The Membrane-Alignment Stage in Fabricating 3-Dimensional Nanostructures

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In previous publications we described efforts to develop a technology for fabricating three-dimensional (3D) nanostructures by stacking pre-patterned membranes[1, 2]. Three-dimensional photonic crystals in Si are the test vehicle for this technology development. To minimize distortion induced by stress, the pre-patterned membranes were removed from the substrates that held them and floated freely on the surface of water[1]. The challenge then is how to transfer membranes from the water surface to a receiving substrate while also aligning them with respect to previously transferred pre-patterned membranes.

To address this challenge, we have developed two approaches. In one, a glass frame with a hole smaller than the membrane is brought up underneath the floating membrane and the membrane is captured on the frame. This is depicted in Fig. 1. A weak water-based bond forms between the membrane and the frame that allows one to handle the membrane without introducing any significant stresses. The glass frame, as well as the receiving substrate, can have alignment marks, such as those used with interferometric-spatial-phase imaging (ISPI) [3], an alignment technique that has demonstrated sub-1nm detectivity [3]. Once the membrane held on the frame is aligned and bonded to the receiving substrate, or a previously bonded membrane, the frame is separated using water and a capillary effect. Figures 2 show the process of stacking, and two membranes that have been aligned and bonded.

The second approach uses a SiNx membrane, patterned to form a screen, to lift the freely floating membrane from the water surface. The azimuthal angle of the Si-membrane pattern relative to the SiNx pattern is reduced below 0.5 degrees at which point the ISPI technique can be used to align the membrane relative to alignment marks on the receiving substrate.

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[1] Ghadarghadr et al., J. Vac. Sci. Technol. B 29, 06F401 (2011); doi:10.1116/1.3628672
[2] A. A. Patel et al, J. Vac. Sci. Technol. B 29, 06F402 (2011); doi:10.1116/1.3643762
[3] E. E. Moon, et al., J. Vac. Sci. Technol. B, 21, no. 3112, 2003

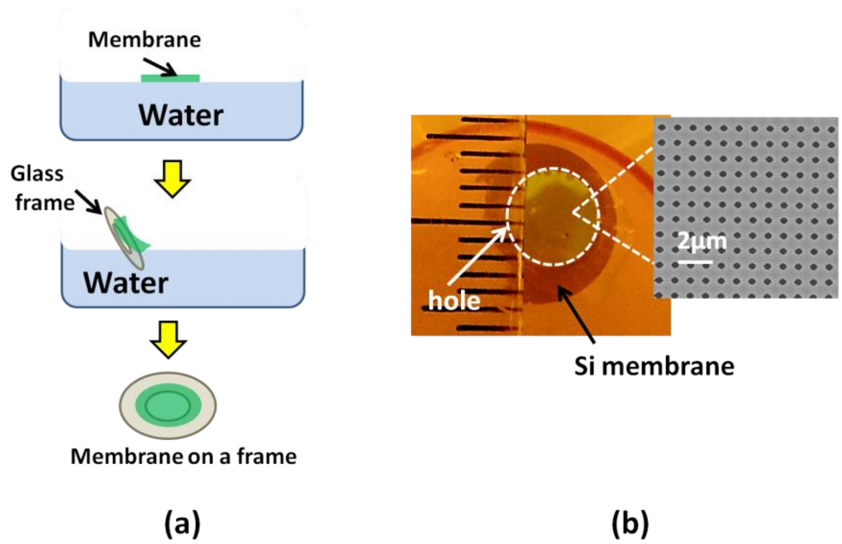

Figure 1: (a) Capturing a free-floating membrane on a frame. (b) Membrane captured on a frame. The membrane is patterned with a grid of holes on a 660nm pitch as shown in the micrograph.

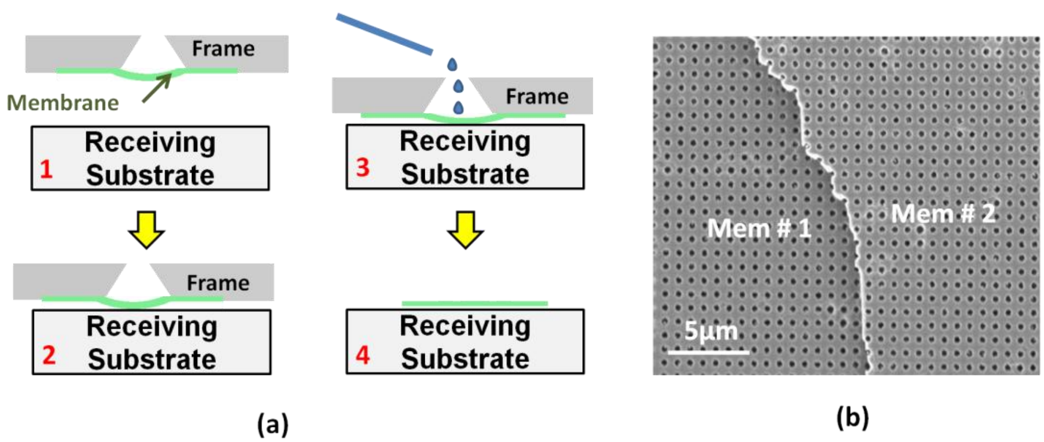

Figure 2: (a) Stacking process: 1- After the freely-floating membrane is picked up on a frame, it has been flipped where due to the gravity the membrane dips down. 2- Using the alignment marks on both the membrane and the receiving substrate we position the membrane with respect to the receiving substrate, then the membrane on the frame is brought down into contact with the receiving substrate. 3- The membrane goes into contact at the center, and then by adding water the membrane detaches from the frame. 4- The membrane forms close contact with the receiving substrate. (b) Stack of two bonded membranes. The first membrane was bonded to the receiving substrate and then using the moiré pattern of the two grids the second membrane is placed and bonded. The micrograph shows a good angular alignment.