

Community Service Project Proposal: Expanding STS2 Etch Capabilities

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Introduction

Current use of the STS2 is limited by the lack of characterization perceived by the user community. It is clear that STS2 should be able to replicate the functionality of STS1 while offering expanded capability. The purpose of this community service project would be to develop recipes useful to the SNF community for specific applications. The initial focus application will be to utilize the unique capabilities of the STS2 to develop recipes for very high aspect ratio narrow trenches.

Initial Work

An existing "SOI Template" recipe exists on the tool and serves as a starting point for etching trenches on SOI wafers. Previous work by Gary Yama has led to a modified version of this recipe in which the passivating C_4F_8 gas flows during the etch step. This modification results in reduced lateral blow-out, but causes significant grassing and pinch-off of the trench profile for depths $>50\mu\text{m}$. For existing processes, these are handled by significant overetching to clear the grass and by limiting the process design to SOI wafers with shallow ($<20\mu\text{m}$) device layers.

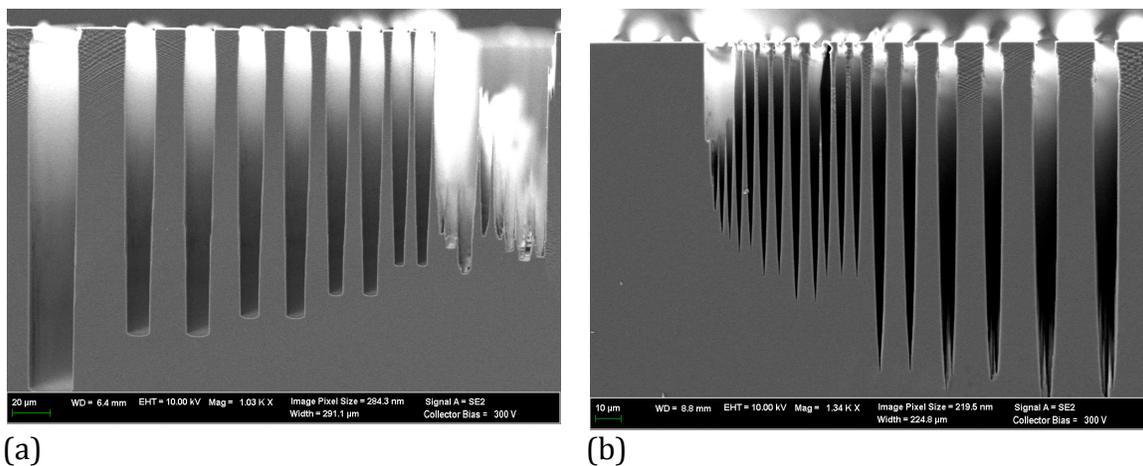
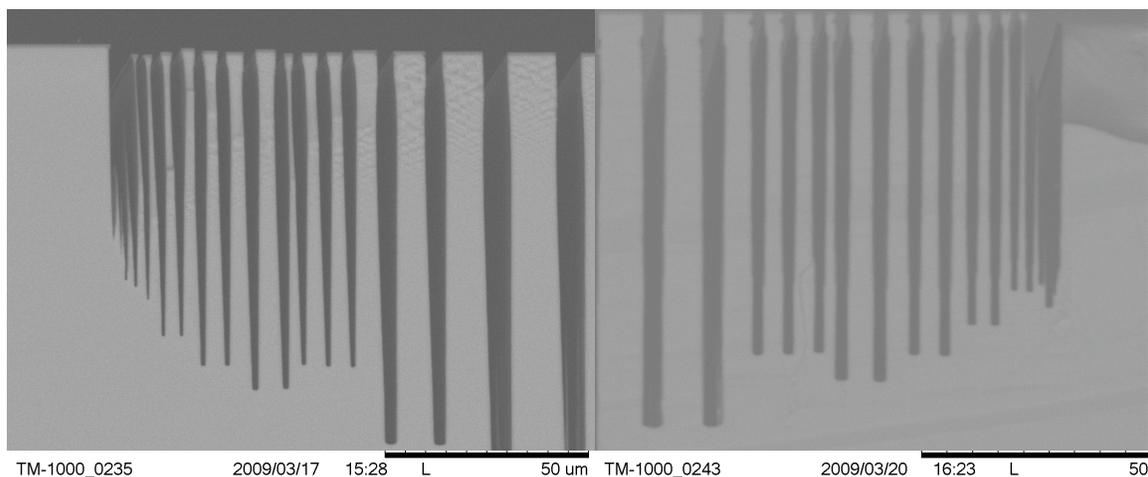


Figure 1. (a) One hour etch using SOI_Template recipe and (b) one hour etch using SOI_Template_gy_withC4F8. Both wafers had a 1um oxide hard mask.

One of the expanded capabilities the STS2 offers over STS1 is the capability to do parameter ramping in the software to tailor the recipe as trench depth (and aspect ratio) increases during the course of the etch. The existing recipe “with C_4F_8 ” sets a flow of 30sccm during the etch phase. Initially reducing that C_4F_8 flow was explored by running an etch with a flow of only 10sccm. The increase in lateral blowout present in the base SOI Template recipe at the top of the trenches was noticeable but the effect of the C_4F_8 in causing deep trenches to pinch-off was also present. Fig. 2(a) shows the effect of ramping the etch step time from 3 sec. to 3.5 sec. over the course of a 30 minute etch to help open the trench bottoms. Fig. 2(b) shows the result of an etch using an initially higher C_4F_8 flow and a more aggressive ramping of etch step time from 3 sec. to 4 sec. in an attempt to better prevent blowout in the tops of the trenches and further open trench bottoms.



(a) (b)
Figure 2. (a) 30 minute etch with fixed C_4F_8 flow of 10sccm and ramped etch time from 3 sec. to 3.5 sec. and (b) 42 minute etch, ramping C_4F_8 in first 12 minutes from 20sccm to 10sccm and then for 30 minutes keeping C_4F_8 flow at 10sccm while ramping etch step time from 3 sec. to 4 sec.

Future Investigation

While parameter ramping is a documented way to enhance trench profiles and attainable aspect ratios, a more dramatic enhancement is desirable for numerous applications. The etch selectivity of the sidewall passivation layer becomes a fundamental limiter of aspect ratio in deep trenches. The initial portion of each SF_6 etch step is spent removing the passivating Teflon-like layer from the bottom of the trench and exposing the silicon, which is then etched by the reactive fluorine radical plasma for the remainder of the etch cycle. The initial depassivation in each etch step plays a critical role in determining the trench profile and limiting the achievable maximum aspect ratio. As trench depth increases during the etch ion flux down to the bottom of the trench falls off and effective removal of the passivation layer at the bottom of the trench becomes harder. Increasing the ion flux by increasing the bias voltage risks excessive attack of the sidewall passivation

layer by scattered energetic ions. Thus fundamentally, the achievable aspect ratios in the Bosch process are in part limited by anisotropy and etch selectivity of the passivation polymer etching step in the SF₆ plasma etch phase.

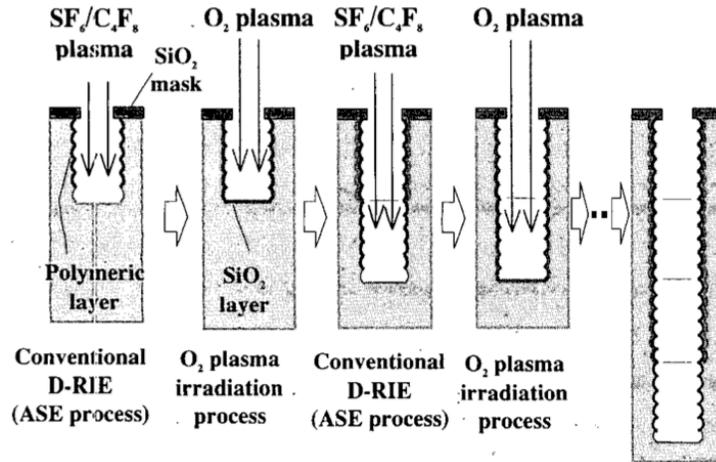


Figure 3. The modified DRIE process with intermittent O₂ plasma processing to generate a secondary SiO₂ sidewall passivation layer, demonstrated by Ohara et al. [1]

	The conventional process	The new process
Trench profile		
Trench depth (μm)	51.2	50.6
Trench width (μm)	2.21	1.10
Aspect ratio	23	46

Figure 4. Figure from Ohara et al. demonstrating significantly improved narrow trench aspect ratios. [1]

Figure 3 illustrates the proposed processing technique. Initial etching of the trench proceeds using the standard two-phase Bosch process. After some period of etching time, the second step is to generate a thin SiO₂ layer on the exposed trench surfaces to form a secondary passivation layer. The authors utilized an O₂ plasma within the etcher chamber to generate a thin (~2nm) oxide layer on the surface. Etching then proceeds again using the conventional DRIE process for some period of time before repeating the O₂ plasma process. After each O₂ plasma step, some period of the subsequent SF₆ etching is spent removing the oxide from the trench bottoms, before direct silicon etching resumes. The interval of standard Bosch processing between O₂ plasma processing is chosen so that the etching of the sidewall SiO₂ forming the secondary passivation is never etched through during the Bosch processing. The success of this technique relies on the fact that SiO₂ has higher etch selectivity than the

Teflon like passivation layer produced during the passivation phases of the Bosch process. Figure 4 demonstrates the dramatic improvement in aspect ratio that was attained by using periodic O₂ plasma steps to produce a secondary passivation layer.

Proposed Experiment

To investigate the use of a thin oxide layer as sidewall passivation during DRIE in the SNF it has been suggested that multiple ways of generating this passivation be explored. Firstly, as done in Ohara et al. an O₂ plasma can be used in the STS2 chamber to generate this thin (~2nm) oxide layer grown at room temperature and without having to break vacuum during the etch. This has the obvious advantage of convenience, as well as the unique aspect that an O₂ plasma is actually etching while at the same time hopefully passivating. Secondly, the Gasonics Aura Asher can be used to quickly grow thin oxides likely thicker than possible in the STS2 chamber. Lastly, simply leaving the wafer with exposed trench out in ambient air for a prolonged period of time should allow a thin oxide to form.

Exploring these three techniques for sidewall passivation should allow for identification of good parameters for sidewall oxide passivation. The ultimate goal would be to combine a best-choice STS2 recipe with an O₂ plasma recipe to generate a procedure for achieving enhanced aspect ratio deep narrow trenches in the STS2.

Equipment and Processing

As already done in the initial work standard silicon test wafers will be used. The ASML stepper and either the p5000 or AMT etcher will be used to expose and pattern the SEM line features into a ~1um thick LTO hard mask. In order to achieve enhanced aspect ratios an appropriate STS2 etch recipe is required. The modified SOI Template recipe with limited C₄F₈ flow is a suitable candidate. The smooth-shallow recipe will also be investigated. The un-modified SOI Template recipe has both a very high oxide mask etch rate as well as significant lateral blow-out.

References

1. "A New Deep Reactive Ion Etching Process By Dual Sidewall Protection Layer", J. Ohara, K. Kano, Y. Takeuchi, N. Ohya, Y. Otsuka, S. Akita, Conf. on Micro Electro Mech. Systems, MEMS 2000, Jan 23-27, Miyazaki, Japan pp. 277-282