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One Company's Approach Semiconductor Equipment Parts Cleaning:

BY DON McK

Cleanliness of parts in semiconductor fabrication equipment is becoming more critical as geometries (critical dimensions) continue to shrink to the low sub-micron range. New fabs are being constructed to meet Class 1 or better, and automation is reducing the human contribution to particulate (defects). The spectacular growth of this industry and huge costs of building new facilities requires higher yields than ever before to support the tremendous cost. Equipment cleanliness is now the leading cause of yield excursions. This article presents Applied Cleaning Technologies experience in a new innovative approach to addressing the issue of semiconductor equipment parts cleaning with the use of CO_2 dry ice.

Conventional cleaning methods employee what is commonly known as the “dip and dunk” technique. This type of cleaning uses expensive wet hoods to clean parts in various acids, caustics and/or solvents. The parts are rinsed in DI water to ensure the rinsing of all the solutions. Most parts are then baked in large bake ovens to dry the water from the material prior to placing them back into the machines.

This technique has a few drawbacks, including hazardous waste generation, lack of employee safety, use of valuable floor space and an unenjoyable fab environment.

The cost of cleaning parts has not been well understood for many years and it is an area that receives very little attention in the fab. When evaluating internal costs, one must include cleaning equipment, chemical costs, disposal costs of these chemicals, labor and other overhead. This cost can approach two million dollars per year in an average size fab. Some of the expenses are difficult to put a dollar amount to, but definitely will impact the fab’s bottom line. Examples include high employee turnover, equipment replacement costs, spare parts replacement, safety issues and training.

The concept of CO_2 cleaning uses dry ice pellets that accelerated onto the surface of the contaminated part at a very high velocity (>500 miles per hour). The dry ice pellet fractures the contaminant and scrubs the surface clean as it changes state from a solid to a gas. When the contaminant is dislodged it is swept away from the surface of the part to the exhaust stream by the continuing flow of CO_2 pellets from the nozzle of the delivery system. The gas vapors and then exhausted through a filtration system and evaporate to the atmosphere leaving only the residue to be disposed. Since no acids or solvents are used, the reduction of hazardous waste is 99% eliminated. Parts after CO_2 cleaning do not require DI water rinse and therefore do not require a high temperature bake. Applied Technology has seen faster pump than previously experienced with conventional cleaning. Another observation was the achievement of longer runs (more runs) between preventive maintenance. This specificially true on etch systems where historically routine particule excursions were seen as the polymer flakes away failed particle process kit substrate material. Figure 1 shows particle counts taken on an Applied Materials 8110 oxide etching after using a conventional cleaning method. The system failed particle specifications at 400 runs and was then cleaned rinising the CO_2 technique. The particle excursions were eliminating and the systems ran 600+ runs before a clean was required. This advantage is achieved through a cleaner and dryer face due to the “dry” cleaning process of CO_2. As a conditioning film or polymer is put down on the surface of

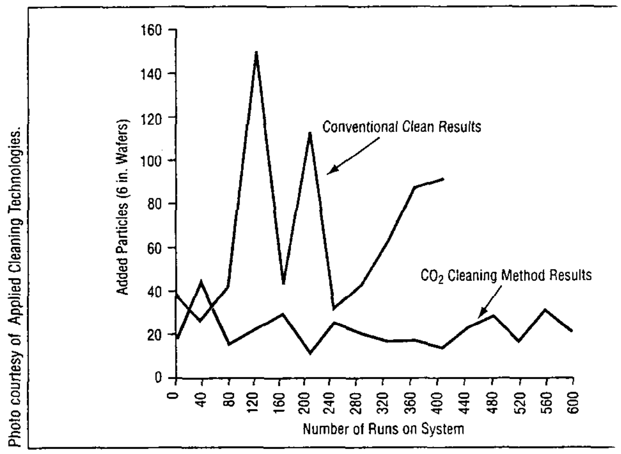

Figure 1. Applied Materials 8110 oxide etcher demonstratin ventional cleaning versus CO_2 cleaning.

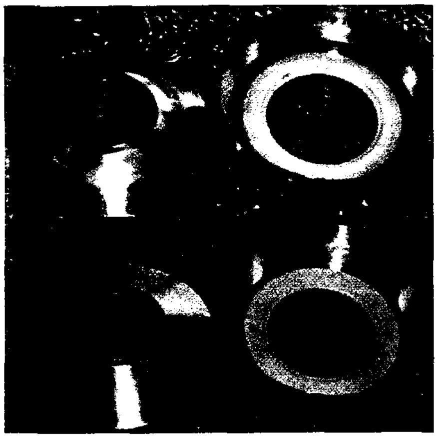

Photo courtesy of Applied Cleaning Technologies.

Figure 2. TEL coater cups before and after CO_2 cleaning.

process kit cleaned with CO_2 it is deposited on a dry oxide-free surface as proven by the faster pump down times and less outgassing observed. Parts that were cleaned with the conventional method. rinsed with DI water and then baked to dry still showed an oxidation (rainbow) on the surface when the polymer contaminant film was removed. This oxidation (rainbow) is not present after CO_2 cleaning.

The CO_2 used for pellet blasting is produced as a by-product from ammonia. natural gas and hydrogen production facilities, as well as petroleum-generating plants. This allows the re-use of the chemical before it is vented into our atmosphere. CO_2 cleaning replaces solvents such as acetone and isopropyl alcohol which evaporate rapidly exposing employees to vapors and are then vented to the outside environment polluting the air. The EPA has classified many solvents used in the semiconductor process as ODS, VOCs and/or HAPs and have limited and eliminated in some cases the use of these chemical types. CO_2 is not an ODS. Figure 2 shows one of many types of parts with which CO_2 cleaning is effective. Contaminants CO_2 cleaning can remove, include photoresist. polymers, ion implant deposits. such as boron, phosphorous and arsenic, resins, adhesives, fingerprints, exhaust line residues and chemical vapor deposited residues. The CO_2 pellet cleaning process has been used on quartz bell jars to remove polymer buildup. CO_2 does not destroy the quartz as does the conventional cleaning method which uses hydrofluoric acid as an etch chemical. This is a major cost savings because quartz used in semiconductor equipment is extremely expensive.

Substrate or base materials from which CO_2 contaminants can be removed range from fragile parts made of plastics, graphite and glass to aluminum and stainless steel.

Another application that has proven successful is wafer carriers (cassettes) and wafer boxes. As the wafers are transported through the production process these carriers collect minute amounts of silicon dust that can be transported to the wafers and cause defects reducing the integrated circuits' yield. Extremely small particles are difficult to remove (<O.3 micron) without some momentum transfer from another body to dislodge it. The dry ice pellet supplies this energy as a scrubbing action and can even remove silicon chips that have penetrated the plastic carrier surface.

Conclusion

CO_2 dry ice cleaning addresses three major issues in the semiconductor fabrication process: (1) the reduction and disposal of hazardous chemicals; (2) the reduction of particulate levels which improves the yield of new devices with geometries approaching the low submicron level: and (3) the improvement of equipment up-time.

This technology is applicable in other fields as well. including food processing, medical (bio-medical), aerospace and tire-molding.