Precise measurement of chromium dry etching rate at low temperatures for ultimate profile control

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Plasma etching in nano-fabrication is one of the most critical steps when it comes to defining nanoscale features with size control and low line edge roughness. At the single digit nanometer regime, new techniques and comprehensive understanding must be developed to overcome challenges such as decreasing selectivity and pattern collapse of small features.

Plasma etched chromium has widespread use in optical lithography mask fabrication and as a highly selectivity etching mask for nano-scale patterning, for instance to produce high-resolution nanoimprint mask. However, most studies of chromium etching focus on optical masks [1-3] which have features sizes ~100 nm — 4x times that printed at the device level.

Here, our goal is to better understand chromium etching mechanisms using Cl_2/O_2 plasma chemistry to find a process window that will allow us to pattern features down to 5 nm half-pitch. Previously we defined chromium hard masks as small as 10 nm half-pitch using PDMS masks produced using block copolymer lithography [4]. The isotropic nature of the chromium etching process resulted in a profile that undercuts the masking material, for example, as demonstrated in Figure 1, and limited our ability to shrink further.

In this work we investigate etching temperature (40 to -100 ° C), oxygen/chlorine (0-80%) flow, and applied bias towards controlling chromium etching at the single digit nanometer level. Spectroscopic ellipsometry (SE) is used as noninvasive and precise method to determine etching rates over a large range of process conditions. Figure 2 shows etching rates measured using SE as a function of substrate temperature and oxygen flow. The etching rate slows with temperature and the extremes of oxygen content. Patterned features as a function of temperature and other oxygen concentration are shown in Figure 3. Oxygen flow can be used to limit undercut. However, at low temperature we create a sidewall passivant that can be used to stop undercut altogether. Figure 4 shows zero undercut for a chromium sample etch at -100 ° C. Mechanisms of chromium etching in light of our results will be discussed.

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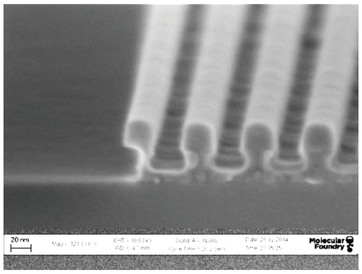

Figure 1: Undercut:
HSQ lines with 60nm pitch on chromium, etched in an CL2/O2 plasma. Open area and patterned area can be seen. Lateral and vertical etch rate are both higher in open area, leading to more undercutting of features.

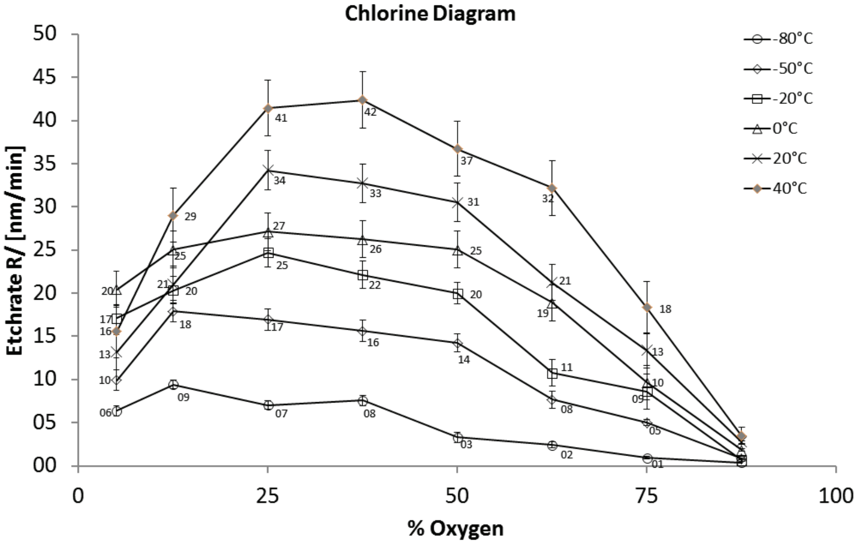

Figure 2: Etchrates in chlorine oxygen plasma: Etch rate vs. %oxygen is shown. Different temperatures are plottet. Etch rate slows down with temperature following Arrhenius-type dependence.

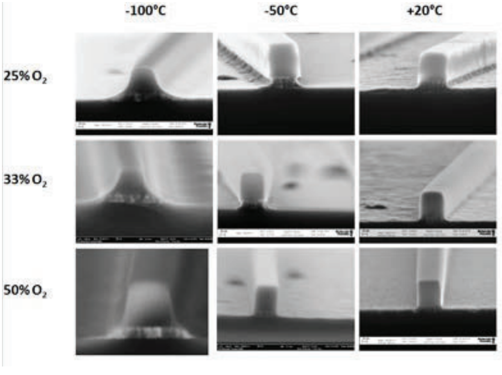

Figure 3: Etched features: HSQ masked chromium was etched under different conditions. Temperature and oxygen concentrations are shown. Higher oxygen concentration indicates less undercut

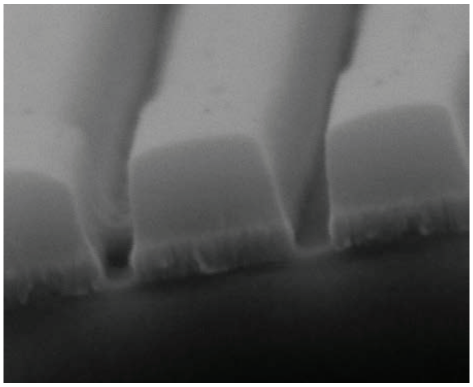

Figure 4: low temperture etching: Passivant build up at -100C in chlorine containing plasma. 200nm pitch. After passivant break through sidewalls of underlying chromium are straight and show no evidence of undercut within features.