# Cryogenic Silicon Process for Etching 15 nm Trenches and Beyond

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As features sizes and mask heights shrink, high mask selectivity and thin passivation layers are crucial for high resolution nanoscale pattern transfer. We are investigating cryogenic $SF_6/O_2$ process for high fidelity nanoscale etching. Cryogenic $SF_6$ etching was first introduced by Tachi *et.al* [1] as a means to anisotropically etch silicon with 30:1 selectivity using an organic mask. More recently, Sieniemi and Franssila, showed extremely high selectivities to $SiO_2$ (150:1) and $Al_2O_3$ (66,000:1).[2] After Tachi, *et. al*.'s work, [1] oxygen was found to be a critical component for anisotropy.[3] *In-situ* studies show the passivation layer is composed of a relatively thin $SiO_xF_y$ layer which partially desorbs when the sample is warmed to room temperature.[4,5] Hence the cryogenic $SF_6/O_2$ process can potentially deliver high selectivity with a thin passivation layer for nanoscale etching. While this process has been studied for larger scale features, we are studying the scalability of the process below 50 nm and down to single digit nano (sub-10 nm) dimensions.

Previously, we have demonstrated this process can define small trenches when oxygen levels are controlled.[6] Here we expand on this work and show how etching mask plays a role at small feature sizes and pattern density. Features were etched using an Oxford Plasmalab 100 with a Cobra source. The process window was tested and trends identified using a 9 level design-of-experiments with 500-1500 nm features sizes. The process was then mapped to sub-100 nm features primarily by modifying the $SF_6/O_2$ ratio. Two electron beam resist masks were tested: hydrogen silsesquioxane (HSQ) and ZEP-520. Figure 1 shows ~15 nm features defined using a HSQ mask while figure 2 shows 20 nm features defined in ZEP-520. Profiles in smaller patterns (~15 nm half-pitch) were determined by mask integrity and process selectivity. Ultimate scalability for single digit nano features using highly etch resistant oxide masks will be discussed.

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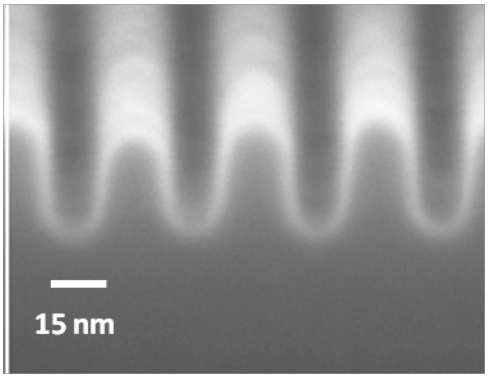


*Figure 1: Sub-15 nm trenches etched in Silicon Using an HSQ mask.* Using the appropriate ratios of $SF_6/O_2$, 15 nm trenches are defined at ~45 nm pitch. Aspect ratio is ~2:1.

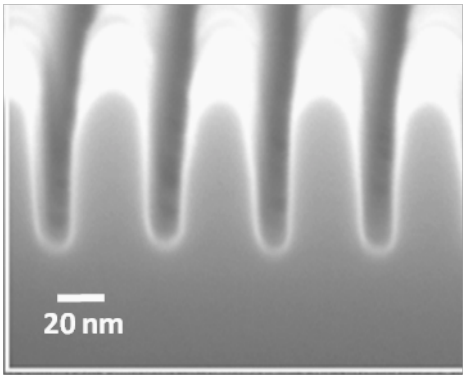


*Figure 2: Sub-15 nm trenches etched in Silicon Using a ZEP-520 mask: sub*-20 nm trenches at ~60 nm pitch are etched into silicon. Aspect ratio is 5:1.

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[1] S. Tachi, K. Tsujimoto, and S Okudaira, Appl. Phys. Lett. **52** (8), 616 (1988).
[2] L. Sainiemi and S. Franssila, J. Vacuum Soc. B **25** (3), 801 (2007).
[3] Johann W. Bartha, Johann Greschner, M. Puech et al., Microelectron.Eng. **27** (1-4), 453 (1995).
[4] R. Dussart and et al., J. Micromech. Microeng. **14** (2), 190 (2004).
[5] X. Mellhaoui, R. Dussart, T. Tillocher et al., J. Appl. Phys. **98** (10), 104901 (2005).
[6] Y. Wu, D. L. Olynick, A. Goodyear et al., Microelectron. Eng. **In Press** (2010).