ROCHESTER INSTITUTE OF TECHNOLOGY
MICROELECTRONIC ENGINEERING

Observational Studies of Particulate Contamination in the RIT Microelectronics Facility

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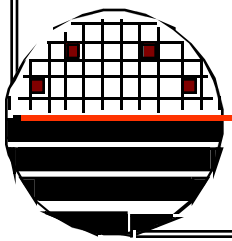
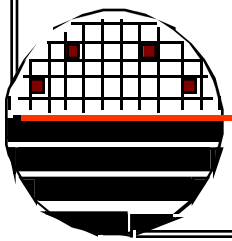


OUTLINE

Accuracy of the Surfscan Particle Measurement Tool
Calibration of Particulate Size
RIT Cleanroom Air Particle Counts
Air Velocity and Particle Counts in Wet Etch I Area
Particle Counts in the MEBES Room
Particle Counts in Gowning
Measurement of Aerosol Particle Deposition Velocities
Particle Counts on Wafers in a box
Particle Counts on Monitor Wafers Setting Out in the Lab
Particle Counts in Clean Hoods
Particle Counts Added in LPCVD System

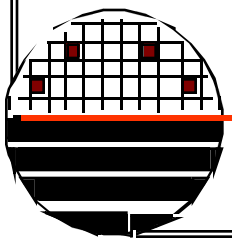


SURFSCAN PARTICLE COUNT ACCURACY

Accuracy of the Surfscan Particle Measurement Tool

Procedure: 1. Start with 8 wafers
four with surface particle counts > 100
four with surface particle counts < 100

2. Measure particle count, remove wafer, measure particle count again and repeat 4 times



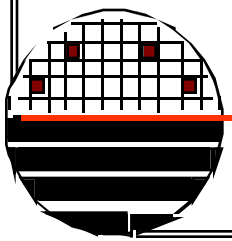
SURFSCAN PARTICLE COUNT ACCURACY

Data: Wafer with large number of particles

Run	W1	W2	W3	W4
1	363	317	115	131
2	371	307	106	95
3	346	269	95	92
4	348	308	107	116
3 Sigma	12	21	8	18

Wafers with smaller number of particles

Run	W5	W6	W7	W8
1	10	16	7	4
2	16	6	4	2
3	7	14	5	16
4	4	4	4	7
3 Sigma	5	6	1	6

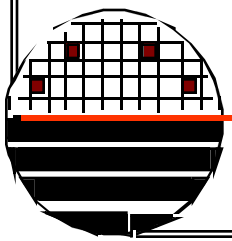


SURFSCAN PARTICLE COUNT ACCURACY

CONCLUSION

1. Three sigma error for counts is as much as +/- 20 counts for wafers with > 100 particles

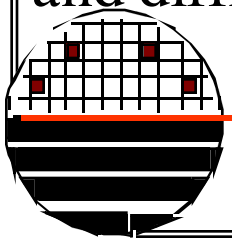
2. Accuracy and repeatability is approximately 20 counts



CALIBRATION OF PARTICLE SIZE

SURFACE PARTICULATE SIZE STANDARD

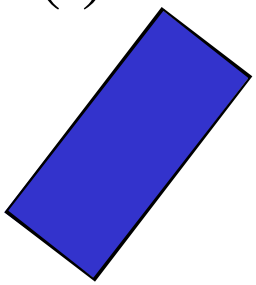
The Surfscan 364 analyzes light scattered from particles illuminated with a spot laser of calibrated size and intensity. The intensity of light scattered from a particle cannot be directly translated into particle size: it also depends on the shape, reflectivity of the substrate, and dielectric constant of the particle. The 364 uses units of scattering cross-section not particle size. The scattering cross-section is the ratio of the power scattered by the particle (watts) to the power density (watts/μm^2) incident on it (units of μm^2). The scattering cross-section includes all light removed from the beam through absorption reflection, refraction and diffraction.



CALIBRATION OF PARTICLE SIZE

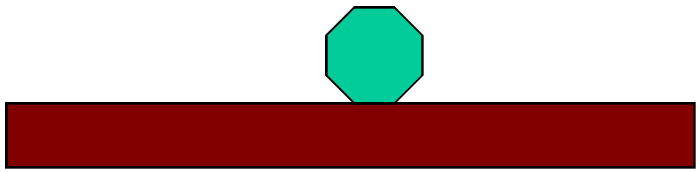
SCATTERING CROSS-SECTION

Incident Laser
Source Intensity (I)
(watts/μm^2)

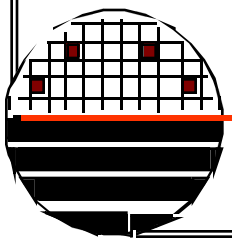


Detected
Power (P)
(watts)

S = scatter cross-section
= P/I (μm^2)



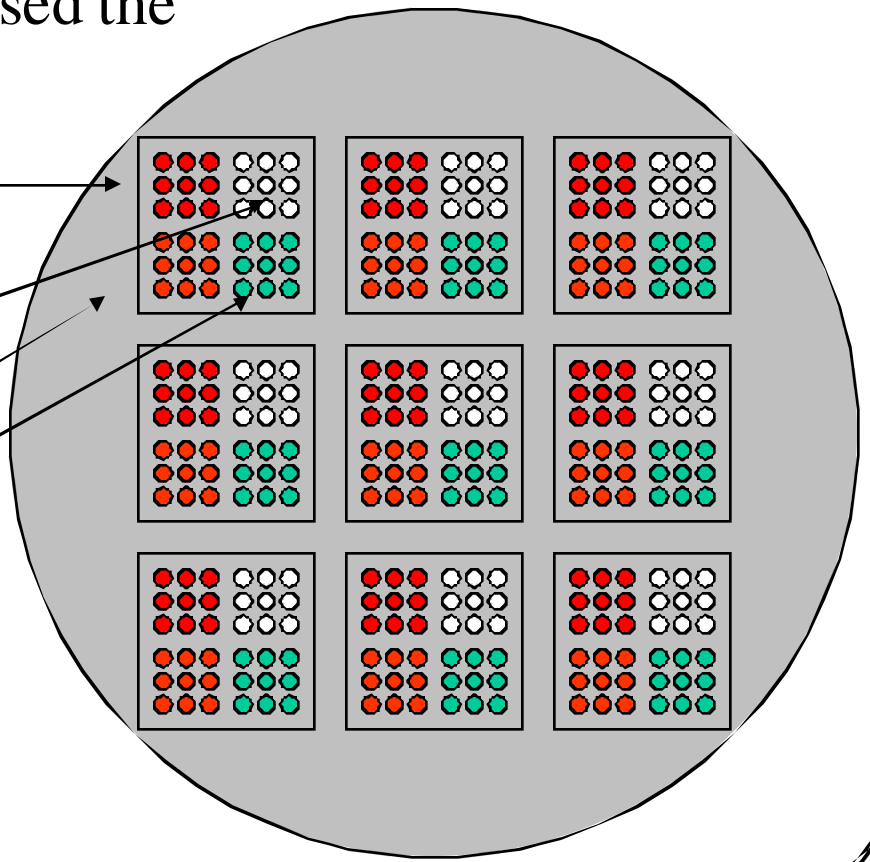
Wafer



CALIBRATION OF PARTICLE SIZE

Typical method to calibrate particle size is to measure a standard at different sensitivities. At low sensitivities only the larger particles will be "seen". As the sensitivity is increased the display shows more of the particles.

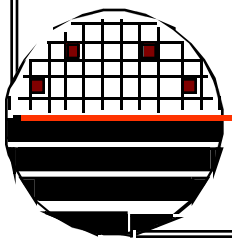
The standard is made by etching rounded holes in an oxide surface. The different sizes are calibrated against latex spheres of known size.



CALIBRATION OF PARTICLE SIZE

CONCLUSION

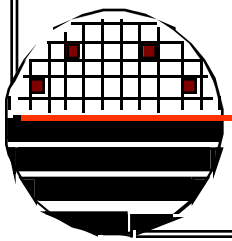
Particulate scatter cross-section can be measured and is related to particulate size (among other parameters) giving measurement results as in this example:



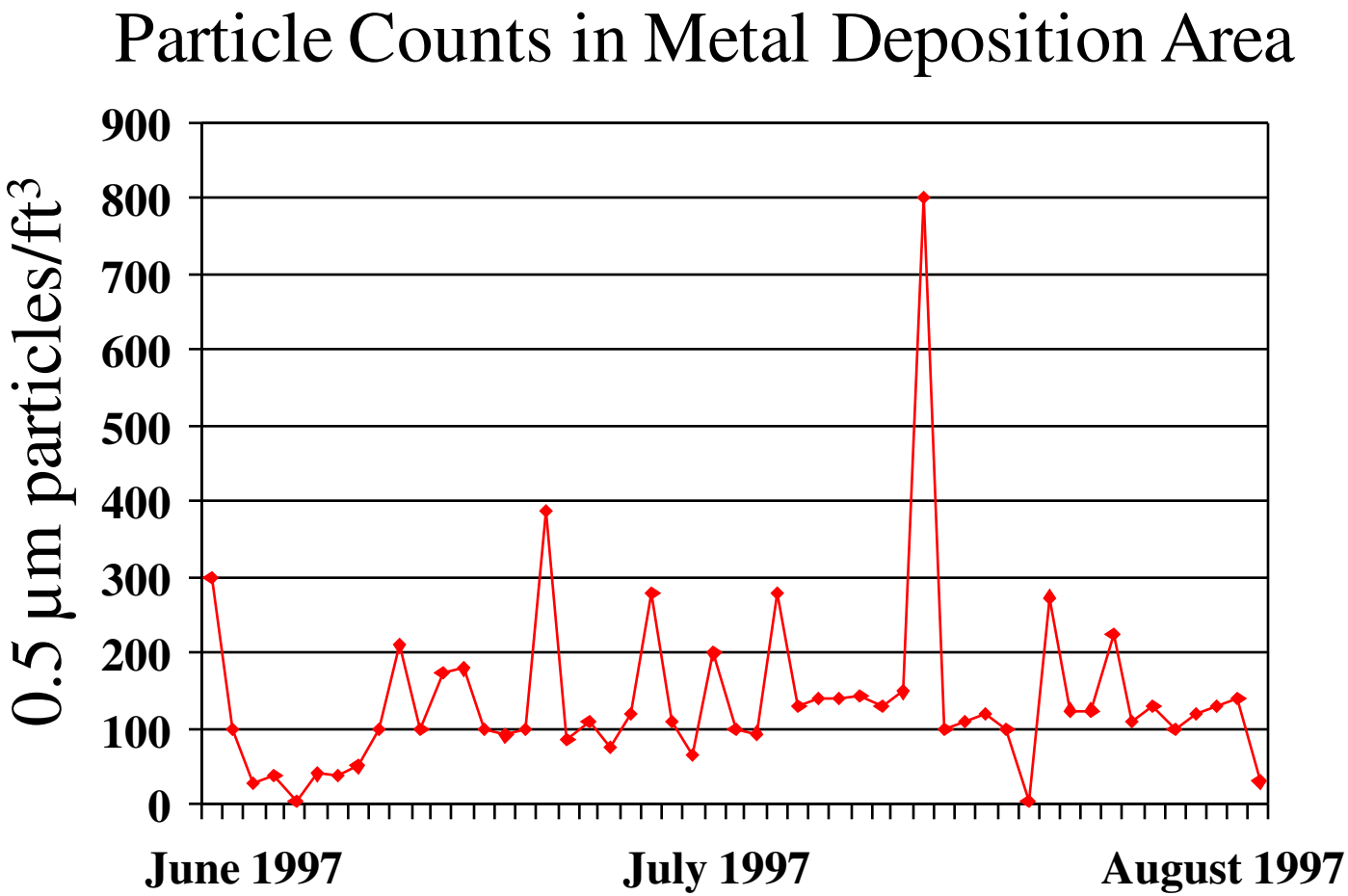
CLEANROOM PARTICLE COUNTS AT RIT

Surface 2527	1563 Optics		1437 Maskmaking	
2334 Analysis	1847		1124	
324 Gowning	Metal 230	104 Wet Etch I 101	56 Wet Etch II 68	65 Diffusion & Ion Implant
937	724 Plasma Etch	45 Photo I 59	60 Photo II 30	68

0.5 um particle counts/ ft3



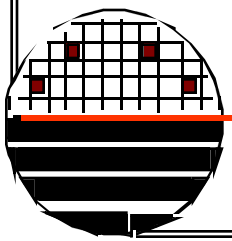
CLEANROOM PARTICLE COUNTS AT RIT



CLEANROOM PARTICLE COUNTS AT RIT

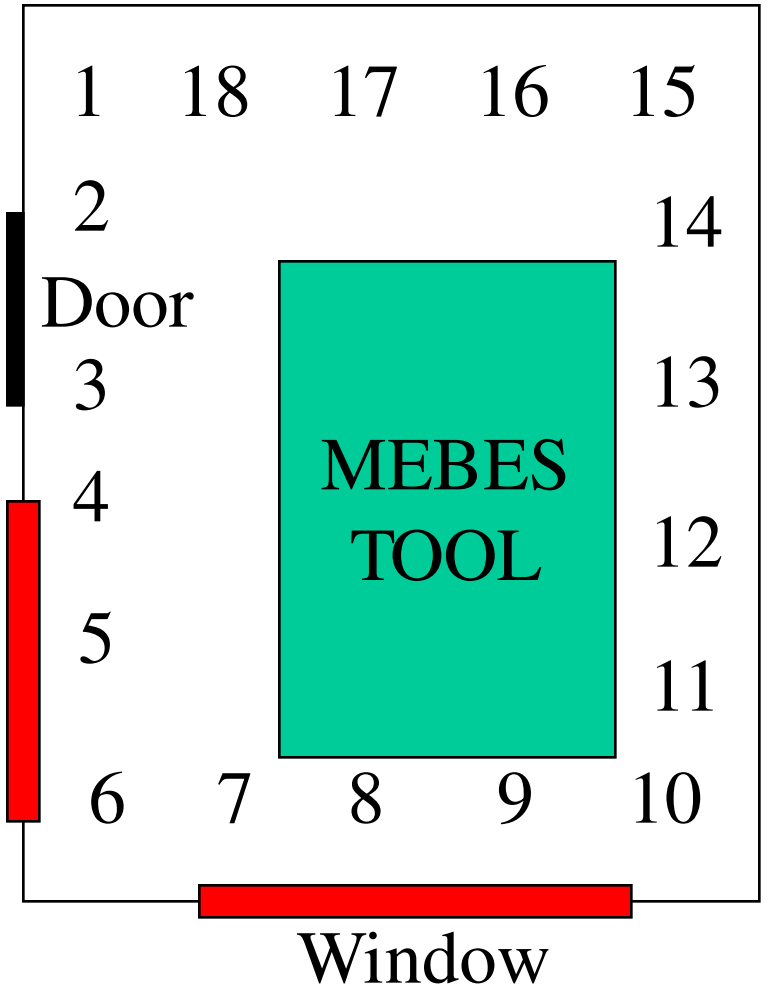
1. The cleanroom at RIT was built to meet class 1000 specifications (less than 1000 half micron or larger particles/ft3). The cleanroom part meets this specification

2. Surprisingly the rooms along the north wall are also quite clean even though they were not set up with HEPA filters in the air supply.

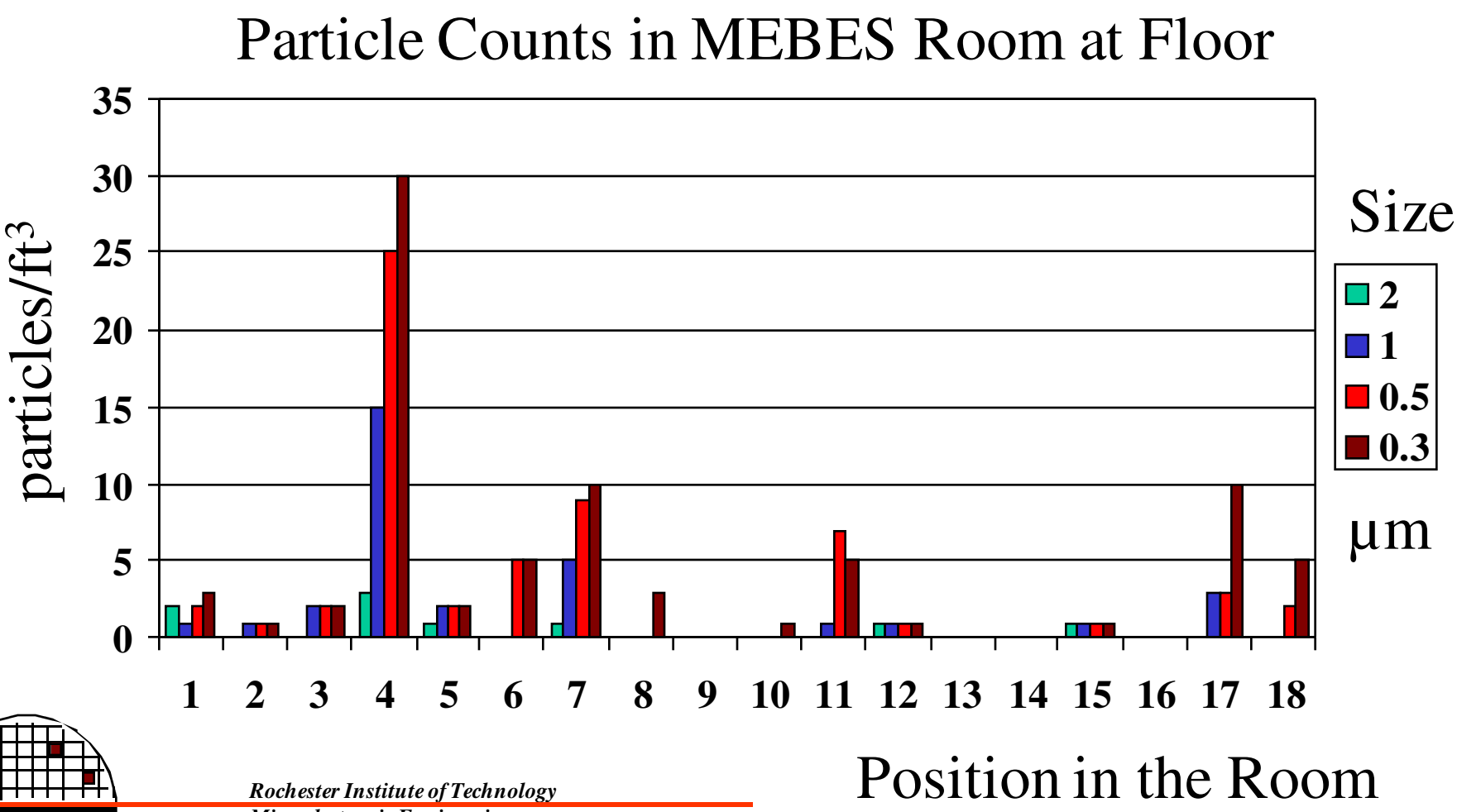


PARTICLE COUNTS IN THE MEBES ROOM

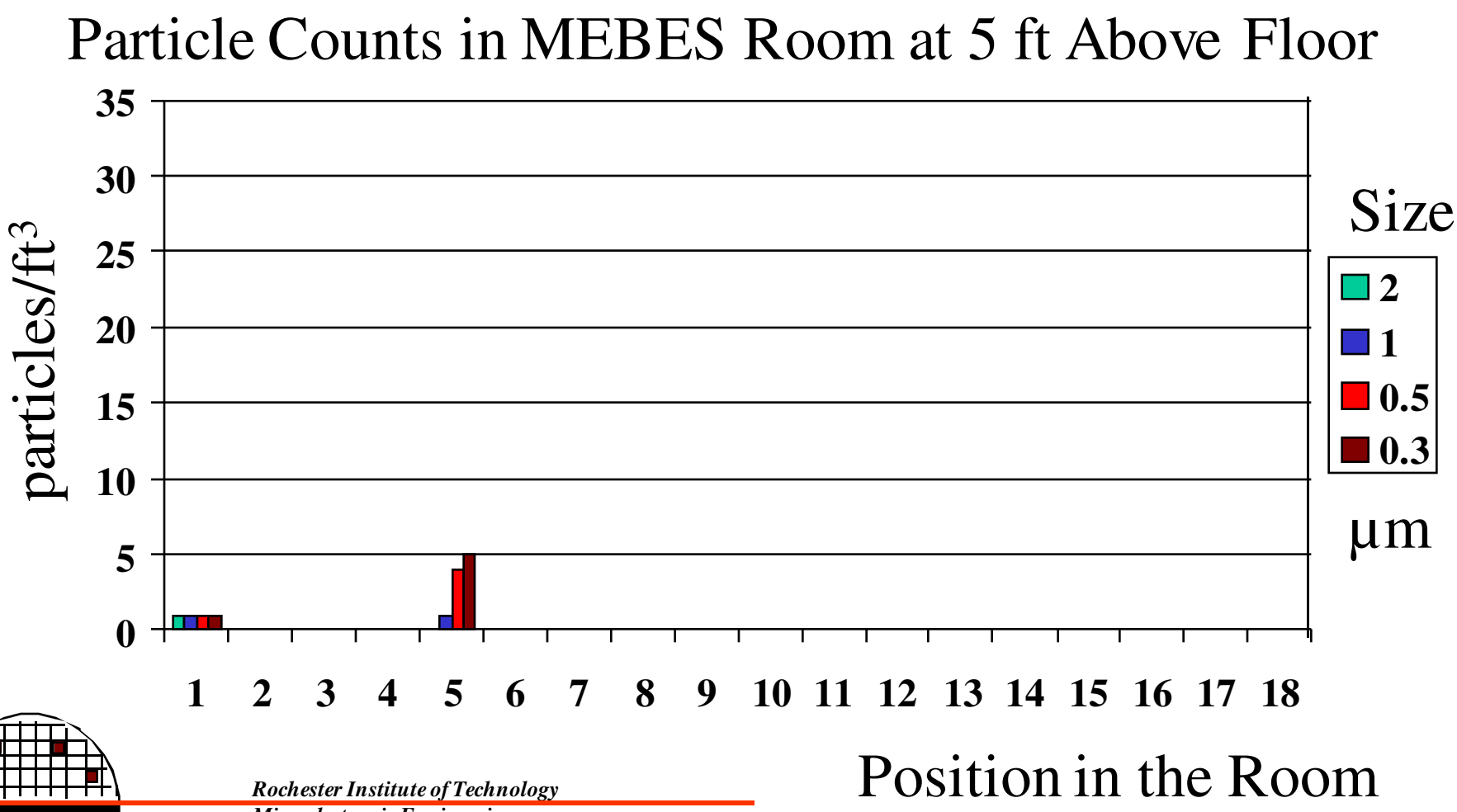
Particle count measurements were made at the floor and at 5 feet above the floor in the 18 locations shown.



PARTICLE COUNTS IN THE MEBES ROOM



PARTICLE COUNTS IN THE MEBES ROOM

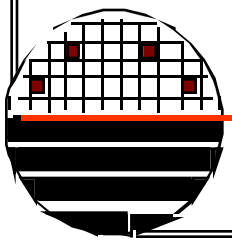


PARTICLE COUNTS IN THE MEBES ROOM

CONCLUSION

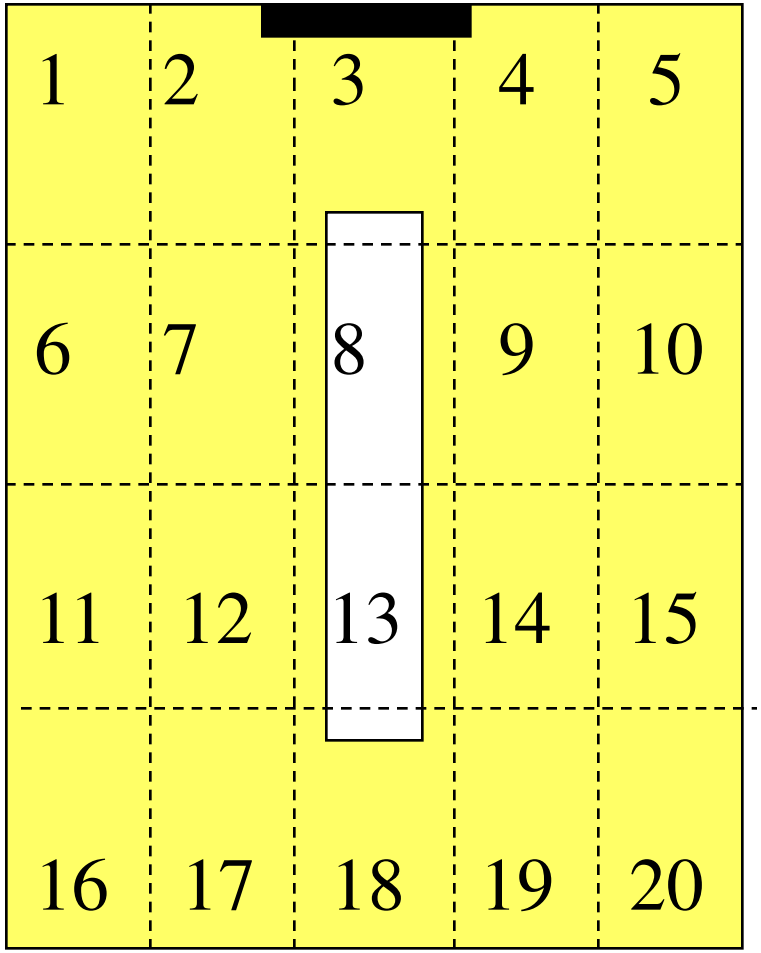
1. The MEBES room at RIT was built to meet class 10 specifications (less than 10 half micron or larger particles/ft3). The MEBES room meets this specification at 5 feet above the floor.

2. The room temperature was designed to be controlled +/- 0.1 °C and relative humidity ~40%. The temperature control is very important.

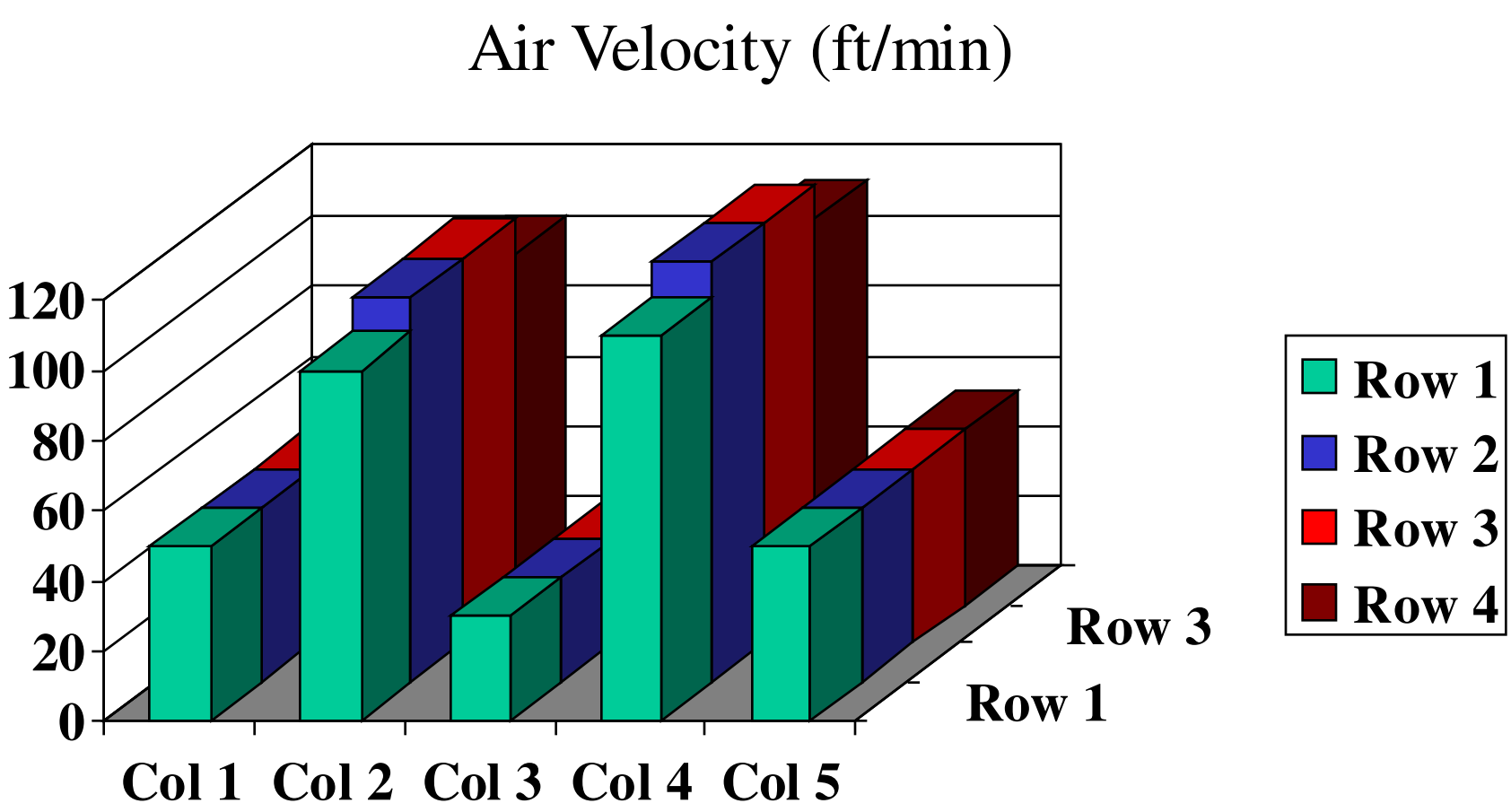


AIR VELOCITY AND PARTICLE COUNTS IN WET ETCH I

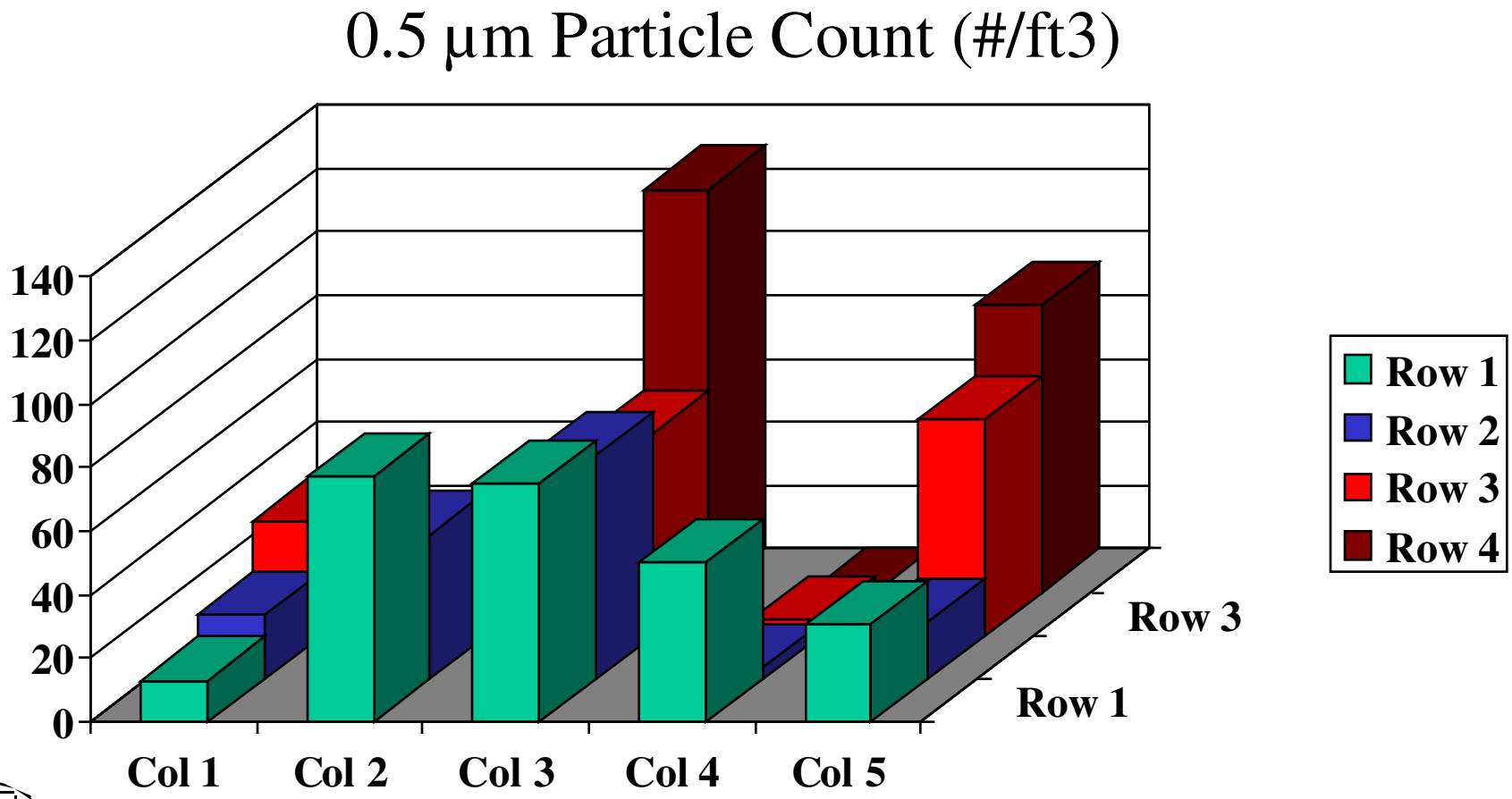
Particle count and air velocity measurements were made at 4 feet above the floor in the 20 locations shown.



AIR VELOCITY AND PARTICLE COUNTS IN WET ETCH I



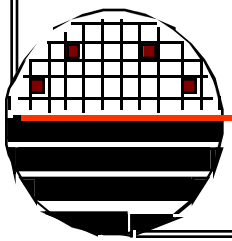
AIR VELOCITY AND PARTICLE COUNTS IN WET ETCH I



AIR VELOCITY AND PARTICLE COUNTS IN WET ETCH I

CONCLUSION

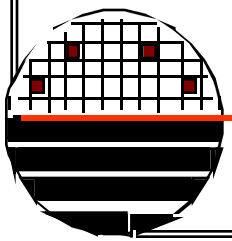
1. The cleanest area is under the HEPA filters.
2. The dirty area is on the white tables.
3. Keep wafers covered if they are on the white table
4. Higher air velocity gives cleaner space.



PARTICLE COUNTS IN GOWNING

Measure air born particle counts at floor, knee and waist for gowning with people in the room changing (A), people in the room changing but just after vacuuming (B), no one in the room (C), and no one in the room after vacuuming (D).

Joanna Kiljan
April 2001



RESULTS

	A		B		C		D	
	0.3u	0.5u	0.3u	0.5u	0.3u	0.5u	0.3u	0.5u
Floor	6550	5415	1145	155	302	155	37	19
Knee	1655	1074	897	59	83	59	119	474
Waist	665	474	216	110	167	110	215	115

A=with people changing

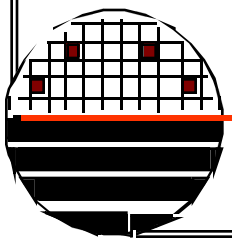
B=after vacuuming and with people in the room

C=no one in the room

D=no one in the room after vacuuming

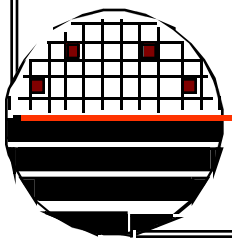
CONCLUSIONS

1. Vacuuming often will reduce particle counts.
2. Air born particle counts are highest near the floor.



AEROSOL PARTICLE DEPOSITION VELOCITY

Wafers were placed in open boats in the center of the white tables in plasma etch area and in Photo I area. Surface particle counts were made initially and after 8 hours. The increase in particle counts was combined with particle counts to calculate an effective particle deposition velocity.



AEROSOL PARTICLE DEPOSITION VELOCITY

SAMPLE CALCULATION

Flux = Concentration x Veff

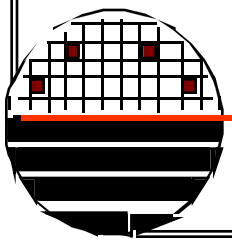
(particles/ft^2-min) = (Particles/ft^3) x (ft/min)

Area = π r^2 = 3.14 (2/12)^2 = 0.0872 ft^2

Flux = (Final - Initial) / Area

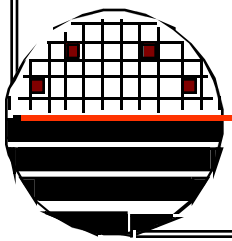
= (26 - 4) / 0.0872 = 252 particles/ft^2-min

Veff = Flux/Concentration = 252/593 = 0.425 ft/min



AEROSOL PARTICLE DEPOSITION VELOCITY

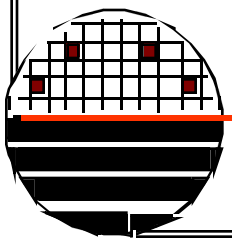
	Initial	Final	#/ft3	Veff
Plasma				
<1	4	26	593	0.425
1-2	25	41	39	4.70
2-5	27	68	9	52.2
5-10	73	187	8	163
Photo 2				
<1	4	210	109	21.7
1-2	78	188	6	210
2-5	45	64	1	217
5-10	33	324	1	1669



AEROSOL PARTICLE DEPOSITION VELOCITY

CONCLUSION

1. Larger particles have higher effective deposition velocity because larger particle obey gravitational forces.
2. Effective velocities are not very close to actual air flow velocities. (~100 ft/min.)

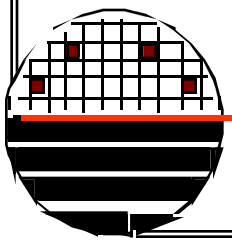


PARTICLE COUNTS ON WAFERS IN BOX

Procedure:

- Clean storage box
- Obtain clean wafers
- Measure particles on each wafer
- Close box and store in gowning
- Measure particles on each wafer (repeat daily)

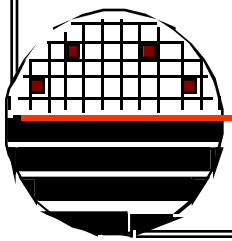
Keep box closed except to get a wafer to measure.



PARTICLE COUNTS ON WAFERS IN A BOX

DATA		Day 1	Day 2	Day 3	Day 4	Day 5
BOX 1	Wafer 1	370	354	424	250	
	Wafer 2	138	207	278	191	
BOX 2	Wafer 1	229	266	289	156	
	Wafer 2	243	222	256	202	
	Wafer 3	304	251	307	263	

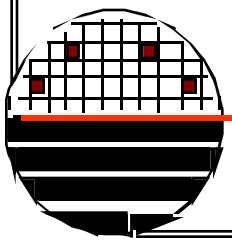
Conclusion: Wafers left in closed box stay clean.



PARTICLE COUNTS ON MONITOR WAFERS SETTING OUT IN THE LAB

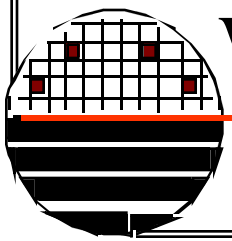
A single wafer was placed on the white table in six locations throughout the lab. Each wafer had its surface scanned at 8:00 am and at 5:00 pm for several days. The locations were:

Metallization	(wafer 1)
Photo I	(wafer 2)
Wet Etch I	(wafer 3)
Wet Etch II	(wafer 4)
Photo II	(wafer 5)
Diffusion	(wafer 6)

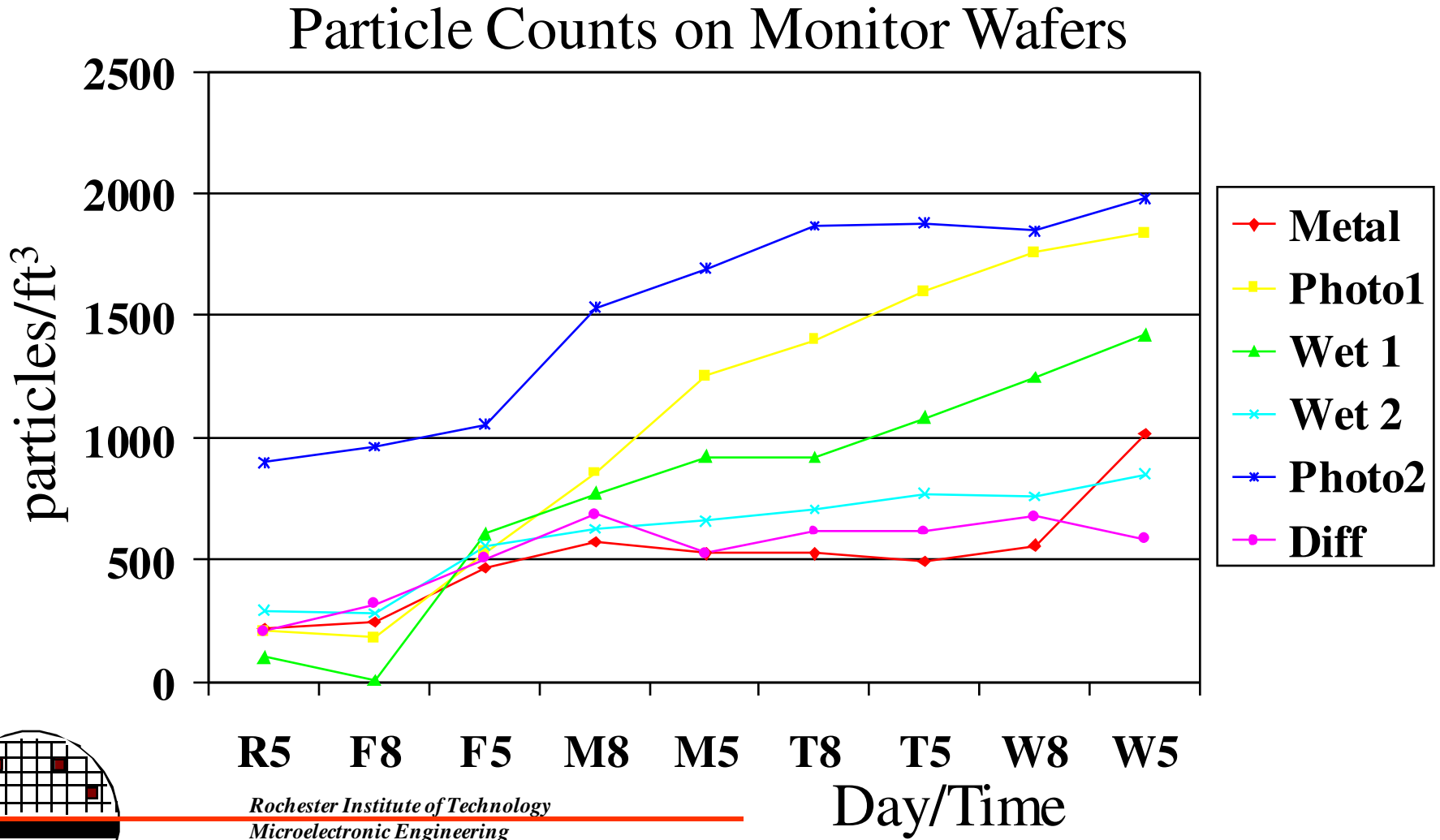


PARTICLE COUNTS ON MONITOR WAFERS SETTING OUT IN THE LAB

	Total Particle Count on Wafer					
Day	1	2	3	4	5	6
Thur@5	219	207	102	293	899	206
Fri@8	247	178	209	280	967	318
Fri@5	467	530	605	559	1057	507
Mon@8	569	859	770	628	1539	685
Mon@5	522	1256	923	659	1694	527
Tue@8	523	1404	920	704	1870	617
Tue@5	494	1602	1084	773	1881	616
Wed@8	560	1764	1251	755	1850	680
Wed@5	1015	1842	1426	850	1981	585



PARTICLE COUNTS ON MONITOR WAFERS SETTING OUT IN THE LAB



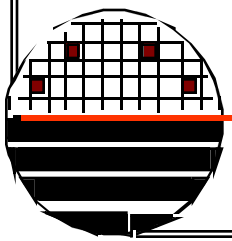
PARTICLE COUNTS ON MONITOR WAFERS SETTING OUT IN THE LAB

CONCLUSION

1. Surface particle count constantly increases.

2. Photo I area had the greatest increase in deposited particles over one week.

3. Metallization, Wet Etch 2 and Furnace areas were the cleanest.

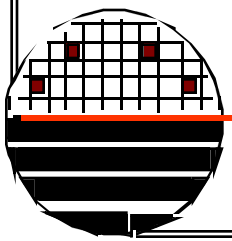


PARTICLE COUNTS IN CLEAN HOODS

Wafer surface particle counts were made on wafers inside the clean hood areas associated with:

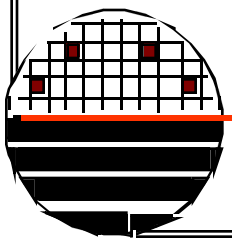
Stepper01 (horizontal at load station)
Furnace14 (vertical in boat outside door)
Spinner in Photo I (horizontal on table)

Aerosol particle counts were also made at the same locations.



PARTICLE COUNTS IN CLEAN HOODS

	Surface Count Added After 5 min. Exposure			Air Born Particle Count		
Size	Stepper	Furnace	Hood	Stepper	Furnace	Hood
0.3	34	11	7	136	15	8
0.5	25	5	4	110	0	0
1.0	35	5	-6	85	4	0
>2	10	4	0	20	3	0

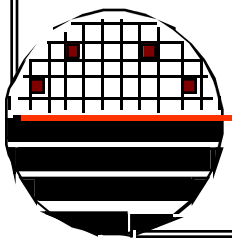


PARTICLE COUNTS IN CLEAN HOODS

CONCLUSION

1. Particles and particle deposition velocity is low under hoods with operational HEPA filters.

2. The Stepper01 enclosure was turned off so as expected the particle counts were high.



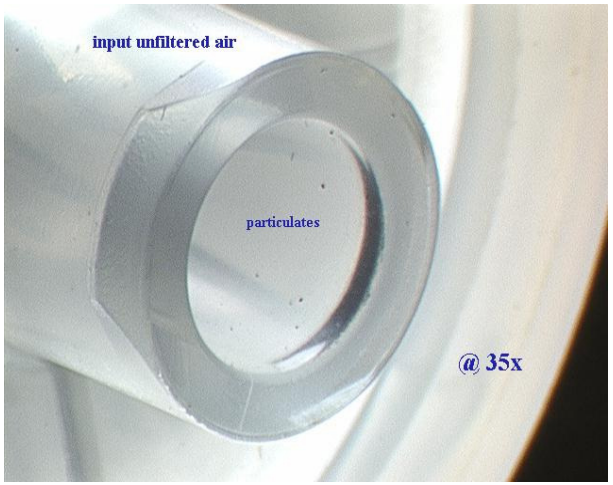
PARTICLES ADDED BY AIR GUNS

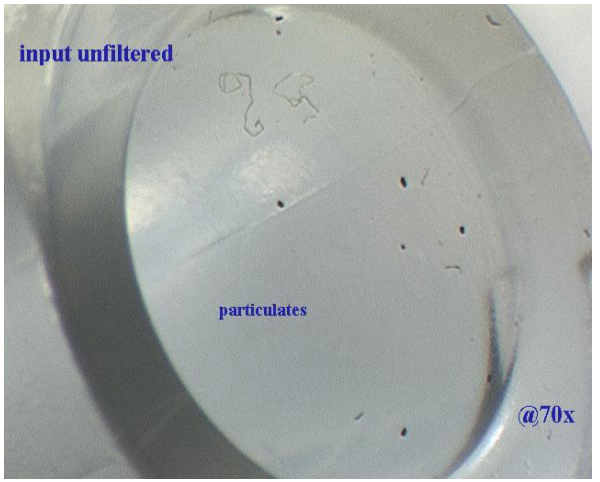
New Bare Wafers initinal wafer surface scan				
Sample Set	C01	C02	C03	C04
Particle Count				
BIN 1	0	88	0	0
BIN 2	0	112	0	99
Bin 3	42	114	183	200
Bin 4	294	153	401	99

AIR BLOWN With Air Wands				
Sample Set	C01	C02	C03	C04
Particle Count				
BIN 1	447	1373	1145	545
BIN 2	608	1552	1053	663
Bin 3	125	293	165	91
Bin 4	314	206	192	230

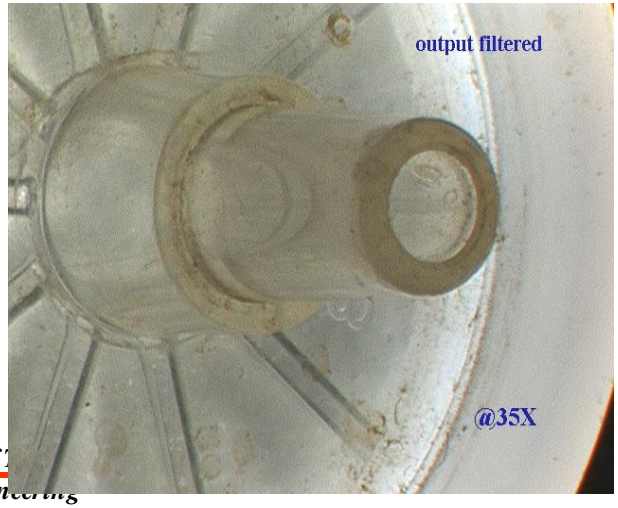
AIR GUN PICTURES

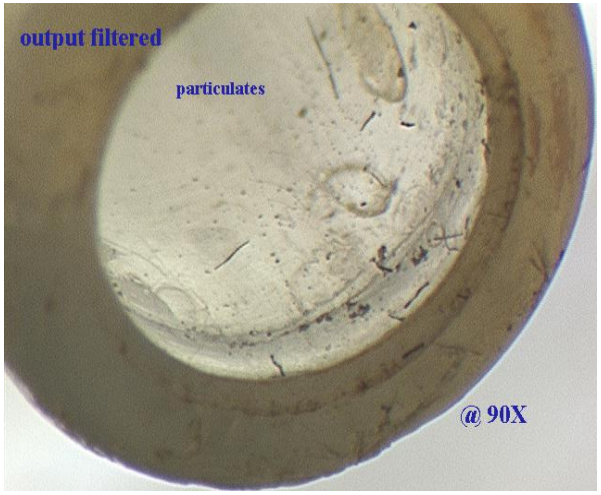
Input Side





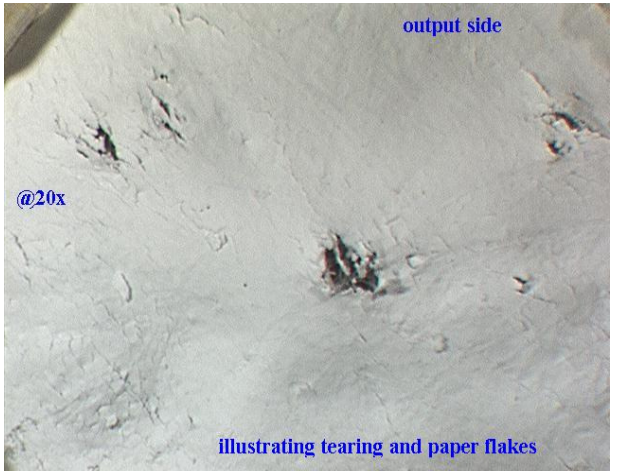
Output Side

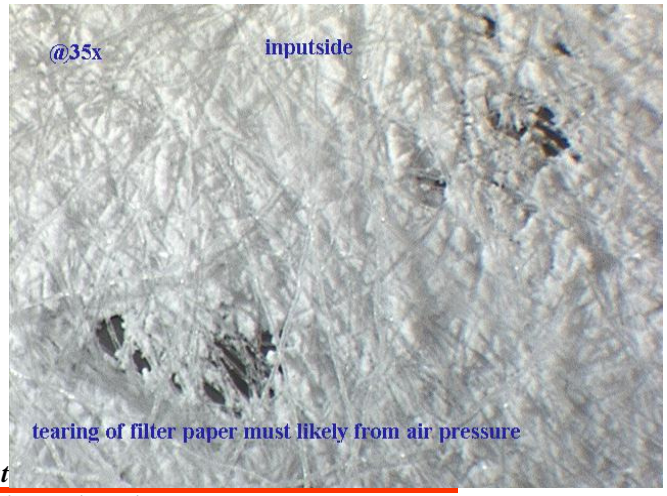


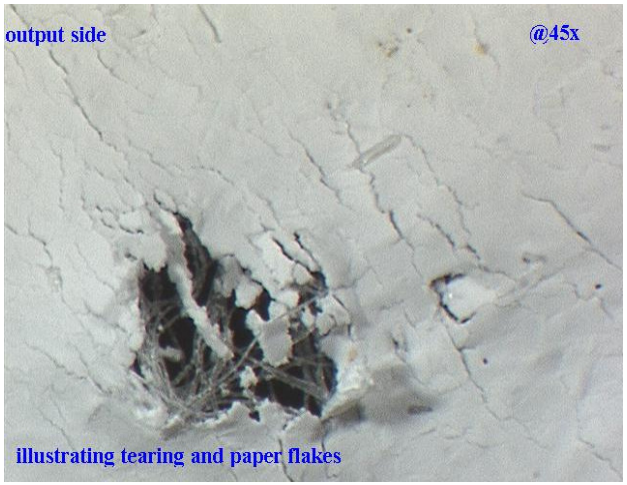


AIR GUN FILTER PICTURES

Pictures of filter material showing tears and source of particles

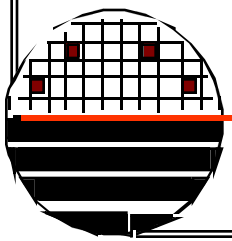






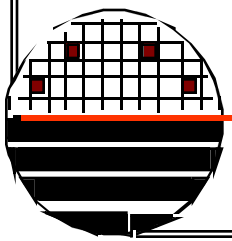
RECOMMENDATIONS

1. Filters should be inspected and replaced more often.
2. Lower supply pressure may help filters last longer before they breakdown.
3. Avoid using air guns on wafers.



PARTICLES ADDED IN LPCVD SYSTEM

Procedure: Obtain clean dummy wafers
Measure particle count before run
place wafers in LPCVD system at 810 C and
610 C for simulated 45 min. deposition
30 min pump, 0 min dep, 5 min pump
2 min purge, 5 min pump, purge
Measure particle count after run.



PARTICLES ADDED IN LPCVD SYSTEM

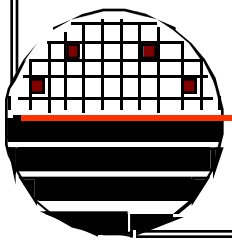
Total Particle Counts

Data: LPCVD Simulation at 810 C

Run	Before	After
1	1997	7875

LPCVD Simulation at 600 C

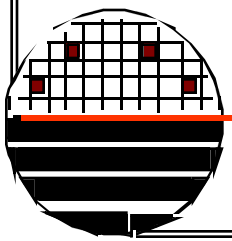
Run	Before	After
1	2047	4209
2	1808	6889



PARTICLES ADDED IN LPCVD SYSTEM

CONCLUSION

1. LPCVD system is dirty

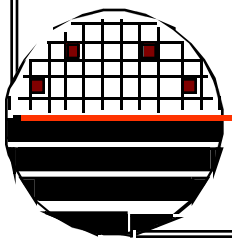


PARTICLES IN THE DRYTECH QUAD

	Wafer	Pre					Post					Adders				
		Bin 1(1)	Bin 2 (2)	Bin 3 (5)	Bin 4 (10)	Total	Bin 1(1)	Bin 2 (2)	Bin 3 (5)	Bin 4 (10)	Total	Bin 1(1)	Bin 2 (2)	Bin 3 (5)	Bin 4 (10)	Total
	Monitor 1	4	2	1	4	11	17	29	11	8	65	13	27	10	4	54
	Monitor 2	15	29	10	7	61	14	36	17	19	86	-1	7	7	12	25
	Monitor 3	5	13	0	1	19	5	11	0	4	20	0	-2	0	3	1
	Monitor 4	7	5	0	1	13	5	10	23	22	60	-2	5	23	21	47
	Monitor 5	9	13	7	7	36	0	26	5	31	62	-9	13	-2	24	26
Chamber 2 60 sec idle w/ vac on	2	0	16	5	6	27	0	1362	5405	1902	8669	0	1346	5400	1896	8642
	3	4	18	3	28	53	725	1127	216	272	2340	721	1109	213	244	2287
	4	3	6	0	3	12	201	384	104	105	794	198	378	104	102	782
	5	2	21	3	11	37	107	116	19	44	286	105	95	16	33	249
Chamber 3 60 sec idle w/ vac on	6	4	11	7	4	26	185	198	53	99	535	181	187	46	95	509
	7	9	10	0	6	25	84	100	26	77	287	75	90	26	71	262
	8	2	8	5	2	17	0	6698	1970	636	9304	-2	6690	1965	634	9287
	9	9	5	0	0	14	723	1037	229	196	2185	714	1032	229	196	2171
Chamber 4 60 sec idle w/ vac on	10	1	3	5	6	15	340	359	112	150	961	339	356	107	144	946
	11	3	1	2	0	6	239	596	169	110	1114	236	595	167	110	1108
	12	7	5	4	8	24	221	457	130	117	925	214	452	126	109	901
	13	4	7	1	3	15	19	67	20	21	127	15	60	19	18	112
Transfer Chnmber 120 sec idle w/ vac on	14	8	33	12	16	69	335	476	110	99	1020	327	443	98	83	951
	15	7	10	3	2	22	29	56	6	27	118	22	46	3	25	96
	16	4	8	1	1	14	32	77	11	24	144	28	69	10	23	130
	17	2	15	1	3	21	198	486	102	82	868	196	471	101	79	847
Chamber 3 w/ 300mT Ar on for 60 s	18	3	10	0	4	17	-	-	-	-	0	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!
	19	6	11	0	7	24	1302	1296	121	139	2858	1296	1285	121	132	2834
	20	2	6	0	2	10	443	410	66	138	1057	441	404	66	136	1047
	21	2	8	2	3	15	420	371	34	51	876	418	363	32	48	861

RESULTS

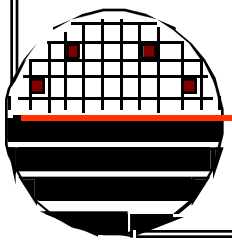
- All chambers deposited thousands of particles in just idle mode.
- The transport chamber yielded less adders than the chambers, but still was very high for 2 of the 4 runs.
- The introduction of process gas did little to change the amount of adders.



Nate Wescott
April 2001

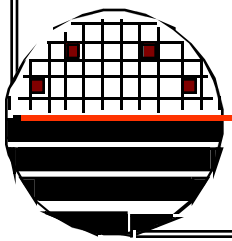
PARTICLES ADDED IN VARIOUS TOOLS

	BEFORE	AFTER	DELTA
RIE	396	481	85
ASHER	25	386	361
STEPPER	108	142	34
ION IMPLANT	15	31	16
SPUTTER	137	349	212
DEVELOP	121	336	215
LPCVD 4”	14	229	215
LPCVD 6”	870	1200	330



PARTICLES ADDED DURING VARIOUS PROCESSES

	BEFORE	AFTER	DELTA
CANON	50	70	20
OLD RCA CLEAN	72	57	-15
NEW MEGASONICS	230	130	-100
NO MEGASONICS	136	70	-66
SPIN DRY	106	121	15
BLOW DRY	139	388	249

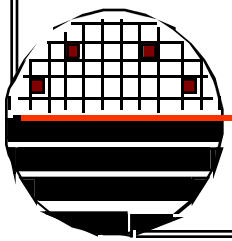


PARTICLE COUNTS AT KODAK

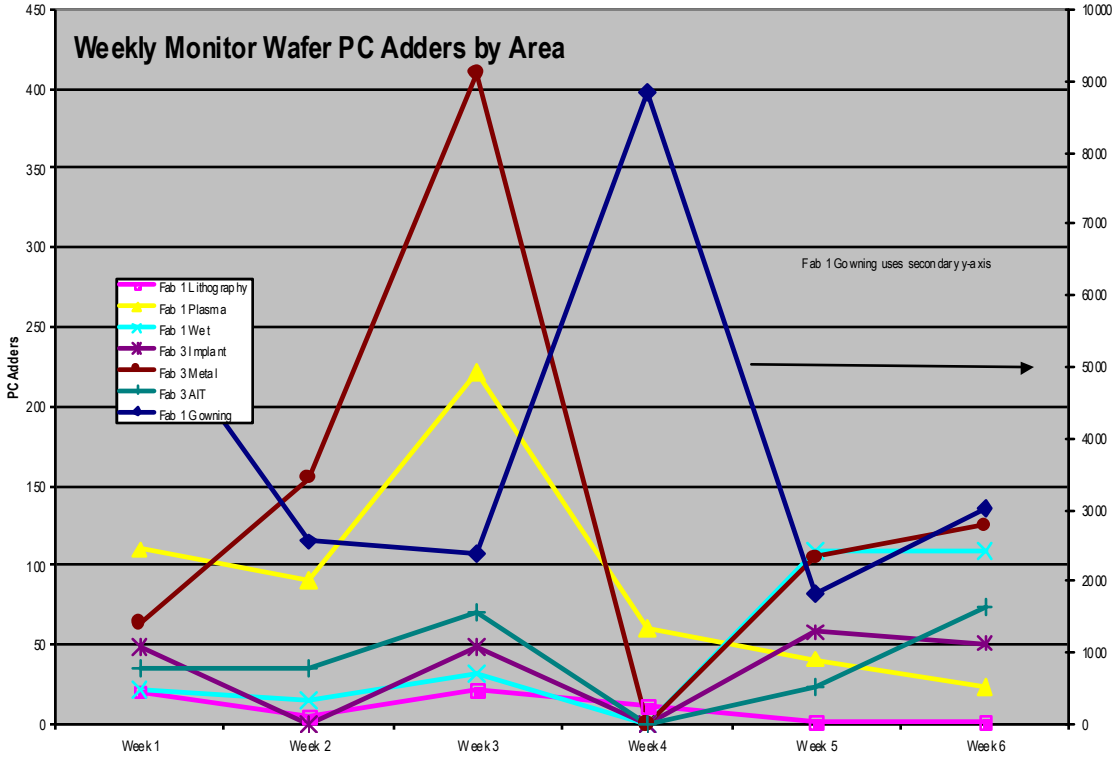
Particle counts were made on 6" bare silicon wafers left out in horizontal positions in various locations throughout the fab at the same time every week for a six-week period. Data shown is the number of particle adders during that time frame.

Particle count measurements were made on bare silicon wafers with a Surfscan 6220 set up to look for >0.5 um particles. Surfscan calibration was checked weekly with latex spheres.

Gowning room numbers use the secondary axis due to their very large magnitude.



KODAK RESULTS



Date	Fab 1 Gowning	Fab 1 Lithography	Fab 1 Plasma	Fab 1 Wet	Fab 3 Implant	Fab 3 Metal	Fab 3 AIT
Week 1	5855	21	110	22	49	64	35
Week 2	2558	5	90	15	0	155	35
Week 3	2400	22	222	32	49	410	70
Week 4	8830	12	60	0	0	0	0
Week 5	1833	2	41	109	58	105	23
Week 6	3031	2	23	109	51	125	74

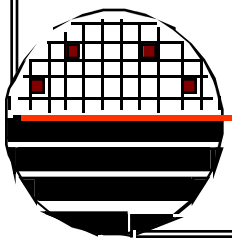
PARTICLES AT FAIRCHILD, MOUNTAINTOP, PA

Particle counts after BOE

Particle counts after BOE followed by Sulfuric 95%/peroxide etch 5% (z-strip)

Fairchild specification is <100 particles on a 150mm wafer

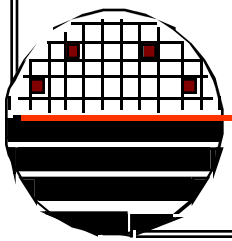
Elias Ullah
April 2001



RESULTS

Wafers get dirty in BOE etch. If they are cleaned further in z-strip the wafers need specification of less than 100 particles.

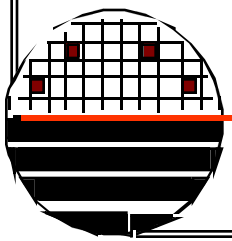
Date	After BOE	After Z-strip
3/23/01	2743	14
3/24/01	7986	65
3/25/01	3301	19
3/26/01	3380	28
3/27/01	2464	29
3/28/01	4999	44
3/29/01	3298	13
3/30/01	3568	37
3/31/01	4287	25
4/1/01	2916	23
4/2/01	3925	21
4/3/01	4334	20
4/4/01	4575	22
4/5/01	3829	61
4/6/01	3233	20
4/7/01	3869	40
4/8/01	4906	27
4/9/01	3789	16
4/19/01	2445	26
4/20/01	3688	127
4/21/01	3670	86
4/22/01	3217	19



EFFECT OF CHLORINE PRECLEAN ON GATE OXIDE QUALITY

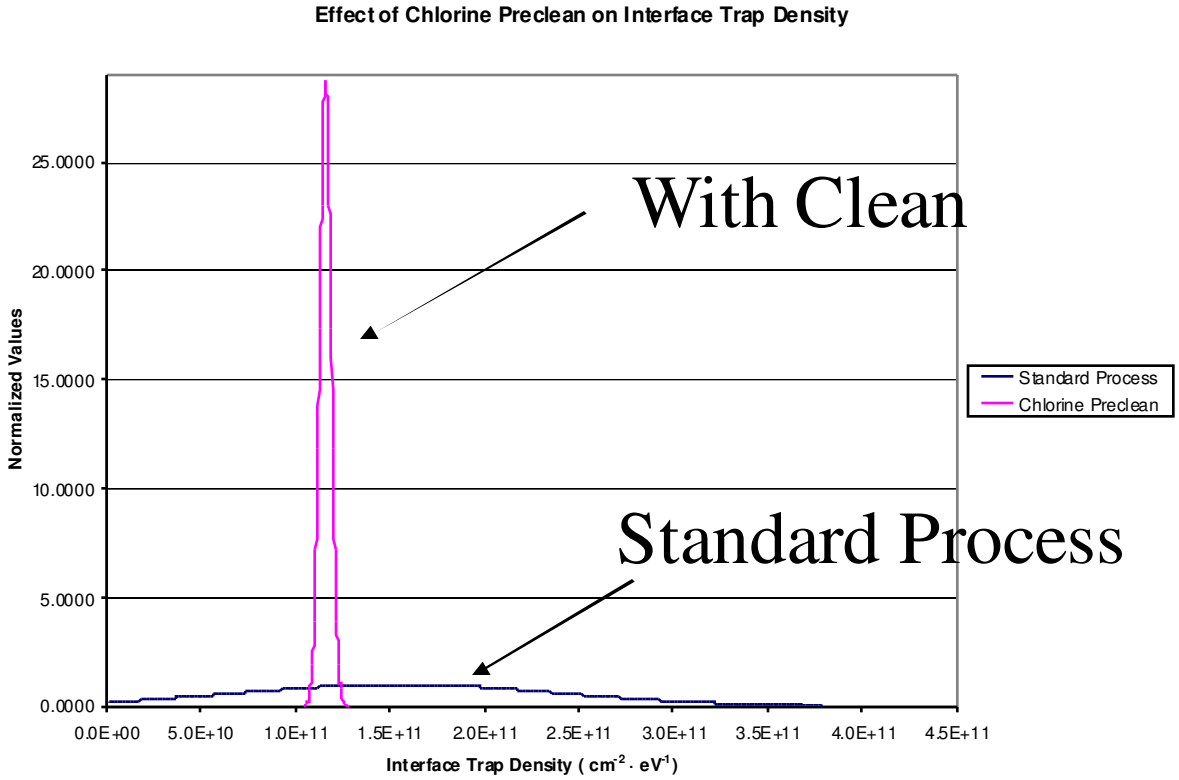
Chlorine tube clean prior to gate oxide growth. Chlorine source is trans-1,2-dichloroethylene (DCE). The results are that chlorine lowers the charged defects within the oxide and helps stabilize the minority carrier lifetimes within the silicon. Chlorine also reduces variation in flat band charges (fixed and mobile), interface traps and carrier lifetime.

Carefully RCA clean, preclean tube (run recipe 50) prior to 250A gate oxide growth and compare to standard gate oxide growth without preclean. (Recipe 50 heats furnace to 1000 C, runs DCE bubbler at 21 C with oxygen flowing during 20 min ramp up and 20 min soak. Then ramps down furnace to 800 C.

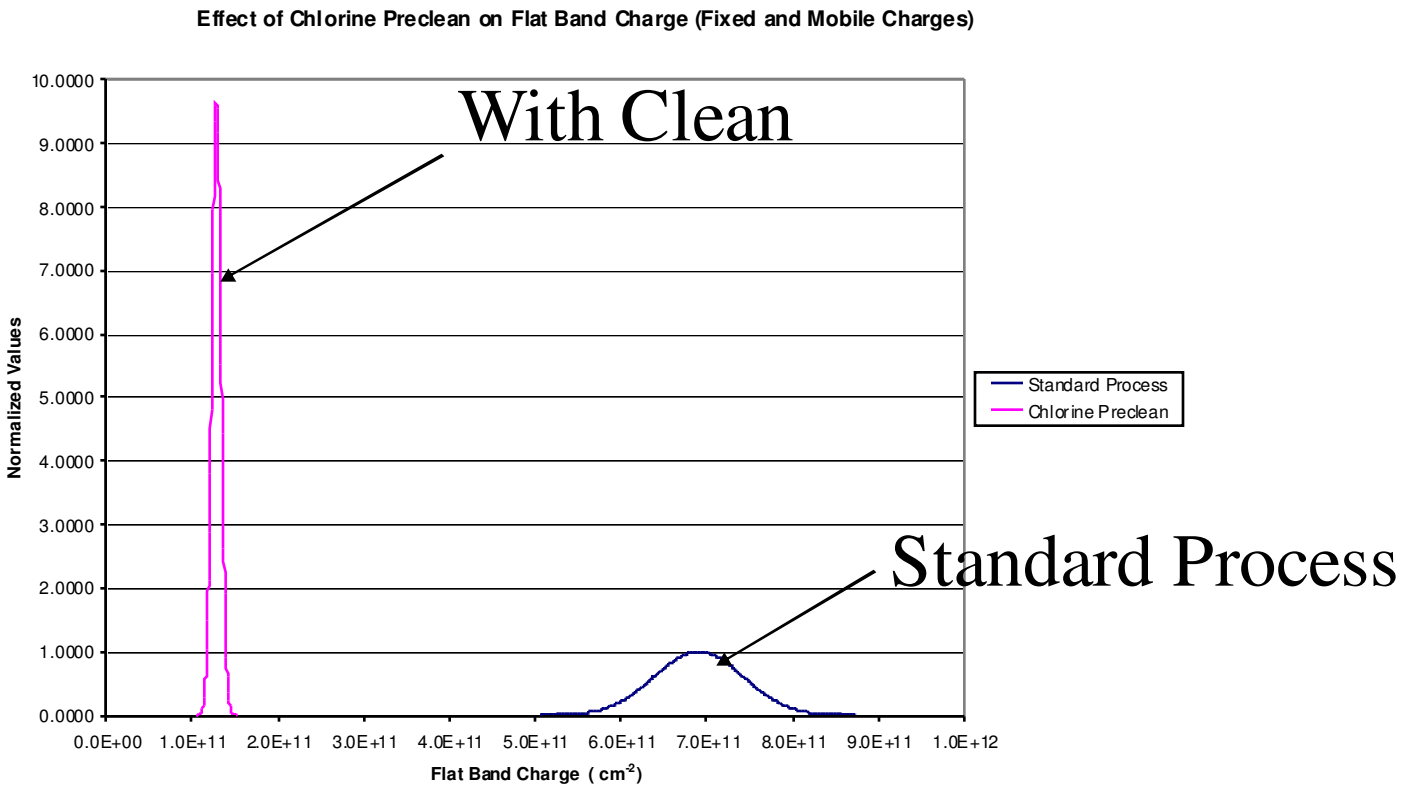


INTERFACE TRAP DENSITY

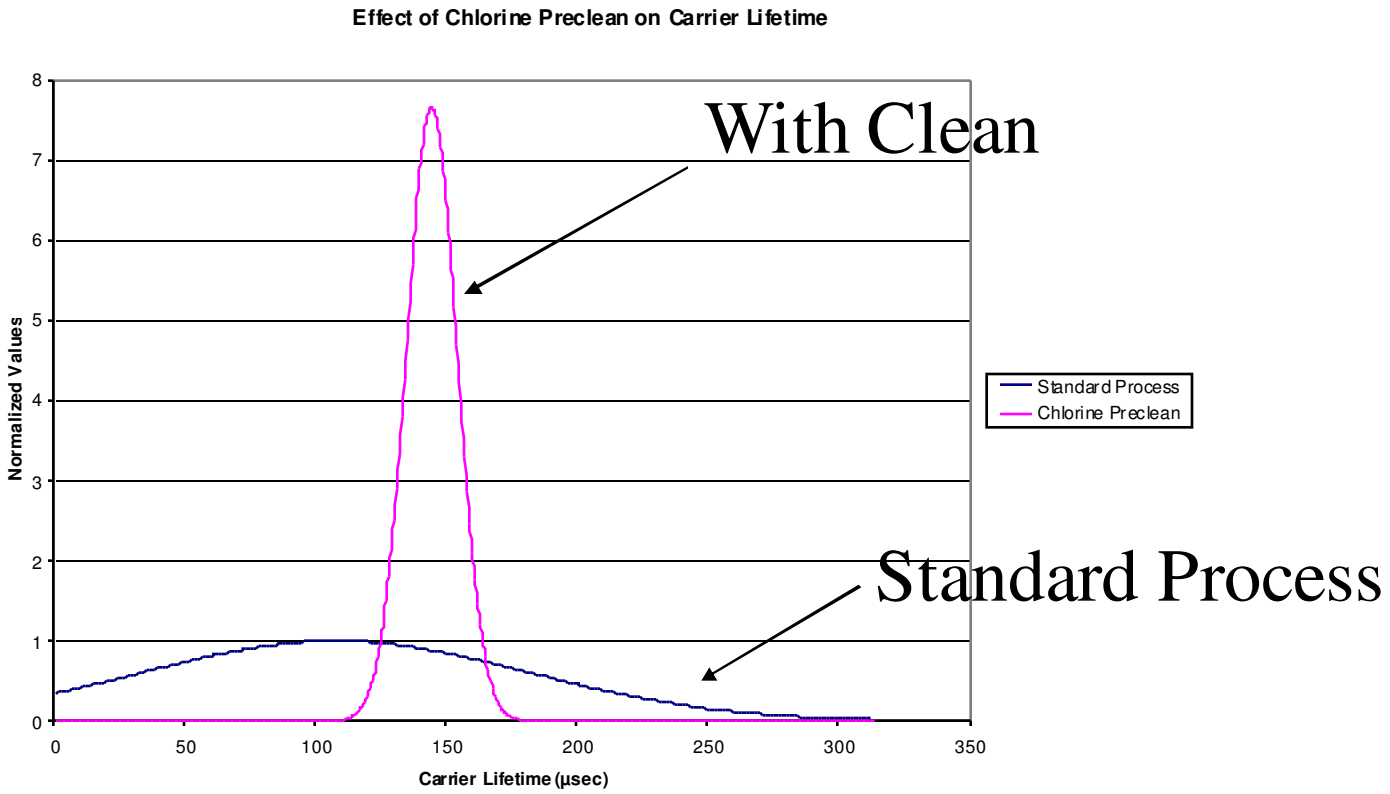
Dit or Nss



FLAT BAND FIXED AND MOBILE CHARGE

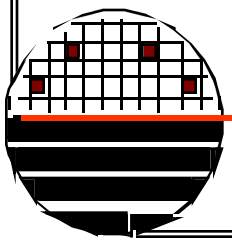


LIFETIME



LAB NOTEBOOKS

- Lab students are currently required to buy a $20 clean room notebook for use in the clean room.
  - These lab notebooks have regular sheets of paper taped and glued into them. They are taken home, and carried around in book bags where they can collect particles
- Do these $20 clean room notebooks really generate fewer particles than a regular spiral bound notebook that can be purchased for $1?



Rochester Institute of Technology
Microelectronic Engineering

Katie McConky
Winter 2005-06

PROCEDURE

1. Four particle count measurements were done on a clean wafer.

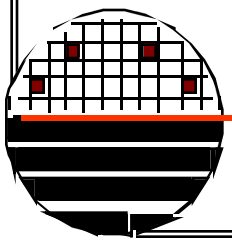
2. The wafer spent 5 min in each of the following setups:
   1. Sitting on a work bench with no notebook activity for 5 minutes.
   2. Sitting on a work bench with a used clean room notebook being flipped through in front of the wafer.
   3. Sitting on a work bench with a spiral bound used regular notebook being flipped through in front of the wafer.
   4. Sitting on a work bench with a brand new clean room notebook being flipped through in front of the wafer.

   After each of the setups the 'adders', or additional particles on the wafer were determined by measuring the wafer particles four times.
   With one minute remaining in each setup the number particles in the air was determined.

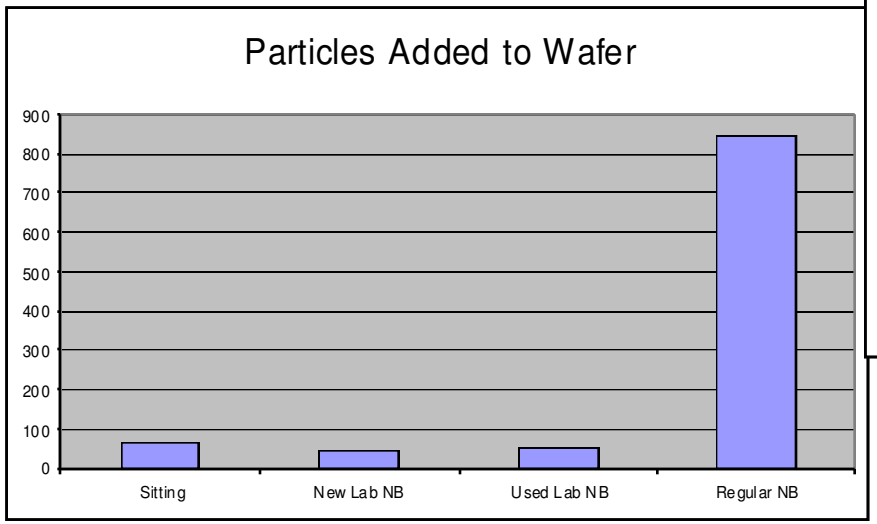
3. The procedure was repeated a second time with a different setup order: 4-1-2-3

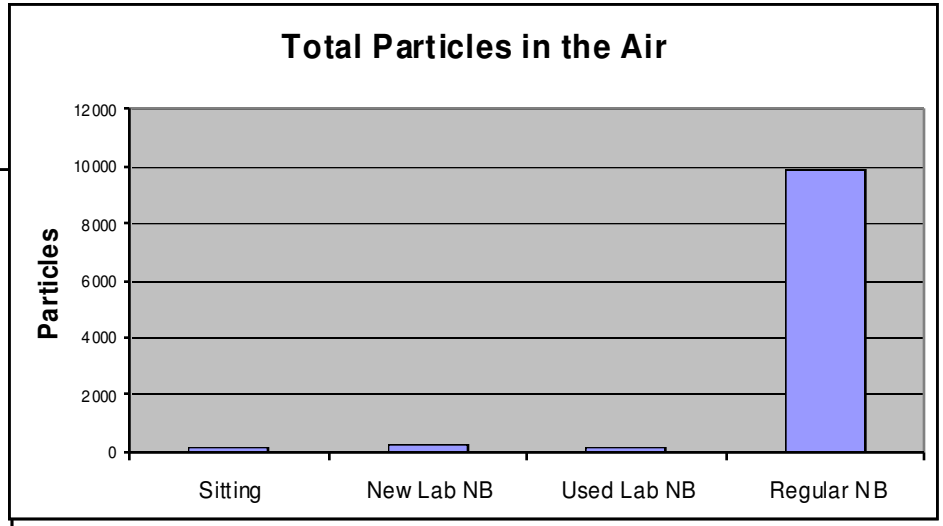
HYPOTHESIS

- Due to the treatment of a typical clean room lab notebook, the number of particles deposited on a wafer from a used clean room notebook will not be significantly different than from a regular notebook. The number of particles caused by a new clean room notebook will be much lower than a used clean room notebook, but larger than a wafer sitting alone on a workbench.



DATA

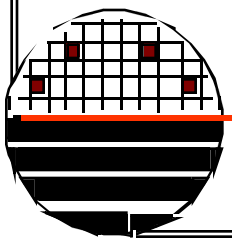




	Total Particles Added		Total Particles in Air	
Situation	Run 1	Run 2	Run 1	Run 2
Sitting	118.75	15	140	100
New Lab NB	44	41.25	250	180
Used Lab NB	103	7.25	170	90
Regular NB	818	874.5	4730	15060

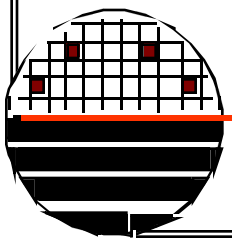
CONCLUSIONS

- My hypothesis was very wrong.
- The type of notebook used has a significant effect on particle deposition.
- The used lab notebook, new lab notebook, and a wafer sitting on a workbench do not generate significantly different numbers of particles.
- *A regular spiral bound notebook generates about 800% more particles!!!!*
- Students should not complain about the expensive notebook price.
- Even if a ferret eats your lab notebook, and drags it under the couch it is still much much much cleaner than a regular notebook.



REFERENCES

1. VLSI Standards Incorporated. 2660 marine Way, Mountain View, CA 94043 (415) 961-3721.
2. Tencore Surfscan 364 Surface Particle Count Operation Manual.
3. Met-One Air Particle Count Operation Manual.



HOMEWORK - PARTICULATE LAB

1. Design a particulate observational study, collect data and write up the results in presentation type format (powerpoint if possible) similar to the examples presented in this package. (your work may become part of this module for future presentations)

HINTS: Always have some control wafers that you do nothing with to verify that the surfscan is working correctly. Repeat your measurement several times. Repeat the experiment several times. Repeat, Repeat, Repeat, ……..