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

Table 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.

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.