# Scallop Free, Positive Tapered Si Via Etch Using $SF_6$ / $O_2$ Non-Bosch DRIE

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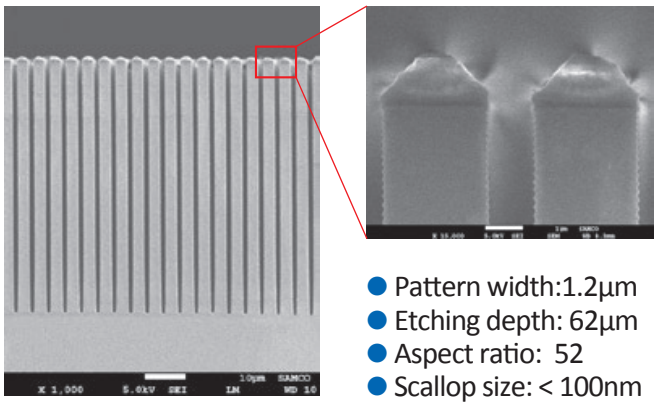
## Introduction

Anisotropic deep silicon etching technologies are largely divided into two groups. Number one is the Bosch process, a multi-step Si DRIE process that alternates between two steps, namely passivation layer deposition and isotropic silicon etching. Number two is a single step, non-Bosch Si DRIE process that simultaneously utilizes gasses for passivation layer deposition and etching.

The Bosch process can achieve high-speed etching, high selectivity over photoresist masks, high aspect ratios and vertical etch profiles. In 2003, Samco became the first Japanese company to license the Bosch process from Robert Bosch GmbH to use for a wide range of applications that require high-aspect-ratio structure fabrication, such as inkjet heads, various types of sensors, healthcare, optical communications and biotechnology.

Figure 1 illustrates examples of structures fabricated by Samco's RIE-800iPBC, a plasma etching system that utilizes the Bosch process.

These structures have smooth sidewalls with high aspect ratios, at a pattern width of 1.2µm and a depth of 62µm.



- Pattern width:1.2µm
- Etching depth: 62µm
- Aspect ratio: 52
- Scallop size: < 100nm

Figure 1 High Aspect Bosch Process Fabrication Results

Although the Bosch process has the advantages of high etch selectivity and vertical profiles, smooth sidewalls are more challenging to achieve due to scallops formed during the cyclic deposition and isotropic etching processes. While scallop minimization is certainly possible with Bosch etching, to do so requires a comparatively slower etch rate.

Non-Bosch Si DRIE, on the other hand, is capable of scallop-free and tapered structure fabrication because its simultaneous etching and passivation ensures smooth sidewalls.

For that reason, depending on the process requirement of the etched profiles, there are cases when $SF_6/O_2$ non-Bosch DRIE is more appropriate than the Bosch process.

Both processes have their merits. For them to be properly used, however, it is necessary to make sure they are suitable for the process demand at hand.

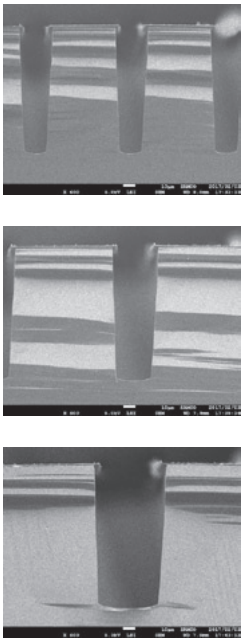
For example, TSV fabrication may require a structure that is 20µm in diameter with a depth of 100µm, in which case a non-Bosch Si DRIE process would be used. A depth greater than 100µm, however, would require Bosch DRIE.

Since previous issues of Samco Now have already covered the Bosch process in more detail, this technical report will focus on and explain our newest findings for a single step non-Bosch DRIE process that utilizes $SF_6/O_2$.

## Process

Figure 2 illustrates the results of $SF_6/O_2$ non-Bosch silicon etching using the Samco system RIE-800iP.

Trenches with a width of 20µm, a depth of 107µm and a tapered profile without any bowing were fabricated at an etching rate of 13.4µm /min. Even if the opening diameter is 30µm wide and 113µm deep, or 50µm wide and 121µm deep, tapered profiles without bowing can still be fabricated.



- Pattern width: 20µm
- Etching depth: 107µm
- Etching rate: 13.4µm/min
- Taper angle: 92.7°

- Pattern width: 30µm
- Etching depth: 113µm
- Etching rate: 14.1µm/min
- Taper angle: 92.5°

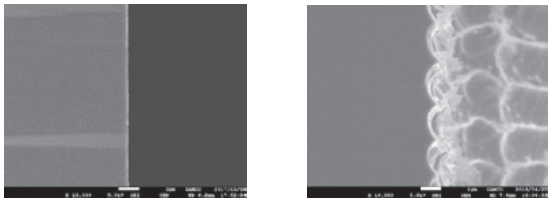
- Pattern width: 50µm
- Etching depth: 121µm
- Etching rate: 15.1µm/min
- Taper angle: 92.2°

Figure 2 Forward Taper Structure Fabrication Results

Etching rates were relatively high compared to the Bosch process, which requires a decreased etch rate in order to control profile smoothness.

Using the $SF_6/O_2$ non-Bosch process, etching rates of 14.1µm/min for a 30µm pattern width and 15.1µm/min for a 50µm pattern width were achieved. For comparison, Samco's Bosch process achieves small scallops at an etching rate of 10µm/min or less.

Figure 3 shows sidewall profiles, (20µm wide, more than 100µm deep, and with an aspect ratio of 6 to 8) which were fabricated using the $SF_6/O_2$ non-Bosch and Bosch processes, respectively.



Non-Bosch Process (Scallop Free) | Bosch Process (Scallop: 800nm)

Figure 3 Silicon Sidewall SEM Image (20µm wide trench)

Even though etch rate of the Bosch process was controlled to 10µm/min (a rate similar to the $SF_6/O_2$ non-Bosch process) to reduce scallops, 800nm wide scallops were found.

On the other hand, the $SF_6/O_2$ non-Bosch process showed smooth, scallop free profiles. Provided that the process demands stay within a certain depth range, it can therefore be said that the $SF_6/O_2$ non-Bosch process is the superior method in terms of etching rate and smooth sidewalls.

Additionally, the $SF_6/O_2$ non-Bosch process is also good for controlling tapered profiles. The sidewall angles can be controlled for an etch angle ranging from 90.4° (almost vertical) to 93.0° Sidewall verticalness can be controlled with the process gas ratios and highly adjustable in-process consideration of etch rate and etch selectivity.

## Conclusion

This report gives a brief overview of deep silicon etching techniques using $SF_6/O_2$ non-Bosch DRIE. For more information concerning deep etching processes and systems, please contact a Samco representative. We would be happy to provide you with process solutions based on your specific needs.

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