SiO_2 plasma etching using SF_6 with O_2/Ar mixtures down to cryogenic temperatures

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Silicon oxide etching processes have been crucial to the development of transistors, memory storage devices, MEMS, etc. for over 50 years. Traditionally, fluorocarbon gases have been used because these chemistries provide selectivity between Si and SiO_2, or between SiO_2 and a resist. However, with such chemistries, there is a need to optimize the fluorocarbon passivation layers.

SF_6 gas has been shown to be an advantageous alternative chemistry to fluorocarbons. Under similar etching conditions, SF_6 had a higher etch rate than CF_4 [1]. Moreover, SF_6 etching moves away from using passivation chemistry to provide selectivity – a method that can induce surface roughness and inhibits critical dimension control [2-3]. SF_6 chemistries also lend themselves to cryogenic etching, which enhanced the fabrication of sub-10 nm features in silicon [4-5].

In this study, we test the utility of SF_6 at cryogenic temperatures when etching sub-100 nm features in silicon oxide for applications such as nanoimprint template formation and 3D NAND. We investigate the SF_6 etching process using two masks, hafnia and chromium, and with complementary gases, Ar and O_2. We find that cryogenic SF_6 has improved selectivity in SiO_2 etching at low temperatures – for instance, with hafnia at temperatures down to -140°C (see Figure 1). These benefits for hafnia are only apparent at lower forward powers. However, cryogenic temperatures improve selectivity for chromium masks even at the higher powers needed to form vertical profiles (Figure 2). Mixtures of both SF_6-Ar and SF_6-O_2 can improve these profiles over pure SF_6 gas, but we see a definitive advantage with 50-50% SF_6-Ar gas composition at -100°C (Figure 2). Finally, we are able to create high-aspect ratio features with 30 nm pitch using a chromium mask (Figure 3). The effect of power, pressure, gas mixtures and temperature will be discussed.

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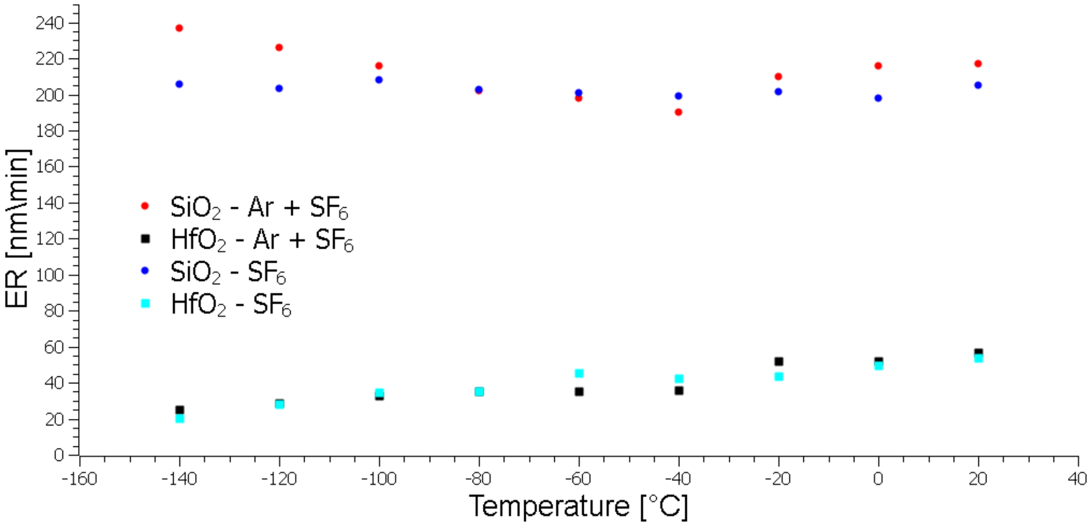

Figure 1: Selectivity data. The etch rates of silicon oxide and hafnia are plotted over a range of temperatures. Selectivity to SiO_2 improves at temperatures below -60°C. Trends are similar for gas compositions of pure SF_6 and 50-50% SF_6-Ar.

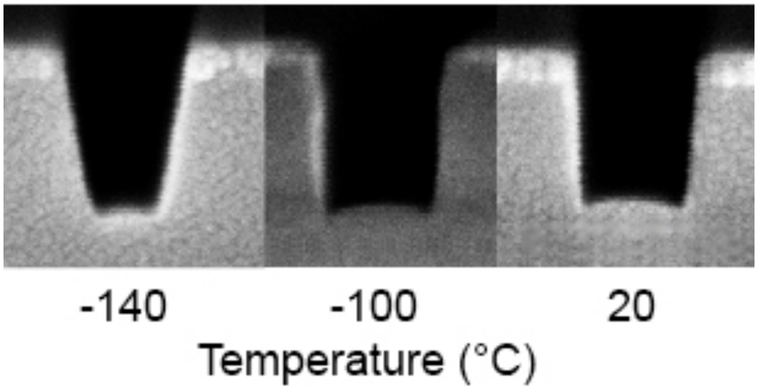

Figure 2: Vertical sidewalls. Straight sidwalls obtained at -100°C with a 50-50% mixture of SF_6 and Ar. Etching at higher temperatures does not improve the profile.

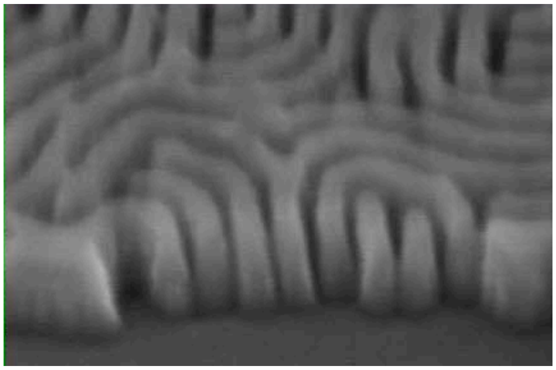

Figure 3: High-aspect ratio features. Features with 30 nm pitch are obtained by using a chromium mask and etching with a 80/20 mixture of SF_6/O_2.