CONTAMINATION IN RIT PROCESSING

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ABSTRACT

Contamination during processing in RIT's cleanroom facility is a leading cause in the failure of fabricated devices and circuits. Detection of these contaminants is possible using an ESTEK WIS-600 surface inspection system. Before and after particle counts were taken using this system when processing wafers in many common RIT procedures. It was found that contamination levels were significant in most areas, and cleaning procedures were useful only to remove large particles.

INTRODUCTION

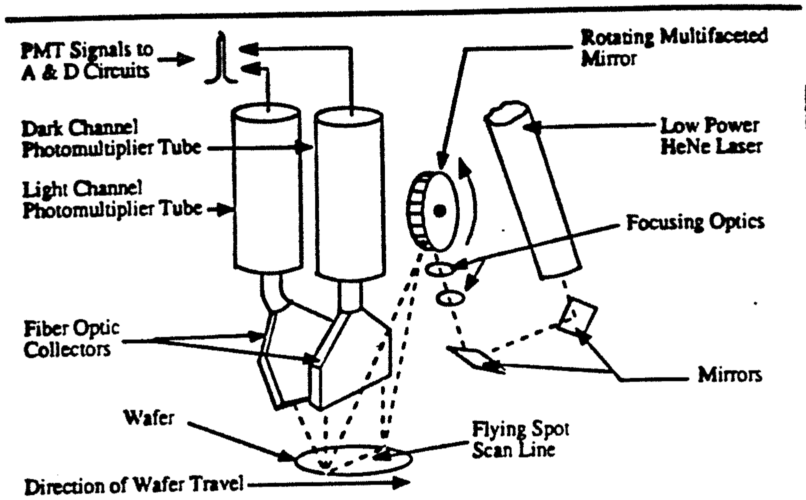
Particle contamination is a leading cause of yield reduction in semiconductor processing. Effects such as short or open circuits and ineffective lithography are among the problems caused by particles on a wafer's surface, as many particles are larger than film thicknesses and minimum linewidths. This experiment will attempt to determine the extent to which wafers are being contaminated in RIT's cleanroom facility during processing.

Particles originate from cleanroom air, chemicals, processing equipment and human sources. Some of the most common contaminants are pump oils, solvent vapors, skin oils, cosmetics, and vacuum pump exhausts. Sources of other contaminants include street clothes, human hair, smoker's breath, and solid film lubricants. Even cleaning processes are guilty of contamination, as residual films may be left behind on a wafer's surface. These particles will adhere to a wafer until proper steps are taken for removal.

Several types of adhesive forces exist which bind particles to wafer surfaces. One such type is electrostatic forces, where a particle is attracted to a wafer via being charged or being an electric dipole. Capillary condensation is another form of adhesive force. In this case a liquid bridge is formed between the surface and particle, and the bridge will not evaporate even at high temperatures. Chemical bonding is a way in which a particle will react with silicon or oxygen and adhere to the wafer. The particles often come to contact surfaces due to Van Der Waal's forces, which draw the particles to large masses nearby. The energy of these adhesive forces must be equaled before removal is possible.

The equipment used to determine the quantity of particles on a wafer surface is the ESTEK WIS-600. This machine uses a HeNe gas laser and a high speed polished rotating multifaceted mirror to generate a line of light of approximately 100um. As the wafer passes through the line, light is scattered and deflected toward fiber optic collectors which direct the light into photomultiplier tubes for conversion into electrical impulses. These signals are electrically analyzed and converted into flaw counts.

WIS-600 Laser Scanning System



The light channel assembly is controlled by two threshold values, t4 and t5, which are fixed scales of sensitivity. These thresholds are set to a level above the electrical noise level so as to measure only real defects on the wafer's surface. The dark channel assembly is controlled by three threshold values, T1-T3, which work similarly to the light channel. These thresholds, however, may be calibrated by usibng standard calibration wafers to detect flaws of a certain size. In this experiment the thresholds are set to detect particles of <1um, 1-5um, and >5um respectively. See the chart below for more details on thresholds and flaw categories.

Flaw Types (Thresholds Utilized)

F1 - Haze (T1).
F2 - Small pits and particulates (0.2 to 2μm) (T2).
F3 - Larger pits and particulates (2 to 20μm) (T3).
F4 - Cumulative sum of flaw types 2, 3, A, and C. Totalization of particulates.
F5 - Scratch count. Flaw types 1, 2, and 3 located in a minimum of four adjacent pixels are converted to flaw type 5.
F6 - Area Defects.
F7 - Orange peel, slip bands, large mounds, and polished out saw marks (T4).
F8 - Distortion with abrasion such as an unpolished out saw mark (T3 and T4).
F9 - Distortion defects of smaller size such as dimples, grooves, mounds and slip lines (T5).
FA - Large particulates (20 to 50 μm) (T3 and T5).
FB - Heavy orange peel and related defects (T4 and T5).
FC - Severe particles or pits (50 to 100 μm) (T3, T4, and T5).
FD - Not used currently.
FE - Not used currently.
FF - Not used currently.
FG - Number of edge types not resolved. Also very large defects above 100μm. (T7).

EXPERIMENT

The experimental procedure consisted of scanning each wafer's surface, performing a processing step or sequence of steps, and rescanning the wafer to find particulate add-on. The treatment each wafer saw and the before and after particle counts appear in the results of this paper.

RESULTS

The standard RCA clean used at RIT, shown below, has a background contamination level of over 700 small (<1um) and over 100 mid-range (1-5um) particles. This process does not add large particles (>5um). The RCA clean is effective in removing large particles, but does not remove the smaller flaws.

$H_2O_2:NH_4OH:H_2O$	$HF:H_2O$	$HCl:H_2O_2:H_2O$	RINSE
1:1:5 10 min	1:10 2 min	1:1:5 10min	18 Meg. To Resistivity

The MTI scruber has a background level of over 100 small and mid-range particles each, while being ineffective in removing contamination. The wafertrac high pressure scrub was better able to clean than the MTI scrub, removing a large percentage of particles >1um, but has a background contamination level of over 400 small particles. Ultrasonic cleaning with Wegman's soap was generally an ineffective process.

Several contaminant sources exist which may not be obvious. The ambient air, airguns, and spin dryer were all found to add high numbers of small particles and a significant number of larger flaws. Also, scribing a wafer causes large numbers of particles of every size to be added, as seen on the included wafer plot.

Photoresist coating removal adds very high numbers of small and mid-range particles, with less of an effect seen when exposure and development are included. Few large particles are added in either case, however, which may indicate that a post-lithography clean is not useful with current cleaning capabilities. Aluminum evaporation and etching adds thousands of small particles and a significant number of large particles. LPCVD processing also adds small particles, but fewer large particles. Ion implantation is a clean process.

The gate oxide and boron predeposition tests performed demonstrate the pitfall of using a scanner on an altered surface, as the reflectance of the wafer's surface has been changed and pours have been formed in the respective tests.

CONCLUSIONS

It was found that the contamination levels in most areas tested were significant, and that the cleaning procedures performed poorly in removing small particles. For some of the current 10um design rules contamination issues are not vital, but as the GCA stepper and MEBES electron beam masks are used to shrink device geometries to 1-2um consideration must be given to contamination.

ACKNOWLEDGEMENTS

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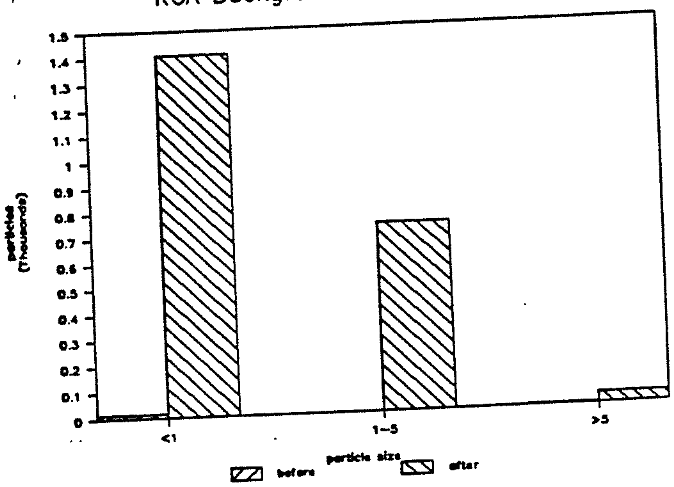
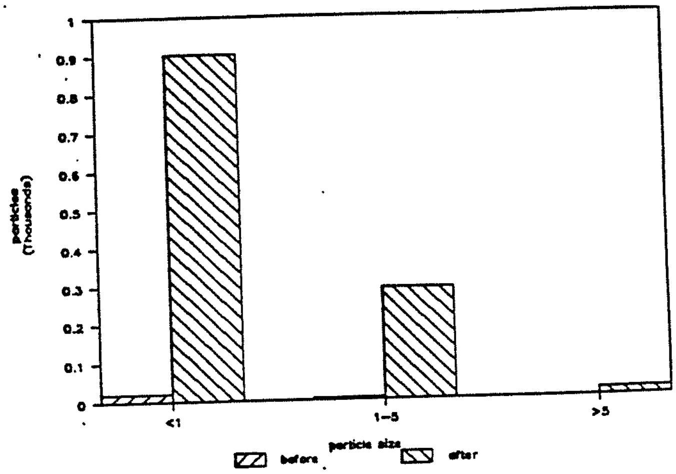
wafer#	treatment	<1um	1-5um	>5um
1	scribed-->RCA clean	765->1353	1043->486	1390->23
2	scribed-->ultrasonic clean	1194->1137	1228->776	295->116
3	tap water contaminated--> ultrasonic clean	2621->2130	1600->1104	142->33
4	tap water contaminated--> MTI scrub	2633->2425	1551->1265	253->37
5	repeat of 4	2644->2332	1306->1200	75->57
6	tap water contaminated--> RCA clean	2246->442	1856->122	277->4
7	virgin-->ambient test	43->105	7->84	0->21
8	virgin-->airline dry	51->169	2->109	0->22
9	virgin-->cascade rinse & dry	43->237	2->162	0->5
10	repeat of 9	54->315	4->208	2->10
11	virgin-->wafertrac:scrub, deh. bake,HMDS,PR,prebake,plasma ash 10min,250w	46->2849	2->386	1->11
12	repeat 11	91->3054	10->412	0->12
13	virgin-->wafertrac:scrub,deh. bake,HMDS,PR,prebake,expose, develop,postbake,ash 10,250	22->901	6->289	1->18
14	repeat 13	20->1303	5->534	2->16
15	virgin-->Al evaporate in CVC,Al etch 45c 3min	9->4012	3->531	0->146
16	repeat 15	9->4337	2->446	0->48
17	virgin-->standard lpcvd run,no silane	14->229	4->105	0->8
18	repeat 17	13->228	0->59	0->14
19	virgin-->Boron predeposit 5000rpm,40s,1100c,10min	45->23	5->3	0->1
20	repeat 19	19->20	1->5	0->4
21	virgin-->gate ox growth 1050c,15min,no tca, 5.06lpm	13->3913	2->0	2->679
22	repeat 21	11->4673	1->515	0->57
23	virgin-->ion implant 60kev,6e12,backside	15->31	5->19	2->9
24	repeat 23	10->16	4->12	0->13
25	virgin-->RCA background	15->1406	2->735	4->41
26	tap water contaminated--> wafertrac scrubbed	1434->796	2514->126	757->6
27	virgin-->wafertrac scrubbed	28->515	6->84	1->4
28	repeat 27	30->408	9->116	3->18
29	virgin-->MTI background	32->240	4->218	0->20
30	repeat 29	13->132	6->135	0->19
31	virgin-->RCA background	18->925	9->195	1->5
32	repeat 31	19->746	4->132	0->8

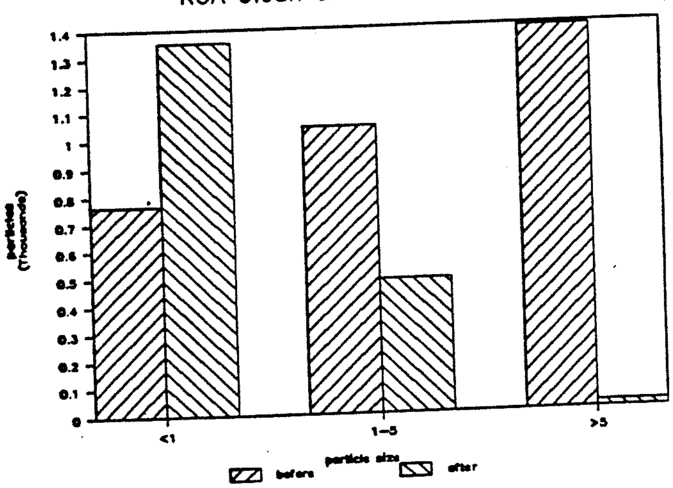
RCA Background Contamination



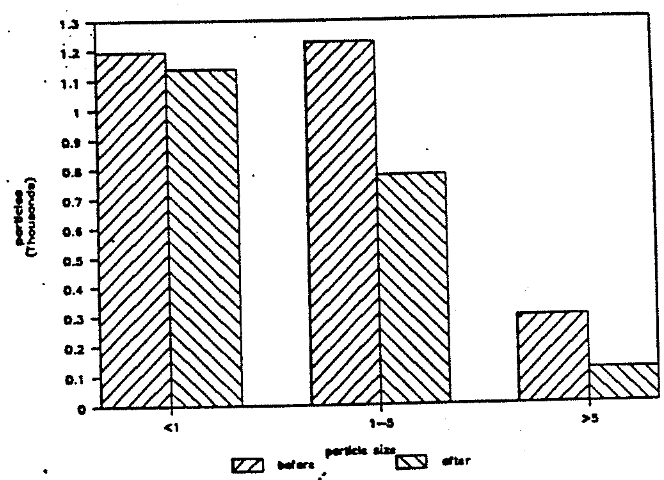
Photoresist coat, exposure, and ash



RCA Clean of Scribed Wafer



Ultrasonic clean of scribed wafer



Al evaporation & etch