Advanced Process Control Increases Yield of Low Open Area Via Etches

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Scaling CMOS technology into the nanotechnology regime allows hundreds of millions of devices to be fabricated on a single chip. To integrate this many active-elements onto one IC, the on-chip metal interconnect system must be able to incorporate up to 10 wiring-levels.

The electrical-resistance and parasitic-capacitance associated with such interconnects have become the dominant factor that limits circuit speed. In an attempt to overcome this limitation, technology has been developed to replace the aluminium interconnect-metal with copper (Cu). Using Cu instead of Al offers reduced resistance and enhances electro-migration reliability.
The Cu material is integrated into the interconnect system by using a dual-damascene (DD) process. This is necessary because Cu does not form a volatile by-product, and is thus difficult to dry-etch. The DD-process slidesteps this problem by eliminating the need to etch Cu. Instead, recesses are dry-etched into interlevel dielectric (ILD) films, and these recesses are then filled with Cu. Any Cu that gets deposited on top of the dielectric is polished back to the surface of the ILD with a CMP process.

The VIA etch process is a critical step in the fabrication of logic devices with critical structure dimensions of 0.18 - 0.13 µm with copper backend.
The low open area oxide, less than 1%, the highly selective chemistry, and the accurate detection of oxide/nitride and nitride/copper interfaces are the main challenges to overcome.

The optical emission spectroscopy is the ideal technique for accurate and reliable in-situ real-time endpoint monitoring of thin film etch processes. This application note clearly illustrates the successful monitoring of the VIA etch process using the HORIBA Jobin Yvon MultiCPM OES system.

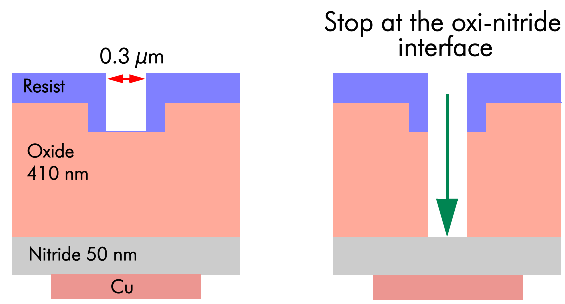
Experimental

Processing is performed in a APPLIED MATERIAL P5200 IPS etch cluster tool.

The MultiCPM was used to collect the plasma emission during the VIA etching process. This system is equipped with a sturdy optical fiber which can be easily mounted on the side window of the plasma chamber. It uses a 2048 CCD sensor designed for multi channel spectroscopy, and covers the spectral range from 190 to 850 nm.

By monitoring the emission intensity of selected wavelengths the MultiCPM tracks the amount of material in the plasma, and hence whether a particular material has been completely removed from the etch surface. Thus the end point is detected based on the changes in the spectrum of optical radiation emitted by the plasma.

The wafer structure is composed of three layers, including a soft mask resist. The VIA process removes the oxide layer down to reach the Si_3N_4 interface using a non selective chemistry.



Starting Point

Step 2: SiO_2 etch

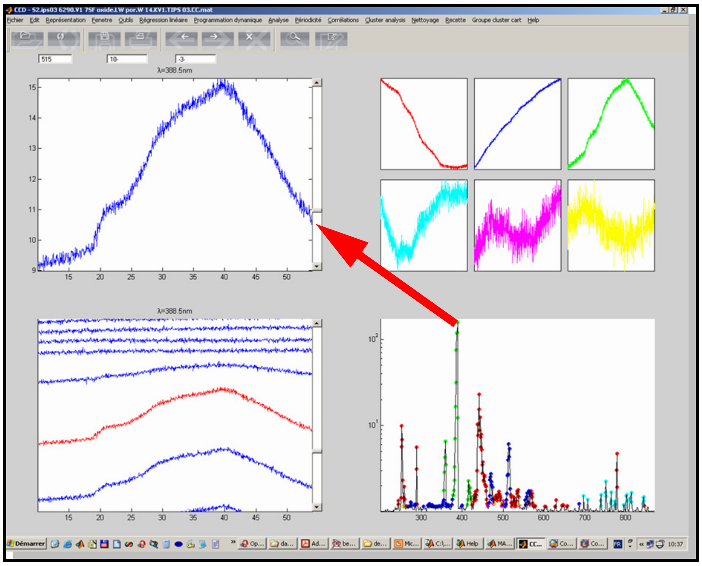
To implement an in-line OES system for the CA etch process step three stages were required:

① The selection of the relevant wavelengths that carry the information about the transition

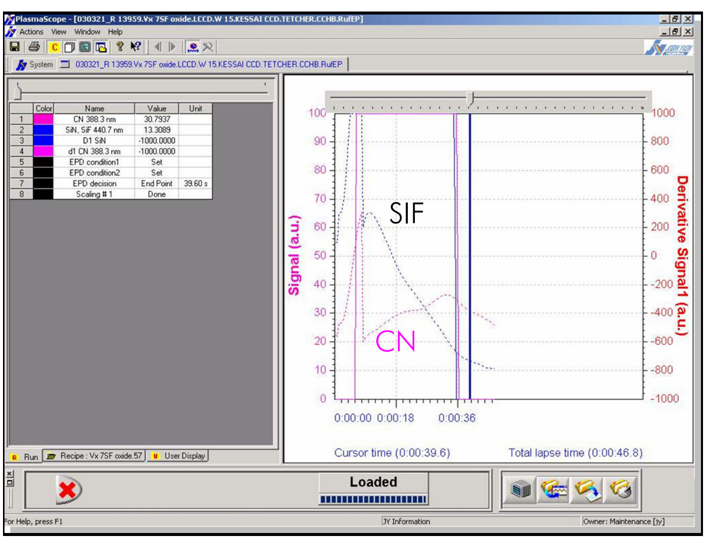
The difficult plasma conditions were overcome by using HORIBA Jobin Yvon's AutoPattern software. It is an advanced Recipe Designer that automatically analyzes the full spectral data over the complete run and classifies each wavelength according to the shape of its intensity profile. It then automatically identifies the relevant emission lines. For the accurate monitoring of the VIA etch process, two spectral lines due to CN and SiF emissions were used by the algorithm.

② Real-time data filtering and the construction of an endpoint indicator

The endpoint recipe can be rapidly constructed to include the CN and SiF wavelengths identified by the AutoPattern software along with advanced signal arithmetic and filtering.



Relevant wavelengths pattern research using Autopattern software

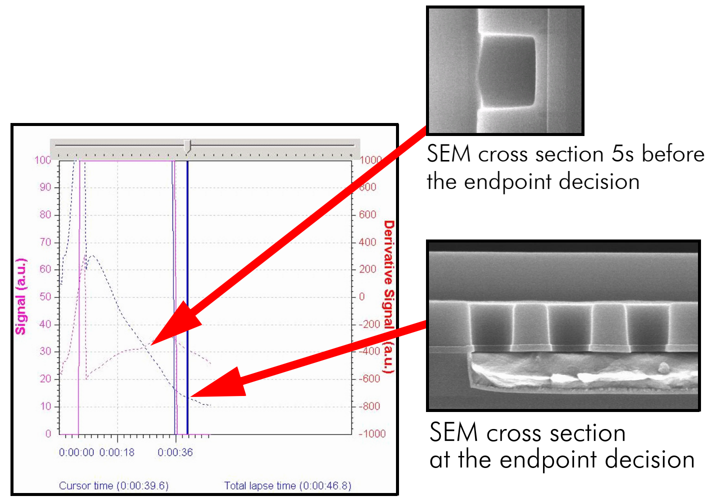


CN and SIF spectral lines selection for endpoint decision

③ A series of tests to expose the algorithm to the reality of production fluctuations

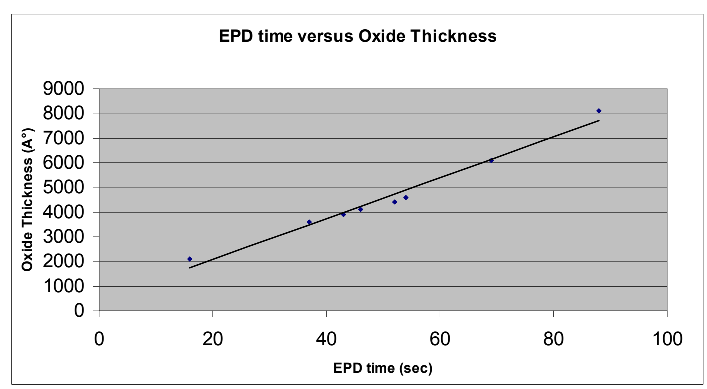
The ex-situ control of etch depth was performed using a scanning electron microscope (SEM). The SEM pictures show that the interface is reached only when the endpoint decision is complete.

SEM pictures and data are provided with the courtesy of ALTIS SEMICONDUCTOR.



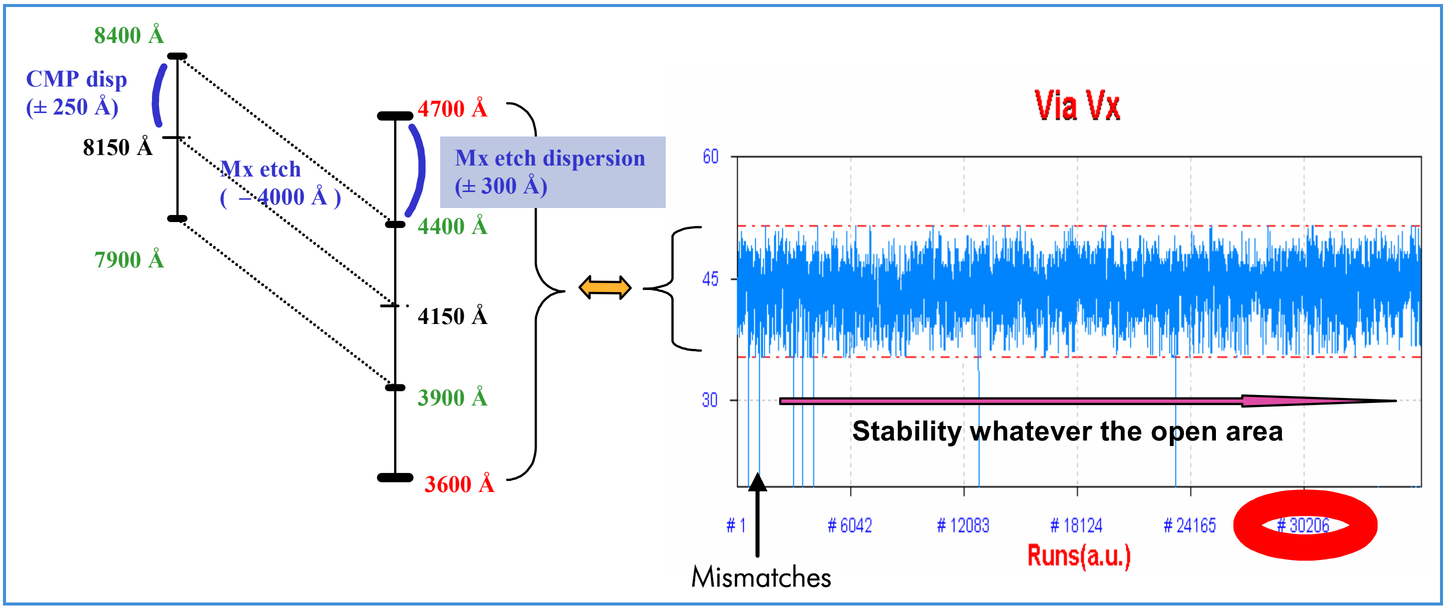
Endpoint trace showing the process termination

Another test was used to validate the endpoint detection. Several wafers with different oxide thickness were processed. The figure shows the excellent correlation between the increase of endpoint detection time and the oxide thickness. It clearly illustrates the MULTICPM's powerful detection capabilities of the SiN interface.



Endpoint algorithm validation

Statistics were performed on more than 30 000 wafers, and 100 % successful endpoint detection was achieved. It demonstrates the robustness of the endpoint algorithm and hence that the optical emission spectroscopy technique is a powerful technique for accurate and reliable control of etching process termination. Moreover the MultiCPM was shown to be production ready by its ability to detect wafer mismatches as no endpoint was called in the case of blanket resist and double etch wafers.



Statistics on production wafers

The end point detection time varied by 15 s is explained by two factors:

- Previous steps (CMP and Mx process) introduce oxide thickness variation. A variation of 500 Å is introduced by the CMP process and then 300 Å more by the Mx process. A potential dispersion of 1100 Å represents a dispersion of 11 s on the endpoint detection with an etch rate of 100 Å/sec.
- Variability caused by different open areas (1 to 6%) from batch to batch

Conclusion

This application note demonstrates the ability of the Multi-CPM - plasma monitor platform to provide accurate and robust endpoint detection in a production environment which is known to generate fluctuations from batch to batch and wafer to wafer.
Only one single endpoint recipe was used whatever the technology and sequence performed enabling the process to be stopped each time the oxi-nitride interface was detected.

The overall performance of the MultiCPM ensures a reliable process control in the VIA etch step and allows a reduction in over etch time and thus an increase yield and process speed.

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