3 D Nanostructures via Aligned Stacking of Pre-patterned Membranes

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In previous publications[1-3] we described efforts to develop a broadly applicable technology for fabricating three-dimensional (3D) nanostructures based on aligning and stacking pre-patterned membranes. Alignment of the membranes relative to one another, with nanometer-level precision, is currently the major challenge. Techniques developed over the past few decades for aligning photomasks relative to substrates employ alignment marks on the photomask and complementary marks on a substrate. Unfortunately, such techniques appear to be incompatible with the stacking of multiple membrane layers.

To address this problem we've developed an approach in which pre-patterned, 1 cm-diameter monocrystalline silicon membranes are first floated on the surface of water to remove stress-induced distortion. They are then lifted from the water surface on a screen, made of silicon-nitride (SiN_x) about 1 μm thick and patterned with 100 μm-diameter holes on a 300 μm grid. The SiN_x screen is then placed in a special water cell, shown in Figure 1, in which water can be forced through the holes to lift the membrane free of the SiN_x.

The membrane position and azimuthal orientation on the screen is arbitrary. However, the screen within the water cell can be rotated and shifted laterally such that the pre-patterned membrane can be aligned in X, Y and θ relative to a fixed reference mark on the receiving substrate using a moiré technique. The membrane is then displaced by several millimeters to the desired location on the receiving substrate for stacking, as illustrated in Figure 2. We will describe details of the techniques, specifically how we ensure nanometer-level alignment in the stacking process despite displacement of several millimeters from the reference site.

[1] A. A. Patel and H. I. Smith, J. Vac. Sci. Technol. B, **25**, 6, 2662 (2007).
[2] S. Ghadarghadr, C. P. Fucetola, L. Lee Cheong, E. E. Moon and H. I. Smith, J. Vac. Sci.Technol. B, **29**, 6, 06F401 (2011).
[3] A. A. Patel, C. P. Fucetola, E. E. Moon and H. I . Smith, J. Vac. Sci. Technol. B, **29**, 6, 06F402 (2011).

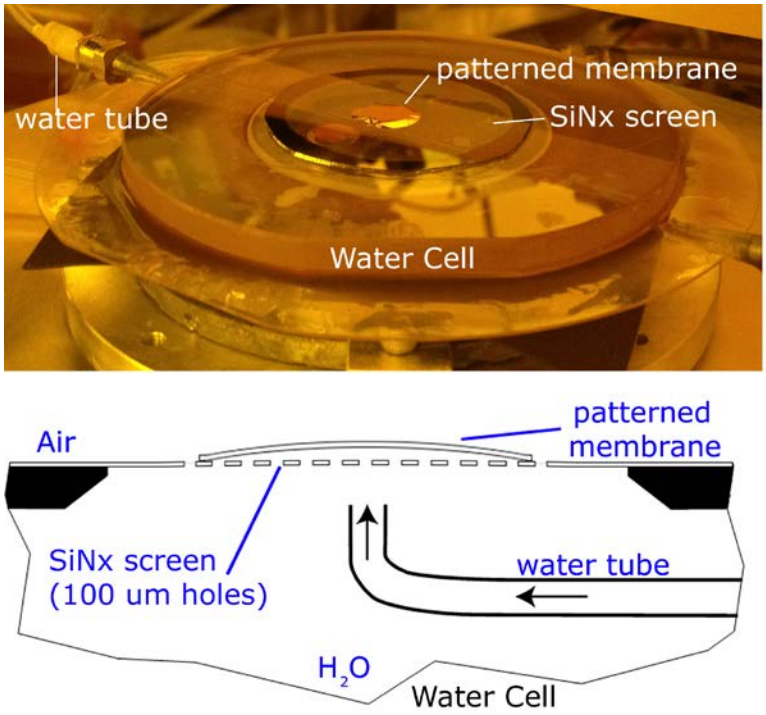

Figure 1: Water is used to detach a patterned membrane from the surface of the SiN_x screen. (top) an image of the water cell, screen and lifted membrane, (bottom) a schematic showing the same.

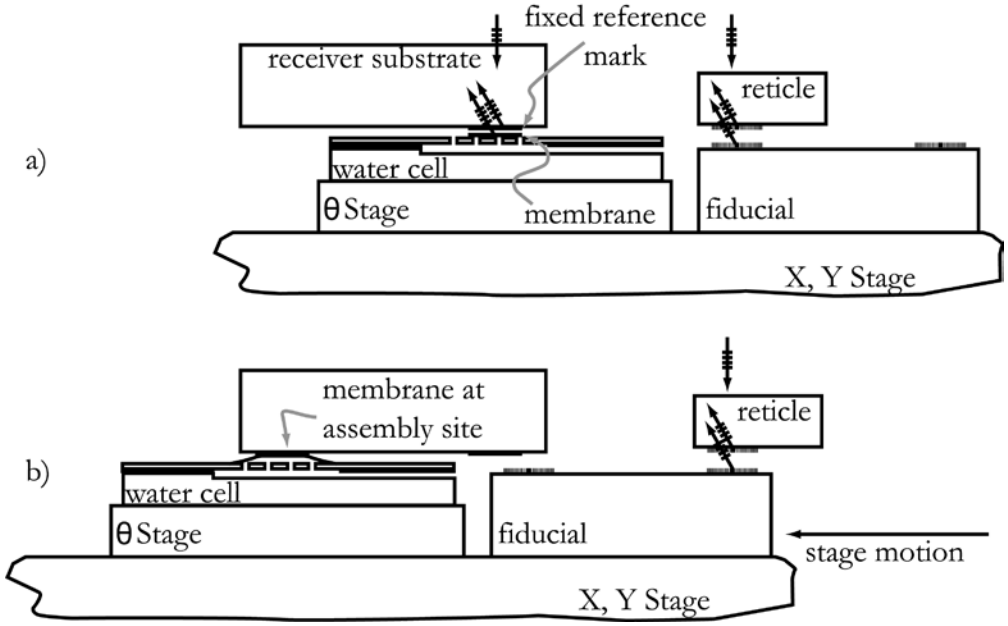

Figure 2: (a) The pre-patterned membrane is shown aligned to the fixed reference mark on the receiving substrate and the reticle is aligned to the left mark on the fiducial. (b) The stage is moved to align the reticle to the identical right fiducial mark allowing the membrane to be stacked at the assembly site.