115-14a

PRELIMINARY CONTROL TECHNOLOGY SURVEY
of
MOTOROLA, INC.
5005 East McDowell Road
Phoenix, Arizona 85008

to

U. S. Environmental Protection Agency
Industrial Environmental Research Laboratory
26 W. St. Clair Avenue
Cincinnati, Ohio 45268

and

National Institute for Occupational Safety and Health
Division of Physical Sciences and Engineering
5555 Ridge Avenue
Cincinnati, Ohio 45268

March 18, 1983

by

L. G. Ungers, R. K. Smith, and S. Rose

BATTELLE
Columbus Laboratories
505 King Avenue
Columbus, Ohio 43201

TABLE OF CONTENTS

		Page
1.0	ABSTRACT	1
2.0	INTRODUCTION	2
3.0	PLANT DESCRIPTION	3
	3.1 General	3
	3.2 Process Gas Supply System	4
	3.3 Ventilation System	5
	3.4 Monitoring Systems	5
4.0	PROCESS DESCRIPTION	6
5.0	DESCRIPTION OF PROGRAMS	8
	5.1 Industrial Hygiene	8
	5.2 Education and Training	9
	5.3 Respirators and Other Personal Protective Equipment	9
	5.4 Medical Program	10
	5.5 Housekeeping	10
6.0	DESCRIPTION OF CONTROL STRATEGIES FOR PROCESS OPERATIONS	10
	6.1 Preparation of Polycrystalline Silicon (poli-Si) Charge	10
	6.2 Single-Crystal Silicon Ingot Growth	12
	6.3 Ingot Cropping, Grinding, and Etching	13
	6.4 Ingot Orientation and Mounting	14
	6.5 Wafer Lapping and Slicing	15
	6.6 Wafer Annealing	16
	6.7 Wafer Polishing and Cleaning	17
	6.8 Epitaxial Growth	18
7.0	CONCLUSIONS AND RECOMMENDATIONS	20

1.0 ABSTRACT

A preliminary control technology survey was conducted at Motorola, Inc., Phoenix, Arizona, on November 3, 1981. The survey was conducted by Battelle Columbus Laboratories and PEDCo Environmental, Inc. as part of a control technology assessment of the electronic component industry. Motorola became involved in silicon technology in the late 1950's and now employs a workforce of approximately 550 persons. The Phoenix, Arizona, facility manufactures silicon crystals and produces silicon wafers.

Process stages reviewed at Motorola include the following:

(1) Semiconductor grade polycrystalline silicon (poly-Si) is etched, reduced, and converted to single-crystal silicon (single-Si);

(2) Single-Si is formed into large ingots that are cropped and sized;

(3) Ingots are lapped and sliced into wafers;

(4) Wafers are cleaned, thermally annealed, and polished;

(5) An epitaxial layer of single-Si is grown on each wafer.

Engineering controls at Motorola vary by process operation. General engineering controls include gas storage in a central area. All lines from gas bottles to equipment are of welded stainless steel. The ventilation system circulates the room air at a rate of 10 air exchanges per hour. Process vent gases are scrubbed by water spray scrubbers inside the equipment and epitaxial vents are exhausted directly to the atmosphere. Shielding from X-ray exposure and electrical interlocks on slicing equipment provide further worker protection. Monitoring of hydrogen gas levels is performed by a Gastech monitor. There is presently no on-line monitor for other compounds such as arsine and phosphine. However, the work area is monitored intermittently by both personal and area samplers.

Three full-time safety engineers are employed at this location of Motorola; one of the engineers is a company industrial hygienist. A registered occupational health nurse is always on duty and physicians are available on an on-call basis. Fire and safety emergency procedures are well established and a disaster plan calling for rapid evacuation is tested quarterly.

New employees are required to attend safety programs and courses.

Production process training includes safety requirements as an integral part of its training programs. Supervisory personnel participate in monthly seminars to discuss safety problems and review the company's safety program. In addition, workers are supplied with protective equipment as needed by work area.

2.0 INTRODUCTION

The manufacture of electronic components, particularly semiconductors, involves several unit processes or operations that are highly specific and are not encountered in any other type of manufacturing process. Thus, hazardous agents associated with these operations require special or novel control methods to prevent or limit emissions.

This control technology assessment will identify the best means of controlling emissions and exposures in the semiconductor industry. Preliminary surveys, such as this one at Motorola, are conducted to identify and evaluate the control technology used to reduce emissions and work exposures. This information will then be used to select sites for more detailed assessments. Upon completion of control technology studies, research needs and priorities can be defined based on the information obtained.

A preliminary survey was conducted on November 3, 1981, at Motorola, Inc., 5005 East McDowell Road, Phoenix, Arizona. The study was performed under U.S. Environmental Protection Agency (U.S. EPA) Contract No. 68-03-3026 through an interagency agreement (No. AR 75-FO-142-0) with the National Institute for Occupational Safety and Health (NIOSH). The survey was conducted by Russell K. Smith of Battelle Columbus Laboratories and Les Ungers of PEDCo Environmental, Inc. Assistance was provided by Mr. James H. Jones of NIOSH. The following individuals were contacted during the Motorola survey:

1.	Mr. Patrick J. Robinson	Semiconductor Sector Safety Director
2.	Mr. Rudy Steckl	Materials Area Coordinator
3.	Mr. William Volz	McDowell Road Site Safety Manager
4.	Mr. H. Theodore Werner	Legal Counsel

5. Mr. Robert Ahle — Manufacturing Manager, Materials Area

6. Mr. Charles Debow — Labor Relations Specialist, Personnel

A study protocol was given to the corporate attorney, Mr. Werner, several weeks in advance of the preliminary survey. An opening conference was held with plant representatives to discuss the study objectives and methods. During this conference, the plant staff provided an overview of Motorola's health and safety program. The plant layout, process description, specific unit operations, monitoring systems, gas handling systems, and the chemical storage program were also reviewed.

Following the conference, specific crystal growing and wafer production operations were toured. The information obtained from this walkthrough was discussed with the plant staff and they identified any confidential material before the preliminary survey ended.

3.0 OPERATIONS DESCRIPTION

3.1. General

In the early 1950s this Motorola facility was established to manufacture germanium materials. This site became involved in silicon technology in the late 1950s and the materials portion of the plant's workforce has grown to approximately 550 persons. Motorola operates three shifts daily with 250 employees on the first shift and approximately 150 employees on each of the remaining shifts. Twelve-hour shifts operate in the epitaxial area and are counted as first and second shifts only. Women comprise approximately 75 percent of the production staff, 40 percent of the administrative staff, and 5 percent of the maintenance staff.

The operations visited at Motorola's McDowell Road facility included silicon crystal growing and wafer production. The entire materials facility consists of 50,000 ft^2* with approximately 60 percent of the floor

---

*4650 m^2.

space devoted to the crystal and wafer production processes. The building in which the materials processes are conducted was built in 1963 and was first occupied in 1964. This building was formerly used to house Germanium operations which were discontinued in 1975. This building is constructed of concrete and houses both administrative and production operations. Production areas vary from Class 100 clean rooms to maintenance, storage, and supply areas that are not particulate sensitive.

3.2. Process Gas Supply System

Process gases are supplied to the process area from a central gas storage area. The gas bottles, when placed into service, are connected to a manifold system that performs pressure regulation and mixing. The purge lines are vented into a mixing box and exhausted. The valve purge system is numbered to avoid confusion in operating the shutoff valves.

All bottles of hydrogen-diluted gases (e.g., silane) are placed in service in ventilated areas. For dilute gases (100 to 250 ppmv), the gases are placed in a plastic shroud covering the regulator and bottle connector and extending down the bottle side. Bottles are strapped to the wall under this hood.

Higher concentration gases in hydrogen (e.g., 10 percent arsine and diborane in a hydrogen carrier) are stored in a locked cabinet that fully contains the bottle.

In the epitaxial reactor area, silicon tetrachloride bottles are connected to the reactors. These bottles contain approximately 5 gallons of silicon tetrachloride. The entrance and exit taps both have valves that can be closed before disconnecting. The bottles are chained to structural supports. These bottle installations are unenclosed and are unventilated except by the turn-over of room air. All process lines from gas bottles to process equipment are constructed from stainless steel with welded joints. After installation in the process, the lines are pressure-decay checked by pressurizing them with nitrogen to assure line integrity.

Gas bottles are changed only by designated personnel, who are trained in handling procedures for the bottles and in emergency procedures to be used in case of valve leakage or other potential hazards.

3.3. Ventilation System

The ventilation system at Motorola's Materials operation is divided into zones for air conditioning system purposes. The rate of room air circulation is 10 air exchanges per hour. Seventy-five percent of the air is recirculated. Recirculated air is blended with fresh air, conditioned for temperature and relative humidity, and then filtered through roll, sock, and absolute filters.

Process vent gases from epitaxial reactors are scrubbed by water spray scrubbers inside the equipment. Epitaxial cabinet vents are not scrubbed, but are instead vented directly to the atmosphere.

Hoods are designed by the process equipment engineer and reviewed by the Motorola Safety Group. General requirements are established for face velocities on hoods. These are:

- Solvent hoods--75 linear feet/minute (lfpm) minimum
- Acid hoods--100 lfpm minimum*
- Hot acid hood--150 lfpm minimum, and
- Diffusion furnace scavenger exhaust--200 lfpm minimum.

Hoods are checked monthly to assure compliance with these values. Ductwork is also checked periodically for flow rate by the facilities department of Motorola to insure specification flows are being achieved.

3.4. Monitoring Systems

Gastech monitors are installed in the epitaxial reactor area. These monitors have a sensing head in the epitaxial reactor, and sound an alarm when hydrogen gas concentrations exceed 20 percent of the lower explosive limit. The monitor shuts down the gas at the cylinder automatically at the 20 percent level.

Currently, no on-line monitor exists at the Phoenix plant for compounds such as arsine and phosphine; however, a Telos sytem is to be tried. Two Miran systems are in use at the Motorola, Austin, Texas, facility. The

---

*100 lfpm = 30 linear meters/minute.

Phoenix plant has received good reports on the Miran monitor from Austin. A Honeywell alarm/purge system monitors the motors on the exhaust ventilating system that services the gas delivery system and gas cylinder boxes. A Motorola-designed system using differential pressure detectors in ducts tied to alarm annunciators is also used to detect low flow conditions.

Emergency power is provided for plant illumination by a natural gas-powered generator. Under a "no power" situation, valves to toxic gas sources close and valves to nitrogen (N_2) purge cylinders open.

4.0 PROCESS DESCRIPTION

The primary purpose of the studied section of Motorola's process facility is to produce finished single crystal silicon wafer substrates with epitaxial layers of single crystal silicon. Along with this homoepitaxial process (silicon on silicon), heteroepitaxy is also performed (nonsilicon glass on silicon).

The process operations at Motorola begin with semiconductor grade polycrystalline silicon (poly-Si) obtained from Motorola and an outside supplier. The poly-Si is etched in a solution of hot hydrogen fluoride (HF), nitric acid (HNO_3), and acetic acid (CH_3COOH). The purpose of the etching is to remove silicon dioxide (SiO_2) deposits that have formed on the poly-Si chunks. The etched poly-Si is rinsed in water before it is sorted and weighed. Oversized chunks are placed in a glove box and manually reduced using a mallet.

Single-crystal silicon (Single-Si) is used as the primary base material for the integrated circuits (IC) discrete semiconductor industry. Poly-Si does not possess the proper physical characteristics for use in semiconductors and must be converted into single-Si before circuit fabrication can begin. Production of the single-Si is achieved by growing a crystal ingot from molten silicon. Equipment most prevalent at Motorola uses the Czochralski growing method.

The single-Si ingots are removed from the Czochralski reactor and transferred to outer diameter (OD) diamond saws for cropping. The cropping operation removes the tapered ends of each ingot. Cropped ingots are then sized to a uniform diameter by grinding. The sized ingot is etched to remove any damage caused during abrasion. The silicon ingot is transferred to X-ray diffraction equipment to identify the type and orientation of its crystal lattice. Once correctly aligned, the ingot is mounted to a holder with epoxy glue.

The mounted ingot is then ready for grinding, an operation that grinds a reference flat along the length of the ingot. After grinding, the silicon ingot is sliced into individual wafers using inside diameter (ID) saws, multi-band saws, or wire saws. The cutting surface is commonly composed of a diamond and nickel or a diamond and carbide matrix. When in use, the wafer slicing equipment produces a slurry of particulate silicon and cutting oil.

Upon completion of slicing, the wafers are cleaned in ultrasonic baths containing isopropanol (IPA). This is followed by another chemical cleaning with sodium hydroxide (NaOH) and drying with a mixture of IPA and Freon (CF_4). The cleaned wafers are thermally annealed in a resistance-heated furnace at approximately 650°C. The annealing process repairs any damage to the crystal lattice that may have occurred during previous processing.

After annealing, the wafers are polished in an alkaline SiO_2 slurry and bathed in cleaning solutions of HF, hot HNO_3, and dilute ammonium hydroxide (NH_4OH).

An epitaxial layer of single-Si is grown on some wafers using one of three types of epitaxial reactors: horizontal, vertical, or cylinder displacement. The process begins with yet another cleaning step in which each wafer is bathed in ammonium hydroxide and IPA and rinsed in deionized water. This last cleaning step removes any organic material that may have contaminated the wafer surface during handling. The wafers are heated in a hydrogen atmosphere to reduce any SiO_2 deposits that may have formed since the last etching process. When enough time has elapsed to reduce all the SiO_2, hydrogen chloride (HCl) gas is introduced into the reactor atmosphere. The HCl etches off a thin layer of silicon. This is the final step in preparing the wafer surface for the deposition of an epitaxial layer.

After the HCl is added, the reactor temperature is lowered and silicon tetrachloride ($SiCl_4$) containing trace amounts of dopant is introduced. Phosphine (PH_3), arsine (AsH_3), and diborane (B_2H_6) are commonly used sources for dopants. The $SiCl_4$ and dopant react with the H_2 atmosphere by depositing a layer of single-Si on the wafer surface. Upon completion of the deposition step, the reactor is purged with nitrogen gas (N_2). The homoepitaxial wafers are now ready for use in circuit fabrication elsewhere in the plant.

5.0 DESCRIPTION OF PROGRAMS

5.1. Industrial Hygiene

Three full-time safety engineers cover the first shift of workers at this Motorola site. One of the engineers also serves as an industrial hygienist. A registered occupational health nurse is on duty during each of the three shifts, and consulting physicians are under contract to perform ad hoc medical services.

The work area is monitored periodically by both personal and area samplers. A continuous hydrogen (H_2) flammable gas detector monitors for H_2 leaks at various points in the facility and also within the epitaxial reactors. Personal sampling is performed periodically for arsenic, phosphorus, silicon, and a variety of industrial solvents. Monitoring of physical agent exposures is limited primarily to the detection of ionizing radiation.

Written programs detailing procedures for both fire and health hazard emergencies are available. A disaster plan for rapid evacuation is tested quarterly. A disaster/emergency headquarters with electronic alarms for high hydrogen levels and fire alarms is presently under construction.

An integral part of Motorola's safety program is the equipment sign-off procedure that must be followed before new equipment or chemicals are brought on-line. Safety department approval must be obtained before any new piece of equipment or new process chemical can be used. This sign-off procedure assures that all potential health, safety, and environmental hazards have been considered. Acceptable items receive a safety inspection decal before incorporation into the process operation. Items without safety decals do not become a part of the physical plant.

During the visit, Motorola personnel expressed their goal to limit worker exposure to no more than 10 percent of the TLV for any given agent. In this way, no breathing protection would be required during any operation.

No samples were taken during this visit. No data from sampling done by the company were reviewed.

5.2. Education and Training

New employees receive a safety indoctrination program when hired. This initial program is followed by a process training course during the first month of employment of which safety is an integral part. The course emphasizes both chemical and fire safety. Volunteers are recruited from the ranks of the process employees to form fire brigades. The brigade members are given hands-on experience in the use of fire fighting and life support equipment. As a supplement to the indoctrination program and initial courses, supervisory personnel participate in monthly fire and chemical safety seminars. The purpose of these seminars is to discuss safety problems and review the company's safety program.

Evacuation alarms are tested on a regular basis. All employees, including supervisory staff, are evacuated during test drills which are performed on a periodic basis. A new emergency response center was to open in early November, 1981, just after this visit.

5.3. Respirators and Other Personal Protective Equipment

Workers at Motorola are supplied with a variety of protective equipment. The type of equipment varies with the work being performed. Employees who are mostly involved with acid etching operations wear chemical safety goggles, vinyl/nylon "granny gowns", neoprene gloves, and rubber boots. During chemical pouring operations, a face shield is also used. Small etching operations or clean room activities require less extensive protection. Workers in clean rooms at Motorola are dressed in standard clean room attire: safety glasses, Tyvek suits, and gloves. Closed toe shoes are required throughout the production facility.

Respirators are not worn during normal process and maintenance operations. Conditions which might have required such precautions are either enclosed and vented or have been re-engineered to preclude the possibility of exposure. Mine Safety Appliances and Survivair self-contained breathing apparatus with full face masks are located at key points throughout the production facility in the event emergency access to the area is required.

5.4. Medical Program

A first aid station staffed with a registered occupational nurse is open during all three shifts at Motorola. Consulting physicians from a local occupational clinic are also on call. The medical program at Motorola includes both preplacement and annual physical examinations. The annual examinations, however, are performed only on individuals in this operation who are involved in processes using arsenic or phosphorus. The preplacement examinations include: complete medical history, pulmonary function tests, and audiometric testing. The annual examination includes: chest x-ray, audiometric retesting, complete blood count, blood chemistrys, urinalysis, and sputum cytology tests.

5.5. Housekeeping

The nature of specific housekeeping activities was not addressed during the preliminary survey. However, the general conditions of the workplace indicated that much attention was given to general hygiene. Floor areas in the wafer slicing rooms were mopped clean and acid bath areas were free of corrosion.

6.0 DESCRIPTION OF CONTROL STRATEGIES FOR PROCESS OPERATIONS

6.1. Preparation of Polycrystalline Silicon (poly-Si) Charge

Semiconductor grade poly-Si is obtained from a supplier in the form of large chunks. The poly-Si chunks need to be etched in acid to remove the surface oxide layer that builds up during shipping and handling. After cleaning, the poly-Si chunks are sorted and large chunks are broken by hand in an enclosure with hand entries using a mallet. Adequately sized chunks are weighed, bagged, and placed in staging areas.

The process equipment used to etch the poly-Si chunks consists of a power hoist, a number of large perforated containers or baskets, and a series of "industrial sized" dip tanks with open surfaces of several square feet. Poly-Si chunks are loaded into a basket; the basket is then raised over the dip tanks and lowered into the acid solution with the power hoist. During etching, the basket is lowered and removed from both acid solutions and water rinses with the power hoist. Baskets containing clean poly-Si are placed in a staging area to dry.

The second step in the preparation of poly-Si is the sorting and size reduction of clean poly-Si to fist-sized chunks. This task is performed using a stainless steel mallet in a plexiglas-enclosed chamber similar in design to a glove box but without integral gloves. The worker strikes each oversized poly-Si chunk with a stainless steel mallet. After reduction, the chunks are sized, weighed, and bagged.

The acid etching solution used to remove silicon oxide (SiO_2) from the poly-Si chunks is a hot mixture of hydrogen fluoride (HF), nitric acid (HNO_3), and acetic acid (CH_3COOH). The postetching rinse uses hot distilled/deionized water.

Ventilation to each acid dip tank is provided by semi-lateral slot plenums. The take-off slots are located just above the surface of the acid solution, opposite the work area. The average face velocity of each lateral slot along the length of the dip tank is maintained at approximately 150 linear feet/minute (lfpm). The chamber used to protect the worker during size reduction is also ventilated.

The dip tank ventilation and the shielded and ventilated size reduction chamber were the only controls engineered into this process. A minimum capture velocity of 150 lfpm is maintained over all hot acid baths. The shielded reduction chamber was designed to protect the worker from flying chips of poly-Si. Because size reduction is carried out in the shielded size reduction chamber, dust is controlled. Siphon systems for spent acids reduce the chance of acid burns from acid handling.

No chemical monitoring is performed at this process on a routine basis. The ventilating system is checked monthly for proper slot velocities and flow rates. During this check the general condition of the hood and plenum is assessed visually. The information gained during the monthly checks is recorded and analyzed to detect any change in the efficacy of the control equipment.

Employees working in the poly-Si etching area are potentially subject to acid exposures during load-in and load-out of the container baskets and acid filling of baths. Motorola provides these workers with chemical safety goggles, protective face shields, acid-resistant synthetic gowns, gloves, and boots to reduce the potential for injury resulting from accidental chemical spills.

Workers involved in the reduction and sizing of cleaned poly-Si chunks are provided with heavy gloves. The shielded chamber is enclosed and vented to the process exhaust, preventing any exposure to particulate poly-Si.

6.2. Single-Crystal Silicon Ingot Growth

Single-Si is the base material used to produce integrated circuits at Motorola. Single-Si is made by growing a 24-inch crystal ingot from molten poly-Si using the Czochralski method. Chunks of semiconductor grade poly-Si are placed in a quartz crucible along with a dopant, such as boron. The added dopant is a solid. The crucible is heated with resistive heaters to produce a silicon melt at a controlled temperature in an argon atmosphere at a pressure lower than atmospheric. A seed crystal of single-Si is introduced and upon contact with the silicon melt, the crystal is slowly rotated and removed at a controlled rate. This allows the molten silicon to deposit on the seed crystal, increasing its diameter to form a large single-Si ingot. The process is computer controlled.

The crucible is made from graphite with a fused silica (quartz) lining and is enclosed in a water cooled silica jacket. It is mounted on a shaft that provides rotation counter to the turning seed crystal. The seed crystal and the silicon melt can be watched by process workers from one or more ports.

A number of controls have been engineered into the ingot growing process machinery. Gold-backed lenses are installed in the viewing ports of each ingot grower. These lenses protect process operators from infra-red radiation. The power elements located around the crucible are shielded. The reactor cannot be opened until the vacuum is released. The computer releases the vacuum only after the ingot is cool.

Because the potential for accidental implosion or other failures of the reactor exists, a number of safety features have been designed into the equipment: dump plates are incorporated for spilled loads, cooling water systems are redundant, and an automatic shut-down procedure is incorporated for power failures.

No local exhaust ventilation of the ingot growing equipment exists; however, dopant vapors present in the internal argon environment are exhausted through the vacuum pump to scrubbers before the crucibles are opened.

Specific environmental area monitoring systems to evaluate work room emissions from the process are not present. Any monitoring of the equipment that does take place is a function of the control requirements of the ingot growing cycle.

Personal protective equipment consists of welding glasses for use during the viewing of silicon melt. No other specific equipment is issued to workers at the ingot growing operations, except employees in the area are routinely monitored by personal samplers.

6.3. Ingot Cropping, Grinding, and Etching

Ingot processing includes cropping the ingot crystal ends, reducing the crystal diameter through grinding, and wet chemical etching of the crystal surface. The single-Si ingots are removed from the Czochralski reactors and transferred to outer diameter (OD) diamond saws for cropping. Cropping removes the tapered ends of each ingot, producing a flat-ended cylinder. The ingot cylinder is then ground to a specified diameter. This process is often referred to as diameter sizing. Standard wafer sizes achieved through this process include 50, 70, and 100 mm. Both the cropping and grinding are performed using a proprietary water-based cutting fluid that produces a slurry of water, cutting fluid additives, and particulate silicon. The nature of the grinding lubrication solution is regarded as proprietary information and can vary in composition.

Grinding leaves a damaged surface on the crystal that must be removed before processing continues. A chemical etching solution -- a mixture of HF, HNO_3, and acetic acid in proportions of approximately 4:1:2 --finishes the crystal surface. No chemical agents other than cutting fluid, grinding lube, and chemical etch solution are used during the ingot cropping, grinding, and etching process.

The cropping and grinding operations are both enclosed to protect the worker from flying particles of silicon. The saw enclosure is equipped with a safety switch that prevents operation of the equipment when the enclosure door is open. The generation of silicon dust within the enclosure is reduced through the use of water spray.

The chemical etching processes at Motorola are all ventilated and the exhausted air is passed through a water scrubber before it is released to the outside. Etching solutions are vented by a minimum capture velocity of 100 lfpm for cold solutions and 150 lfpm for hot baths.

Environmental monitoring systems to evaluate specific work room emissions are not present. The ventilating system is checked monthly for proper face velocities and flow rates. During this check, the general condition of the hood and plenum is assessed visually. The information gained during the monthly checks is recorded and analyzed to detect any change in the efficacy of the control equipment.

Each employee working in the chemical etching area is required to wear protective clothing. This clothing consists of chemical safety goggles, face shield (for pouring acids), protective gown, protective gloves, and closed toe shoes. Workers in the ingot cropping and grinding area wear safety glasses and aprons.

6.4. Ingot Orientation and Mounting

Fabrication of single-Si wafers requires that the orientation of the silicon crystal lattice be known. X-ray diffraction analysis identifies the orientation of each ingot. An ingot is taken from the preparation process, is X-rayed to identify its orientation, and is mounted on a holder using an epoxy glue.

The X-ray diffraction analysis of each ingot requires the use of chemical agents related to epoxy glue. The X-ray diffraction analysis is shielded to prevent worker exposure to excessive levels of ionizing radiation.

All electrical equipment used in the analysis is grounded. Exhaust ventilation is provided to remove solvent fumes from the epoxy glue; minimum capture velocity is at or above 75 lfpm.

Specific environmental monitoring systems to evaluate worker exposures are not present. Periodic checks are conducted for emissions from X-ray diffraction equipment. The ventilating system is checked monthly for proper face velocities and flow rates. During this check the general condition of the hood and plenum is assessed visually. The information gained during the monthly checks is recorded and analyzed to detect any change in the efficacy of the control equipment.

No protective clothing or equipment specific to the process is required of employees working in the ingot orientation and mounting operations. Standard requirements of safety glasses and closed toe shoes are enforced.

6.5. Crystal Orientation and Slicing

When crystals are oriented, a reference or identification flat is ground longitudinally along the ingot. Typically one, but as many as two, flats may be ground into each ingot to achieve proper identification of the crystal type and its orientation.

The silicon ingots are most commonly sliced into individual wafers using inside-diameter (ID) saws, multi-band saws, or wire saws. All of these saws are covered to prevent flying debris and are ventilated by local exhausts. Regardless of the saw used, the cutting surface is generally composed of a diamond/nickel or carbide matrix. During the cutting process, 30 percent or more of the silicon ingot is lost. The lost silicon is in the form of particulate due to the saw kerf. This material combines with the cutting fluid solution to produce a silicon slurry. The cutting fluid is regularly changed. The waste is placed in an unsealed can to prevent hydrogen buildup and is sent from the reaction of silicon with water for disposal by a contractor. As in the case of ingot grinding, the exact composition of the cutting solution is proprietary information.

Upon completion of the slicing operation, the wafers are cleaned in ultrasonic baths containing isopropanol (IPA). The wafers are then spun dry in an enclosed centrifuge.

Safety guards are present on all wafer slicing and lapping equipment. Lapping machines at Motorola are equipped with dual activation controls that require the use of both hands. This type of interlock mechanism prevents the worker from handling the wafer while it is being lapped. The centrifugal spin dryer also has an interlock feature that prevents the worker from opening the dryer while the wafers are still revolving.

The ultrasonic baths and centrifuge are exhausted to remove IPA vapors during the cleaning process. A minimum capture velocity of 75 lfpm is maintained over the ultrasonic baths.

Misting or flooding the ingot with cutting solution during slicing and lapping effectively reduces the suspension of silicon particulate in ambient air during the slicing process. The cutting fluid reservoirs are vented to the room, to allow the hydrogen formed during a slow reaction of silicon with water.

Specific environmental monitoring systems to evaluate worker exposures are not present. The ventilating system is checked monthly for proper slot velocities and flow rates. During this check the general condition of the hood and plenum is assessed visually. The information gained during the monthly checks is recorded and analyzed to detect any change in the efficacy of the control equipment.

Safety glasses are required at both the grinding and slicing operations; safety shoes are optional. No other protective equipment is required for workers in this area.

6.6. Chemical Etching and Thermal Treating of Wafers

The wafer process consists of a chemical etching operation and a thermal treatment operation. The chemical etching is achieved using an alkaline system containing sodium hydroxide (NaOH) and water. The etched wafers are dried with a mixture of isopropanol (IPA) and a fluorinated hydrocarbon solvent. The heat treating of silicon wafers stabilizes the active oxygen in the wafers. Wafers are loaded into a resistance-heated furnace and heat treated at a temperature of approximately 650°C. The finished wafers are removed from the annealing furnace while they are still hot.

Exhaust ventilation is maintained over the chemical cleaning operation at a minimum capture velocity of 100 lfpm. No other engineering controls were evident at the annealing operation.

Specific environmental monitoring systems to evaluate worker exposures are not present. The ventilating system is checked monthly for proper slot velocities and flow rates. During this check the general condition of the hood and plenum is assessed visually. The information gained during the monthly checks is recorded and analyzed to detect any change in the efficacy of the control equipment.

Workers in the chemical etch area are required to wear protective clothing. Safety goggles, aprons, and closed toe shoes are worn around the chemical cleaning operation. Operators using the thermal annealing equipment are supplied with protective gloves in case contact with hot wafers or equipment parts becomes necessary. Under normal conditions, the hot wafers are not touched.

The work practices of individual employees were not observed. Submersion of wafers into baths is done manually. Pouring of fresh alkaline solution is also a manual operation. Both of these activities represent potential chemical burn or fume exposure activities.

6.7. Wafer Polishing and Cleaning

The heat treated silicon wafers require polishing and cleaning before they are ready to receive an epitaxial layer. The polishing process is performed mechanically using an alkaline SiO_2 slurry. The wafers are placed on large disks which rotate the wafer in an epicycle about the machine axis, against a static plate. The polished wafers are cleaned by using three solutions; hydrogen fluoride (HF), hot nitric acid (HNO_3), and dilute ammonium hydroxide (NH_4OH).

The polishing equipment is designed with guards and lockouts to prevent worker contact with the point of operation. The spent slurry used as an abrasive to polish the wafers is drained to an industrial waste drain.

The cleaning solutions are exhaust-ventilated by take-off slots located next to the HF, HNO_3, and NH_4OH baths opposite to the work position. Capture velocities of 150 lfpm are maintained over the hot acid baths.

No continuous monitoring of the work environment is provided for the wafer polishing and cleaning operations, but industrial hygiene monitoring is performed periodically for worker exposure to the cleaning acid vapors and mists. The ventilating system is checked monthly for proper slot velocities and flow rates. The general condition of the exhaust plenums is also assessed monthly.

Workers in the wafer polishing area are not required to wear specific protective equipment. Safety glasses and closed toe shoes are standard apparel. Workers in the wafer cleaning operation are required to wear safety glasses, chemical aprons, gloves, and face shields.

6.8. Epitaxial Growth

An epitaxial layer is a silicon layer that is grown onto a substrate under controlled conditions. The layer is an extension of the substrate's crystal lattice. Epitaxial layers are grown with specific electrical properties by introducing dopant gases during the growth process.

Three types of epitaxial reactors were in use at Motorola: horizontal, vertical, and cylinder displacement. The horizontal and vertical reactors are indirectly heated by radio frequency (RF) sources; the cylinder reactors are radiant heated.

The process begins with silicon wafers that have been cleaned in ammonia (NH_3), isopropanol (IPA), and deionized water baths. The clean wafers are mounted on a silicon carbide-coated carbon plate called a susceptor and loaded into a quartz reactor. The epitaxial reactor is heated and purged with hydrogen (H_2). The hot hydrogen atmosphere reduces the layer of SiO_2 that develops on the surface of exposed wafers during exposure to air and water. When enough time has elapsed to reduce all of the SiO_2, hydrogen chloride gas (HCl) is introduced to the reactor. The HCl etchs off the top layer of the silicon substrate, effectively removing any scratches or damage that may have occurred during slicing. Following the introduction of HCl, the epitaxial reactor temperature is lowered and silicon tetrachloride ($SiCl_4$) and trace amounts of a dopant are added. Phosphine (PH_3), arsine (AsH_3), and diborane (B_2H_6) are the most commonly used dopants. The $SiCl_4$ and dopant react with the H_2 resulting in the deposition of new, doped, single-crystal silicon on the substrate surface. The finished wafers cool while the reactor is purged with nitrogen gas (N_2).

A number of controls have been engineered into the epitaxial growth process. Radio frequency (RF) sources at Motorola are located beneath the process room floor, reducing the potential for worker exposure to non-ionizing radiation. Both the gas line "jungle" and the epitaxial reactor are ventilated. Exhausted gas is scrubbed in a water spray/filter scrubber and completely vented to the ambient atmosphere. Ventilation is also provided in the wafer cleanup area with effective capture velocities in excess of 75 lfpm. In addition to the exhaust ventilation, overhead and vertical laminar flow is provided in the process work area. Gas sources (except for $SiCl_4$) are contained in ventilated enclosures. The silicon tetrachloride liquid is located very close to the reactor, to reduce condensation in lines. The containers are not exhausted except by general ventilation.

Continuous monitoring for hydrogen gas is performed using a Gastech continuous monitor. If a hydrogen gas leak develops, alarms are automatically sounded and the gas system is shut down and purged with nitrogen gas. In a similar fashion, alarms at the process are sounded, the equipment is shut down, and the systems are purged when the exhaust ventilation fails. A pressure differential switch is located in the exhaust duct. If the pressure differential becomes less than a preset value, the system is shut down. This system was designed and built by Motorola.

Arsenic and phosphorus are monitored on a regular basis. Exposure profiles are determined for workers in the epitaxial growth areas using approved NIOSH sampling and analytical methods.

The epitaxial process equipment and the control of process gases are accomplished by a main frame computer. Use of a main frame computer facilitates central control of equipment usually monitored by microprocessors.

No additional protective equipment is required around the epitaxial growth area beyond safety glasses and clean room gowns.

Precautions are taken during $SiCl_4$ cylinder changing include assigning specific employees the task of replacing empty cylinders, capping the open lines, and purging the lines with nitrogen when they are capped.

7.0 CONCLUSIONS AND RECOMMENDATIONS

Although the areas visited during this walkthrough were limited, it appears that the Motorola plant in Phoenix has well-established safety and industrial hygiene programs. All aspects of potential safety hazards, including often neglected areas such as refresher training and evacuation procedures, appear to be addressed.

During the walkthrough survey, among special engineering controls noted was the wire sawing of ingots into wafers. Use of a wire saw may present an improvement in engineering controls.

However, our visit suggests that the epitaxy area should be considered for detailed survey. Ventilating the gas supply jungle and placing RF sources below the process floor appear to be good concepts for control of toxic gases and RF exposure. Nevertheless, the lack of engineering controls used in the $SiCl_4$ supply to epitaxy may be worth evaluating, to determine whether there is any adverse effect on environmental quality within the epitaxy room, and what the potential risk is if one of these bottles is ruptured or develops a leak.

AGREEMENT

This Agreement effective November 3, 1981, between MOTOROLA, INC. (hereinafter "the Company"), the Columbus Laboratories of Battelle Memorial Institute (hereinafter "BCL") and PEDCo,

WHEREAS, BCL and PEDCo are conducting a study sponsored by the U.S. Environmental Protection Agency (EPA) in conjunction with the National Institute for Occupational Safety and Health (NIOSH), and

WHEREAS, BCL and PEDCo desire to acquire information on the Company's industrial hygiene and control technology practices by onsite inspection and examination of engineering controls, work practices, monitoring systems, and personal protection practices, and

WHEREAS, said inspection and examination may reveal to BCL and/or PEDCo proprietary information concerning the Company's products, equipment, inventions, ideas, designs and processes.

NOW, THEREFORE, the parties agree as follows in consideration of mutual agreement hereinafter set forth:

1. BCL and PEDCo agree that they will not disclose said proprietary information to others or use any part of the information disclosed for any purpose other than in conjunction with said study sponsored by the EPA and NIOSH, except any part thereof which may be in public use, or published, or on sale, or independently disclosed to BCL and/or PEDCo by third parties, or which may already be in the possession of BCL and/or PEDCo, their affiliates, or any of their employees, or which may be independently developed by BCL and/or PEDCo.

2. This Agreement shall not apply to the use or disclosure of said proprietary information in conjunction with the above referenced sponsored research for EPA and NIOSH.

3. This Agreement shall be governed by the laws of the State of Ohio and shall terminate upon the public use or publication of said proprietary information by anyone other than BCL and/or PEDCo and in any event shall terminate three (3) years after the date of disclosure to BCL and/or PEDCo, if not terminated sooner.

MOTOROLA, INC.

By William G. Howard Jr.

Title V.P. & Director, Technology & Planning

Date 11-3-81

BATTELLE MEMORIAL INSTITUTE
Columbus Laboratories

By ______________________

Title ______________________

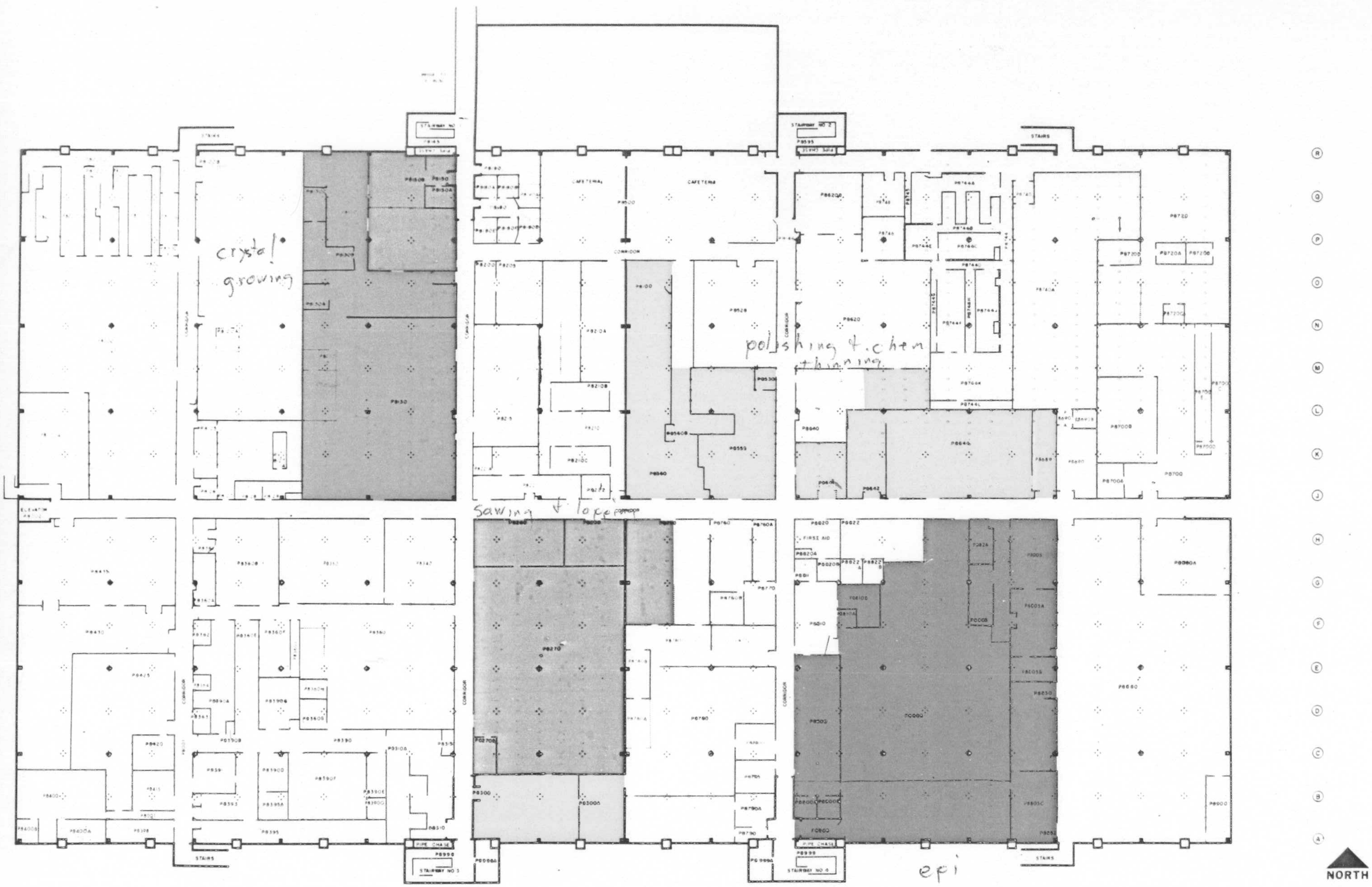
Date ______________________

PEDCo

By ______________________

Title ______________________

Date ______________________



BUILDING
P
SECOND FLOOR

CRYSTAL

Operation	Hazard	Precautions
Clean silicon	Nitric, HF, HAc Etch with 4:1:2; hot water	Vented hood, etching gear, goggles, face mask, gown, gloves, boots
	Heavy basket	Overhead crane
Poly silicon breaking	Flying chips	Shielded chamber, enclosed and vented, gloves
Crystal Growth boron phosphorus arsenic antimony	High temperature; IR radiation; RF radiation; implosion; heavy loads; spillage of molten silicon; power and water failure; overheating; dopant vapors; water leak into crystal grower	Protective equipment; gold backed lenses for IR; welding glasses for brightness; shielding; overhead crane; dump plate for spilled load; power failure-unit shuts down; cooling water system-backup with city water; runaway heat-units shuts down; dopant vapors-scrubbed out of exhaust gases; pressure release valves directing upward; fire extinguishers large and small
Crop crystal and O.D. grinding	Cuts and flying particles	Saw in enclosed chamber; door with safety switch-if opened saw stops; vented; water spray for dust

All solvents handled in vented hood. Hot plates in vented hoods.

All acids and solvents in vented storage cabinets and special containers.

Furnace cleaning with central vacuum system.

SAWING

Safety glasses required in all grinding and sawing operations.

Various guards to prevent accidents.

All electrical equipment grounded.

Operation	Hazard	Precautions
Chemicl etch crystal	Chemicals HF, HNO_3 Acetic	Operation in hood, exhausted and scrubbed. Protective clothing required.
Mount crystal	epoxy Glue vapors	Exhausted
Orientation	X-ray	Shields in place; radiation hazard sign; red light. Machines checked for radiation periodically.
Sawing	Cuts	Guards in place; safety glasses. Central glycol/water coolant stops-alarm goes off. Safety shoes optional.
Clean ultrasonic	Isopropyl alcohol vapors	Exhausted tank and hood
Lapping	Leave hands in machine	Both hands needed to activate lapping machine.
Spin dry	Mechanical	Enclosed - cannot open unless RPM = 0
Chem thin	45% NaOH or 5:1:~~8~~1 Isopropyl alcohol and freon for drying	Protective clothing; hoods; volume of air exhausted checked periodically, as is water rinse. All solvents handled in hoods.
Anneal 625°C	Thermal resistance heating	Not allowed to touch wafers.
Polish	Mechanical SiO_2 slurry KOH or NaOH Ph-11	Equipment constructed to prevent accidental sticking in fingers; automatic stop buttons
Pad preparation	Solvents	Exhausted
Clean	11:1 HF hot HNO_3 Dilute NH_4OH	Hood

MOTOROLA INC.
Semiconductor Products Sector

November 3, 1981

James H. Jones
Industrial Hygienist
National Institute for Occupational Safety and Health
4676 Columbia Parkway
Cincinnati, OH 45226

Dear Mr. Jones

Per our conversation I am sending you the address in Scotland of the company which manufactures silicon based monitoring equipment.

A. M. Dries
SEMA
Unit 32
Dundonald Camp
Irvine, Ayrshire KA11 5BJ
Scotland

I am sure you can obtain some literature at least from this address.

Sincerely,

Pat Robinson

P. J. Robinson, P.E.
Director of Safety

/djp

5005 East McDowell Road, Phoenix, Arizona 85008 (602) 244-6900

Battelle
Columbus Laboratories
505 King Avenue
Columbus, Ohio 43201
Telephone (614) 424-6424
Telex 24-5454

October 15, 1981

Mr. Ted Werner
Motorola, Inc.
4350 E. Camelback Road, Suite 250 G
Phoenix, Arizona 85018

Dear Mr. Werner:

As you requested in our meeting in Phoenix, we have enclosed the resumes of the persons who will be assisting NIOSH in conducting the walkthrough survey. Also as you requested, I will not be a member of the survey team. Mr. Smith, a Certified Industrial Hygienist, will be the Battelle representative coordinating the survey on my behalf. Mr. Les Ungers, a representative of our subcontractor PEDCo Environmental, will be accompanying Mr. Smith.

I have enclosed three copies of each resume in case you want to distribute them to others in your organization.

Thank you very much for your time and cooperation in setting up our survey at Motorola. The assistance you provided has been invaluable.

Very truly yours,

Ralph I. Mitchell

Ralph I. Mitchell
Project Manager
Environmental Programs Office

RIM:llp

Enclosures

BCC: J. Jones
R. Hartley

Battelle
Columbus Laboratories
505 King Avenue
Columbus, Ohio 43201
Telephone (614) 424-6424
Telex 24-5454

August 27, 1981

Mr. Ted Werner
Senior Division Council
Motorola Inc.
4350 E. Camelback Road
Suite 2506
Phoenix, Arizona 85018

Dear Ted:

Enclosed is our Protocol and Site Visit Survey form for our impending walk-through at your Phoenix facility on Thursday, September 3, 1981. As I stated on the phone, we are interested in four operations: (1) ingot growing, (2) wafer preparation, (3) diffusion systems, and (4) your best gas handling systems. If most of the information associated with these four operations can be obtained before our opening conference next Thursday, it will expedite the procedure and we can minimize our stay.

Also enclosed are three copies of our confidentiality agreement which you or the appropriate person at Motorola should sign.

We are looking forward to seeing you next week and I want to thank you in advance for making the necessary arrangements for this walk-through.

Sincerely,

Ralph I. Mitchell

Ralph I. Mitchell
Project Manager
Environmental Programs Office

RIM:llp

BCC: J. Jones
R. Hartley

MOTOROLA INC.

June 18, 1981

Mr. Ralph I. Mitchell
Project Manager, Environmental Programs Office
Battelle
Columbus Laboratories
505 King Avenue
Columbus, Ohio 43201

Dear Mr. Mitchell:

This is to follow up on your letter of June 12th to Mr. Pat Robinson of Motorola and also to our telephone conference call with Mr. Robinson.

To give you a sense of Motorola's concern regarding the information request and the elements of your proposed study, I am attaching a copy of the hand out recently distributed at an Open House at the Mesa, Arizona facility. You can see the building layout of the facility and the listing of the major categories and areas at the facility.

The information request is without limit. You indicate that Motorola's participation is voluntary. You also indicate that you intend to talk with one Process Engineer and one Industrial Hygenist. You indicate you want the visit to take no more than two days.

As Pat Robinson indicated, the attitude of management toward voluntary, non-productive efforts is that they do not want to participate. If you will compare your request and visit plans with the attached, you will find that it is impossible to believe that a productive effort can be accomplished. If there is some way that you can zero in on what you are looking for, maybe the task at Motorola can be productive. You will then be giving me a realistic task of discussing Motorola's participation with our management. Without that, there is no way your request can be honored in the time available and there is no method by which you and your associates can accomplish your desires within the time available.

Camel Square 4350 East Camelback Road • Phoenix, Arizona 85018 • (602) 244-6900

In addition, I need to know the statutory reference and work scope description applicable to this project from the Interagency Agreement. With that, maybe I can be of some assistance in figuring out what can be done.

Sincerely yours,

H. Theodore Werner

H. Theodore Werner
Senior Division Counsel

HTW/mae
1408.1.6.2

cc: Pat Robinson (w/atch)
Marv Scheunemann (w/atch)
David Sherman

Attachment

Jones

MOTOROLA INC.

July 2, 1981

Ralph I. Mitchell, Project Manager
Environmental Programs Office
Battelle - Columbus Laboratories
505 King Avenue
Columbus, Ohio 43201

Dear Mr. Mitchell:

This is to confirm my conversation with Mr. Jay Jones concerning the proposed visit to Motorola by yourself and representatives of NIOSH. The entire project is deferred until August.

In the interim, you will have to define the scope of your project to meet your ability for the visit and our ability to be a host. We could do this if you would provide us with a copy of the contract under which you are operating and the scope of work and description of the goals for the project.

You indicated in our telephone conversation that the time available for a visit to Motorola would be a matter of hours. Motorola must then insist that the inquiry relate to what you can accomplish in the amount of time provided, i.e. getting preliminary information for areas you can not cover is non-productive. Also, there is no purpose in having a large number of personnel stand by when you can only talk to two or three.

You undoubtedly know far better than I of the microscopic and exact nature of the technology in the semiconductor industry much less the electronics components industry. Each element in each process line relates to other elements. Many items are included because of conditions in that particular area or process. Some items are installed in one location to protect personnel and in other areas to protect product. Sometimes equipment used can accomplish both. Your letter of June 12th seemed initially concerned with exposure to chemical and physical agents. Later, your letter and the attachment seem more like a

Camel Square 4350 East Camelback Road • Phoenix, Arizona 85018 • (602) 244-6900

Department of Commerce survey of the industry. I suggest you select a tour effort on the basis of the type of chemical you desire to investigate.

Motorola is sincerely interested in making this industry a safer place for all concerned and has spent considerable time and money to accomplish that task. It continues to do so on a daily basis. Therefore, it must insist that any program have a realistic opportunity for success and resist efforts to expend time and effort where there is no chance of success.

If you are still interested in visiting Motorola in August, you will have to submit a plan which is realistic for what time and effort you are willing to expend and which provides some connection between what you are attempting to do and what you are doing. The June 12, 1981 proposal fails on both counts.

Sincerely yours,

H. Theodore Werner by [illegible]

H. Theodore Werner
Senior Division Counsel

HTW/mae
1408.1.6.2

cc: Pat Robinson, Motorola

(dictated but not read)

Battelle
Columbus Laboratories
505 King Avenue
Columbus, Ohio 43201
Telephone (614) 424-6424
Telex 24-5454

March 1, 1982

Mr. James H. Jones
National Institute for Occupational
Safety and Health
4676 Columbus Parkway
Cincinnati, Ohio 45226

Dear Mr. Jones:

Enclosed are three copies of the draft preliminary report for Motorola, Inc., Phoenix, Arizona. One copy should be sent to Mr. Ted Werner, Legal Counsel, Motorola, Inc., 5005 East McDowell Road, Phoenix, Arizona, 85008. Also, please forward one copy to Mr. Bob Hartley, Project Officer, U.S. EPA, IERL, 5555 Ridge Road, Cincinnati, Ohio 45268, and retain one for your files. Note that the reports are in a draft stage subject to Motorola, Inc. revisions as outlined in our protocol. Motorola should make revisions and forward those to you. The final preliminary survey report will include their revisions, after which the report can be distributed to the NIOSH and OSHA regional offices. I suggest that this procedure be detailed in your cover letter to Motorola.

Sincerely,

Russ Smith

Russell K. Smith
Associate Manager
Hazardous Materials and Biotechnology/
Chemical Processes Section

RKS:ms

Enc. (3)

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
OFFICE OF RESEARCH AND DEVELOPMENT
INDUSTRIAL ENVIRONMENTAL RESEARCH LABORATORY
CINCINNATI, OHIO 45268

April 8, 1982

Dr. Ralph I. Mitchell
Battelle-Columbus Laboratories
505 King Avenue
Columbus, Ohio 43201

Dear Ralph:

Enclosed is a marked-up copy of the "Draft Preliminary Report on Preliminary Control Technology Survey of Motorola, Inc." The black marks belong to Jay Jones and I'll claim the blue ones. Of course, as in all of these, NIOSH requirements are of first concern.

My comments are much like you have seen before from me. The important ones are written on the cover and consist of two general shortcomings: (1) the potential for exposures at various processes is not discussed well, and (2) work practices are virtually not described. Jay Jones shares the second concern I believe. They should be addressed to the extent possible, realizing of course that going back to the plants is not feasible. This makes these concerns all the more important, of course, in the detailed surveys.

Assuming this report has not gone to Motorola for review, you should clear a revised version through Jay and I prior to sending it to them.

Sincerely,

Bob H.

Robert P. Hartley
Research Program Manager
Alternate Energy Sources Branch
Energy Pollution Control Division

Enclosure

cc: Jay Jones, NIOSH w/encl.
E.F. Harris, w/o encl.

Battelle
Columbus Laboratories
505 King Avenue
Columbus, Ohio 43201
Telephone (614) 424-6424
Telex 24-5454

July 20, 1982

3 each - reports to J. Jones 7/23/82

Mr. Robert P. Hartley
Research Program Manager
Alternate Energy Sources Branch
U.S. Environmental Protection Agency
Energy Pollution Control Division
5555 Ridge Avenue
Cincinnati Ohio 45268

Dear Bob:

Enclosed are four copies each of the revised reports for the following companies:

Motorola, Inc.
Jet Propulsion Laboratory
Texas Instruments

These Preliminary Industrial Hygiene Survey reports are now ready to be sent to the above companies for their comments.

I am also enclosing four copies of the survey report on Optifab, Inc. This report is now final.

Sincerely,

Ralph I. Mitchell
Project Manager
Environmental Programs Office

RIM:llp

Enclosures

Jay Jones: 3 copies each report (2)
5/21/82 - RPH

Battelle
Columbus Laboratories
505 King Avenue
Columbus, Ohio 43201
Telephone (614) 424-6424
Telex 24-5454

May 19, 1982

Mr. Robert P. Hartley
Industrial Environmental Research Laboratory
U.S. Environmental Protection Agency
5555 Ridge Avenue
Cincinnati, Ohio 45268

Dear Bob:

Enclosed are four (4) copies each of the draft preliminary report on the walk-throughs conducted at Motorola, Inc. and OPTIFAB. The Motorola report has been revised in accordance with your guidelines, and should be sent to them for review. The address is:

Mr. G. Theodore Werner
Legal Counsel
Motorola, Inc.
5005 East McDowall Road
Phoenix, Arizona 85062

The OPTIFAB report is prepared in accordance with your suggested format modifications. Please review it, and if you think it is appropriate, transmit it to:

Mr. Robert Loeb
President
OPTIFAB, Inc.
1550 West Van Buren Street
Phoenix, Arizona 85007

Any comments or questions may be directed to me at FTS 976-7441 or to Mr. Russell Smith, FTS 976-5167.

Very truly yours,

Ralph I. Mitchell

Ralph I. Mitchell
Project Officer

xc: Mr. Leslie Ungers, PEDCo, Inc.

RIM:ssf

Battelle
Columbus Laboratories
505 King Avenue
Columbus, Ohio 43201
Telephone (614) 424-6424
Telex 24-5454

March 15, 1982

Mr. Robert Hartley
Industrial Environmental Research
  Laboraotry
U.S. Environmenal Protection Agency
5555 Ridge Avenue
Cincinnati, Ohio 45268

Dear Mr. Hartley:

Enclosed is Battelle's preliminary survey report detailing the walkthrough survey conducted with Mr. James Jones, NIOSH,on November 3, 1981. This copy represents a corrected version of a report provided Mr. Jones on March 1, 1982. Please give him one copy for review.

Provided that you find this report satisfactory, please have NIOSH forward a copy of this report to the following address:

Mr. Ted Werner
Motorola, Inc.
5005 East McDowell Road
Phoenix, Arizona 85008

This report is in draft state, and requires comment by Motorola, Inc. The final report will be prepared based upon direction from NIOSH and USEPA; only then should distribution to NIOSH, OSHA, and EPA regional offices be performed. I suggest this procedure be detailed in Mr. Jones' letter to Motorola.

Very truly yours,

Ralph I Mitchell

Ralph I. Mitchell
Projects Manager

RIM:ms

Enc. (3)

xc: L. Ungers, PEDCo
    S. Rose, RTP