Fabrication and characterization of nanopores in Si based materials

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Abstract

The use of single nanopores (NPs) as biomolecule sensing elements has gained a lot of interest in recent years. In such biosensors the change in ionic current when the analyte molecule translocates through the NP is monitored, providing both quantitative and qualitative analytical information. The membrane's material is important factor for determining the resulting shape and surface properties that are extremely important for the sensing process, and also affects fabrication conditions. Thus, there is a constant quest for novel techniques allowing the fabrication of NPs tunable, in both size and materials properties. Herein, we present fabrication, electrical and shape characterization methodologies of NPs drilled in silicon based membranes, including Si_3N_4, crystalline Si and multilayered $SiO_2/Si/SiO_2$ membranes.

A novel method for the fabrication of NPs using focused electron beam induced etching (FEBIE) will be presented [1-3]. In this technique, pores are etched by a cyclic process of reducing either nitride or oxide membrane to elementary oxide followed by spontaneous etching of the Si by XeF_2. NPs can be drilled with high precision with diameter in the range of 10–200 nm, depending on electron exposure time and acceleration voltage, and XeF_2 pressure. The 3D shape of the NP is shown to depend on the type of membrane used. Forming NPs in both Si_3N_4 and $SiO_2/Si/SiO_2$ multilayers membranes results in a funnel-like shape NPs [2, 3]. However, in the latter case cylindrical shape can be obtained, depending on the post exposure time to XeF_2. This method facilitates the formation of high aspect-ratio structures in rather thick membranes, for which other the traditional NP drilling by transmission electron microscope (TEM) fails. Additionally, due to the chemical nature of the method, the chemical structure of the NP rims is identical to that of the bulk material. This single step process opens the way to fast integration with silicon technology, making the suggested devices especially suited for lab-on-chip applications.

I will further present a model we developed to extract the 3D shape of the NPs from the dependence of the ionic conductance of NPs on the ionic strength of the electrolyte used in the experiments [4], eliminating the need for elaborated and expensive electron microscope analysis. The suggested methodology can be used to monitor changes in the NP shape after manufacture and during electrical characterizations with high precision.

References

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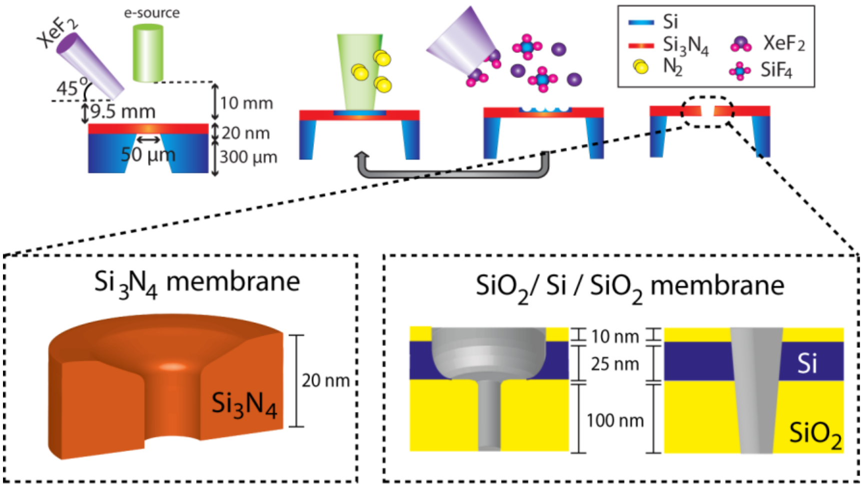
Figure 1



XeF2
e-source
45°
9.5 mm
10 mm
20 nm
50 µm
300 µm
Si
Si3N4
N2
XeF2
SiF4
Si3N4 membrane
20 nm
Si3N4
SiO2/ Si / SiO2 membrane
10 nm
25 nm
100 nm
Si
SiO2