# Optimized Reactive Ion Etching for Fabrication of PhoXonic Crystals

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To control the propagation of light and sound simultaneously in one device structures with feature dimensions in nanometer scale are required [1]. In the so-called PhoXonic crystal [2] the photonic and phononic crystal are merged in a 3D silicon slab with a lateral array of air holes in a hexagonal lattice structure. The band-gap is caused by a periodic variation of the density and/or elastic constants for phonons [3] and of the refractive index for photons within this structure. PhoXonic band-gaps have their origin in the destructive interference of multiply scattered waves in periodic structures. Computation of acoustic and electromagnetic waves in such a crystal have been shown that a large band gap appears when the filling fraction is high [4]. Concerning the communication wavelength of 1.55µm we vary the diameter of the holes from 360nm to 470nm at a constant pitch of 500nm to obtain a high filling fraction. This implies the control of the lateral silicon wall between two holes down to 30nm over the whole profile depth with a high aspect ratio exceeding 1:5 which is difficult to obtain in a reactive ion etching (RIE) process. Figure 1 shows the increase in filling fraction with increasing diameter of one unit-cell of the structure. Additionally, low silicon crystal damage and surface roughness have to be ensured to prevent phonon and photon scattering inside the structure.

To perform this high quality structures we applied etching experiments with a deep reactive ion etching machine by optimizing the following parameters:

i) chamber pressure,
ii) gas flow rate of $SF_6$ ,$C_4F_8$ and $O_2$,
iii) rf-power,
iv) treatment time in a continuous etching process.

The etch mask was a 200nm thin PMMA polymer in which the PhoXonic crystal structure was patterned with electron beam lithography (EBL). By the parameter variation of the plasma reactor we studied the influence of ion energy and density on the silicon substrate and obtained the optimal condition for the process. Post-prepared simulations show the average energy and concentration of the active ions that contributed to the sputtering and chemical etching of the silicon. These simulation results are used to estimate the damage and roughness of the silicon single crystal substrate. After each etching experiment the structures were inspected by scanning electron microscope (SEM).

Finally, all results from each etching cycle will be summarized into a graph showing the etching velocity of the silicon and the selectivity to the polymer resist considering the roughness and the angle of the sidewalls.

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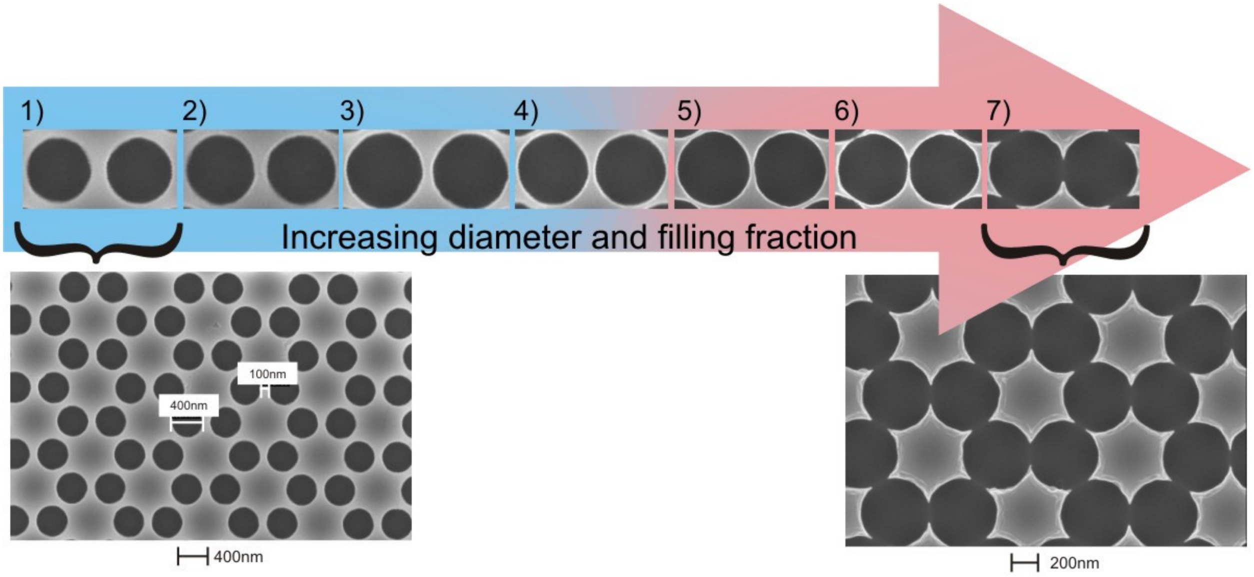

Figure 1: SEM images inside the arrow indicating the increasing filling fraction of the PhoXonic crystal structure. Bottom images show the array of air holes inside silicon after the RIE etching process with left) low filling fraction and right) overetching.