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Plasma Etching Pushes the Limits of a Shrinking World

Plasma etching, essential for semiconductor device fabrication in the nanoelectronics age, confronts the fundamental limits of physics and chemistry.

SALT LAKE CITY—Plasma etching (using an ionized gas to carve tiny components on silicon wafers) has long enabled the perpetuation of Moore's Law—the observation that the number of transistors that can be squeezed into an integrated circuit doubles about every two years. Without the compensating capabilities of plasma etching, Moore's Law would have faltered around 1980 with transistor sizes at about 1 micron (the diameter of a human hair is approximately 40-50 microns wide). Today, etch compensation helps create devices that are smaller than 20 nanometers (1,000 times smaller than a micron).

Now more than ever, plasma etch technology is used to extend semiconductor device fabrication into the nanoelectronics age—and technologists at Lam Research are developing techniques for the manufacture of even smaller, faster, and more densely packed multi-functionality chips. The question now is how much smaller and faster can the semiconductor industry go? The answer has much to do with plasma etch technology.

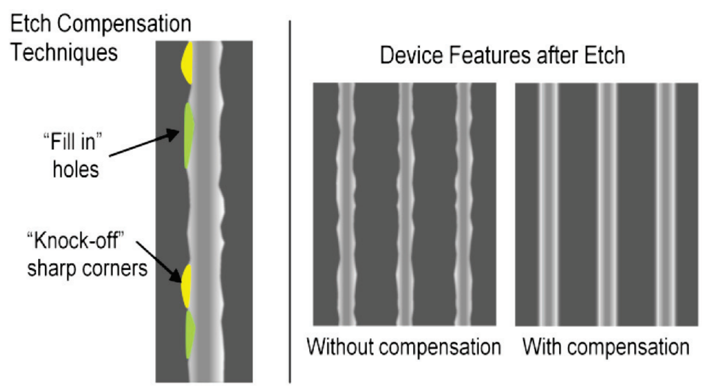

Figure 1. One of the ways plasma etching compensates for lithography shortcomings is by filling holes and removing bumps at the edge of individual components and wires, allowing more transistors to be packed closer together on integrated circuits.

One of the most critical steps of semiconductor manufacturing, plasma etching creates finely delineated features in the conductive and dielectric (insulating) layers on integrated circuits. Plasma etch techniques can also compensate for limitations in lithography, the optical process that develops the "template" for creating nanoelectronic structures on silicon wafers. Transistors and other components are now so small that lithography can no longer produce templates with the necessary precision to pack millions of transistors onto small integrated circuits. While researchers are working on new lithography technology (extreme ultraviolet or EUV) to overcome this limitation, plasma etching is used to compensate for lithography's imperfections by filling in gaps and smoothing out edges of the tiny components on the chip (Figure 1). Plasma etching also enables other techniques that extend current lithography capabilities, including double patterning (a method of overlaying two patterns to achieve the original design) and directly shrinking structures smaller than the template dimensions.

Yet, plasma etching itself is now facing the fundamental limits imposed by the basic laws of physics and chemistry. Because etching is involved in forming the critical structures of every semiconductor device, Lam Research technologists are learning to better control the behavior of the various components of the plasma (a gaseous mixture of charged and neutral particles) during the etching process. The ultimate goal would be to selectively etch one layer of atoms at a time (atomic-layer etching or ALE), without disturbing the bulk of the material underneath.

Over the next 5 years, improving plasma etch technology will be key to extending Moore's Law further and manufacturing the next-generation of consumer electronics devices.

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Abstracts:

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