GIS – Gas injection system

Helios Nanolab 600

The combination of a focused ion beam and a reactive gas offers a number of advantages over conventional milling (sputtering):

- Increased material removal rates
- Higher removal selectivity between some materials
- Absence of re-deposited material

Delineation Etch

Delineation Etch is used for the etching of integrated circuit (IC) cross sections.
Its oxide-specific gas performs in situ delineation. The etch rate is dependent on the composition and deposition conditions of the oxide, resulting in excellent delineation of layers and fine structure. The gas is nonhazardous and does not spontaneously attack silicon or polysilicon. This latter characteristic facilitates imaging transistor regions without damaging the polysilicon and deprocessing chips and wafers down to the polysilicon layer.

Benefits

Delineation Etch offers the following benefits:

- Complete cross-section analysis of full wafers
- No damage on any exposed silicon, polysilicon, or metal lines
- Saves hours of preparation time
- Immediate delineation without sample removal
- Can be used for cross sections with exposed silicon in which the silicon needs to remain intact
- Safer than xenon difluoride (XeF_2)
- Eliminates the need for hazardous chemicals associated with wet etching, e.g., hydrogen fluoride
- Serves double duty as a delineation etch gas and a copper/metal-compatible oxide etching material
- A chemical life in excess of 200 hours

Insulator Enhanced Etch

Insulator Enhanced Etch (IEE) is used to rapidly etch films of many types of insulating material with the assistance of xenon difluoride (XeF_2), a halogen compound. The IEE process is particularly useful when removing passivation from a circuit area containing several metal layers. The apparatus and methods are similar to those used in the Enhanced Etch (EE) process, and, like EE, the IEE process removes material faster than normal ion beam milling. In IEE, XeF_2 is positioned in a fine needle close to the sample surface, producing a high local flux of the halogen gas. The ion beam is then used to induce reactions between the gas and the scanned area. IEE removes insulating materials preferentially and leaves the conductor.

Cross-section images can often be improved by using IEE staining of the vertical face. In an ion beam image, the materials contrast between layers is normally higher than that found in an electron beam image made in a DualBeam or SEM system, particularly between insulative and conductive layers. Even so, ion beam images can also sometimes benefit from some form of staining.

Table 1 provides sputter rates and typical enhancements for various materials when using a 30 kV beam voltage. Actual values vary depending upon the conditions.

Table 1 Etch Rates and Enhancements for Various Materials

Material	Typical Sputter Rate (μm^3/nC)	Typical Etch Rate Enhancement with IEE
Silicon (Si)	0.2	7–12
Aluminum (Al)	0.5	2.13
Gallium Arsenide (GaAs)	0.7	—
Indium Phosphide (InP)	1.2	—
Gold (Au)	0.6–1.6	1
Tetraethyl orthosilicate (TEOS)	0.3	7.2
Thermal Oxide	0.3	7.2
Titanium Nitride (TiN)	0.26	7.5
Silicon Nitride (Si_3N_4)	0.16	7

The available methods of staining include:

- FIB milling
- EE—metal selective etching (I_2)
- IEE—insulator selective etch (XeF_2)

Selective Carbon Mill

Selective Carbon Mill (SCM) uses water vapor to increase the removal rate of carbon-containing materials such as polyimide, PMMA (polymethyl methacrylate), and other resistive materials by **a factor of 20** (relative to normal FIB sputtering rates), and that of **diamond by a factor of 10.** In addition, SCM decreases the removal rate of other materials (e.g., Si and Al). This effectively increases the etch selectivity of polymers over these other materials.

SCM has proven effective in the following applications:

- Cross-sectioning resist lines for accurate profile measurement
- Process development and process characterization of environments
- Selective removal of top-layer polyimide in IC design modification
- Failure analysis and process characterization of devices constructed with various polymers such as printer heads
- Micromachining diamond for MEMS (microelectromechanical devices) and sensor applications

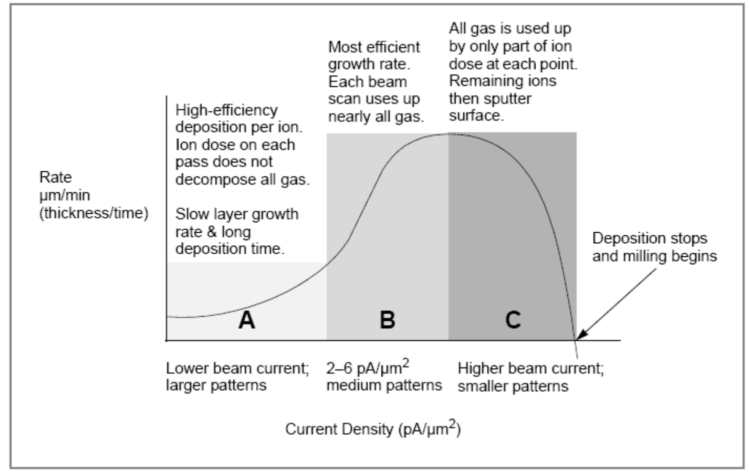
Enhancement Factors

The sputter rate enhancement (and retardation) of SCM appears to be directly related to the reaction products of H_2O and the material being sputtered. The yields of carbon-based materials, which combine with H2O to form volatile products, are greatly enhanced with SCM.

The yield of materials such as Au, which do not react significantly with H_2O, is unaltered when using SCM. However, the yields of materials such as Al, Si, and compounds of Si, which react with H_2O to form nonvolatile products that are relatively resistant to sputtering, are significantly reduced.

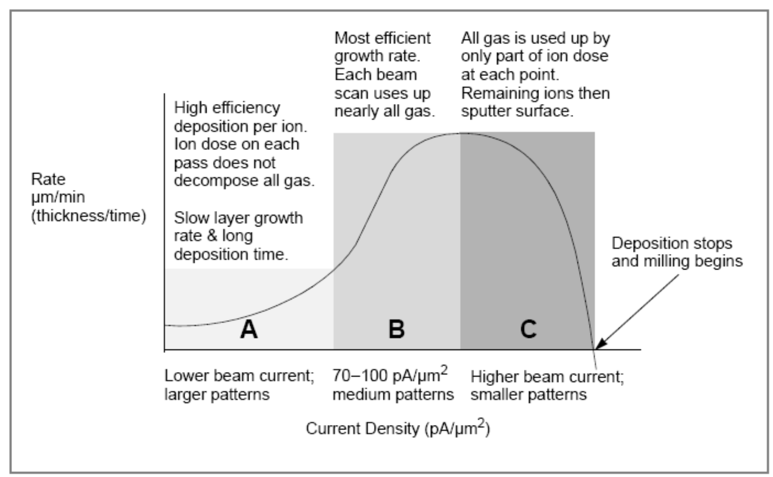
Platinum deposition

Figure 1 Deposition Efficiency for Platinum



Tungsten deposition

Figure 1 Deposition Efficiency for Tungsten



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Delineation Etch

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Platinum deposition

Rule of thumb

6 pA/µm²

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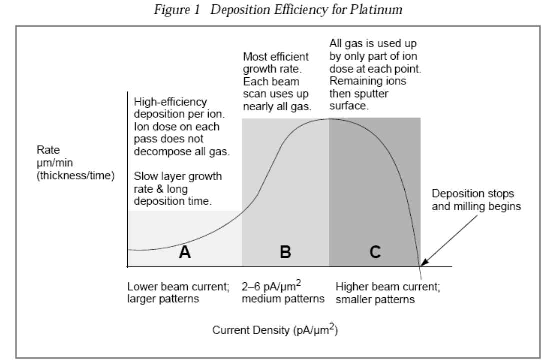

Tungsten deposition

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10 pA/µm²

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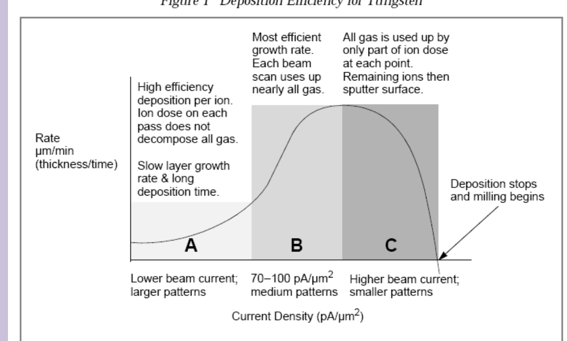

Delineation Etch

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Its oxide-specific gas performs in situ delineation, surpassing conventional failure analysis techniques in which samples are prepared by mechanical polishing and wet chemical etch. A specially designed coaxial gas delivery needle directs the gas flow down to the substrate, parallel to the ion beam, to provide optimum gas flux, even into the smallest vias. The etch rate is dependent on the composition and deposition conditions of the oxide, resulting in excellent delineation of layers and fine structure. The gas is nonhazardous and does not spontaneously attack silicon or polysilicon. This latter characteristic facilitates imaging transistor regions without damaging the polysilicon and deprocessing chips and wafers
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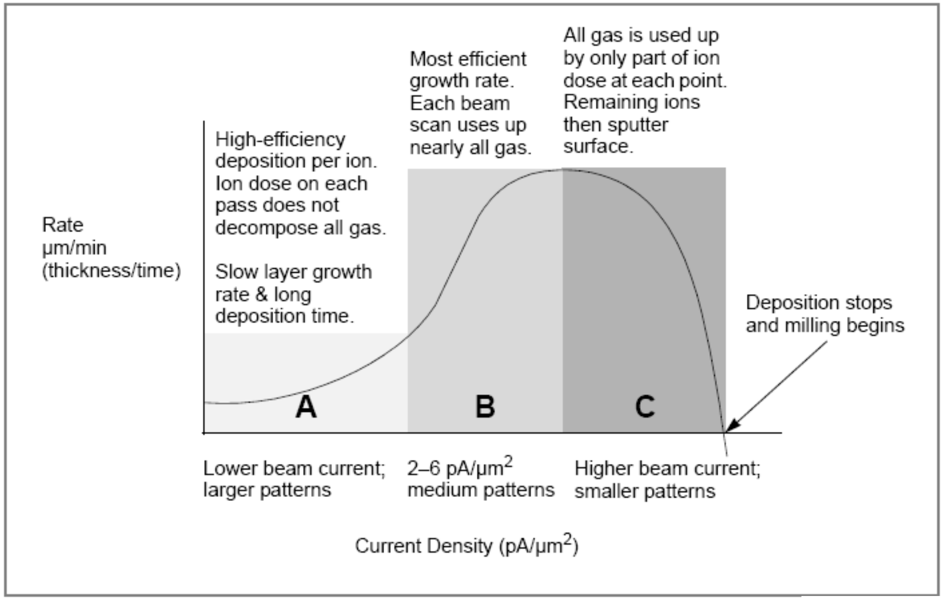
SCM on PMMA increases yield by a factor of 20, from 0.4 µm3/nC with no H2O to nearly 8 µm3/nC with SCM. The large increase produced by SCM suggests that the enhancement is due to reactions that form COX as the main product. These volatile species would then readily desorb from the surface, resulting in a higher material removal rate.

Other polymeric materials such as polyimide, positive-tone photoresists, and negative-tone chemically amplified photoresists exhibit similarly enhanced sputter yields in the presence of H2O. Results obtained for PMMA will, to a large extent, apply to other polymers, and, to a lesser extent, to carbon-based materials in general. The sputter enhancement of pure O2 is significantly poorer. The performance of SCM over straight O2 suggests that the sticking coefficient of SCM may have a large effect on the sputter rate by allowing more gas molecules to adhere to the sample surface. This adherence provides more available chemical for reaction with the sample.

Figure 1 Deposition Efficiency for Platinum



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