UNIVERSITY CLEAN ROOM MANAGEMENT PROGRAM

by

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ABSTRACT

The implementation of a computerized clean room monitoring system at the RIT facility and the benefits of the RIT Management Program are discussed in this paper. Clean room parameters of interest with respect to environment, contamination, and process control were identified and the management of a commercial and university clean room will be contrasted.

INTRODUCTION

The importance of cleanliness to microelectronic processing is gaining increased recognition. Several models have been developed to describe the anticipated product yield in a typical environment as a function of chip size and circuit complexity. The Bose-Einstein model, for example, can be used to illustrate this problem. The yield (percentage of working chips) is given as

$$Y = (1 + AD)^{-n}$$

where Y = yield, A = chip area (cm2), D = defect density (defects/cm2/level), and n = number of critical levels [4]. For a typical 64K DRAM, the chip area is 0.25 cm2 and the typical defect density is 0.5 defects/cm2/level. There are usually five critical levels, and defect density is related to the number of contaminant particles per unit feature area. All other factors equal, a yield of 55% can be expected for the manufacturing of this chip. However, if an upgrade to a 256K DRAM is made (feature dimensions reduced, defect density increased, chip size and critical levels increased), the contamination level becomes the controlling factor in the equation. Unless the contamination level can be controlled, the next generation of microelectronic devices may not be producible at all-- unless yields of 1% or so can be considered acceptable [4].

Not only is the concentration of particles in the clean room a major concern, but the size of these particles as well. A conventional approach to estimating the impact of contaminants on semiconductors is to compare the size the of particle to the minimum dimension of an integrated circuit (e.g. gate oxide thickness). Generally, the diameter of "direct killer" particles (i.e. those with immediate physical effects) is one forth the pattern size; an "indirect killer" (10-20% of the minimum design rule) represents the type of contaminant that does not have any one physical effect but whose chemical composition may cause the device to fail [3]. Hence, semiconductor device manufacturers are reaching a stage where particles of almost any size can be critical to device yields. Consequently, the tasks of a clean room manager become more difficult every year.

Federal Standard 209C, scheduled for approval this year by the Institute of Environmental Sciences, requires that a minimum of 400 sample locations be tested in a 10,000 ft2 room to be certified at Class 100, 10 or 1 (although the latest version does not mandate automatic, or simultaneous monitoring locations). The number of options available to the user to monitor clean room performance has at least doubled in the last three years. New innovations in monitoring technology have produced a wide variety of instruments that vary greatly in performance, size, and automation capabilities.

What contamination sources should be considered by a clean room manager?

1. Equipment: This encompasses all equipment and benches used in wafer processing, handling, transportation, storage, and monitoring, as well as all computerized systems that are used to collect the data and to monitor and control the lab.

2. Materials: All materials used in the process (DI water, chemicals, general gases, reactive and doping gases, pure metals, etc.)

3. Product and Processes: product concept, design, and process steps

4. Organization and Management: organization and management of technology and support areas, personnel, and costs

5. Environment: All building and clean room parameters; air quality, airflow, clean room design, physical contamination (e.g., vibrations, electrostatic discharge) and construction materials. Although not a direct contaminant, the desired temperature in a VLSI clean room is 68 +/- 1 degrees F. Humidity measurements

are critical to photo operations in order to maintain normal characteristics of the photoresist. The typical relative humidity in a VLSI clean room is 40 +/- 5%. If it is higher, corrosion and rusting of equipment may also occur.

6. People: production, manufacturing, and engineering personnel, all maintenance, service, and safety personnel

Now that we have established the major environmental and contamination concerns of a manager designing or running a VLSI clean room, we can consider the special concerns of a university clean room and its manager.

PROGRAM

The clean room in RIT's Center for Microelectronic Engineering includes a complete three inch wafer processing facility, a maskmaking facility, darkrooms, and areas for test and evaluation, chemical and gas storage, gowning, and line maintenance. The clean room consists of 10,000 sq ft of class 1000, vibration-free processing space, which is often much cleaner than Class 100.

With more emphasis was placed on educational aspects rather than yield during the design of the facility, this clean room has characteristics not found in the industry. The processing bays were designed wider to accomidate large amounts of students clustered around equipment. Equipment is duplicated in bottle-neck areas (e.g., mask aligners). Long tables are included in the center of the bays to accomidate lab notebooks and student materials. The daily cleaning and monitoring of the facility is done by the students under faculty guidance.

A program was therefore initiated to establish what clean room parameters needed to be monitored, what priority each would have, how these parameters could be monitored using limited equipment, who should do the monitoring, and how the results should be reported. The RIT University Clean Room Management program was born.

The first problem facing the faculty was to bring the temperature and humidity of the clean room under control. Using strip graph recorders and the temperature/humidity probe on a Met One Particle Counter, readings were taken throughout the facility both at continually and at discrete times to establish trends. The responsibility of taking these readings was given to the student maintenance personnel, a small group of underclassmen hired to clean and monitor specific sections of the clean room. Their duties include mopping, wiping down equipment, checking supplies,

noting any down equipment, and now the measurement of temperature, humidity, particle counts and air velocities within their areas.

To make efficient use of this data, an automated report system was established on the VAX mainframe computer system. A new computer account was obtained with both faculty and student access. Using "20/20" Integrated Spreadsheet software from Access Technology, Inc. (already on the mainframe system), a data file and report macro file were created. The students take the required readings during their daily cleaning, and then enter the data into a file from a terminal inside the clean room. Readings are recorded throughout the week, and at the end of the week the coordinator or faculty person can use the report file to compile the data, do the necessary statistical analysis, plot graphs, and print out a concise weekly report in a matter of seconds from within his own office. Reports show the raw data [Figure 1] and all statistical parameters (means, standard deviations, ranges). Temperature, humidity, and particle counts are displayed on separate clean room floor plans with readings located at the points they were measured [Figure 2]. The reader can see spatial trends, effects of construction on nearby locations, air handler problems, and effects of student activity.

RESULTS

Although the program appears modest now, there is considerable room for expansion and automation. DI parameters (resistivity, bacteria counts) could easily be included into the report. Future plans are to make the report on a daily basis to give better resolution, include information with regard to equipment status within each bay, and to automatically keep and update control charts for each area in the clean room. Since the programs run on the campus mainframe, there is also the possibility of upgrading the system to automated monitoring systems (i.e. have the computer take the readings directly from the equipment itself through the network lines). Inventory, lot monitoring, material usage, and cost analysis could easily be added to the system.

The benefits, both to the program and to the industry, are numerous:

1. The RIT program gives the faculty the ability to monitor the new facility and to catch problems before serious damage results to processes or equipment. Since the environment in the clean room is not under the direct control of the faculty, the reports provide a means of informing the facilities people of problems. Already the reports have identified temperature gradient and excessive humidity problems, both of which have been brought within desired specifications.

ROCHESTER INSTITUTE OF TECHNOLOGY
University Cleanroom Management
Weekly Environmental Control Report
Period Ending: 1 May 87

RAW DATA

	Gowning(S) 17-2700			Plasma(S) 17-2710			Metal(S) 17-2720			Photo1(S) 17-2730			Etch1(S) 17-2740		
	Temp	Hdty	P>.5	Temp	Hdty	P>.5	Temp	Hdty	P>.5	Temp	Hdty	P>.5	Temp	Hdty	P>.5
Mon	68.1	31.6	867	63.0	31.9	156	62.0	32.0	89	66.6	26.0	347	69.0	32.0	141
Tue	64.0	33.7	882	63.1	34.0	319	62.4	32.0	95	63.5	34.9	1	63.3	36.5	256
Wed	65.0	31.3	845	62.2	37.1	371	62.9	32.5	334	68.7	33.1	212	65.3	34.5	256
Thr	65.1	26.7	1425	62.2	27.2	404	62.9	26.0	527	63.1	31.9	75	62.5	30.1	381
Fri	69.4	29.4	392	62.5	37.7	811	63.6	31.9	440						
mean	66.5	30.5	882	62.6	33.0	428	62.8	31.0	297	65.5	31.5	159	65.0	33.3	259
st dev	2.2	2.6	366	0.4	4.4	244	0.6	2.8	199	2.7	3.9	153	2.9	2.8	90
range	5.4	7.0	1033	0.9	10.5	655	1.6	6.8	430	5.6	8.9	346	6.5	6.4	240

	Gowning(N) 17-2700			Plasma(N) 17-2710			Metal(N) 17-2720			Photo1(N) 17-2730			Etch1(N) 17-2740		
	Temp	Hdty	P>.5	Temp	Hdty	P>.5	Temp	Hdty	P>.5	Temp	Hdty	P>.5	Temp	Hdty	P>.5
Mon	68.2	36.9	138	64.0	31.0	109	63.0	32.4	234	67.1	28.0	144	68.5	33.5	259
Tue	64.5	32.8	604	64.0	31.7	122	63.5	32.0	275	65.9	32.0	104	62.5	39.3	109
Wed	65.0	32.4	746	62.3	30.5	208	62.8	32.7	359	64.5	35.8	400	64.8	35.5	722
Thr	64.4	32.1	109	62.7	26.7	381	62.7	26.4	106	63.1	33.0	132	62.4	26.2	147
Fri	68.4	31.0	42	62.5	31.9	491	63.7	32.4	374						
mean	66.1	33.0	344	63.1	32.0	270	63.1	31.2	286	65.2	32.2	195	64.6	33.6	309
st dev	2.0	2.3	311	0.8	4.2	165	0.4	2.7	80	1.7	3.2	130	2.9	5.5	282
range	4.0	5.9	704	1.7	11.0	382	1.0	6.3	188	4.0	7.8	296	6.1	13.1	613

	Photo2(S) 17-2750			Etch2(S) 17-2760			Diffusion(S) 17-2770			Test(S) 17-2810			Mask1(S) 17-2830			Mask2(S) 17-2850		
	Temp	Hdty	P>.5	Temp	Hdty	P>.5	Temp	Hdty	P>.5	Temp	Hdty	P>.5	Temp	Hdty	P>.5	Temp	Hdty	P>.5
Mon	69.1	24.9	870	65.6	32.3	176	64.0	32.0	456				70.5	22.2	6715	68.2	25.2	6830
Tue	64.5	32.6	203	63.9	35.9	485	64.2	32.6	1116				77.0	26.2	3978	70.8	25.0	379
Wed	67.3	29.2	957	65.7	31.3	334	61.2	35.7	70				75.0	32.5	14071	67.4	34.2	1503
Thr	70.1	19.8	245	70.7	21.2	147	65.9	27.1	901									
Fri							66.7	27.6	1015				78.9	18.7	5518	69.7	18.0	482.
mean	67.8	26.6	569	66.5	30.2	286	64.4	31.0	712				75.4	24.9	7571	69.0	25.6	762
st dev	2.5	5.5	400	2.9	6.3	156	2.1	3.6	438				3.6	5.9	4476	1.5	6.6	510
range	5.6	12.8	754	6.8	14.7	338	5.5	8.6	1046				8.4	13.8	10093	3.4	16.2	1123

	Photo2(N) 17-2750			Etch2(N) 17-2760			Diffusion(N) 17-2770			Test(N) 17-2810			Mask1(N) 17-2830			Mask2(N) 17-2850		
	Temp	Hdty	P>.5	Temp	Hdty	P>.5	Temp	Hdty	P>.5	Temp	Hdty	P>.5	Temp	Hdty	P>.5	Temp	Hdty	P>.
Mon	69.1	24.9	556	67.2	28.3	280	62.0	34.6	347				72.4	21.3	10535	68.5	24.6	506
Tue	63.4	34.8	284	67.0	32.5	493	62.9	34.0	631				70.0	24.0	5924	70.7	27.0	122
Wed	65.6	29.8	74	66.7	31.9	483	60.6	35.2	85				73.5	20.8	22509	67.7	32.4	1178
Thr	72.6	18.3	92	69.0	22.9	395	63.2	28.4	402									
Fri							65.2	27.4	286				79.0	16.7	10313	71.4	19.7	327
mean	67.7	27.0	252	67.5	28.9	413	62.8	31.9	350				75.7	22.7	12340	69.6	25.9	533
st dev	4.0	7.0	224	1.0	4.4	99	1.7	3.7	197				3.3	5.1	7155	1.8	5.3	457
range	9.2	16.5	402	2.3	9.6	213	4.6	7.8	546				6.6	12.1	16665	3.7	12.7	1055

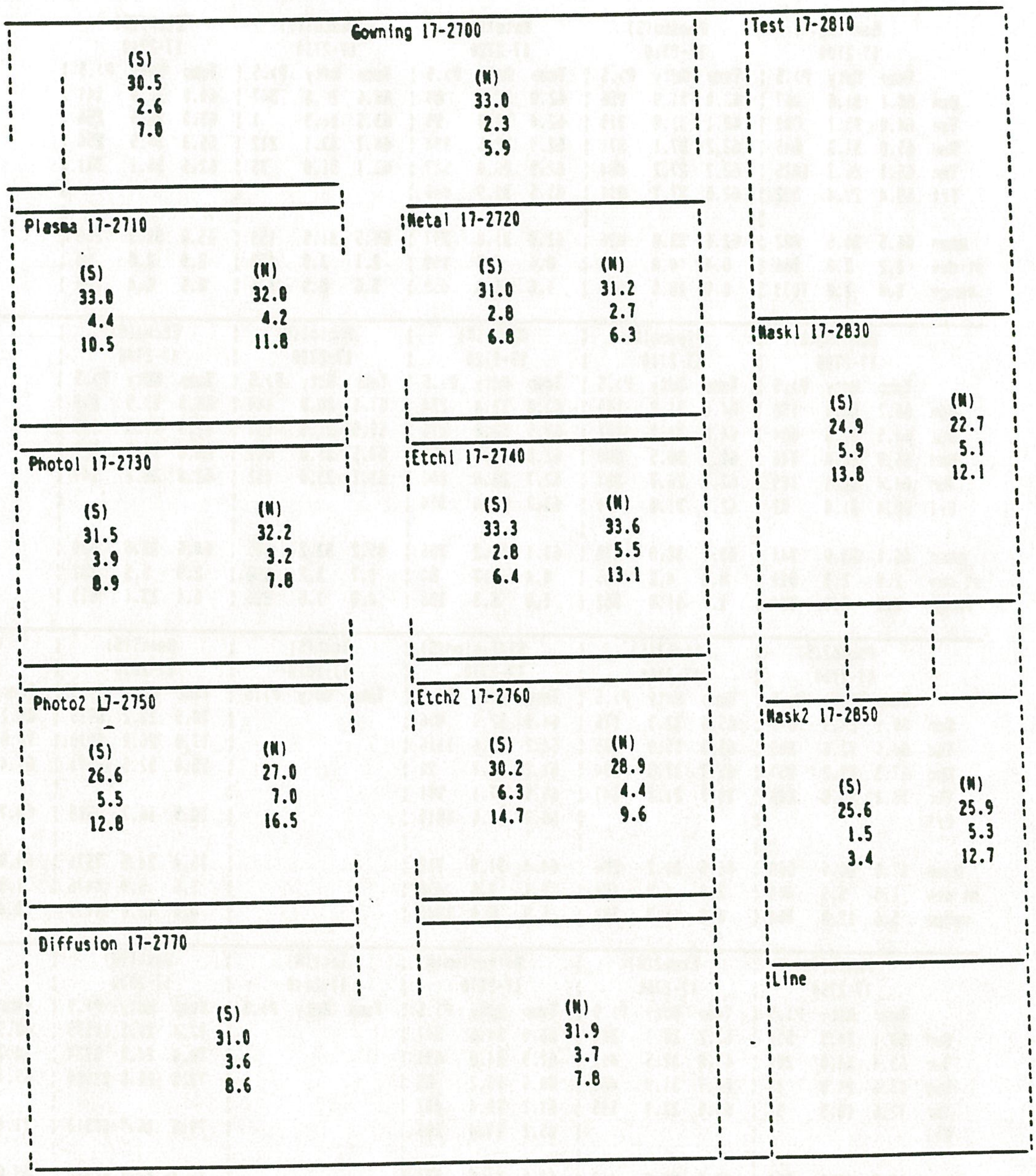
Comments:

Figure 1

ROCHESTER INSTITUTE OF TECHNOLOGY
University Cleanroom Management
Weekly Environmental Control Report
Period Ending: 1 May 87

Weekly Average Humidities
1. Mean
2. Standard Deviation
3. Range (max-min)

North--->



Process Area Spec: 40% +/- 5 <------| |----> Maskmaking <40%

Figure 2

2. Students gain a valuable experience in contamination control. Contamination control is not an active part of the curriculum due to time limitations; involving students in this area lessens the load on faculty and can spark interest in this increasingly more important area of wafer processing. As the program grows, results and case histories can be incorporated back into the curriculum (statistics and processing classes). There is a constant influx of fresh ideas, and the existing set up can easily be modified or upgraded. New measurement techniques or equipment could be developed at the university level to benefit the industry.

3. Students who are trained with good clean room habits and a respect for clean room procedures will take that respect with them when they enter the work force. Many contamination control engineers complain that their toughest problem is breaking operator bad habits (e.g., using a face mask as a chin rest, opening doors to hallways to talk to friends, smoking before entering the lab, etc.). If the importance of contamination control is stressed at the university level, it would be easier to maintain at the industry level. In talking with the student maintenance crew many show a sincere interest in the condition and environment in the facility; if something is wrong, they are quick to point it out. If something does appear right (e.g. an unusually high particle count), they are quick to ask, "Why?" The production of next-generation ULSI chips will demand extreme discipline from operators and engineers within the clean room, and a concern for the quality of the environment they work in.

CONCLUSION

The University Clean Room Management program was born out of necessity. A simple, efficient, inexpensive method has been established to monitor a university clean room. The benefits, however, will reach out much farther than the confines of the RIT clean room.

ACKNOWLEDGMENTS

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