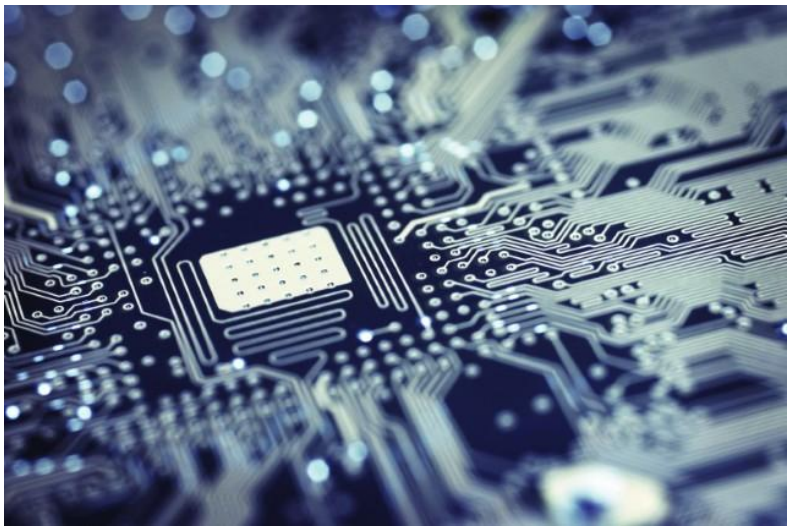
Moisture Measurement as Quality Assurance In Semiconductor Manufacturing

Reactors perform two functions: Chemical Vapour Deposition, which is used to grow a semiconductor film on a silicon wafer. And Plasma Etching, which allows accurate removal of semiconductor film from the wafer. Both are crucial processes in the production of modern integrated circuits.

Chemical Vapor Deposition



CVD apparatuses work by chemically reacting a semiconductor gas onto a silicon wafer to grow a film. However, since it is not possible in principle to react all material gases on the wafer, by-products end up adhering to various locations on the inside walls of the reactor. These by-products have a negative impact on the quality of subsequent films, so it is necessary to perform maintenance to clean the inside walls of the reactor.

In a CVD apparatus for growing thick films, maintenance is required around once every 3-4 days. The required cleaning can be achieved in two ways, the first of which is opening the chamber to clean it directly with solvent.

However, since the apparatus is opened to the atmosphere during maintenance, a large amount of ambient moisture adsorbs onto the interior walls of the reactor.

If moisture is present in the atmosphere during growth of semiconductor films, it reacts with the semiconductor material gas resulting in the formation of metal impurities or the formation of particles that worsen the film quality.

Consequently, following maintenance, it is necessary to purge the inside of the apparatus with high-purity nitrogen or other inert gas to lower the moisture concentration to an extent that does not have a detrimental effect on film quality.

The internals of CVD apparatuses have an extremely complex shape, so it takes a great deal of time to purge the moisture from the chamber down to an acceptable level.

In addition, the completion of purging is judged based on an evaluation of the quality of a film that is actually grown following a certain degree of purging. Consequently, material gas and time were wasted on growth until a film having product level quality was obtained.

The alternative to this is to use a moisture analyser to measure the purge gas after it has passed through the chamber. Once the moisture content drops to an acceptable level – close to that of the gas leaving the bottle – the chamber can be considered to be sufficiently purged.

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Plasma Etching and Cleaning

Fully fluorinated compounds (FFCs), such as CF_4, C_2F_6, C_3F_8 and NF_3 are used for both plasma cleaning of CVD chambers and plasma etching of the thin insulating and metal layers.

The FFCs allow manufacturers to accurately etch the submicron-scale patterns on these metal and dielectric layers and perform rapid chemical cleaning of CVD tool chambers. The carbon and fluorine that these compounds deliver in a plasma are essential when etching advanced integrated circuits because, in addition to etching, they form polymers, which allow for highly selective film removal.

Once the electronic components (e.g., transistors) have been fabricated in the silicon, thin conducting material is added – the minute wires –to interconnect individual circuit components. In complex devices the length of this wiring will exceed 4 km per cm2 of device area. The pathways for these wires are etched into the insulating layers using etch chambers or etch tools. These etch tools also use FFCs in a plasma. In etch tools, both F-atoms and polyatomic species such as CF2 are created and react at the film surface (following prescribed patterns) to selectively remove (etch) substrate material. Etch processes are used to form, for example, trenches that are subsequently filled with metal to form the wires. CF_4, CHF_3, C_2F_6, C_3F_8, c-C_4F_8, NF_3 and SF_6 are etching gases. In some etching processes it is important that certain CF-containing polymers are formed on surfaces, which permits highly selective and directional removal of film material.

Moisture will interfere with the formation of the plasma and also the quality of the etch, so sampling the FFCs before introduction to the etcher or CVD chamber is a key quality assurance process.

Michell Instruments offers the QMA401 precision moisture analyzer which is ideally suited for these applications, based on the Quartz Crystal Microbalance, which measure the frequency change in a hygroscopic-coated quartz crystal as it adsorbs and desorbs moisture.

QMA401

The QMA401 uses a Quartz Crystal Microbalance moisture measurement technique which is accurate, reliable and very fast to respond. The system incorporates an internal calibrated moisture source, which is used to perform calibration verification and adjustment of the analyser automatically.

Quartz crystal microbalance:

- Responds very quickly to changes in moisture content.
- Consumes a very small amount of gas to make a measurement (300ml/min without a bypass loop)
- Automatically self-adjusts, using a calibrated internal moisture source

The analyzer is equipped with a modern touch-screen UI, which is configurable for the displayed parameters and outputs the customer requires. On-board datalogging, plus USB and Ethernet communications are provided as standard. The instrument is supplied with a traceable calibration certificate.

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The QMA401 is an ideal analyzer for measuring an absolute quantity of water vapor using only a very small volume of gas. Its detection method is extremely sensitive to small changes in moisture content, and does not need to wait for measurement equilibrium to produce accurate results.

Key Features

Measurement Range	0.1 to 2000ppm$_V$	HMI	7" Resistive Touch Screen
Measurement Units	ppm$_V$, ppm$_W$, mg/nm^3, vapor pressure (Pa), Frost point (°C), lb/MMscf	Data Logging	Direct logging to SD card or PC via application software
Accuracy	±10% of reading from 1 to 2000 ppmv 0.1 ppmv between 0.1 & 1 ppmv	Outputs	Analogue: 2 channels, user selectable 4–20 mA or 1 to 5 V Digital: USB or Ethernet (Modbus TCP) Alarms: 1 x System alarm, volt-free change-over (FORM C) 1 x Flow alarm, volt-free change-over (FORM C) settable high or low 2 x Level alarm, for ppm$_V$ or DP, settable to be active high or low
Repeatability	±5% of reading from 1 to 2000 ppm$_V$ ±0.1 ppm$_V$ between 0.1 & 1 ppm$_V$	Additional Features	Automated flow control, automated self calibration at either 0.5, 5 or 50ppm$_V$

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