

MEMS Development at Maxim Using STS VPX

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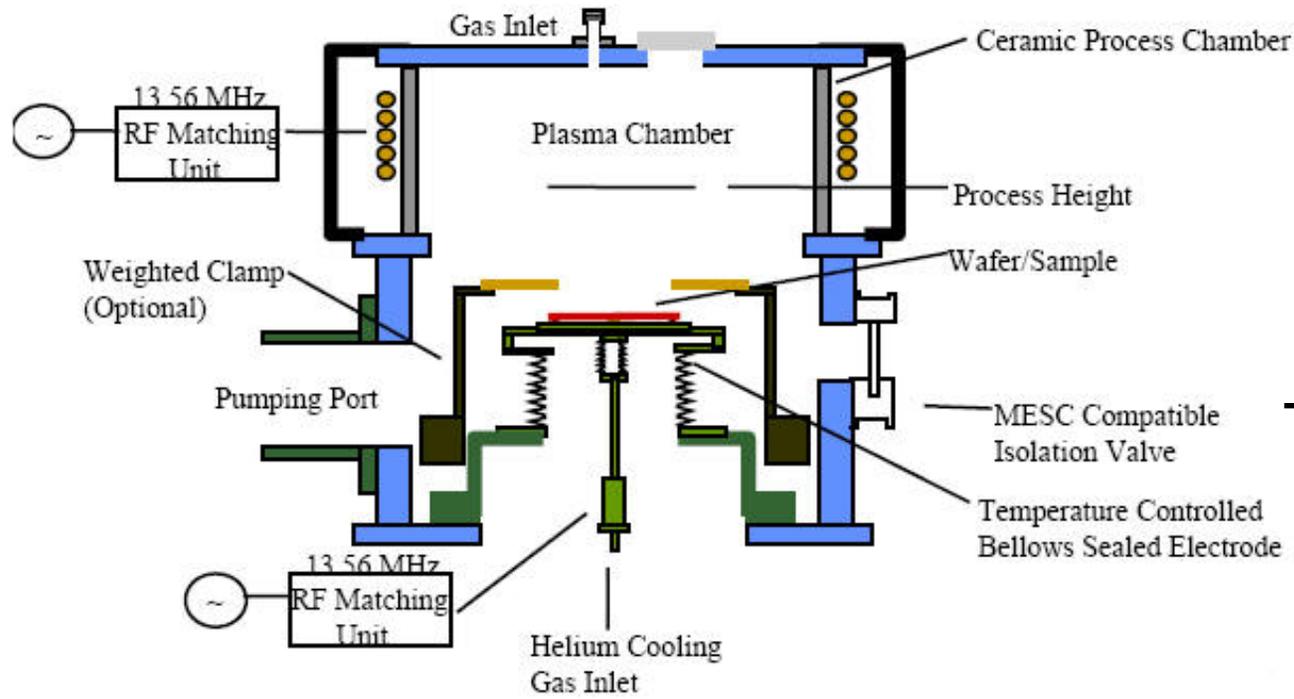
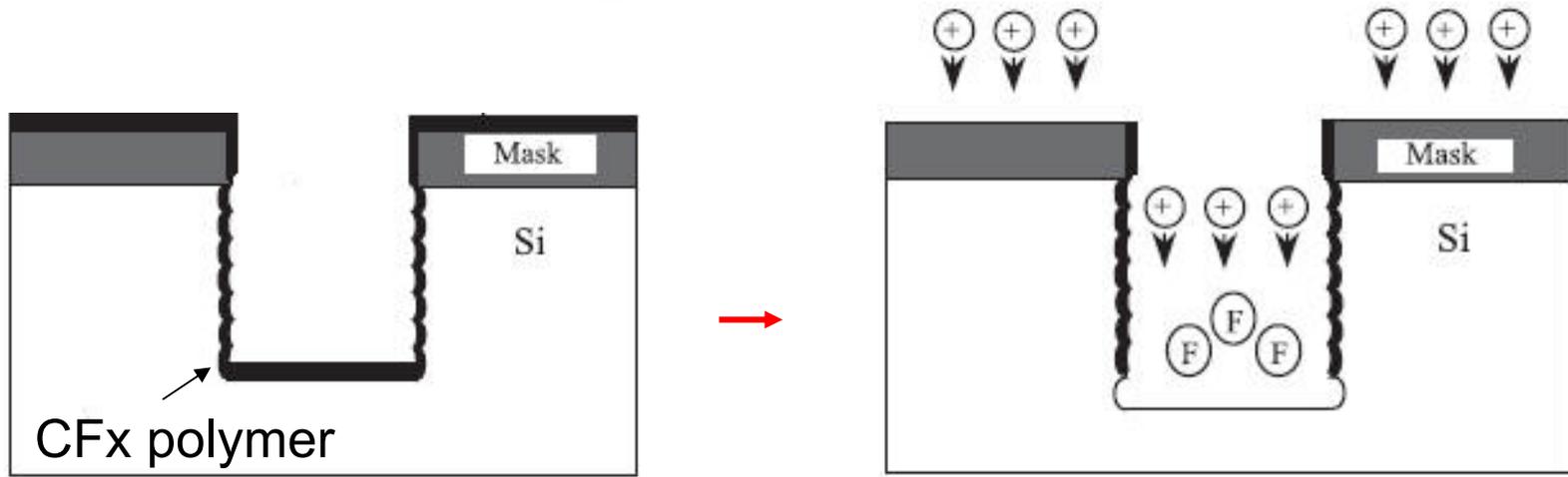
Outline

- STS VPX Introduction
- MEMS Development Examples
- Summary

STS VPX Platform

- Released January 2006, up to three process chambers to share a common automated wafer transport platform
- Provide advanced high rate for silicon and compound semiconductor DRIE
- Well-suited for pilot production markets to transfer new device technology from R&D

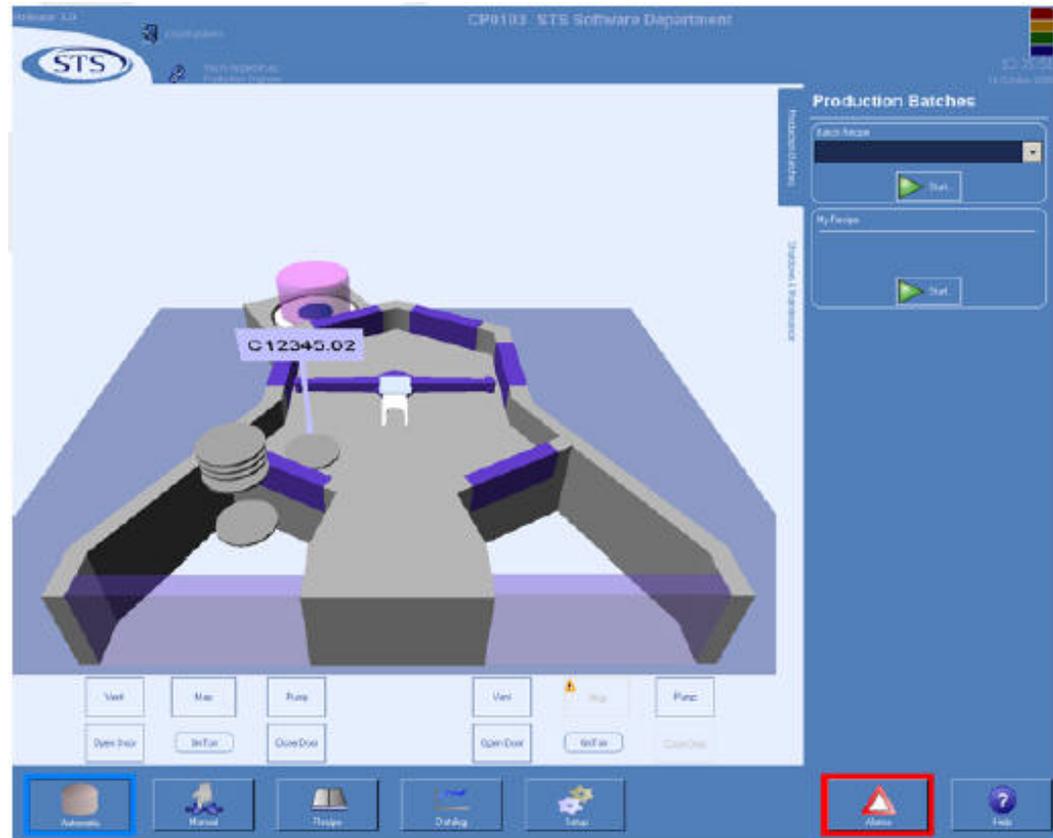
General Principle – ASE™ Bosch Process



ASE Anisotropic Etching schematic (Top)

Typical STS ICP system schematic (Bottom)

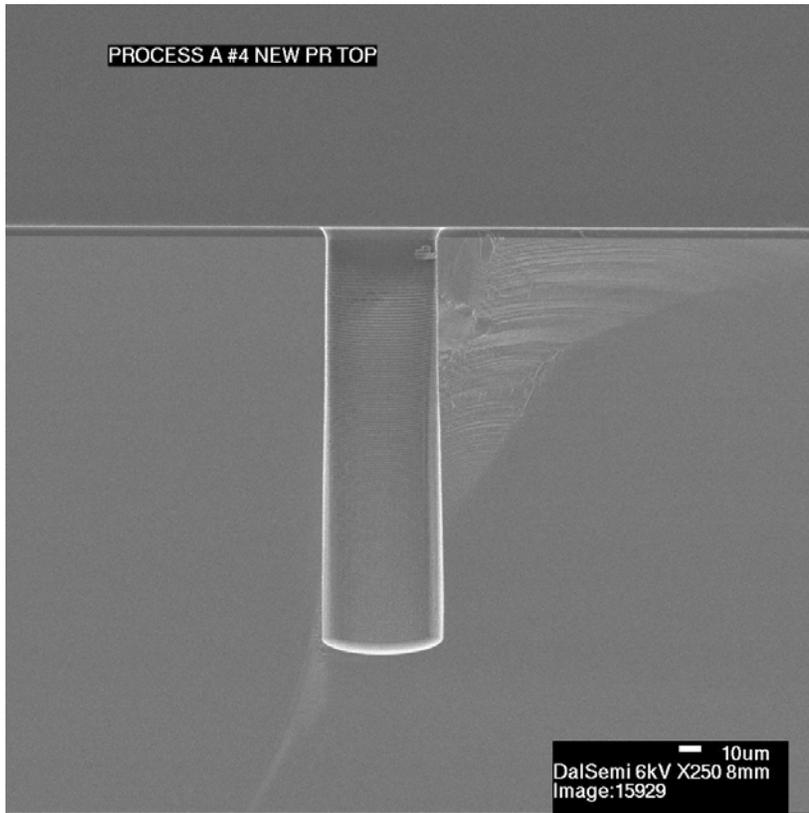
Maxim STS VPX System



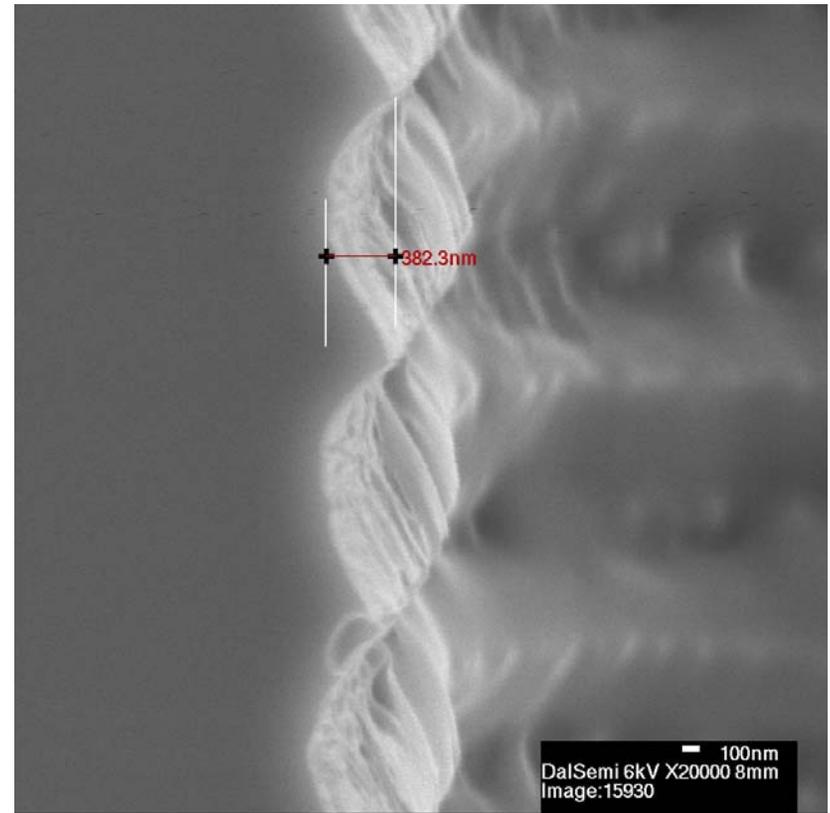
Process Development 1

Etch Characteristics	Specification	STS UK Results	Dallas Results
Depth (μm)	200	227.3	188
Etch Rate ($\mu\text{m}/\text{min}$)	10	10.3	11.8
Uniformity ($\pm\%$)	3	1.9	1.3
Repeatability (%)	3	0.3	2.2
Selectivity to PR	80:1	90:1	>90:1
Profile ($^{\circ}$)	90 ± 1	90.7	91
Initial Mask Undercut ($\mu\text{m}/\text{edge}$)	<1	0.52	0.3
Scalloping (nm)	<500	352.4	438.8

SEM Micrographs



(a)



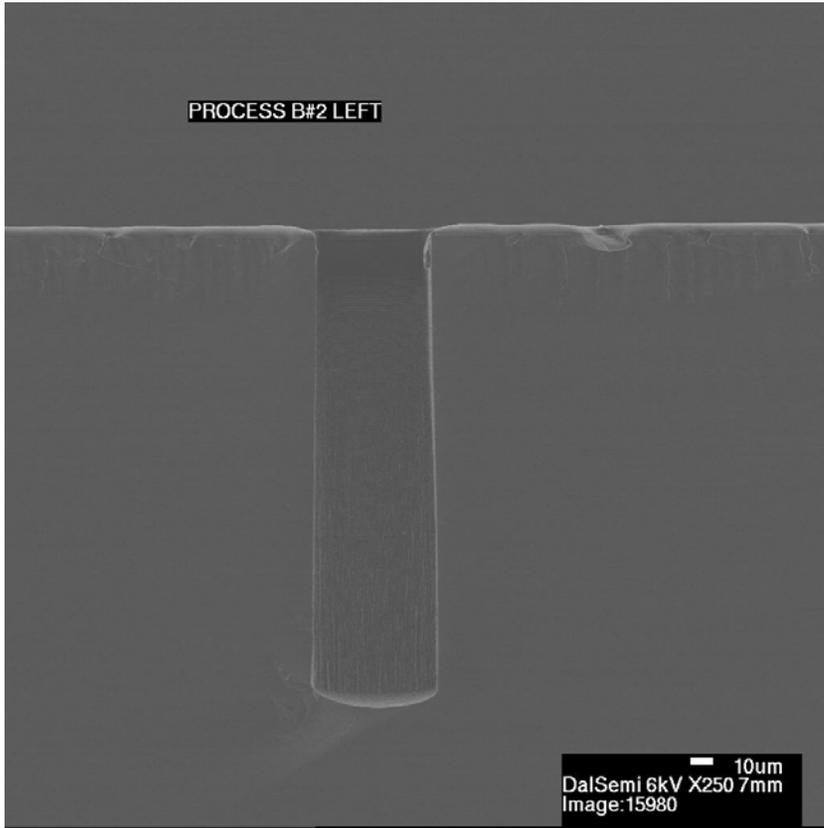
(b)

SEM micrograph for a 200- μm -deep trench with 382 nm scalloping

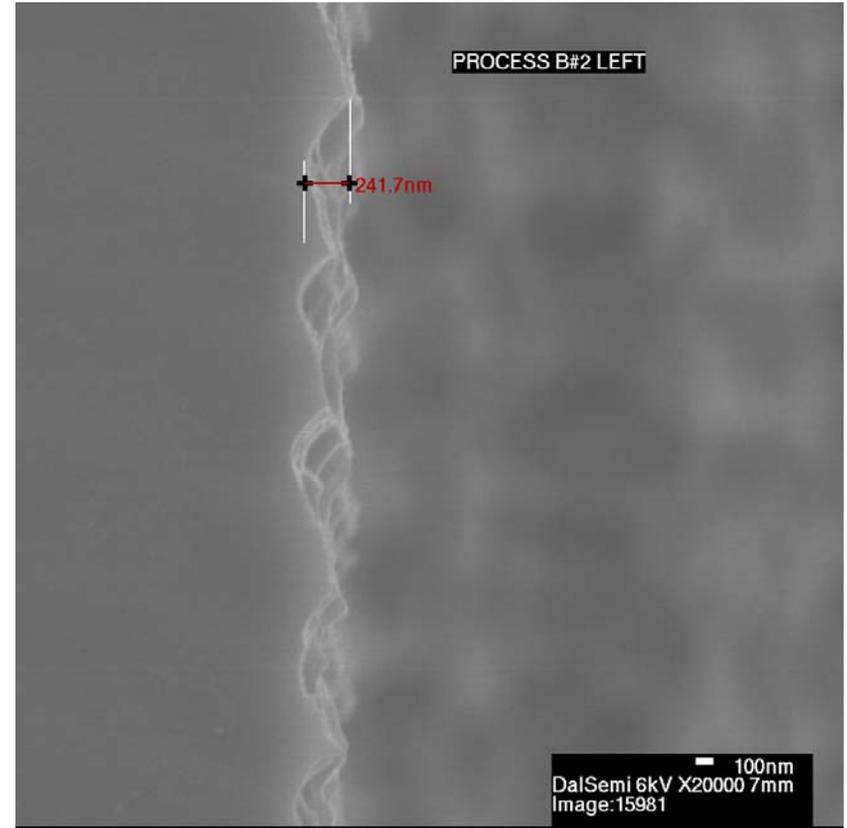
Process Development 2

Etch Characteristics	Specification	STS UK Results	Dallas Results
Depth (μm)	200	200	203
Etch Rate ($\mu\text{m}/\text{min}$)	>7	9.1	9.3
Uniformity ($\pm\%$)	3	1.3	1
Repeatability (%)	3	1.3	1.1
Selectivity to PR	60	72	>61:1
Profile ($^{\circ}$)	90 \pm 1	90.6	90.6
Initial Mask Undercut ($\mu\text{m}/\text{edge}$)	<1	0.33	0.26
Scalloping (nm)	<300	290.8	236.4

SEM Micrographs



(a)



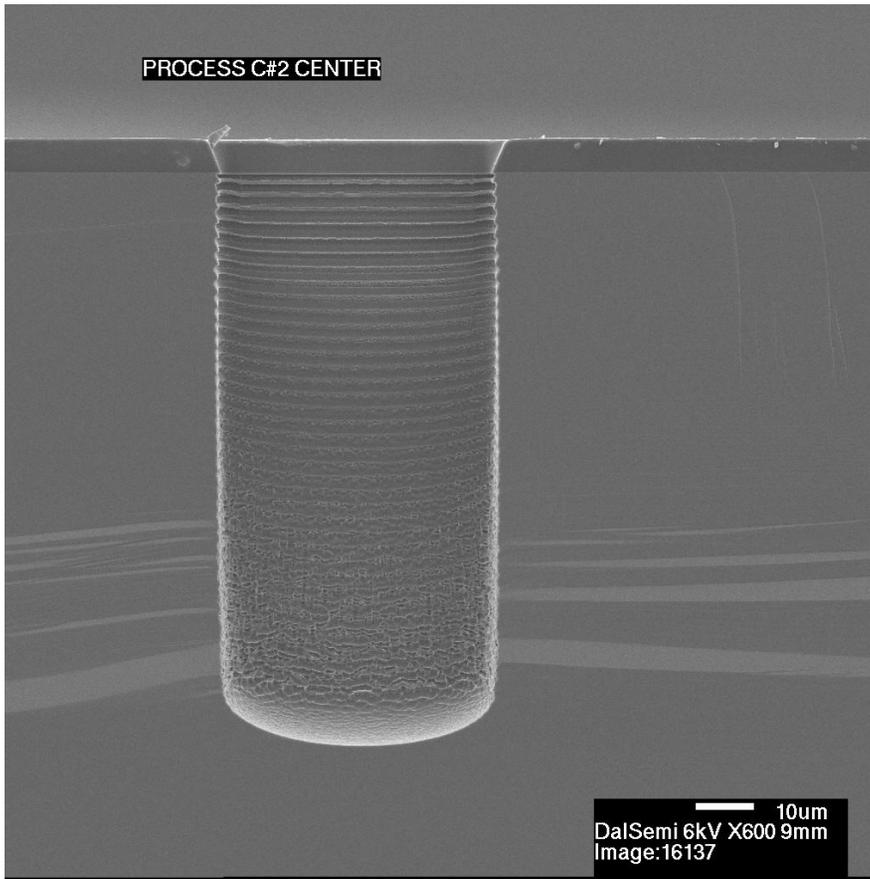
(b)

SEM micrograph for a 200- μm -deep trench with 242 nm scalloping

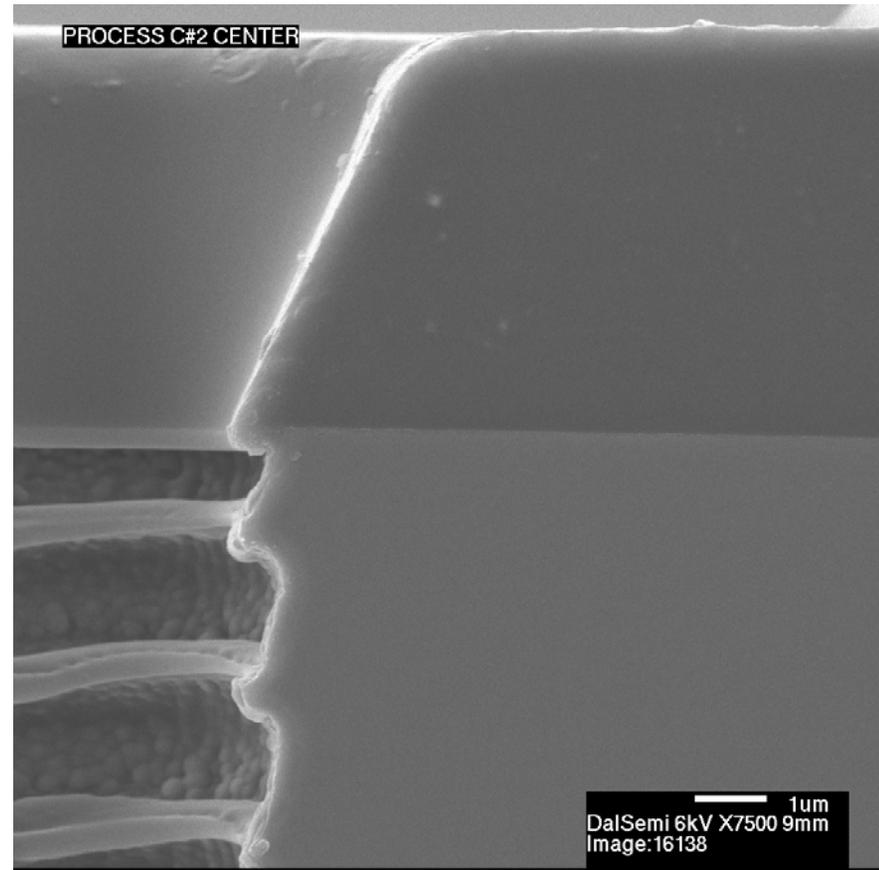
Process Development 3

Etch Characteristics	Specification	Dallas Results
Depth (μm)	100	101
Etch Rate ($\mu\text{m}/\text{min}$)	>10	12
Uniformity ($\pm\%$)	3	1.23
Selectivity to PR	70:1	>78:1
Profile ($^{\circ}$)	slightly positive	89.6
Initial Mask Undercut ($\mu\text{m}/\text{edge}$)	<1.2	0.83
Scalloping (nm)	<1000	800

SEM Micrographs



(a)



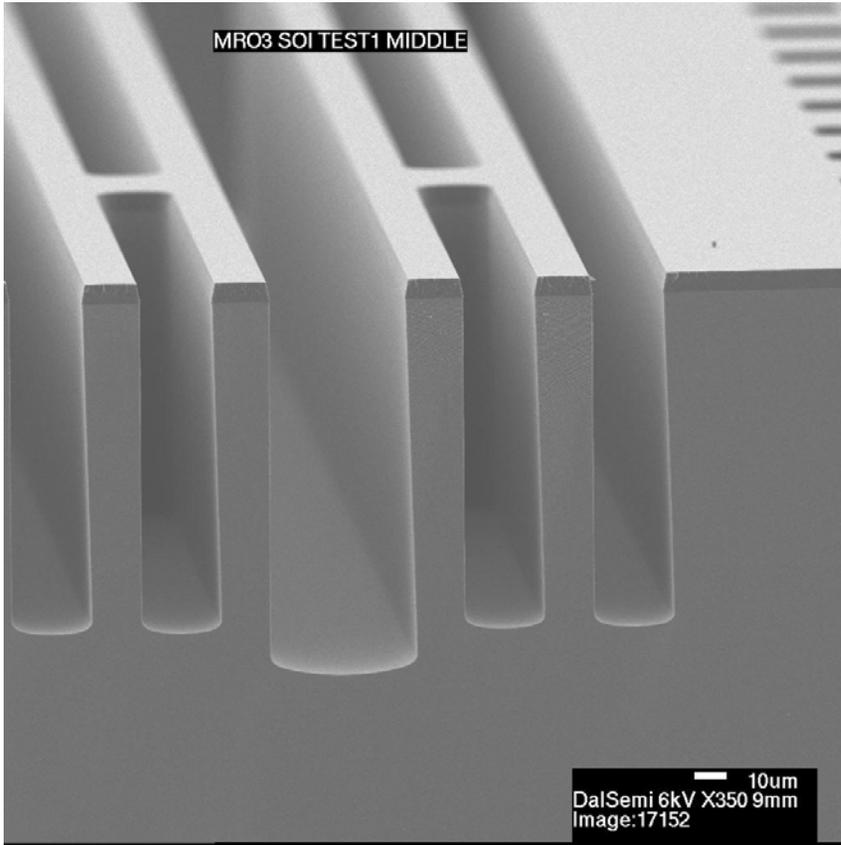
(b)

SEM micrograph for a 100- μ m-deep trench with 600 nm scalloping

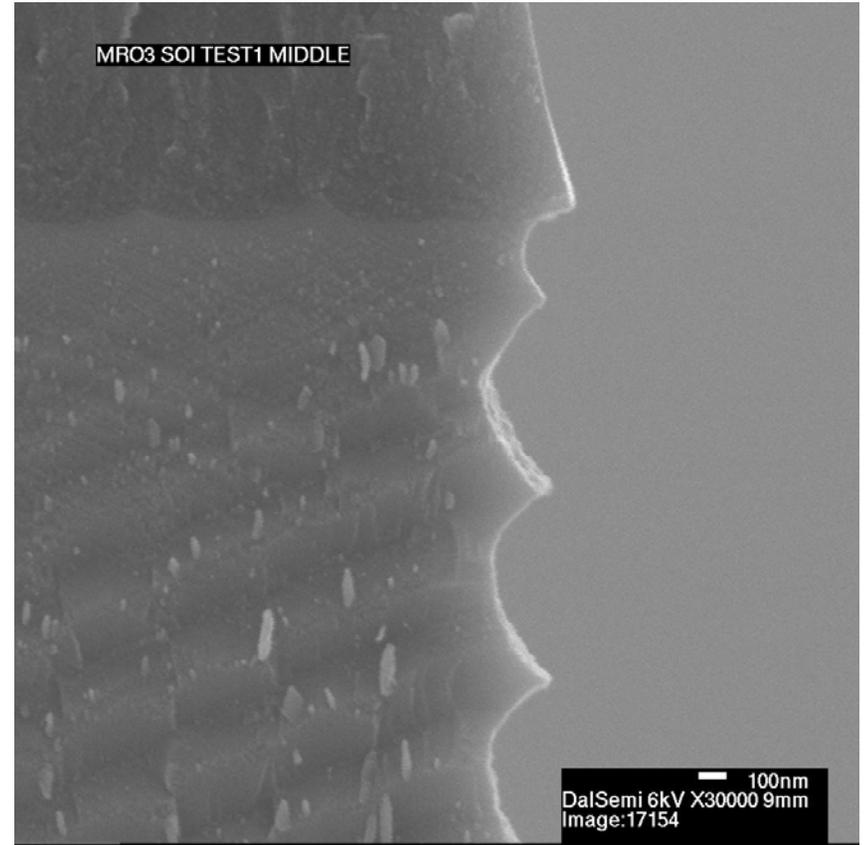
Process Development 4

- 80-100 μm silicon DRIE on SOI substrate without micro-grassing, good selectivity over oxide layer
- No notching issue at the interface of device silicon layer and buried oxide layer
- ARDE ratio should be less than 2:1

SEM Micrographs



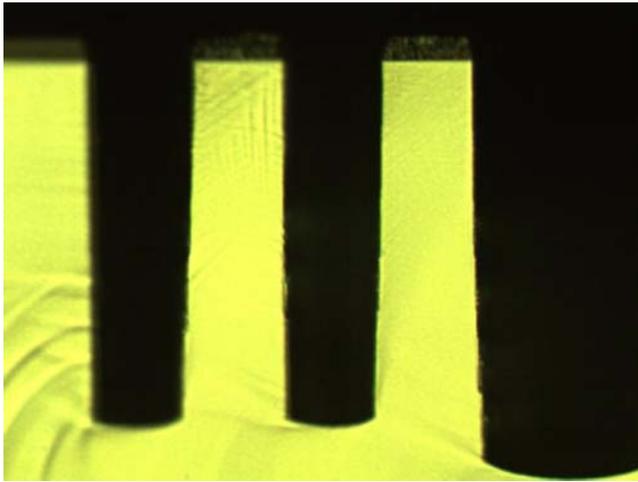
(a)



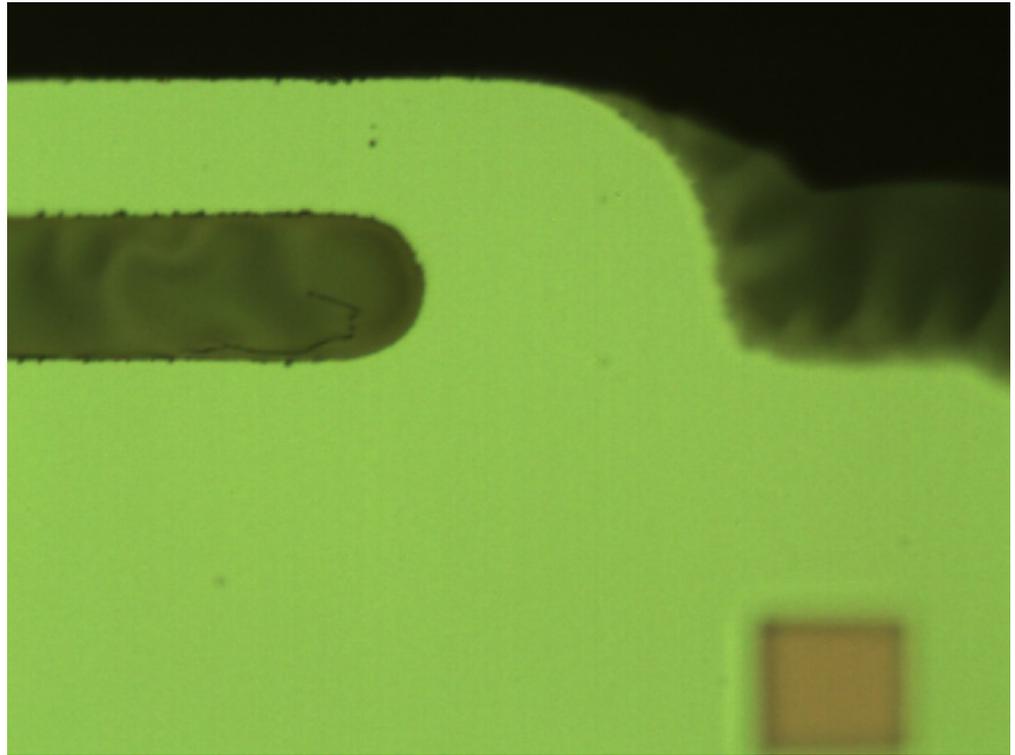
(b)

SOI 100-μm-deep release with 210 nm scalloping

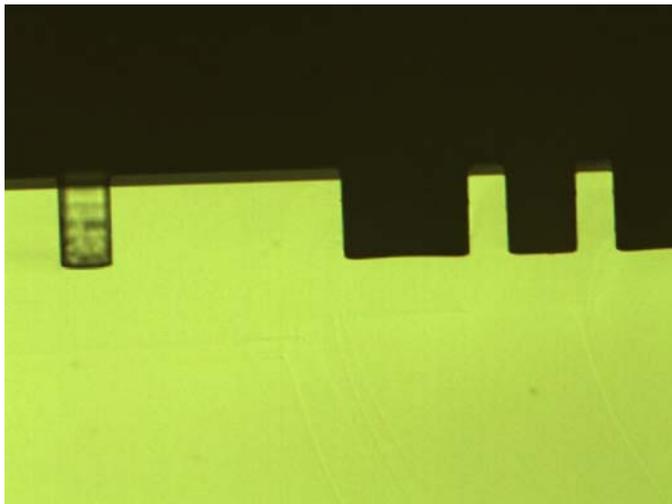
Other Development for Process 4



Positive slope



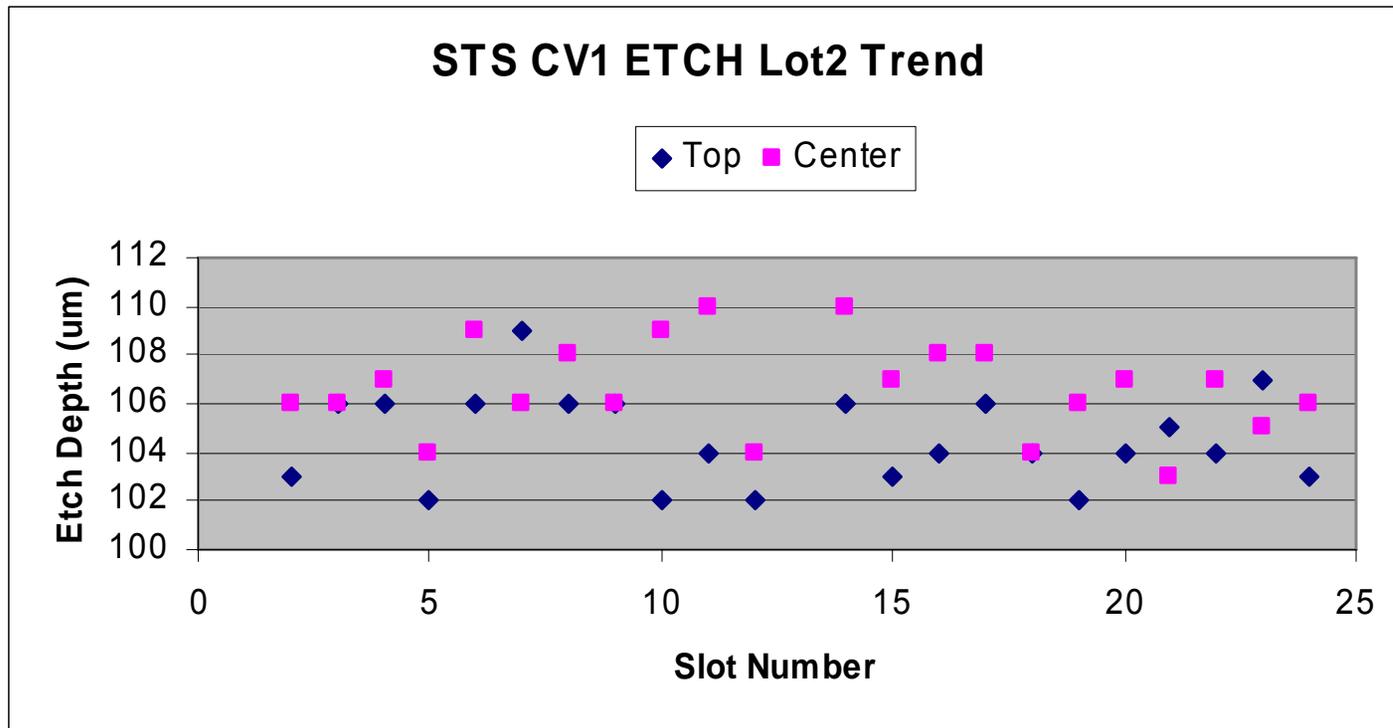
No notching at the silicon and oxide interface with ER 8 $\mu\text{m}/\text{min}$ and selectivity to oxide over 200:1



No ARDE effect for 50 μm etch

Production Implement Example

- High throughput for Process 3 (100 μm trench): 5 wafer/hr, including loading, wafer transfer, and unloading.
- Lot manufacturing is stable and meets IOS target



Current Issue for the VPX Platform

- Wafer handling repeatability is not 100% guaranteed.



STS Pro Scheduler v6.1.4.14796

scheduler 1 scheduler 2 H552 Cassette 1 Arm

Scheduler Resume Finish Reset

```
22:00:30.171 : [TMC]Robot.TRJobAdmin.cmd_n = 0 [Unknown]
22:00:30.187 : RobotArm.TRJobServer Scheduler.RobotArm.TRJobServer.st_nJobState changed to 4
22:00:30.187 : RobotArm.TRJobServer : JobStatus changed to Running
22:00:30.187 : RobotArm.TRJobServer : Idle.Exit
22:00:30.187 : RobotArm.TRJobServer : Active.Entry
22:00:30.187 : RobotArm.TRJobServer : Active.Init
22:00:30.187 : RobotArm.TRJobServer : Running.Entry
22:00:30.187 : Substrate_C00296.12 : Processing.Exit
22:00:30.187 : Substrate_C00296.12 : TransferringToDestination.Entry
22:00:30.187 : Substrate_C00296.13 : Idle.PRJobFinished
22:00:30.187 : [ToolJobAdmin] Checking for Path Clear for C00296.13 from 'Cassette 1'
22:00:30.187 : [ToolJobAdmin] Path being checked is
22:00:30.187 : [ToolJobAdmin] No valid Path Found - transfer already in progress
22:00:30.187 : DispatchQ.QCommandEvent(Job_Finished,H552,230,STS.Pro.Scheduler.Execution.Schedule.Cluster.SubstrateSt.
22:00:30.281 : [TMC]Robot.TRJobAdmin.st_nDisplay = 9
22:00:30.281 : Arm Changed Behaviour State to ActiveService
22:00:30.281 : Aligner Changed Behaviour State to ActiveService
22:00:30.375 : [PMC2]PMC_PRJobAdmin.au_n[0] = 0
22:00:31.109 : Cassette 1 Changed Behaviour State to ActiveService
22:00:42.421 : [TMC]Robot.TRJobAdmin.st_nDisplay = 10
22:00:44.468 : [TMC]S_MAP.RobotArm.Slot[1].ss_nStatus = Present(True) Active(False) Slot(Occupied) Sub(Processed)
22:00:44.468 : [TMC]S_MAP.RobotArm.Slot[1].sp_aSubstrateID - value changed to C00296.12
22:00:44.468 : [TMC]S_MAP.RobotArm.Slot[1].sp_bSubstrateAligned - value changed to True
22:00:44.484 : [TMC]S_MAP.Chamber2.Slot[1].sp_aSubstrateID - value changed to
22:00:44.484 : [TMC]S_MAP.Chamber2.Slot[1].ss_nStatus = Present(True) Active(False) Slot(Empty) Sub(Unprocessed)
22:00:44.484 : [TMC]S_MAP.Chamber2.Slot[1].sp_bSubstrateAligned - value changed to False
22:00:47.875 : [TMC]Robot.TRJobAdmin.st_nDisplay = 11
22:00:50.234 : [TMC]S_MAP.RobotArm.Slot[1].sp_aSubstrateID - value changed to
22:00:50.234 : [TMC]S_MAP.RobotArm.Slot[1].ss_nStatus = Present(True) Active(False) Slot(Empty) Sub(Unprocessed)
22:00:50.234 : [TMC]S_MAP.Aligner.Slot[1].sp_aSubstrateID - value changed to C00296.12
22:00:50.234 : [TMC]S_MAP.Aligner.Slot[1].ss_nStatus = Present(True) Active(False) Slot(Occupied) Sub(Processed)
22:00:50.234 : [TMC]S_MAP.Aligner.Slot[1].sp_bSubstrateAligned - value changed to True
22:00:50.234 : [TMC]S_MAP.RobotArm.Slot[1].sp_bSubstrateAligned - value changed to False
22:00:52.140 : [TMC]S_MAP.Chamber2.Slot[1].ss_nStatus = Present(True) Active(False) Slot(Empty) Sub(Illegal)
22:00:55.734 : [TMC]S_MAP.RobotArm.Slot[1].ss_nStatus = Present(True) Active(False) Slot(Occupied) Sub(Unprocessed)
22:00:56.218 : [TMC]S_MAP.Aligner.Slot[1].sp_aSubstrateID - value changed to
22:00:56.218 : [TMC]S_MAP.Aligner.Slot[1].ss_nStatus = Present(True) Active(False) Slot(Empty) Sub(Unprocessed)
22:00:56.218 : [TMC]S_MAP.Aligner.Slot[1].sp_bSubstrateAligned - value changed to False
22:00:56.218 : [TMC]S_MAP.RobotArm.Slot[1].sp_aSubstrateID - value changed to C00296.12
```

Log Mimic Options Alarms Tool Status scheduler 1 Status scheduler 2 Status

Scheduler	Run Time	Progress	Status
ToolJobAdmin	1.10:35:38.4375000	764 of 1000	Transferring C00296.15 from Cassette 1 to H552
ToolJobAdmin2			Idle

Opacity ▾

During a 1000-wafer handling test, the scheduler log showed an error for wafer transfer in either robot or aligner stage for the No. 764 wafer.

Summary

- High Etch Rate
- High selectivity over oxide and photoresist
- Good uniformity
- Versatile tunable parameters provide the flexibility for varied MEMS device structures realization
- Wafer handling repeatability is not so stable yet due to glitches in the operation software and Brooks Robot control

**→ Powerful and convenient platform for
MEMS production**