Abstract #2126, 224th ECS Meeting, © 2013 The Electrochemical Society

Non-stiction Performance of Various Post Wet-clean Drying Schemes on High-aspect-ratio Device Structures

Han-Wen Chen, Roman Gouk, Steven Verhaverbeke,
Robert Visser
Applied Materials, Inc.
3050 Bowers Avenue, P.O. Box 58039,
Santa Clara, CA 95054-3299, U.S.A.

Objectives

Line collapse or distortion of high-aspect-ratio nanostructures during drying step in wet process has been an issue in semiconductor industry due to feature size shrinkage following rapid technology advancement. Fig. 1 shows a 2x NAND STI structure with trench aspect ratio up to 20 and an image of line stiction after wet clean. Imbalanced capillary pressure induced when device feature is exposed to both liquid and gas interfaces during drying process contributes to line deformation and/or collapse. The objective of this work is to investigate various drying methods, including solvent vapor exposure, surface modification, and sublimation, to assess effectiveness in pattern collapse prevention.

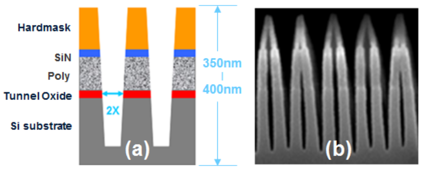

Figure 1. Post-STI-etch structure with 2x half pitch. (a) Schematics, (b) Image of line collapse after wet clean.

Results

Tab. 1 lists physical properties of common solvents. 2x NAND STI structures without pre-wetting were directly exposed to solvent vapor for screening. With low surface tension and high evaporation rate, Acetone vapor demonstrated the best performance with high-aspect-ratio trenches intact. Line stiction was globally observed on the device structure treated by IPA vapor, of which viscosity is high with evaporation rate much lower than Acetone vapor. Deionized water vapor exposure resulted in severe stiction and pattern collapse as expected on delicate features (Fig. 2).

Table 1. Properties of common solvents.

Chemical	Chemical Formula	Molar Mass (g/mol)	Boiling Point (°C)	Evaporation Rate (Butyl Acetate = 1)	Surface Tension (dyn/cm)		Miscibility in Water	Viscosity @ 25°C (cP)
					@ 20°C	@ boiling point		
Water	H_2O	18.02	100.0	0.36	72.75	58.85	N/A	0.89
Acetone	C_3H_6O	58.08	56.0-57.0	6.60	23.70	18.98	Miscible	0.31
Isopropyl Alcohol	C_3H_8O	60.10	82.5	1.50	21.70	17.00	Miscible	1.96

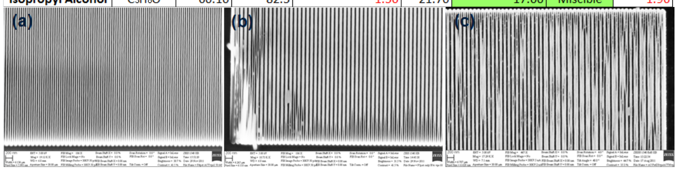

Figure 2. Top-down SEM image of 2x NAND STI structures after solvent vapor exposure. (a) Acetone vapor at 57°C, (b) IPA vapor at 83°C, (c) Deionized water vapor at 50°C.

Non-stiction performance was demonstrated on 2x NAND STI device structure in coupon level as presented in Fig 3. However, this vapor-assisted drying is very sensitive to large-scale condensation on wafer surface with narrow process window.

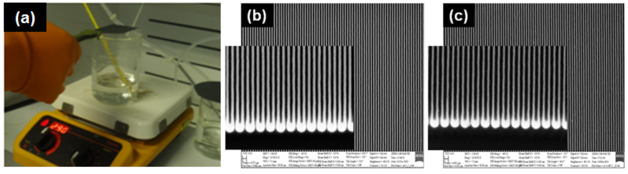

Figure 3. Non-stiction results of Acetone vapor drying. (a) Experimental setup, (b) Drying after DI water rinse, (c) Drying after dHF clean and DI water rinse.

'Sublimation drying' concept was proposed to bypass aqueous phase during drying step so liquid properties would no longer be the bottleneck. Fig. 4 depicts this drying approach on a phase diagram, where a solvent in solid state under SATP (Standard Ambient Temperature and Pressure) is heated above its melting temperature, coated on a wet STI wafer surface, swiftly cooled down to form a solid cap on the structure, and then sublimated in a vacuum chamber at ambient temperature.

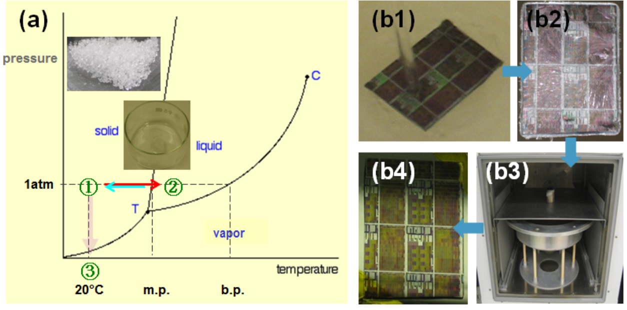

Figure 4. Sublimation drying. (a) Phase diagram for concept illustration, (b) Experimental procedure : b1. melted solvent application, b2. cooled solvent with crystal-like appearance, b3. sample in vacuum chamber, b4. post sublimation.

Preliminary tests with sublimation drying showed non-stiction performance on STI structure with higher spacing and trench aspect ratio ~10, while global stiction was observed on the same feature with narrower spacing (Fig. 5).

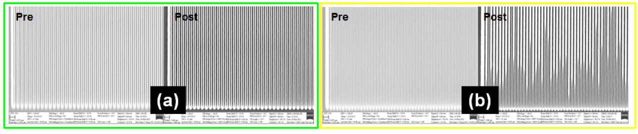

Figure 5. Sublimation drying test results on NAND STI structures. (a) 32nm line with 40nm spacing, (b) Same line width with only 20nm spacing.

Drying with device surface modification by self-assembled monolayer (SAM) is one of the advanced drying methods currently adopted in the industry. Specialty chemical is applied to the device surface to form SAM and create hydrophobic coverage to reduce surface tension, as shown in Fig. 6a. Tests with segregated hydrofluoroether also achieved stiction-free performance on the STI feature with 40nm spacing but failed the feature with higher trench aspect ratio of ~20 (fig. 6b).

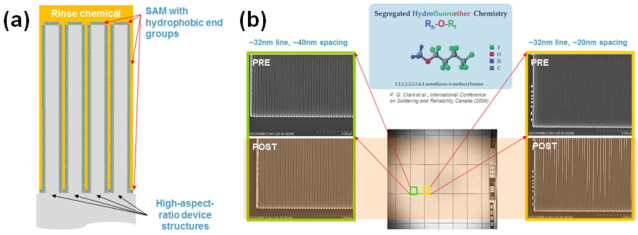

Figure 6. Drying with surface modification on NAND STI structures. (a) Principle, (b) Test results.

Conclusion

In this work, three drying schemes, including drying with solvent vapor exposure, by sublimation, and following surface modification, were compared on 2x NAND STI structures. Acetone vapor assisted drying achieved non-stiction performance on high-aspect-ratio trenches with both 40nm and 20nm spacing. Sublimation and SAM formation only worked on the features with 40nm spacing. Further investigation to follow for failure mechanism study and stiction-free drying development.