# Influence of water background on the etching rate of silicon and photoresist of a broad reactive ion beam

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The production of ultra-precise and functional optical surfaces has gained importance in recent years. Broad reactive ion beam etching processes are used for patterning and smoothing of high-end spectroscopic diffraction gratings such as pulse compression gratings for high-power laser applications[1,2], special slanted gratings in optical systems for augmented reality applications[3] as well as ultra-precise gratings for synchrotron and free-electron laser beamlines[4]. These high-end applications require minimal mean square roughness in sub-nm range and ultra-precise shape or pattern to achieve the lowest possible stray light content and maximum efficiency[5]. In vacuum systems suitable for processing large optics, there is often no load-lock installed. Depending on the introduced water content during the installation of the optics, the effective chamber surface and the pumping time, the water partial pressure can vary from etching process to etching process and influence the reactive ion beam etching performance.

A custom-build water leakage system was used to set a defined water background pressure in the ion beam etching system. Partial pressures were measured with a residual gas analyzer. A commercially available broad-beam ion source with an excitation frequency of 13.56 MHz and a gas mixture of $CHF_3$ and $O_2$ was used for the etching experiments. The removal of crystalline silicon and photoresist was measured, and the selectivity was calculated spatially resolved on a 100 mm wafer. Photoresist roughness was observed by atomic force microscopy and scanning electron microscopy spatially resolved on a 100 mm wafer.

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[2] Annemarie Finzel, Felix Koch, Gregor Dornberg, Dennis Lehr, Frank Frost, and Tilman Glaser, Optical Engineering **58** (09) (2019).

[3] Vincent Ip, Frederick Pearsall, Tania Henry, and Riju Singhal, *Reactive ion beam etch of slanted gratings for augmented reality*. (SPIE, 2021).

[4] F. Siewert, B. Lochel, J. Buchheim, F. Eggenstein, A. Firsov, G. Gwalt, O. Kutz, S. Lemke, B. Nelles, I. Rudolph, F. Schafers, T. Seliger, F. Senf, A. Sokolov, C. Waberski, J. Wolf, T. Zeschke, I. Zizak, R. Follath, T. Arnold, F. Frost, F. Pietag, and A. Erko, J Synchrotron Radiat **25** (Pt 1), 91 (2018).

[5] Tilman Glaser, Advanced Optical Technologies **4** (1) (2015).

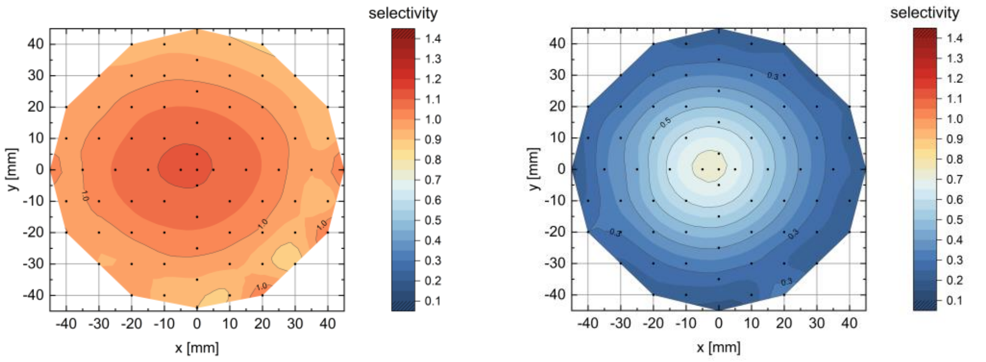

Figure 1: Spatially resolved selectivity on a 100 mm wafer at (left) water partial pressure of 0.08 x $10^{-5}$ mbar and (right) water partial pressure of 12.7 x $10^{-5}$ mbar for an operation of the ion beam source with a mixture of $CHF_3$ and $O_2$. A gradient of selectivity is observed from the center to the edge of the sample. Adding water to the process significantly decreases the selectivity. The measurement points are represented by the dots in the graph.

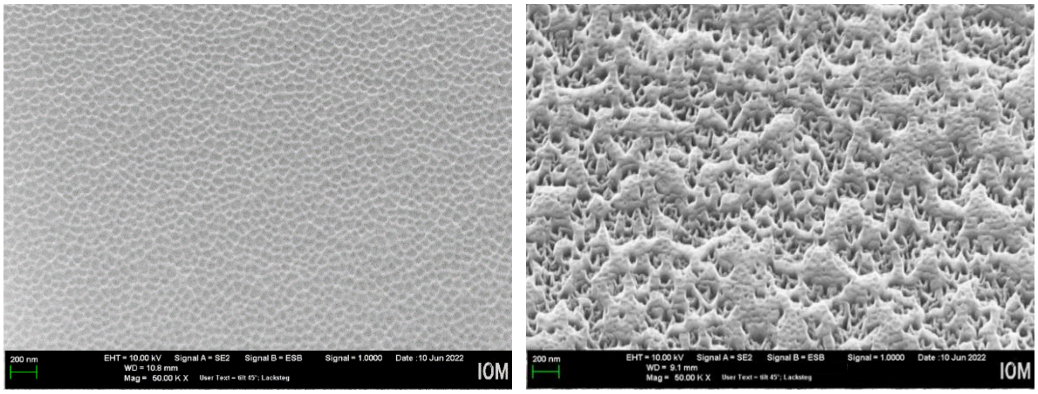

Figure 2: Scanning electron microscope images of the photoresist at a water partial pressure of 0.08 x $10^{-5}$ mbar (left) in the center of the wafer (R = 0 mm) and (right) at the edge (R = 40 mm).