17TH US-KOREA FORUM ON NANOTECHNOLOGY, SEOUL, APRIL 3-4, 2023

Reducing Slurry Consumption while Boosting Chemical Mechanical Planarization (CMP) Process Performance

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In IC manufacturing, CMP is the second most expensive process (with lithography leading the list). Thirty percent of this is due to the need to use expensive processing equipment while the remaining 70% is due to consumables such as slurries, pads, and diamond discs. The latter two account for about 20% of the total COO as they are expensive and need to be changed after every 30 hours of use. The slurry, which is the greatest component of the total COO (50%) is an expensive specialty chemical as it contains high amounts of ultra-high purity colloidal silica or ceria nano-particles. Moreover, more than 90% of the slurry that is dispensed on the pad leaves the system without even entering the rotating pad-wafer interface to participate in the planarization process. Such large amounts of wastage bring about environmental health and safety concerns as slurries typically contain chemical oxidizers, nano-particles, surfactants, chelating agents, pad fragments, acids and bases, as well as anti-bacterial and anti-fungal agents. When introduced into the environment, these ingredients will have negative and often irreversible effects on myriad types of life and environmental cycles. As such, slurry waste streams must be treated with expensive capital equipment prior to discharge. This adds another 5% to the COO. Although the recovery and reuse of spent CMP slurries has been investigated in the past, no IC maker has managed to viably reclaim and recycle CMP slurries for device fabrication. This is mostly due to the fact that waste stream contains high amounts of rinse water which dilutes the slurry to a point where recovery is very costly. Besides, slurry makers, in spite of their iron-clad NDAs with IC makers, have not been forthcoming with their secret formulations. This has made it impossible for IC makers to accurately reconstitute the slurry from the waste stream. Simply put, slurry reduction is not in the best interest of slurry makers as it cuts into their revenues. At the same time, due to the extremely competitive landscape, IC makers are expected to continuously increase product yield and increase wafer throughput, while embracing the need to reduce COO, stop large amounts of slurry waste, and act and appear as good environmental citizens.

In this paper we introduce two novel methods that have proven to reduce slurry use while boosting CMP process performance. One of the methods is Flucto-CMP® while the other uses a slurry injection system (SIS®). Both methods can be used separately, and also together, for maximum impact. Flucto-CMP® changes the chemical and mechanical characteristics of CMP slurries at point-of-use (through megasonic irradiation). As such, one can instantaneously tune polishing performance for reduced wafer-level defects and tool-level vibrations while optimizing removal rate (RR) selectivities and increasing RRs. Lower defects and less tool vibrations mean higher product yield. This means that the same production volume can be attained via less polishers thus avoiding excess capital expenditures which can be higher than 60MM USD per factory. As higher removal rate processes require shorter polish times, Flucto-CMP® will result in proportionally lower slurry consumption and higher wafer throughput. Such a sono-activated device should also allow the integration of bulk and soft-landing metal CMP processes into a single platen process by toggling the RR of the slurry as well as the RR selectivity that is needed to manage bulk and soft-landing processes without needing one to change the slurry.

As it relates to SIS®, we have been able to improve slurry utilization by efficiently introducing fresh slurry into the pad-wafer interface. As the slurry flows out of the body of the SIS®, it enters the pad-wafer interface almost immediately and reacts with the wafer surface. In addition, as we place the SIS® on top of the pad surface during polishing, its leading edge blocks any spent slurry (i.e., containing polishing by-products that may decrease material removal rate and cause polishing defects), and residual water from the previous pad rinsing step, from re-entering the pad-wafer interface, minimizing the slurry mixing and dilution effects. Through more efficient slurry delivery and minimum slurry mixing and dilution, SIS® achieves the same material removal rate (along with fewer polishing defects) while significantly lowering slurry use. As slurry consumption is reduced, less waste is generated. As such, this technology not only reduces the COO of CMP processes for IC manufacturers, but it also makes the CMP processes more environmentally benign.

In this work, we show that Flucto-CMP® and SIS® can each reduce polish times by at least 30%. As a result, the industry will also end up using at least 30% less pads and conditioning discs. Pads are made of polyurethane, taking more than 150 years to biodegrade. A 30% reduction in their use translates to not having to discard 2MM kilograms of solid polyurethane each year. Moreover, each conditioning disc contains up to 30,000 synthetic diamonds with only about 100 of them doing the job of actively rejuvenating the pad surface. Diamonds require massive amounts of electricity to be manufactured as their synthesis takes place at temperatures and pressures of 1,700 degrees Celsius, and 70,000 ATMs, respectively. A 30% reduction in waste, and the energy for making slurries, pads and diamond discs is quite significant in light of the industry’s long-term environmental, health and safety goals. SIS ® and Flucto-CMP® can certainly do that.