Preparation of platforms for nanopore membrane sensing

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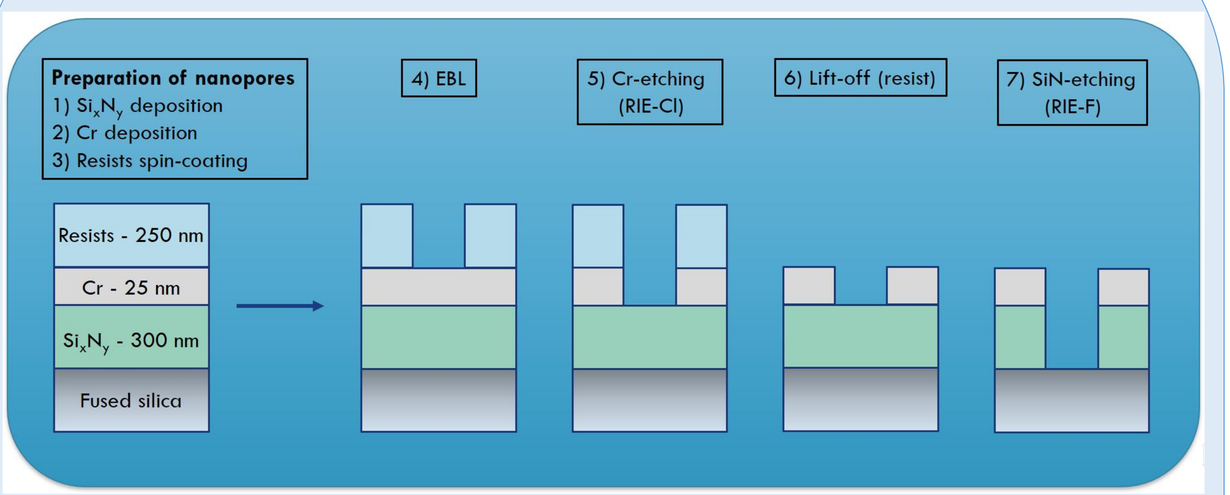
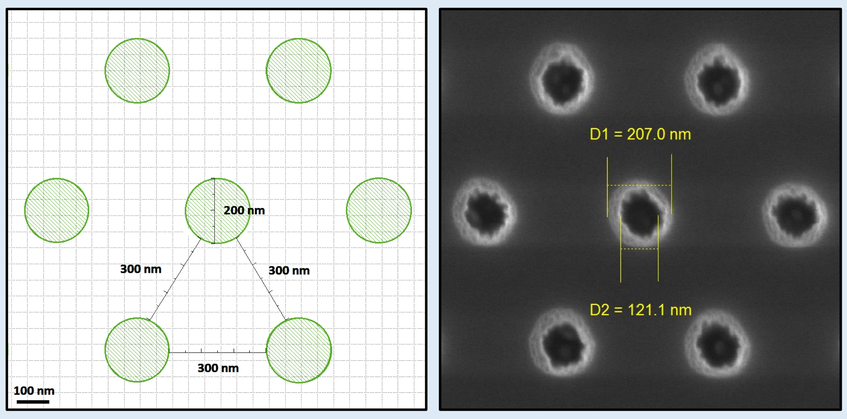
Introduction

We are working on the preparation of platforms which allow us to study interaction of the artificial cell membranes with small particles (e.g. drugs) delivered on their surface [1, 2, 3]. Development of our chip-based platforms has several parts. The first part is focused on the preparation of arrays of nanopores in silicon nitride thin film which is deposited on the optical transparent substrate (in our case fused silica). Electron-beam lithography (EBL), double-step reactive ion etching (RIE) and Lift-off technique are used. The second part covers formation of optically active (plasmonic) structures inside the pores (gold nanomenhirs) for reading information from each membrane. Selection of proper deposition technique and correct deposition parameters (tilt of sample, deposition rate) are crucial. Usability of the chips is tested by functionalization of nanopores, fusion of phospholipid bilayer forming membrane and measuring plasmonic response.

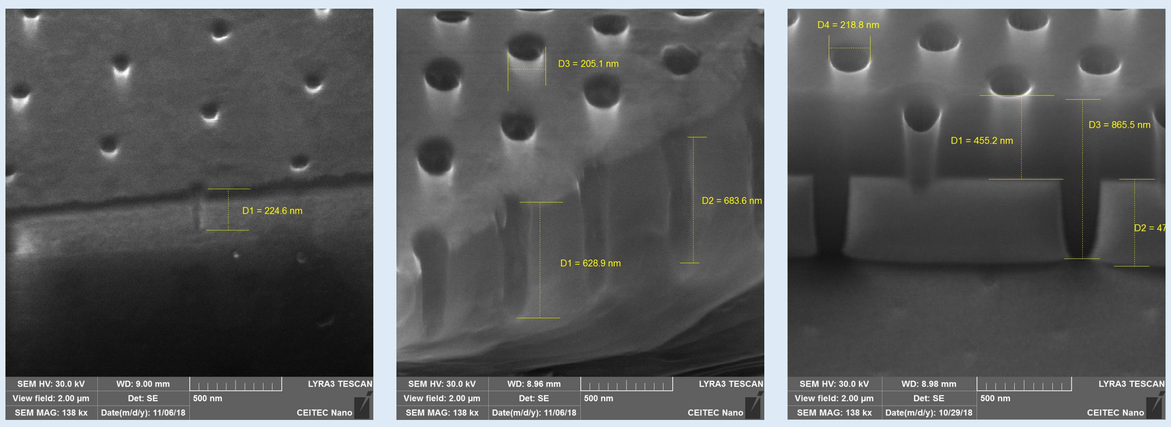
Preparation of nanopores



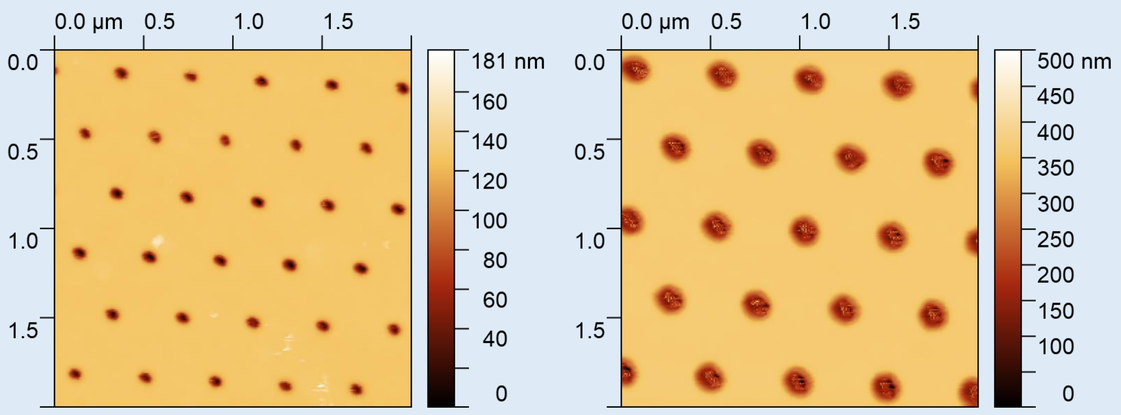
Circular structures with diameter of 50, 100, and 200 nm and variable spacing (300, 500, 1000 nm) were patterned by EBL on MIRA3, TESCAN.



Example of design and final nanopores (circles with diameter of 200 nm, pitch 300 nm).

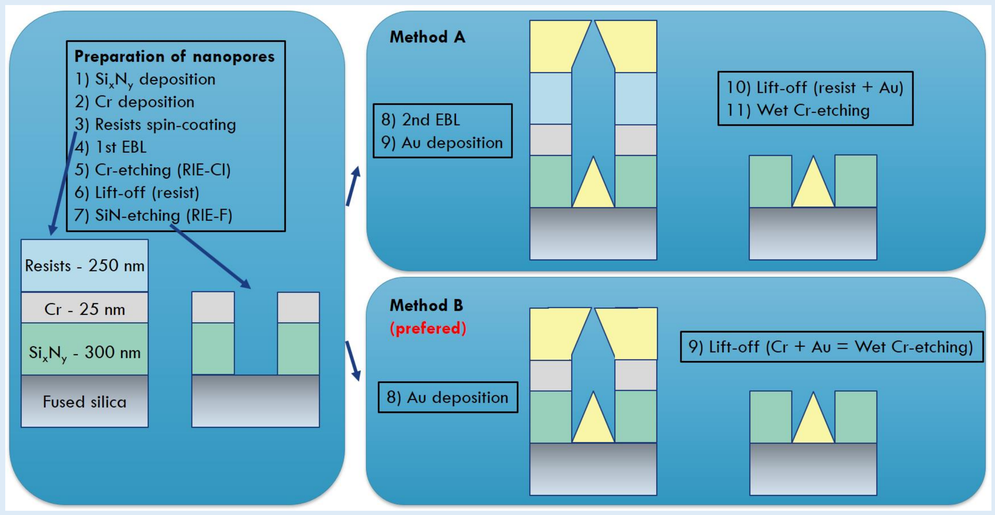


Cross-sections of 100-nm nanopores (pitch 500 nm) and 200-nm nanopores (pitch 300 nm) on the edge of cracks or cut prepared by FIB milling, tilt of 55° (LYRA3, TESCAN).



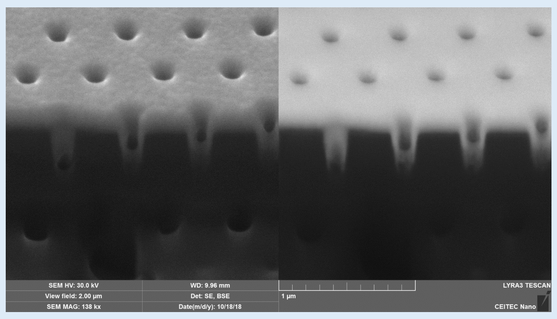
Topography of 100-nm and 200-nm nanopores (pitch 300 nm) using atomic force microscopy technique (DIMENSION ICON, BRUKER).

Preparation of nanomenhirs in nanopores

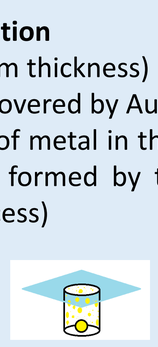


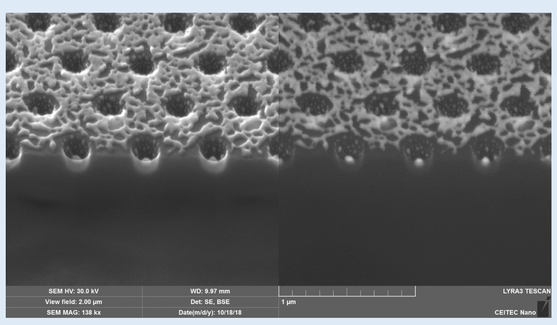
Finding the good deposition properties are the most crucial (rate > 1.5 Å/s [4], tilt 0°, thickness of film similar to depth of pores, E-Beam evaporator).

Deposition under angle
(Au-200 nm, appropriate film thickness)
- Wall of pores fully covered by Au
- Almost no material in the centre of pores

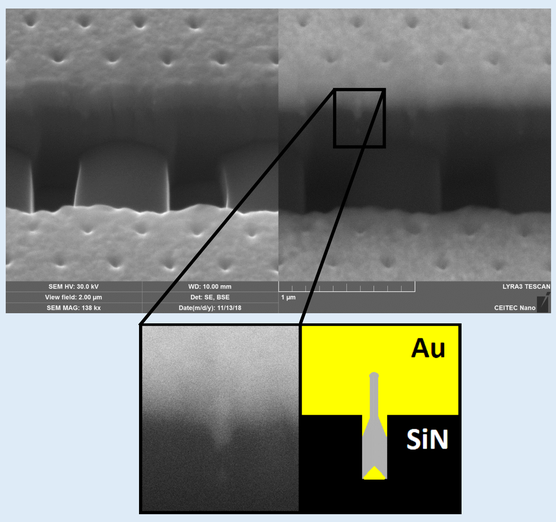


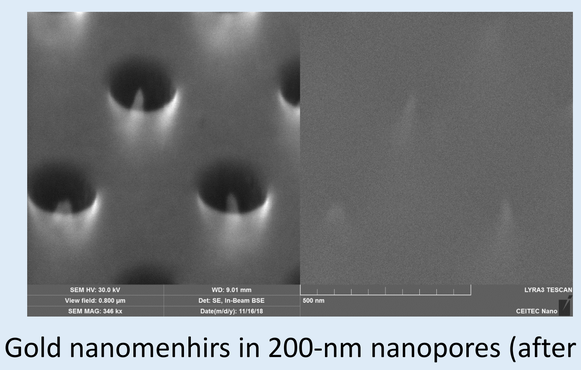
Zero-angle deposition
(Au-50 nm, low film thickness)
- Wall of pores covered by Au islands
- Small amount of metal in the centre of pores (drops can be formed by themselves or by dewetting process)

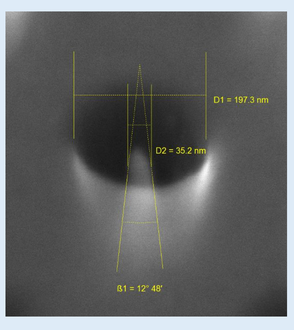




Zero-angle deposition
(Au-200 nm, appropriate film thickness)
- Wall of pores fully covered by Au (can be removed by Lift-off or mechanical exfoliation)
- Nananomenhirs formed in the centre of pores by self-shading effect (Clogging effect)







Gold nanomenhirs in 200-nm nanopores (after the mechanical exfoliation).

References

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