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OPERATION CONTROL ROOM

Misao Saga
Tetsuo Ichikawa
Koji Miyasaka
Takeo Takahashi

1 INTRODUCTION

With integration of IC chip enhanced, cleanliness and other conditions are becoming severer in the manufacturing and processing environments. For example, regarding the cleanliness, class of clean room (hereinafter abbreviated to as CR) has been upgraded from 1000 to 100, and minimum diameter of the particles to be eliminated has also been reduced from 0.5 μm to 0.3 μm. Further, in case of super LSI, such a very high level as class 10 at 0.1 μm is being required as shown in *Table 1*.

The conventionally applied Federal Standard (USA) 209b which is based on the number of 0.5 μm diameter or larger particles per cubic foot is no longer being practical. The trend like this has occurred because;

(1) In a reduced pattern size, even a small fault which did not conventionally affect element characteristics does become a problem.
(2) As chip area is increased, probability of fault occurrence within a chip rises.

In addition, for temperature and humidity also, those devices which require the most severe conditions such as an exposure equipment with a built-in precise optical system tend to require a high precision of ±0.1°C, ±2%.

Standing on the above described background, operations of CR for semiconductors are described mainly about the cleanliness as follows.

2 SEMCONDUCTOR ELEMENT MANUFACTURING AND CLEANLINESS

2.1 Progress of CR structure

Fig. 1 shows progress of the cleanliness which has been required in correspondence with the improvement of integration and reduction of pattern size. To be more specific, for the minimum pattern size, the cleanliness is 2 to 3 μm at the 64k bit dynamic RAM which is a step to the super LSI, or 1.5 to 2 μ m at the 256k bit dynamic RAM which is about to be practical.

For the diameter of particles to be eliminated, it is generally said that particles the diameter of which is 10% or greater of the minimum pattern size will cause a fault, and therefore, at 256k bit RAM, 0.15 to 0.2 μm or higher cleanliness has been required. Further, for the development of a 1M bit element which is the next generation of the 256k bit, it is said that 0.1 μm or higher cleanliness will be necessary. It should also be noticed that the 0.1 μm class is the range where number of particles cannot be measured at present.

On the other hand, for manufacturing machines and equipment used in a semi-conductor process, in addition to the development of automation which is aimed at a labor saving, reproducibility and prevention of contamination, increase of scale is being proceeded to increase processing ability. In this trend, it is not advantageous to maintain

Table 1 Standards of cleanlinesss, temperature and humidity

Standard	Cleanliness			Temperature (°C)			Humidity (%)		
	Class	Diameter of particle to be eliminated (μm)	Number of accumulated particles (piece/cu.ft)	Ambient	Recommended temperature	Tolerance	Maximum	Minimum	Tolerance
Federal standard (USA)	100	≧0.5	≦ 100	19.4~25	22.2	±2.8 Especially ±0.28	45	30	±10 Especially ±5
	10,000	≧0.5 ≧5.0	≦ 10,000 ≦ 65						
	100,000	≧0.5 ≧5.0	≦100,000 ≦ 700						
Example of clean space for super LSI	10(Note)	≧0.1	≦ 10	–	–	±0.1	–	–	±2

(Note) The expression differs from the conventional expression because the diameter of particles to be eliminated is 0.1 μm or larger.

Fig. 1 Progress of cleanliness based on rise of accumulation level

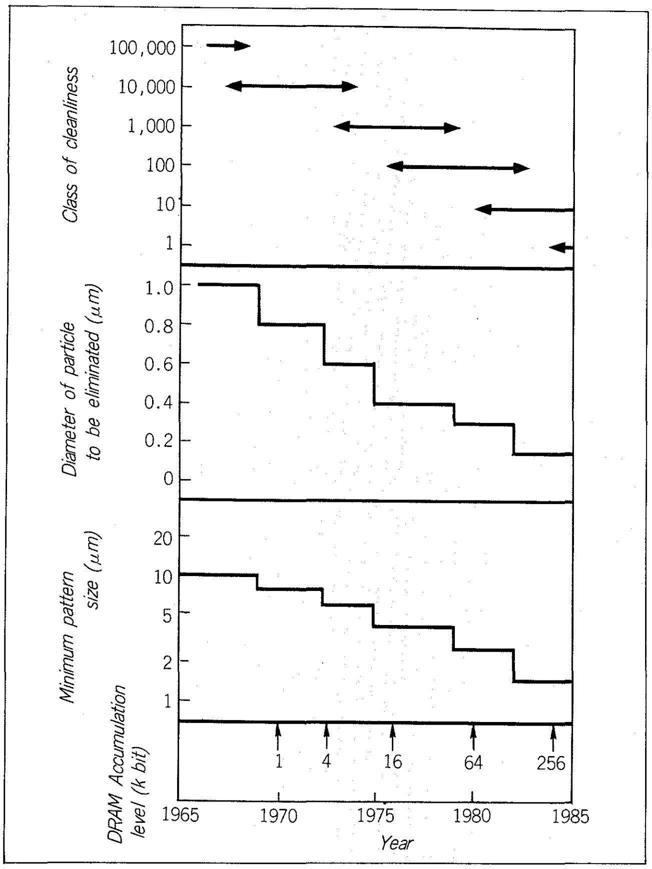
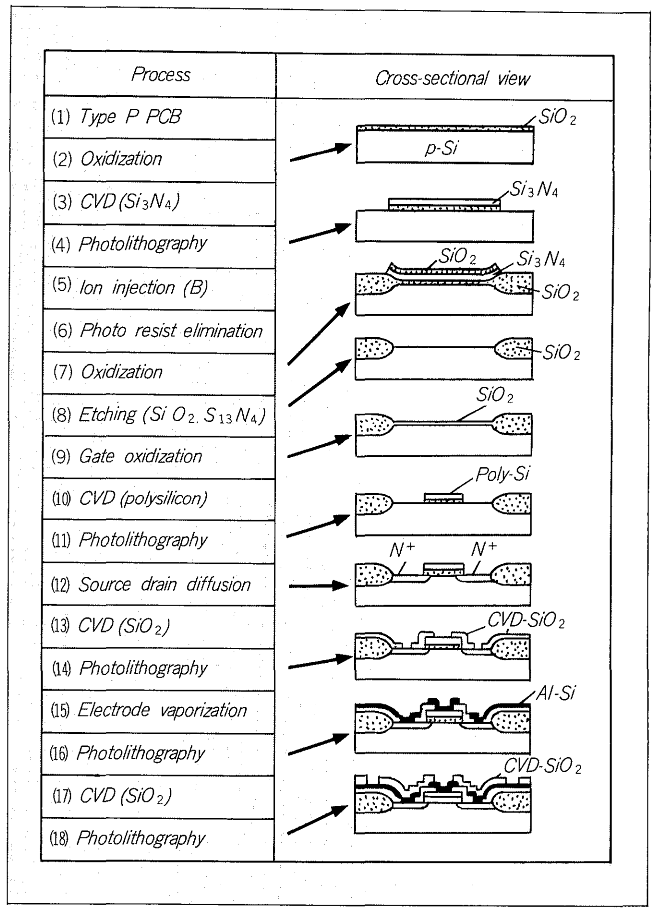


Fig. 2 Fabrication process of N-channel MOSFET



the overall CR or manufacturing machines and equipment under the above described level because of the required operating cost, and such a CR structure as that a high cleanliness is adequately employed locally has been employed.

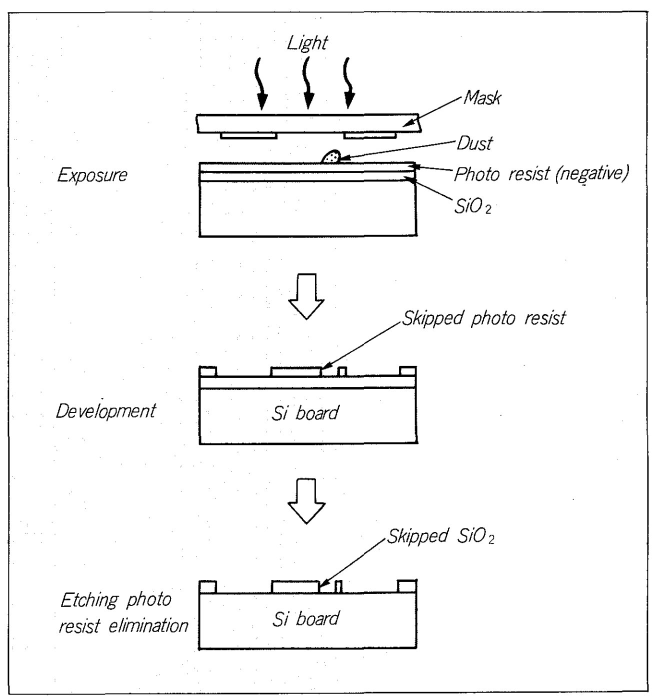
2.2 Contamination by dust

In a semi-conductor element manufacturing process, causes of contaminations by dust are room environment, manufacturing machines and equipment, various materials including gas and chemical and workers.

Fig. 2 shows an example of N channel MOSIC manufacturing process which is, at present, used mostly in the digital IC technologies. As it may be understood from the figure, the manufacturing process consists of four basic techniques, namely, oxidation and diffusion, photolithography, electrode wiring formation and passivation. Out of these processes, the photolithography takes about one third of the total process, and this process is likely to be greatly affected by dust.

Fig. 3 shows examples of faults caused by dusts. This figure shows a dust sticked ont he photo resist during exposure process of the photolithograry, which caused a fault on the base SiO_2. Beside this type of fault, faults also occur due to surface contamination on the wafer during each process and contamination of photo-mask. Further, it is not detailed hereon, but there is a process such as CVD process which has a factor to easily cause wafer surface contamination on the processing equipment itself.

Fig. 3 Defect caused by sticking of dust



For the relationship between fault density and manufacturing yield point, there are several estimating equations.

The following equation is one of them.

$$Y = \frac{1}{1 + D_1 \cdot A} \cdot \frac{1}{1 + D_2 \cdot A} \cdots\cdots \frac{1}{1 + D_n \cdot A} \cdots\cdots \quad (1)$$

where, Y: Yielding point
A: Chip area
$D_1, D_2, \ldots\ldots, D_n$: Fault density at each mode

Now, when number of photolithography processes is assumed to be 10, it is assumed that faults of the same density occurs at each process, that density is expressed as $10^{-2}/\text{mm}^2$, and chip area is assumed to be 25mm^2, the yielding point drops to about 11%. Further, under the same assumptions, when fault densities are $10^{-3}/\text{mm}^2$ and $10^{-4}/\text{mm}^2$, the yielding points become 78% and 98% respectively. However, as all the faults do not necessarily affect element characteristics, actually, it is reasonable to apply a constant to the above equation.

2.3 CR operation control

To maintain cleanliness of a CR at a rated level or below, needless to say, it should be examined from the CR designing stage. The principles of the controls to be made thereafter are;

(1) Prevention of dust intrusion from the outside.
(2) Prevention of occurrence of dust in the room.
(3) Quick elimination of generated dusts.

Table 2 shows the major countermeasures for the principles. For further detailed operation controls, [Clean Room Operation Control Guide (JACA No. 14-1980)] has been issued from Japan Air Clean Association, and therefore, this paper does not touch them. Next, a few items for which considerations are required in maintaining cleanliness

Table 2 Cleanliness control in clean room

Fundamentals of control	Main countermeasures
Prevention of dust intrusion	1 Installation of HEPA filter in intake system and proper management of the filter 2 Maintaining correct pressure in the room 3 Prevention of leakage from surroundings of duct and filter 4 Cleaning machines, equipment, chemicals and materials before deliverying into the room
Prevention of dust generation	1 Supression of dust from machines and equipment by properly installing exhaust system, cover, etc. 2 Control of dust-free cloth and supression of dust generation from workers by automation of processing line. 3 Use of interior finishing materials of less dust generation
Elimination of generated dust	1 Increase of number of ventilations 2 Proper layout 3 Immediate elimination of dust by periodical cleaning, wiping, etc.

Table 3 Several factors having influence on motion of dust

Factor	Velocity
Deposition by gravity	0.001~0.3
Brown motion	0.0009~0.0002
Movement by static field	~5
Dispersion by boiling water	~200
Air stream rise by heat	~30
Circumference speed of turning shaft	~500
Circulation of clean air flow in the CR	10~200

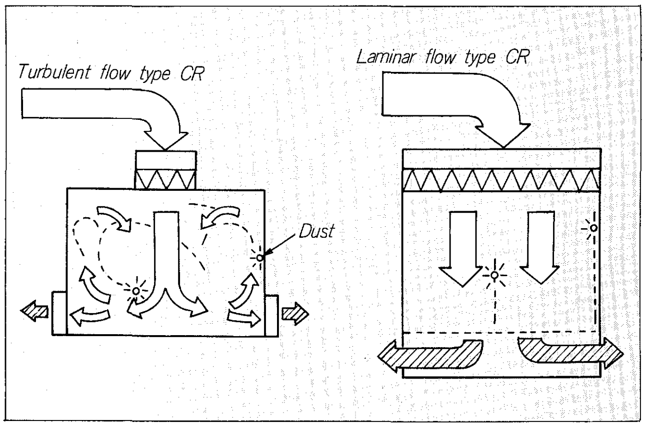
2.3.1 Generation of air flow

When planning to maintain cleanliness of a CR, it is extremely important to know air flow in the room, and the layout must be made with the air flow taken into considerations. Needless to say, air flow in a CR is managed by incoming and outgoing flows of the air conditions, but not only with them, it is affected by the layout of various manufacturing machines and equipment and air intake and exhaust devices attached to the machines and equipment. Beside the incoming and outgoing flows of the air conditioner, major causes of changing and inducing air flows are;

(1) Layout of manufacturing machines and equipment
(2) Draft and exhaust of the manufacturing equipment
(3) Motions of the manufacturing equipment
(4) Thermal interference due to the heat generated by the machines and equipment such as diffusion furnace and oven.
(5) Movements of humanbeing.

Table 3 shows some causes which affect movements of dust and their sizes. The particles dischaged by motions of machines and equipment, etc. lose their speed component immediately around the machines and equipment, and thereafter, they are managed by the air flow in the room. *Fig. 4* shows motions of dust which differ by each air conditioner. In case of a laminar flow, moving route of the dust can be known in advance, while in case of turbulent flow, it is difficult. *Fig. 4* shows indicates this. This is one of the reasons why laminar flow system is used in highly clean rooms.

Fig. 4 Motion of dust based on difference of air conditioning system



2.3.2 Number of ventilations and cleanliness

As described previously, a highly clean space has been required as integration grade of IC has been achieved, and the highly clean space has been made by employing a clean tunnel system. *Fig. 5* shows cleanliness of turbulent type

Fig. 5 Effect of number of ventilations on cleanliness

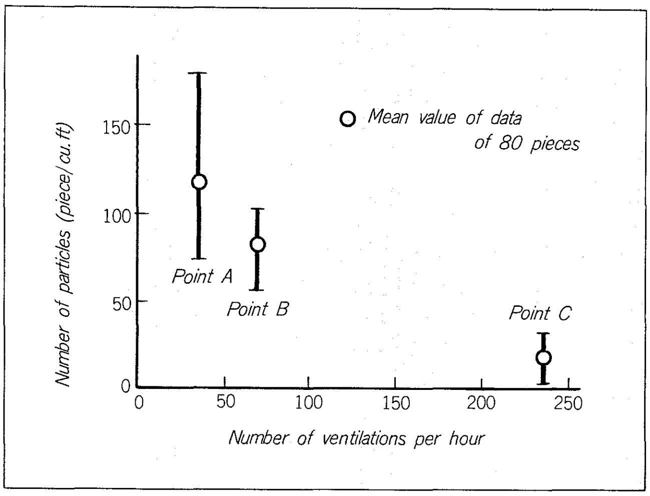
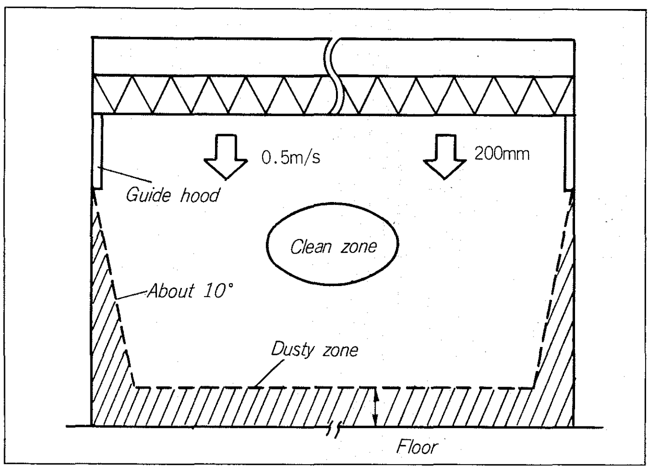


Fig. 6 Clean zone under laminar flow clean booth



CR including a larminar flow type clean booth. In this figure, point C is below the larminar flow type clean booth, and points A and B are positioned in the turbulent flow domain. The measurements were made 80 times toward 40 days. These values are affected by the layout in the room and motions of the workers and machines and equipment, and the values change time-to-time. Therefore, it cannot be said generally, but the values indicate that even if number of ventilations is 50 times, class 100 or below could happen. It is generally said that, under a larminar flow of 0.5m/s surface velocity, class 100 or blow could be possible.

On the other hand, care must be exercised for clean zone in a clean booth or clean bench. *Fig. 6* shows an example of clean zone in a clean booth the surface velocity of which is 0.5m/s. where the cleanliness is reduced in the zone down to about 200mm from the floor level and at the laminar flow zone end. The contamination at the floor is considered to be due to redispersion of the dust sticked on the floor.

2.3.3 Contamination by workers

Generations of dusts in working space occur in many cases due to workers. To avoid contamination by workers, worker's wears must be selected and controlled correctly and position of the worker and operating method in the working space must also be examined. It is, of course, necessary to thoroughly train the workers.

Examples of dust generating value measurement are described next.

2.3.3.1 Dust generating values by type of cloth and motion

Table 4 shows the results of measurements of dust generation (0.5 μm or greater particles) by various cloths and motions of male workers. Dust generating value is the minimum with the overall type cloth for CR, and ordinar working wear and cloth for surgery are following in that order.

As for dust generations by motions, dust is generated mostly when the entire body is moved, and when the neck is moved up and down or left and right or when the worker is working at seat, dust generation is less. In case of the overall type cloth for CR, dust generation was about 50,000

Table 4 Detachable particle densities classified by garment fabrics and human actions (0.5 μm or greater)

Type of action	Ordinary garment	Garment for surgery		Overall type garment A for CR			Overall type garment B for CR
		Cotton material	Non-woven cloth	Before washing	After ordinary washing with water	Afterwashing with solvent	(worn for a week)
Vertical arm motion	1,620	12,500	1,530	612	46	41.3	1,170
Upper half body bending	2,930	8,730	7,150	118	198	3.0	109
Vertical and horizontal neck motions	71	543	255	21	35	3.0	12
Upper half body twisting	486	5,880	1,170	303	35	79.7	385
Seating (Note 1)	55	510	75	6	23	0.0	6
Seating (Note 2)	143	14,000	610	30	2,140	11.8	24
Going up and down a step	2,220	11,700	11,000	167	111	186	370
Standing up and seating	2,630	31,700	5,920	990	343	153	600
Knee bending	2,740	26,100	8,650	324	157	47.2	856
Exercise (Physical)	3,420	13,100	3,160	1,140	303	47.2	951
Free arm motions	3,580	33,900	3,320	488	166	76.7	306
Stepping (90 steps per minute)	1,640	24,000	4,330	267	192	189	241
Mean value of the above 12 motions	1,794	13,139	3,056	372	346	69.8	419

(Note 1) Right arm and head light motions (Note 2) Motions of arm, hand, head and body to 5,000,000 particles per minute per person.

2.3.3.2 Cleaning effect and dust generation by particle size

With the cloth for CR, reduction of dust generation by an ordinary water rinsing is small. While, when the cloth is washed in accordance with the method indicated in the CR Operation Control Guide mentioned in 2.3 above, dust generation is reduced to 1/5.

Figs. 7 and 8 indicate distributions of generated particles by the sizes at two types of motions which represent upper and lower half body motions. It seems that cleaning effect of cloth for CR is high at particles of 5 μm or larger particularly.

Fig. 7 Size distribution of detachable particles from a garment worn by human in bending action

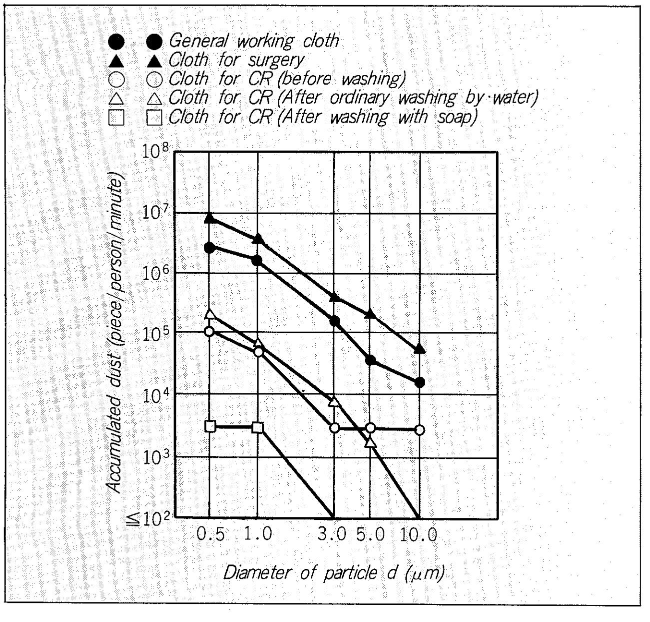
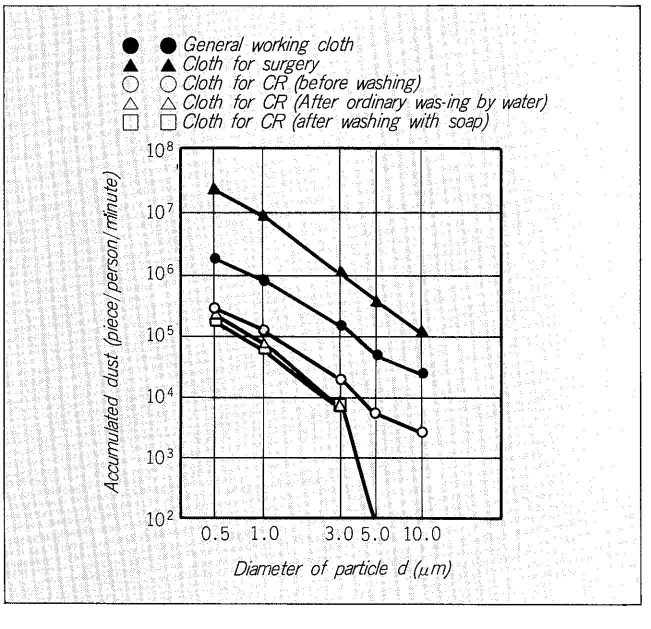


Fig. 8 Size distribution of detachable particles from a garment worn by human in stepping action



It is said that large size particles having higher probability of adhesion affect products more, and in this meaning, the solvent cleaning method which reduces large size dust generation may be said to be desirable.

2.3.4 Influences by NOx, H_2S, etc.

When the plant is located near a beach or in the area where air pollution is considerable, the cleanliness is sometimes affected by gas of small particle diameter such as NOx and H_2S which cannot be collected by HEPA filters. For example, when performing photolithography by using negaresist in an environment of high oxidant concentration, it has been known that a part of the resist may remain in a portion other than the light applied portions.

Results of photolithography were examined against oxidant concentration. *Table 5* shows the results. From this figure, it can be understood that a photoresist has remained when the concentration comes near 0.1 ppm. This happens because bridge of the negaresist is caused to proveed by other than light, and this can be prevented by installing active carbon filter in the air intake system. Further, recently, clean benches with built-in active carbon filters are available in the markets, and they are displaying the effects.

Table 5 Influence of oxidant concentration against remaining photo resist

Experiment No.	Oxidant concentration (ppm)	Remaining photo resist
1	0.042	○
2	0.058	○
3	0.060	○
4	0.090	X
5	0.106	X

3 TEMPERATURE AND HUMIDITY CONTROL

Generally, in the most cases, CRs are maitained under temperature of 22 to 24°C plus or minus 2°C and humidity of 55% or less throughout a year. In some cases, however, for example, in case of an exposure device used for fine treatment of LSI and super LSI, ±0.1°C or below and ±2% or below are required.

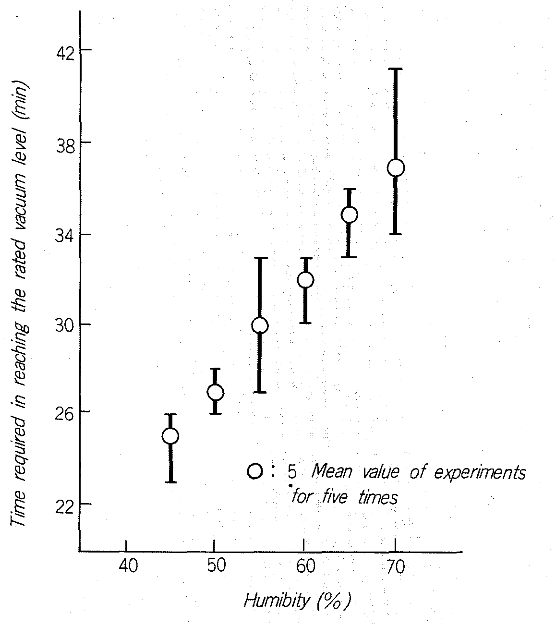
While, for the recent CRs, 20 to 50% of the room air is exhausted through draft, etc. because of;

(1) Enlarged size of the facility
(2) Increased use of harmful, inflammable or corrosive gas for ion injection, CVD and dry etching.
(3) Increased rotary devices such as rotary pump due to introduction of equipment for ion injection which requires a vacuum system.

Consequently, volume of replenished fresh air increases, and a large energy is required to control temperature and humidity.

For this reason, to thoroughly control temperature and humidity with an energy saving countermeasure taken into

Fig. 9 Influence of humidity upon time required bo achieve a nomal vacuum level



consideration, care should be exercised on the following matters.

(1) Executions of local high cleanliness, temperature and humidity controls
(2) Devise to minimize exhaust of clean bench and thermal chamber
(3) For those equipment such as diffusion furnace which has a heat source, devises to seal and discharge heat, to place only working face in the CR and place the furnace portion outside the CR.
(4) Execution of sealed exhausting for those equipment such as rotary pump which has a sliding parts.
(5) Minimization of opening of draft.

Fig. 9 shows the relationship of the time required in reaching the rated vacuum of a vaporising device against humidity change of the surrounding environment. In the recent processing equipment, many number of equipment such as various vaporising devices and ion injectors are likely to self-contain high vacuum systems. Therefore, when these systems are released under a high humidity environment, it requires a long time to obtain the original vacuum and contamination is likely to occur. These occurrences should be taken into considerations.

4 POST SCRIPT

Regarding the maintenances of cleanliness, temperature and humidity, controls of CR operations were described. It is assumed that the high integration of IC will cause semiconductor manufacturing environment to be severer. To cope with such trend, improvement of the peripheral techniques such as 0.1 μm particle measuring method is essential in addition to the use of clean tunnel and clean tube. On the other hand, automation of processing equipment in the process line and continuity of operations between processes including wafer transit will be further advanced, contributing to the dust eliminations.

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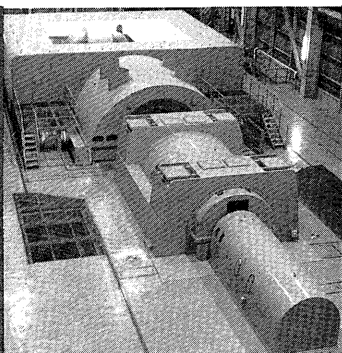

- Nuclear Power
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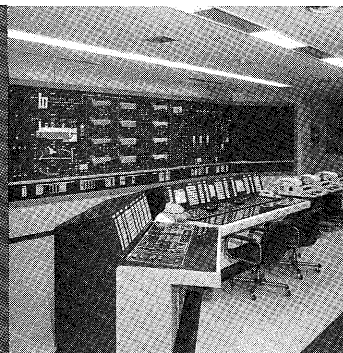

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- Standard Electrical Equipment

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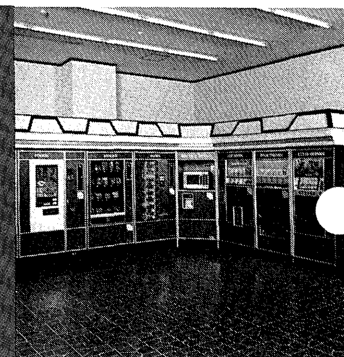

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