Fabrication of 200 nm period blazed transmission gratings on silicon-on-insulator wafers

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We have developed a new, high-efficiency transmission grating for the extreme ultraviolet to x-ray band, which requires free-standing grating bars with a very high aspect ratio (>100) and smooth sidewalls[1]. We have previously introduced the concept of this critical-angle-transmission (CAT) grating and fabricated 574 nm-period CAT grating prototypes on 10 µm silicon-on-insulator (SOI) wafers. Diffraction tests of these gratings with low energy x-rays (<0.5 keV) have shown high-efficiency blazing as predicted by theory[2]. However, for higher energy x-ray applications, shorter period CAT gratings are required[3]. We will present progress in the fabrication of 200 nm-period CAT gratings with a 25 µm-pitch support mesh on 3-5 µm thick SOI wafers.

We have used potassium hydroxide (KOH) solutions to fabricate high aspect ratio gratings on <110> SOI wafers. In order to achieve 5 µm tall and 50 nm wide grating bars by etching, etch anisotropy between <110> and <111> should be at least 200, considering the silicon nitride mask linewidth (<100 nm) formed by interference lithography and reactive ion etch (RIE) and undercut during KOH etching. Therefore, we improved the KOH etching process to minimize the lateral undercut through precise grating alignment to <111> planes within ±0.05° and a room temperature etch process with 50 wt% KOH as shown in Fig. 1. In addition, an image reversal technique with a high silicon content spin-on polymer was applied to increase process latitude by making the nitride mask wider. A surfactant was also added to the KOH solution to promote H_2 bubble release[4].

We achieved very high etch anisotropy of about 500-1000 on a <110> silicon wafer as shown Fig. 2, which enables us to fabricate ultra-high-aspect ratio structures on SOI wafers. Comparing Fig. 1 and 2(a), the lateral <111> etch rate was only 1.25 nm/hr while the vertical <110> etch rate was about 1.4 µm/hr. With high etch anisotropy, precise control of the duty cycle (width/period) and excellent etch uniformity through the 5 µm device layer can be achieved by over-etching the grating. Figure 2(b) shows the maximum etch depth is limited by the support mesh space due to the titled <111> planes, which reduces the free-standing CAT grating area. We are investigating a procedure to ameliorate this problem.

References

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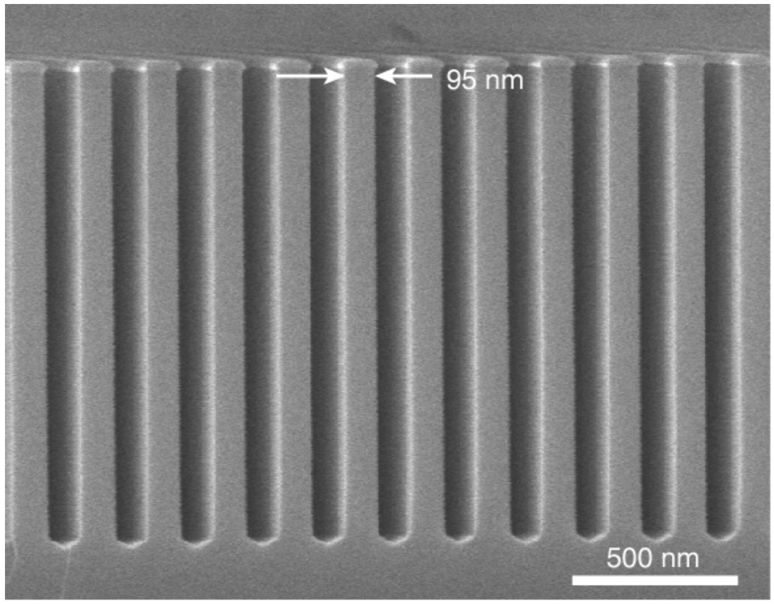

Figure 1. Electron micrograph of a high aspect ratio 200 nm-period silicon grating in a <110> silicon wafer. The sample was etched in surfactant-added 50 wt% KOH at room temperature for one hour. The grating bars are 1.4 µm deep and 95 nm wide at the top. The nitride mask is left to show the amount of undercut.

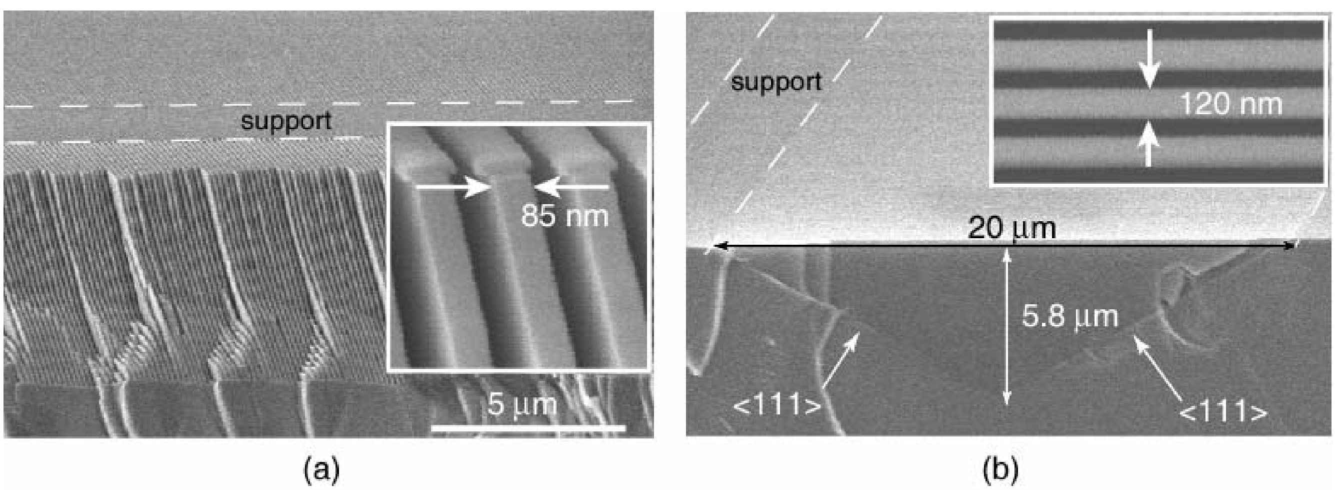

Figure 2. Electron micrograph of a 200 nm-period grating etched in the same solution as the sample in Fig.1 for 5 hours and dried in a critical point dryer. (a) Grating cross sectional view along the support mesh. The inset shows the undercut increased only by about 5 nm on each side during four more hours of etching compared to the sample in Fig. 1. Thus the lateral <111> etch rate is close to 1.25 nm/hr. (b) Cross section along the grating bars to show a grating sidewall between the support bars. One <111> direction is normal to the grating sidewall, but there are two other slanted <111> planes, which limit the maximum etch depth to 5.8 µm. The inset shows the top view of the sample with the nitride mask remaining.