J.T.Baker® Microelectronic Materials

TECHNICAL NOTE

Advances in Cleaning Technologies Using JTB-100 in the BakerClean® Process

Several basic parameters have been established in the semiconductor industry for evaluating and measuring wafer cleaning performance. They are: metal removal, particle removal and microroughness. These performance measurements will be used to demonstrate improvements in cleaning technologies using JTB-100 and the BakerClean process.

The RCA Clean has been used as the primary cleaning process in the industry for nearly 30 years[1]. This two step process uses a mixture of ammonium hydroxide (NH_4OH) and hydrogen peroxide(H_2O_2) [SC-1], followed by a second bath of hydrochloric acid (HCl) and hydrogen peroxide (SC-2) to achieve effective particle and metals removal from the wafer surface, The process can also include pretreatment in piranha (sulfuric acid [H_2SO_4] and hydrogen peroxide) and dilute hydrofluoric acid. One or both of these steps are commonly removed in the cleaning sequence. Some of the problems associated with the RCA clean are:

Throughput:	Multiple (2) step process
Bath stability:	H_2O_2 decomposition
Particles:	Higher particle counts after the SC-2 process

As the microelectronics industry moves toward smaller geometries and higher performance demands, more efficient cleaning processes are required. Although the use of high purity chemicals can provide some improvements, technological advances are needed to provide a stable cleaning process that can be used in a manufacturing environment.

To meet these demands, Mallinckrodt Baker, Inc. has developed a unique cleaning solution, JTB-100, that combines particle removal capabilities superior to SC-1 with the ability to leave low levels of metals on the wafer surface. This alkaline based cleaner effectively removes and prevents redeposition of metals and particles on the substrate.

The unique chemistry of JTB-100 provides IC manufacturers with a one step alkaline clean that replaces the current SC-1, SC-2 process. Hydrogen peroxide decomposition rates are lowered to provide order of magnitude reductions in compositional change. In addition, particle counts are significantly reduced with the improved particle removal capabilities of the BakerClean process.

A study comparing the cleaning performance of the BakerClean and the RCA processes will be reviewed. The performance measurements discussed above will be used to show how improvements in one or more parameters can lead to better device electrical performance.

PARTICLE REMOVAL

The use of HCl as the last step in the RCA Clean can result in higher particle counts on the wafer surface. This can be better understood by reviewing the physics of particle adsorption on surfaces. The zeta potential of a particle is closely related to the surface charge or "effective" surface potential of that particle.[2] In order to effectively remove particles from a given surface and prevent deposition, it is important to keep the potential of the particle and the wafer surface at the same polarity and highest absolute value. This will maximize the mutual repulsions that are necessary for effective cleaning. Zeta potential values are strongly dependent on pH and generally become more negative at higher pH values. The negative zeta potential of alkaline solutions effect the surface charge of particles and repel them from the negatively charged SiO_2 surface. The pH value of SC-2 solutions are typically <1. In this acidic environment particle adhesion to the wafer surface is favored.

This effect of mutual repulsion is illustrated in the comparison of the RCA clean process to the BakerClean process using JTB-l00 (see Table 1).

Polystyrene latex spheres were used as a common source for wafer contamination studies. Cleaning was performed in a static bath with no filtration or recirculation.

The RCA process was run as follows
SC-1 ($NH_40H:H_20_2:H_20$) (1/1/5) 70°C for 10 minutes
SC-2 (HCl: $H_20_2:H_20$) (1/1/5) 70°C for 10 minutes

The BakerClean process was run as follows:
JTB-100 (JTB-100:$H_20_2:H_20$) (1/0.2/5) 70°C for 10 minutes

The BakerClean process reduced the number of particles well below the original or virgin wafer particle count value. The RCA clean was not as effective in this very challenging environment. The particle removal performance is clearly a major benefit of using JTB-100 and the BakerClean process.

Table 1. Particle removal data

Virgin Wafer Particle Count	Particle Count* after Contamination**	Cleaning Chemistry***	Final Particle Count
476	2326	RCA	1802
275	2199	BakerClean	138

* Particle counts were performed on a PMS 3600 particle counter
** Wafers contaminated with 0.1,0.2, and 1.0 µm polystyrene latex spheres
*** Static bath no filtration or recirculation

METALS REMOVAL

JTB-100 removes metal contaminants by forming soluble complexes. These stable metal complexes remain in solution and do not redeposit on the wafer surface. In addition, JTB-100's ability to etch silicon oxide facilitates the removal of metals embedded in the surface.

This is accomplished while simultaneously growing a clean silicon oxide layer on the substrate. In a study comparing the RCA and BakerClean processes, droplet surface etching (DSE)[3]/ICP MS measurements were used to evaluate cleaning effectiveness. Wafers were pre-treated with piranha and dilute HF in both cases to provide identical starting surfaces.

The data (see Table 2) indicates the one step BakerClean process performs as well as the two step RCA process.

Table 2. Metals removal efficiency

Wafer Treatment	Surface: 10^{10} atoms/cm^2				
	Al	Fe	Cu	Ni	Zn
Virgin Wafer	2230	65	20	<2	15
RCA Clean (70°C)	<20*	<20	<6	<2	<8
BakerClean (70°C)	<20*	<20	<6	<2	<8

*During replication, some individual wafer values were at or lower than detection limit.

MICRO-ROUGHNESS

Micro-roughness is the third critical parameter that must be monitored in IC cleaning processes. Recent studies by Hedge, et al at Motorola show a correlation between increased micro-roughness and poor electrical performance on active devices[4]. A comparative study of surface micro-roughness after the RCA clean and BakerClean processes was performed using High Amplitude Resonance Atomic Force Microscopy (HAR-AFM). (see Table 3)

Wafers cleaned with JTB-100 resulted in smoother oxide surfaces in comparison to the RCA process. In addition, the micro-roughness values were not significantly different from the reference wafers.

Table 3. Micro-roughness

TREATMENT	RMS(Rq) (nm)
Reference wafer*	0.186±0.002
BakerClean	0.190±0.009
Standard RCA Clean	0.253±0.016

* Cleaned in piranha at 90°C for 10 minutes.

INDUSTRY PROVEN RESULTS

In studies at Motorola on a CMOS micro controller tunnel oxide clean, JTB-100 was directly compared to an RCA clean in a spray tool[5]. The parameters used to monitor the cleaning process were: particles on the wafer, trace impurities on or near the surface, and total time to dielectric die breakdown. Although the JTB-100 process was not optimized, the study identified a 10% improvement in time to dielectric breakdown compared to wafers cleaned with the factory's standard RCA process. Results of SIMS and TXRF analysis found trace impurities lower than the detection limit. Since the trace impurities were below the detection limit, the improvement could not be correlated to lower metal levels on the surface. The data does, however, suggest that the combination of low level surface contamination (metals and particles), contribute to the overall improvement in time to dielectric breakdown found in the study.

CONCLUSIONS

Improvements in cleaning technologies, as demonstrated with JTB-100, provide simplified manufacturing processes and superior cleaning performance when compared to the RCA Clean. Increased throughput is achieved by moving from a two step (RCA) process to a one step (BakerClean) process. A review of the three key performance parameters identified improved surface particle control and comparable levels of trace metals when using JTB-100. A significant improvement in surface microroughness was also observed. The data supports the use of technological advances in chemistry to achieve the improvements required in state of the art wafer processing.

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PRODUCT LISTING:

Description	Product Numbers
BakerClean JTB-100	6420-05; 6430-09

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