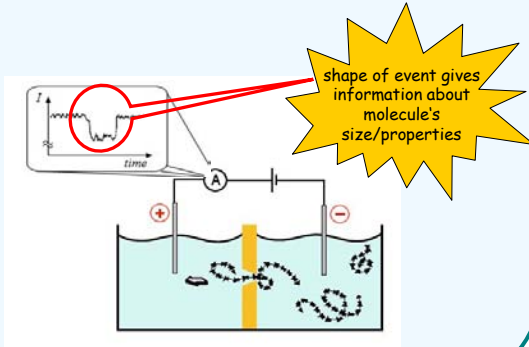


Abstract In recent years, nanopores have become an important tool to study the properties of single biomolecules in ionic solutions. This technique is based on the translocation of these molecules through a pore of comparable size, which are recorded as changes in the pore conductance. Among the various topics that can be studied with this technique are e.g. DNA unzipping or protein denaturation. Here we present a way to fabricate sub-5 nm pores in 20-100 nm thick SiC membranes by direct drilling with a focussed ion beam. In order to obtain a user-friendly setup allowing low-noise measurements, these membranes have to be carefully integrated into an electrolytic cell. For this purpose, the membranes are fixed on a piece of Pyrex containing a micrometer sized aperture, which is used to select the desired pore and at the same time reduces the area of the membrane which is exposed to the liquid, thus reducing the capacitance and the noise of the system.

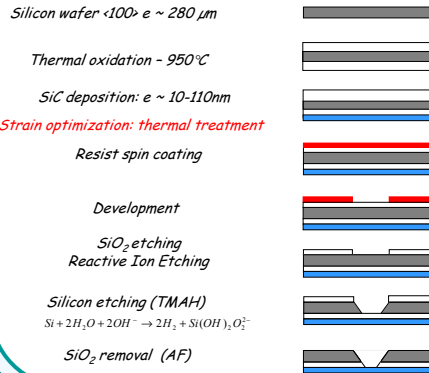
1. Aim: Electronic detection of single biomolecules

Method: charged molecules are drawn through the pore by an electric field and block the ionic current during their passage

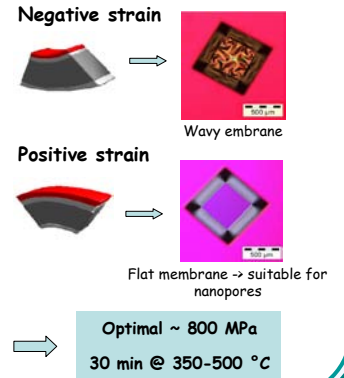


2. Thin (10-110 nm) SiC Membrane production

Fabrication process



Strain optimization by annealing



3. Nanopore creation by FIB direct drilling [1,2]

Principle

Pore size limited by grain size of SiC membrane

Smallest pores **Shape**

Bulk irradiation:

- Deposited energy shape and extension governed via collision cascades and lateral scattering
- can be accurately modeled using TRIM simulations,

Ultra thin target (membrane):

- improved energy transfer localization: if membrane thickness ~ mean free path of implanted gallium ions:
- i) Upper side sputtering, surface erosion and in depth damage injection
- ii) Lower side stamping initiated when $E_{dc} >$ Material binding energy
- iii) Forward scattering along the wall of the nanopore

Parallel fabrication

Using an automated patterning procedure ~200 membranes on a 2 inch wafer can be fabricated. This is a major advantage compared to TEM based nanopore fabrication methods that require one by one handling.

Reference file

Optical microscope image of part of the final wafer with membranes containing one nanopore each

Dose calibration

MAX. dose (~5.10⁷ ions/point) ΔN min. dose (~5.10⁵ ions/dot)

• Dose needed for specific size of pore depends on membrane thickness but also local properties such as tension and crystallinity

• Threshold for pore formation depending on thickness

Position marking

At low doses (400 ions/nm²): surface modification

Array of pores Single pore

4. Integration

Principle: Membrane glued on a microscopic (~50 μm) pore in Pyrex to

- reduce area exposed to liquid and thus capacitance of the membrane
- be able to use membranes with multiple pores
- facilitate handling and improve stability

- Covering Pyrex with wax**
- Align nanopore over aperture**
- Bonding by temperature**

a) For integration in electrolytic cell

b) For use with Nanion Port-a-Patch

5. First characterization

Pore size

Resistance of cylinder 50 nm long @ 0.1 M KCl

$$R = \frac{U}{I} = \frac{4L}{\pi r^2 \kappa}$$

L: length of pore
r: diameter of pore
 κ : conductivity of electrolyte

Size determined by conductivity corresponds to SEM

Current trace

Stable ion current signal