Semiconductor Technology from A to Z

Dry Etching

Reactor Types

General: Structure of a Dry Etch Tool

Every dry etch tool consists of the same basic components: a process chamber, a gas inlet – often designed as a so-called showerhead directly above the wafer for uniform gas distribution – a pumping system made up of a turbomolecular pump and a backing roughing pump for the required vacuum, RF coupling for plasma generation, and the wafer chuck.

How these components are implemented in detail differs strongly between reactor types – and largely determines which processes a given tool can perform.

Reactor Types: CCP and ICP in Practice

As described in the Deposition section, in capacitively coupled reactors (CCP) the same voltage determines both ion density and ion energy – the two cannot be set independently. Inductively coupled reactors (ICP) separate these two quantities using a separate bias voltage at the wafer electrode.

This separation matters especially for etching: a high etch rate needs many reactive species, i.e. a high ion density, while a clean anisotropic profile needs controlled, not too high, ion energy. The construction differs accordingly: CCP reactors often use silicon or SiC electrodes as consumable material to avoid metal contamination of the wafer; the chamber walls are usually anodized aluminum, which must withstand the aggressive fluorine and chlorine radicals. In ICP reactors, the coil sits outside a dielectric chamber window made of quartz or ceramic, through which the alternating field can penetrate.

The achievable ion density with ICP is typically 10 to 100 times higher than with CCP – the main reason why ICP is the standard today for demanding etch processes with high aspect ratios.

Electron Cyclotron Resonance (ECR)

In ECR reactors, a combination of microwave coupling – usually at 2.45 GHz – and a magnetic field generates very high plasma densities at particularly low pressure. The microwave frequency is tuned precisely to the electron cyclotron resonance frequency in the magnetic field, enabling very efficient energy transfer.

Historically, ECR was an important precursor to today's ICP technology, but has largely been displaced by ICP due to the more complex and expensive equipment – additional magnetic coils, a microwave source instead of a simple RF generator. It is still used in niche applications that require particularly low ion energies combined with high density, for example with especially damage-sensitive layers.

Wafer Chuck: Temperature Control and Electrostatic Clamping

The electrostatic chuck (ESC) holds the wafer flat and mechanically stable during the process, without mechanical clamps that could damage or shadow the wafer edge.

Since there is no convection in vacuum, targeted backside cooling with helium gas – fed through fine channels between the chuck and the wafer backside – provides the necessary heat transfer. This temperature control is critical: etch rate, selectivity and profile shape all depend strongly on wafer temperature, which is why modern chucks regulate temperature to within a few degrees, both throughout the process and across the wafer.