Characterization and Optimization of Single Wafer Equipment With Advanced Aqueous Formulations to Achieve Lower Cost of Ownership for Advanced Cu Interconnect Cleaning Processes

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The drive to minimize the RC delay in logic copper / low-κ interconnect requires new material strategies. Implementation of porous low-κ films in 45 nm and beyond has created new wet cleaning demands that cannot be met by incumbent cleaning offerings, which can range from high solvent, high viscosity chemistries to extremely dilute hydrofluoric acid-based (dHF) blends. The gap in unsatisfied needs has been filled by the development and commercialization of advanced aqueous cleaning formulations. These highly aqueous formulations meet customer technical-roadmap requirements as well as provide environmental sustainability. Advanced aqueous chemistries provide excellent film compatibility, particularly on porous low-κ materials. From a process standpoint, they enable faster chemical dispense coverage on the wafer, readily penetrate very small, high aspect-ratio features, and require significantly shorter deionized water (DI) rinse times than more traditional, solvent-based mixtures. These cleaning attributes lead to process cycle-time reductions, higher wafer throughput, and contribute to a lower cost-of-ownership (CoO).

The significant chemical and physical property differences between incumbent solvent offerings and newer advanced aqueous formulations strongly influence equipment setup when single-wafer cleaning platforms are used. Single-wafer cleaning recipes that are designed for high viscosity solvent formulations may not work well for advanced aqueous cleaners, and vice-versa. A direct impact of these differences can be seen in the area of chemical usage. This study focuses on characterizing the interaction of an advanced aqueous chemistry in a single-wafer cleaning tool, and subsequently optimizing the single-wafer equipment setup to minimize chemical usage. Segmentation of where chemical loss occurs and proposed mechanisms for the chemical loss are discussed. The segmentation data are then translated into an optimized best-known method (BKM) for the equipment setup, which includes both equipment facilities settings and specific process recipe parameters. The optimized setup is then validated through a series of marathon wafer runs to calculate process performance and chemical usage. Marathon testing results yielded a more than 20% reduction in chemical loss while maintaining equal or better cleaning performance compared to the previous process-of-record (POR) for solvents. This emphasizes the importance of matching process and chemistry to provide optimal performance and lower CoO. Further cleaning simulations performed using chemical dispense time and process temperature show that optimization can lead to additional chemical savings in excess of 33%.