2$. Silver metal was used as a test case, but the technique may be easily modified for use with other metals, including gold and platinum. We will discuss the structure of the metal plated pore, as characterized by electron microscopy and ionic conduction, as a function of electroplating conditions.

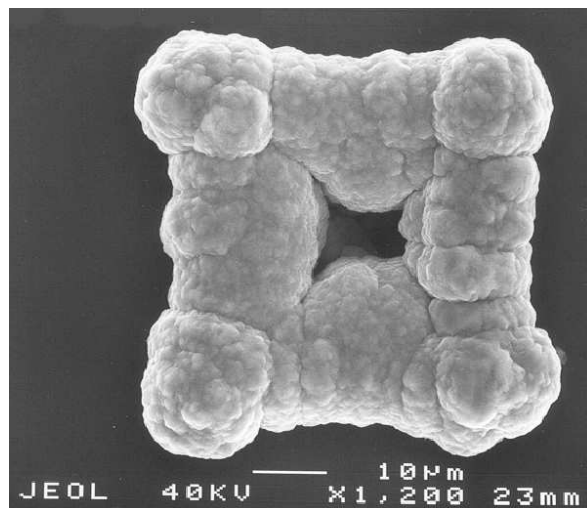


Fig. 1. Scanning electron micrograph of silver plated pore prototype. Ten micrometer scale bar given on image. Original opening in silicon substrate was approximately $900 \mu\text{m}^2$.

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