Optical Emission Spectroscopy for small open area end point detection on dielectric dry etching tools

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In semiconductor development and manufacturing, aggressive technology scaling is a continuous challenge in term of scientific knowledge and money gain and the shrinking implicates structure's dimensions hugely small and open area even lower than 1 %. Dry etching processes are well controlled by end point (EP) detection technique, that means to stop the etching step when an appropriate optical trace at fixed wavelength changes its intensity due to the consumption or the modification of the reactant's and by-products' concentration. In case of open area lower than 1 %, like as contact or via applications, the emission become extremely critical and the chosen of the right wavelength by the total spectra is the right key.

The aim of the job is the qualification of an optical emission spectroscopy tool on Lam Exelan HPT equipment able for copper dual damascene applications. The HW consists of a spectrometer and a standalone computer connected to the main tool via Ethernet, while the spectrometer is linked to the reactor by an optical fiber.

The β-site activity, carried on joint with the supplier (Lam Research), consisted to implement end point for Via application on Flash NOR devices for 0.090 μm technology node, which replaces anti reflecting coating layer, fluorine silicon glass as dielectric and photo resist. At the beginning two different etching chemistries (C_4F_8 and C_4F_6) were analyzed and according to the spectra emission four wavelengths were investigated. The two recipes used in this preliminary demo have significant flows of process gas CO, and its presence in the etch chemistry dampen or obscure transitions in CO and CN coming from etch by-products when films are cleared. C_4F_6 chemistry increases under layer selectivity to SiN_x and so the combination of the above two factors and an effective 0.5% exposed area, allows a formidable task in capturing an endpoint.

The following major work was oriented to understand any process shift induced by the Confinement Ring (CR) locking to reduce the EP fluctuation that will lead to erroneous EP detection: on two wafers CD measurements and SEM cross section differences between CR lock delay and standard configuration are negligible.

By means Principal Components Analysis (PCA), a proper algorithm was set and few wafers were etched calling the end point by OES application. Cross sections demonstrated the whole provided stack, till to Si_3N_4, was etched and replaced, so the called EP time was appropriate.

To guarantee high repeatability the end point algorithm was put in collective mode on standard production wafers and compared with the end point collection mode by Bias Compensation End Point (BiCEP) technique.

After about two months of collection, 974 were processed and from the simulation analysis only 7 wafers were rejected for EP not achieved. Trace analysis on wide production and PCA allowed to identify the best end point algorithm: signal is the filtered slope of a linear combination of three integrated wide wavelength bands and the end point calling is the turning point of the slope signal. Further simulation ran on 1137 production wafers gave zero failures.

Finally chamber warm to avoid first wafer effect and trace intensity degradation were also studied.