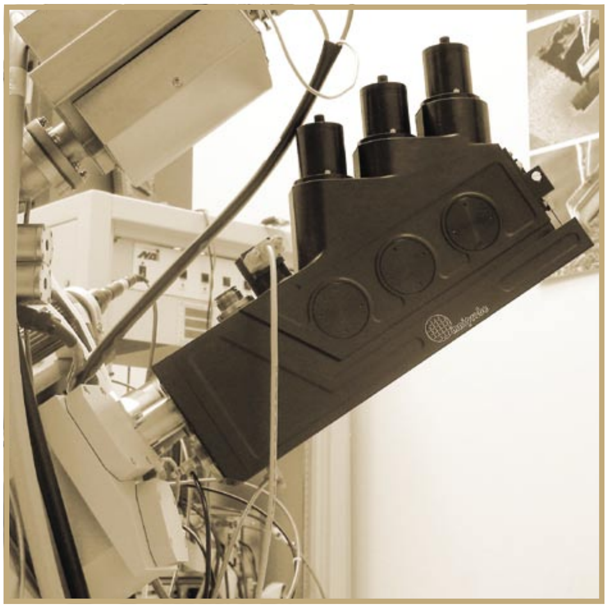
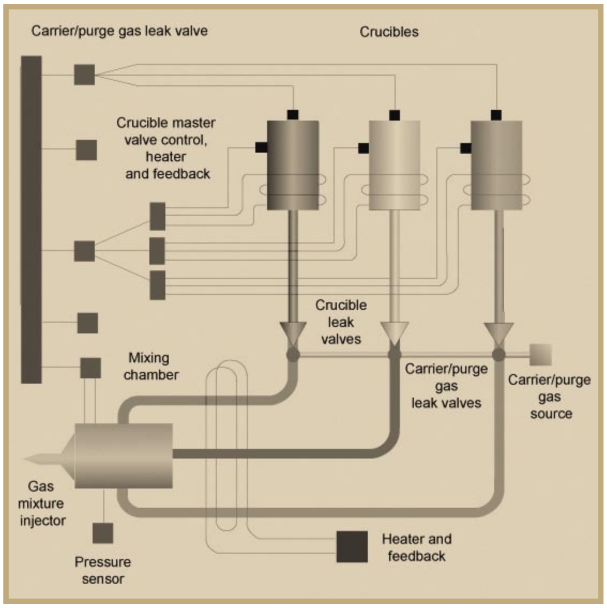
# AUTOMATED GAS CHEMISTRY IN THE FIB

Gas chemistries in the Focused Ion Beam (FIB) microscope play an important role in semiconductor metrology and process control. Patterned ion and electron beam-assisted chemical vapor deposition (CVD) of materials and etch removal of material have made the FIB an efficient platform for design-edit, mask revision verification, fault isolation, failure analysis and materials analysis.

In the FIB in-situ lift-out process, gas-assisted etching speeds the milling process. Beam-assisted CVD in the FIB is important for attachment of lift-out samples to the probe tip and TEM sample holder, for the deposition of protective layers on the surface prior to TEM lift-out, and for the deposition of gap-fill materials, such as silicon dioxide, so that inspected wafers can be returned to the process flow [1,2]. There is a need for accurate and rapid feedback control of these etch and deposition processes to enable high-throughput TEM sample preparation in the FIB.



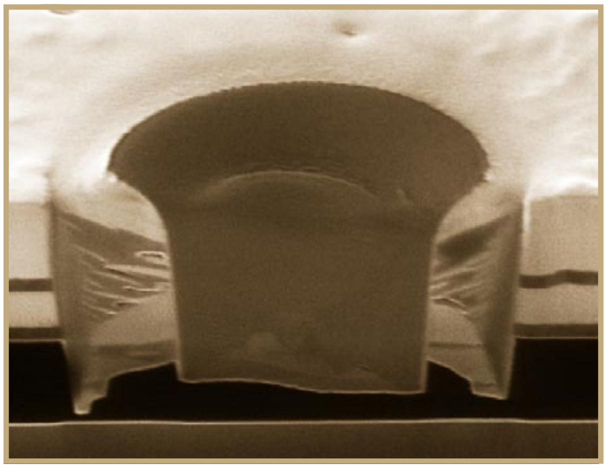


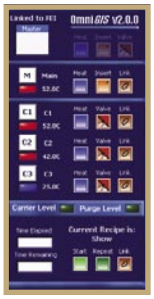
By integrating the computer control of the AutoProbe™ nanomanipulator and the OmniGIS™, the in-situ lift-out process can be streamlined and automated for high throughput and improved reproducibility. There is also a need for more efficient use of existing ports on commercial FIB vacuum chambers due to the variety of gas chemistries in use and competition for port locations from other accessories such as optical microscopes and x-ray detectors.

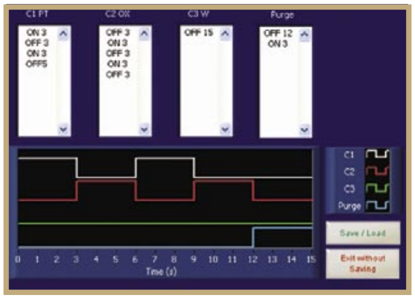
The OmniGIS™ system (Fig. 1) makes three sources available on one FIB GIS port as well as one external carrier/purge gas. The three crucible sources can be individually accessed for discrete layers, or combined for more complex deposits or custom etches. The external purge gas will quickly clear the remnants of the previous precursor before a subsequent process is begun. The operational flowchart of the OmniGIS™ is shown in Fig. 2. The OmniGIS™ system contains three crucibles, a carrier/purge gas, gas flow feedback control, and programmable process flows ("recipes"). The individual sources can be maintained at different temperatures to maintain the desired vapor pressure of each precursor. Computer-controlled metering valves determine the flow from each crucible and the flow of the carrier/purge gas. The individual transfer tubes from the crucibles to the mixing chamber are heated to prevent condensation or decomposition of the precursors. The source gases from the transfer tubes are combined in the final mixing chamber before being presented to the sample surface through a single injection tube.

User-programmable process flows, called "recipes", can be easily created, stored and recalled for single or multiple source processes (fig 4). These recipes can be initiated from the OmniGIS™ control software, or can be triggered by standard GIS activation from the FIB. For example, this would enable a complicated deposition and etch process to be programmed and then recalled for improved reproducibility and automation. Gas flow feedback control eliminates the uncertainty about whether the source is depleted or not, and maintains a constant monitoring of crucible output.

A performance monitor feature in the OmniGIS™ software tracks crucible output and warns if the source is nearing depletion based on hours of use and the trend in crucible output. An example of a via obtained using an automated etch and deposition routine with the OmniGIS™ is shown in Figure 3. The importance of using the carrier gas to enhance the deposition or etch rate has been widely discussed.[3,4] The OmniGIS™ provides a powerful and flexible platform not only for controlling and automating routine deposition and etch processes, but also for the exploration of innovative gas chemistries for both ion beam and electron beam induced reactions.







C1 PT
ON 3
OFF 3
ON 3
OFF5

C2 OX
OFF 3
ON 3
OFF 3
ON 3
OFF 3

C3 W
OFF 15

Purge
OFF 12
ON 3

## References

[1] F.A.Stevie et al. Focused Ion Beam Gases for Deposition and Enhanced Etch, in Introduction to Focused Ion Beams: Instrumentation, Theory, Techniques, and Practice, L.A. Giannuzzi, F.A. Stevie (eds), Springer-Verlag New York, 53 (2004).

[2] A.D.D. Ratta et al., J. Vac. Sci. Technol. B11, 2195 (1993).

[3] D.M. Thaus et al., J. Vac. Sci. Technol. B14, 3928 (1996).

[4] J.R. Casey Jr., J. Vac. Sci. Technol. B20, 2682 (2002).