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A STUDY OF THE EFFECTIVENESS OF THE REMOVAL OF HYDROCARBON CONTAMINATION BY OXIDATIVE CLEANING INSIDE THE SEM.

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Critical Dimension measurements for process control in semiconductor lithography are routinely made using Scanning Electron Microscopy (CD SEM). In many situations, organic contamination of the CD SEM chamber cannot be prevented due to the outgassing of hydrocarbons present in the photoresist films used to define device structures. In other cases advantageous hydrocarbons are deposited from the room air before the wafer is brought into the machine, or there are residual deposits left over from manufacturing of the tool. The interaction of the primary beam with these hydrocarbons, resident in the SEM chamber, results in a deposition of a hydrocarbon film, whose thickness is dependant upon the total dose provided to the structure of interest. This deposited film not only reduces the available image contrast but also physically changes the size of the measured feature. In extreme cases, such changes have been reported to be as large as several nanometers[1 2] during a typical measurement sequence. Such a value approaches the entire metrology error budget for the most advanced processes.

A new anti-contamination system the EVACTRON® SEM-CLEAN system can be used to control contamination in SEMs[3]. The EVACTRON device (US Patent 6,105,589) is designed to remove hydrocarbons from SEM specimens and SEM chambers to prevent contamination artifacts *in-situ* within the electron microscope. The device uses a low-powered RF plasma to make oxygen radicals from air that then oxidize and chemically etch away hydrocarbons from the interior of the SEM. The device is mounted on a specimen chamber port. The plasma itself is confined to the EVACTRON chamber, which prevents ion and electron bombardment damage to the instrument or specimen. The radicals are carried out of the plasma into the whole of the specimen chamber by convection. These radicals oxidize hydrocarbons to make CO, H_2O, and CO_2 gases to be removed by the vacuum pump. The use of air as an oxygen source is convenient to the SEM operator, but limits the cleaning effectiveness of the system in relatively short time to easily oxidized carbon species such as vacuum pump oil and skin oil hydrocarbons.

Plasma cleaning using air requires that the RF plasma be operated at low temperature to produce sufficient Oxygen radicals. At higher plasma temperatures Nitrogen ion production becomes significant and lead to the destruction of the O radicals to produce NO+ ions. The NO+ ion is a low energy species that is stable and has no cleaning ability. The EVACTRON system facilitates production of low temperate plasma and the adjustment of the operating pressure to maximize the oxygen radical flux.

The EVACTRON SEM-CLEAN was developed for use on analytical SEMs. In these SEMs the chambers and specimen are typically cleaned with relatively short cleaning times of 2 to 5 minutes. CD SEMs have larger chambers to handle wafers up to 300mm in diameter. To give full access to the surface of the wafer, the chamber dimension are close to 1 meter square. This makes for very large SEM chambers volumes and surfaces to be cleaned. The question was whether the Evactron

SEM-CLEAN system could clean a large chamber in a reasonable time to stop line width measurement drift.

The experiments were done using both a 200mm and a 300mm CD SEM system. An XEI Scientific "Evactron SEM-CLEAN ™" system was mounted on one port. When the cleaning system was operated the specimen chamber vacuum was maintained at 100 Pa by a controlled leak of air into the device. At this pressure this leak created a viscous flow of gas to the roughing pump that quickly removed the oxidation product gases. Inside a low-powered, RF (13.56 MHz) glow discharge created oxygen radicals. The Evactron was run under these operating conditions for approximately 25 minutes.

Contamination rate measurements were conducted prior to and immediately following the operation of the Evactron unit for both the 200mm and 300mm system. Each of the measurements replicate a typical production CD measurement and are conducted over a series of 20 repeats. The results are shown in figures 1 & 2 below. The results demonstrate significant improvement in the rate of contamination. In the case of the 200 mm chamber, the rate of linewidth growth was reduced by a factor of 1.8 – from 0.33 nm to 0.18 nm per measurement. The improvement for the 300 mm chamber was by a factor of 2.7 – from 0.21 nm to 0.08 nm per measurement pass

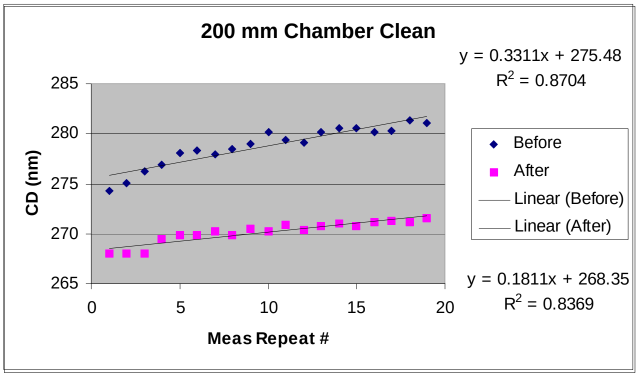

Figure 1: 200mm test results

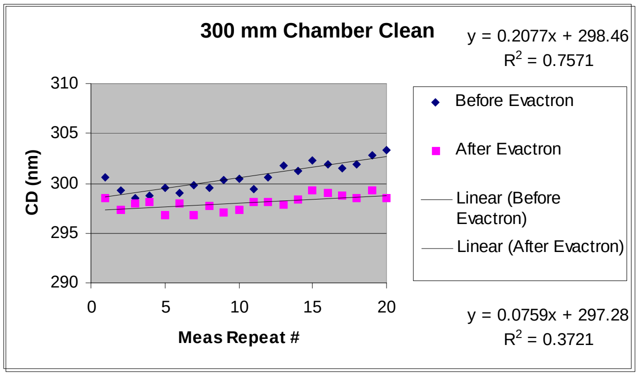

Figure 2: 300 mm test results

Conclusion

A new device and technique for in-situ SEM cleaning has been shown to significantly reduce the beam induced contamination rate of fine line geometry semiconductor samples. The new technique is fast and non-destructive to the SEM instrument. It is compatible with Field Emission SEMs since it takes place with gun valve closed which prevents the poisoning of the cathode by oxygen. It is expected that multiple cleaning cycles with this device would control beam induced contamination on fine line geometry.

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