Manufacturing process for 10 nm SiN_x membranes

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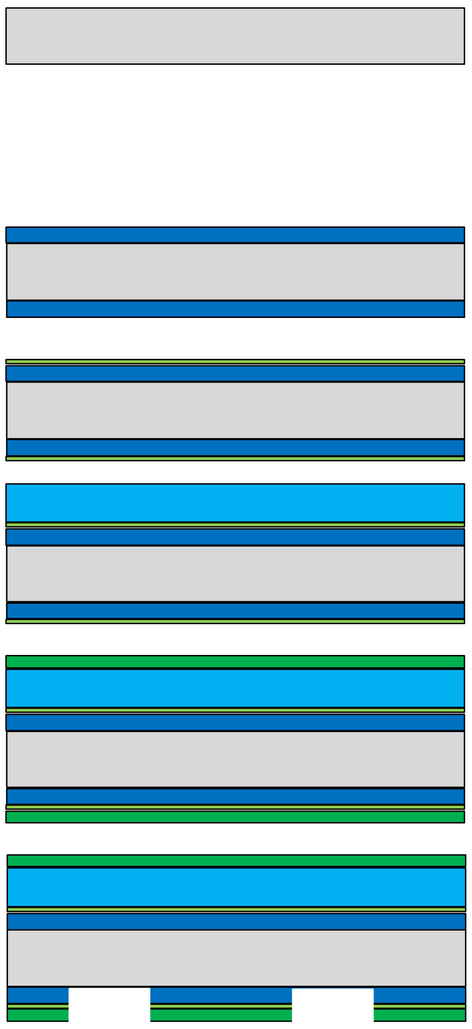
Motivation & Background

Solid-state nanopores are more robust compared to biological nanopores and can be operated at higher voltages thus enhancing signal to noise ratio. Solid-state nanopore sensors typically use silicon nitride (SiN_x) thin film membranes which are fabricated by standard microfabrication techniques.

For nanopore sensing, thinner membranes are preferred as they improve spatial resolution and therefore enhance sensitivity.

One option to fabricate thin membranes is thinning thicker membranes by etching. This leads to significantly rougher surfaces. Our approach uses the direct deposition of very thin, homogeneous SiN_x films by low pressure chemical vapor deposition (LPCVD) which have to be protected during the fabrication process. We use a stack of SiO_2 and SiN_x layers to protect the membrane during a KOH etch.

Process Flow for 10 nm SiN_x membranes



1. 300 µm thick Si <100> wafer, front and back side polished; front side lithography, Si-DRIE, and photo resist removal
2. Wet oxidation (wOx) of silicon wafer (40 nm)
3. Low temperature (710°C) LPCVD of SiN_x (10 nm, membrane layer)
4. PECVD of SiO_2 on front side (300 nm, protective coating for membrane)
5. LPCVD of SiN_x on front and back side (100 nm, KOH-etch mask)
6. Back side lithography, SiN_x and wOx removal by RIE
7. KOH wet etch through the wafer
8. Removal of SiN_x KOH mask on front side by RIE
9. Removal of wOx underlayer with vapor HF (vHF)
10. Removal of PECVD-SiO_2 on front side with vHF

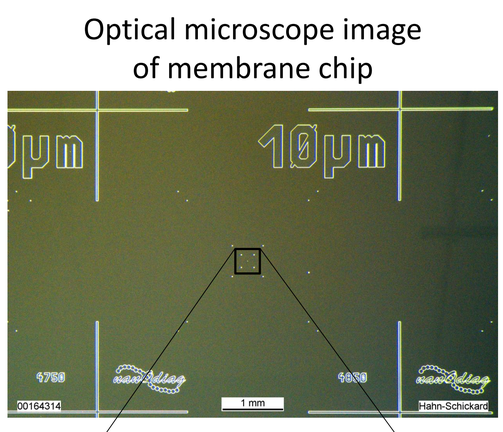
Characterization Methods

- Measurement of thickness and refractive index of single films and layer stacks using ellipsometry
- Measurement of membrane windows size with optical microscopy
- Membrane buckling measurement with a 3D laser scanning microscope (3D-LSM) and stress measurement by wafer bow using a wafer geometry measurement device
- Detailed imaging of membranes with SEM
- Imaging of membrane and layer stack cross sections with FIB and SEM

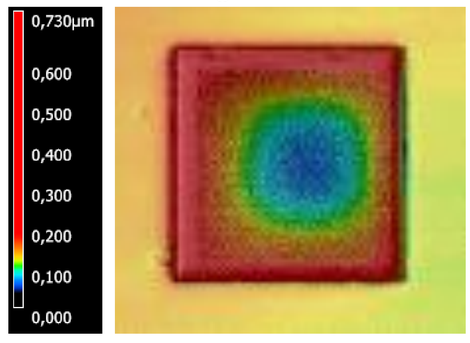
Results

10 nm membranes of direct deposited LPCVD SiN_x achieved!

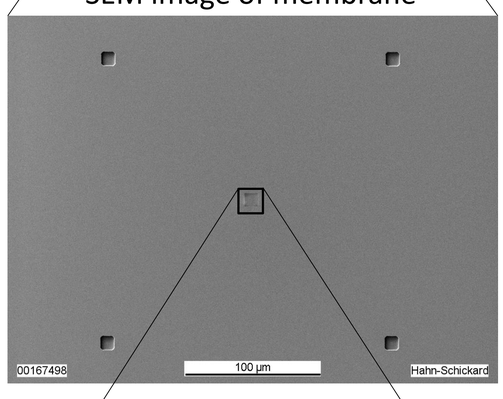
Optical microscope image of membrane chip



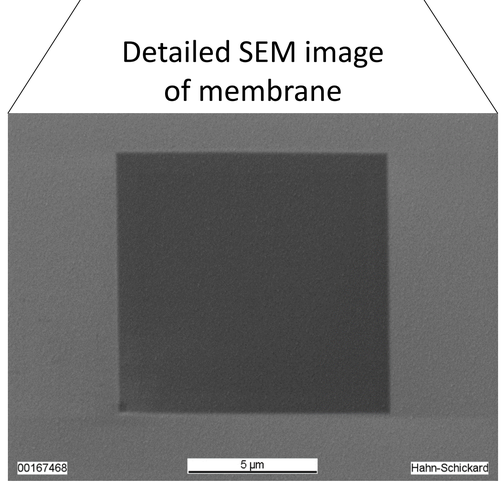
3D-LSM image of membrane



SEM image of membrane



Detailed SEM image of membrane



Membrane parameters:

- Stoichiometric low temperature SiN_x membrane
- 10.5 nm thickness after deposition
- Refractive index of 1.895
- 1.0 GPa high tensile stress
- Nearly unbuckled membrane (100 nm) due to stress compensation with
  - ➢ 40 nm wOx on both sides with approx. -500 MPa compressive stress and
  - ➢ 100 nm LPCVD low-stress SiN_x with approx. 200 MPa tensile stress on the back side

Next Steps

- Effect of processing steps on final membrane thickness
- Experiments using protective coating on front side and SiN_x on back side as protection for KOH etch