Single-Wafer Polymer Removal for 0.18-micron to 0.25-micron Technology

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Single wafer spin-processors are used with newly developed chemistries to fulfil the cleaning requirements of sub-quarter micron technology, especially when extended to 300 mm wafers.

The move to shrinking device features according to Moore's law is ongoing. The path approaching 100 nm features necessitates new, improved materials and equipment to replace older, well-characterized process tools, which are no longer efficient in meeting performance requirements. New substrate materials being integrated include copper, TaN, low-k, $Ta_2 0_5$, BST, Ru, $CoSi_2$ and others. Process engineers are confronted with new challenges to clean sub-quarter micron lines and vias containing residue and polymers. Standard chemistry and batch equipment no longer provide sufficient selectivity, uniformity, corrosion resistance, process control and repeatability required wafer to wafer and within a wafer. New and more efficient removers and equipment must be found. Furthermore, cost and environmental concerns are essential to maintain competitiveness in a global market moving to 300 mm substrates.

Chemistry

Standard polymer strippers, generally used at high temperatures between 65-95°C, are being upgraded and replaced by a new generations of chemicals that work at room temperature. The market also is demanding shorter process times to improve throughput. Precise chemical dispense and efficient equipment operation are needed to control corrosion and to prevent attack of exposed layers and structures. Quick, complete rinsing is required to neutralize this new class of "removers". Care must be taken to avoid mixing water with the active chemistry, since chemical residue that comes into contact with water may form compounds that can attack exposed metal, oxides or low-k layers. Some suppliers have responded by formulating new strippers that are very high in viscosity, which creates difficulty in processing copper and low-k materials for cleaning. We have worked to identify a process that allows equipment and chemistry to work synergistically as a complete process solution.

Single-Wafer Spin-Processor

Single wafer tools offer the advantage of excellent consistency within a wafer and from wafer to wafer. Higher cleaning effectiveness is achieved by improved chemical reaction due to rapid exchange of the chemical on the surface. Static systems such as immersion tanks offer no mechanical velocity, operating by increased the thermal activation at higher temperatures or very high flow rates through the wafer cassette. Spray batch processors function by wetting and rinsing the chemical sprayed from outside of the carrier using enormous liquid turbulence in the chamber as the form of agitation.

In a Single Wafer Spin-Processor **(Figure 1)** the remover is dispensed from above and across the rotating wafer by a moving dispense arm. The result is excellent uniformity and process control. The remover is immediately spun off into the process chamber where it can be re-circulated. In addition, a multi-stack chamber has the outstanding advantage of complete separation of several chemical and rinse levels. A short high-speed spin-off step of the chemical before water rinse removes excess chemical from the wafer surface, thus improving the effectiveness of the DI water rinse and acts as a temporary stop for the remover.

Experimental Results

Several chemistries were used on a SEZ Single Wafer Spin-Processor for different metal and via hole structures (0.18 –0.25 µm) to verify complete post-dry-etch residue removal from production wafers. All testing was done at the SEZ Research Lab in Villach, Austria. The first experiments were conducted with standard high-temperature chemicals (60-90°C), using short process times of 30-60 seconds to clean salicided polysilicon gates, aluminum lines and vias. A 10 to 30-second rinse was followed by a 15-second spin-dry step. Elevated temperatures increased the thermal activation of the chemical, resulting in outgassing and thermal degradation of the chemical. This class of organic-based mixtures was judged to be less effective at removing the organo-metallic residues of <0.25 µm features. Therefore, we worked with EKC Technology to develop improved products that operate at ambient temperatures. These new removers were then used in a second series of tests.

Characteristics for these advanced removers include low viscosity and excellent surface-acting components. These new EKC chemistries demonstrated improved removal of organo-metallic residues formed during the most demanding dry etch process. These semi-aqueous chemistries have been developed to specifically control and eliminate any attack on metal, low-k dielectric or other exposed materials. Short process times demonstrated etch rates of less than 10 Å/min for any substrate and achieved excellent cleaning results. Typical blanket wafer etch rates are shown in **Table 1**.

Different types of metal wafers were used in this study, including oxide/titanium/TiN/AlCu metal stack etched by a LAM TCP9600 etcher. The wafer samples after metal etch were cleaned on a SEZ Single Wafer Spin-Processor, using new chemistries provided by EKC that can be used at room temperature. Cleaning times varied from 10 to 120 seconds, the remover flow rate was set from 0.8 to 2.0 liter/minute, and spinning speed varied from 400 to 800 rpm on 200 mm wafers. **Figures 2a and 2b** show the cleaning result on 0.23-micron metal lines after only a 10 to 20-second processing using EKC630™. Specially designed single wafer spin processors with stacked multiple chambers do not require an intermediate rinse, so more than one chemical may be used in a recipe. A final rinse with DI water for 15 to 30-seconds and a spin-dry step for 15 seconds allows an in-situ cleaning, rinsing and drying sequence.

Assuming a process time of 30 seconds with a flow rate of 1.5 liter per minute and a 15-second DI water rinse, only 0.75 liter of chemical and 0.5 liter of DI-water is needed per wafer. (Additionally the chemical will be re-circulated, filtered and re-used). This significant reduction in material usage lowers the Cost of Ownership (CoO), since consumables generally contribute a major portion of CoO calculations.

Conclusion

Single wafer post dry-etch residue removal has been proven as a serious alternative to commonly used batch systems such as wet bench or spray systems. Improved removal efficiency of 10-20 times higher has been achieved. A combination of four chambers next to each other (e.g. SEZ 4200 with a footprint of 4-5 m^2 with integrated chemical tank) can yield a throughout of up to 200 wafers per hour (200-300 mm). Shorter process times, precise control of chemistry application, reduced use of DI water use and excellent cleaning results translate into improved performance and reduced cost. This contributes to low CoO and environmental requirements.

References

1. Brown, P.T., et al, *Environmental Impacts and COO of Two Wet Clean Tools*, Web Exclusive Semiconductor International/February 1999.
2. Gaulhofer, E., et al, *Polymer Removal on Single Wafer Tools*, Merck-Kanto Seminar 1998.
3. Kruwinus, H., et al, *Single Wafer Polymer Removal, 8th ISSM, 1999*, California, USA.
4. Rathbone, R., et al, *Evaluation of Frontside Application on SEZ Spin-Etcher 203*, S.E.A. Project EFASEM 26.414, 1999

Figure 1: Spin-Processing

Figure 2a: 0.23-micron Metal Line (Oxide/Ti/TiN/AlCu/TiN) - Before Clean

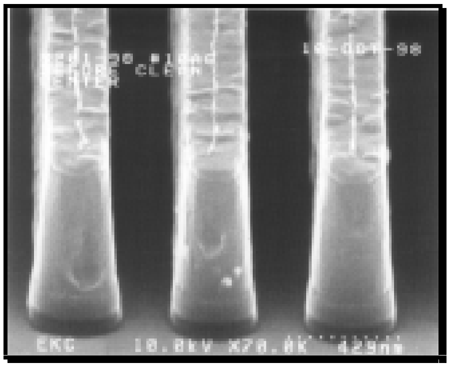

Figure 2b: 0.23-micron Metal Line (Oxide/Ti/TiN/AlCu/TiN) - After Clean in EKC630™ with SEZ Equipment

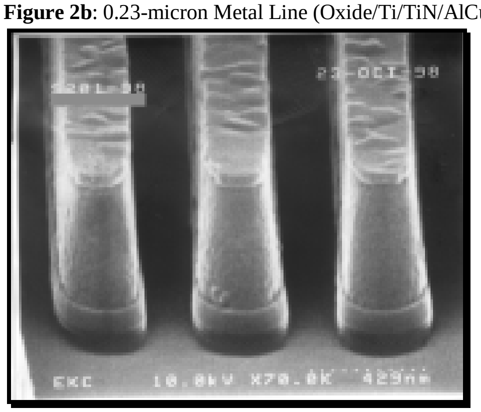

Table 1: Typical Blanket Etch Rates of EKC Semi-Aqueous Chemistries

Film Type	**Test Conditions**	**Initial Film Thickness**	**Etch Rate (Å/minute)**
AlCu (0.5%)	R.T.	1.0 µm	< 5
Ti	R.T.	1.0 µm	< 0.7
W	R.T.	3000 Å	< 0.5
Cu	R.T.	1.60 µm	< 2
BPSG	R.T.	1.0 µm	< 2
TEOS	R.T.	1.0 µm	< 1
Thermal Oxide	20° C	1.0 µm	0.2
SiLK ™	20° C	1.0 µm	3
FOx ™	R.T	5600 Å	< 1