PRELIMINARY SURVEY REPORT

on

CONTROL TECHNOLOGY FOR INTEGRATED CIRCUIT FABRICATION

at

HONEYWELL OPTOELECTRONICS DIVISION
Richardson, Texas

to

U.S. ENVIRONMENTAL PROTECTION AGENCY
INDUSTRIAL ENVIRONMENTAL RESEARCH LABORATORY

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and

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Report No. 115-17a

PLANT SURVEYED:	Honeywell Optoelectronics Division 830 East Arapaho Road Richardson, Texas 75081
SIC CODE:	3674
SURVEY DATE:	December 10, 1981
SURVEY CONDUCTED BY:	Leslie J. Ungers, C.I.H. PEDCo Environmental, Inc. Russell K. Smith, C.I.H. Battelle Columbus Laboratories James H. Jones, C.I.H. NIOSH
EMPLOYER REPRESENTATIVES CONTACTED:	Jim Wilhite, Operations Manager Gary Horton, Facilities Engineer Charles Rosenthal, Purchasing Manager Wayne St. John, Front End Engineering Manager Meyer Levine, Sustaining Engineering Manager
EMPLOYEE REPRESENTATIVES CONTACTED:	None (No Union)

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1.0 ABSTRACT

As part of a U.S. EPA and NIOSH assessment of control practices in industry, Battelle Columbus Laboratories conducted a walk-through survey of Honeywell's Optoelectronic Division facility at Richardson, Texas. This facility manufactures light emitting diodes (LEDs) of the "III-V" (Ga-As and Ga-As-P) types. The purpose of the walk-through was to make some comparisons between the Ga-As industry of the future and current silicon technology.

The process equipment used for processes from wafer receipt through metallization were observed. Control technology for particulates is less stringent than found in conventional silicon plants, because LED circuits are not as microminiaturized. The controls to safeguard human health consisted primarily of general and local ventilation and isolation enclosure of the epitaxy area and gas bottle storage.

The liquid waste handling system was exemplary at this site. The system allows segregation of wastes by placing them in individual containers. The containers are wheeled, which allows them to be pulled out to the waste drumming area. The wastes are pumped into drums from the wheeled containers. In this manner exposure in waste handling operations is minimized. A detailed survey of this site is not recommended, because the control strategy for LEDs is different from microelectronic processes and particulate control in the fabrication areas is not as stringent as it is for conventional microelectronic circuits.

2.0 INTRODUCTION

A preliminary survey was conducted at Honeywell Optoelectronics Division, Richardson, Texas, on December 10, 1981, as part of a control technology assessment of the semiconductor manufacturing industry. The assessment is being performed by Battelle's Columbus Laboratories, under U.S. Environmental Protection Agency (EPA) contract 68-03-3026. The study is being coordinated by EPA with the National Institute for Occupational Safety and Health (NIOSH) through interagency agreement number AR 75-F0-142-0. The survey was conducted by Russell K. Smith of Battelle's Columbus Laboratories and Leslie J. Ungers of PEDCo Environmental. James H. Jones, NIOSH Division of Physical Sciences and Engineering, accompanied the survey team.

This particular facility was selected because it produces GaAs devices. This walk-through survey was conducted to assess the applicability of results from silicon manufacturing processes to GaAs processes, which may one day supplant silicon devices.

The following individuals were contacted at Honeywell Optoelectronics Division:

- Jim Wilhite, Operations Manager
- Gary Horton, Facilities Engineer
- Charles Rosenthal, Purchasing Manager, and
- Wayne St. John, Front End Engineering Manager

A study protocol was provided to Mr. Wilhite prior to the survey. During the opening conference, the study objectives, organization of the study team, study methods, and the reporting methods were discussed. The plant staff provided responses to the applicable protocol questions.

Following the opening conference, the team toured the facility, including the production area, gas and chemical storage area, air handling system, and waste management areas. A closing conference was held following the tour.

3.0 PLANT DESCRIPTION

3.1 General

This plant is a division of Honeywell, Inc., a large manufacturer of electronic devices used for process control and security systems. This facility is involved in the manufacture of high brightness light emitting diodes (LED's) for both government and industrial applications. This facility does not do the circuit design. Instead it subcontracts the circuit engineering and mask production functions. The facility performs all operations on wafers from epitaxy through encapsulation.

This facility produces "III-V" technology products such as Gallium Arsenide (GaAs), Gallium Arsenide Phosphide (GaAP) and Gallium Arsenide Aluminum (GaAsAl) products. Approximately 350 workers are employed in this facility, on one manufacturing shift. Ninety people are involved in actual manufacturing with approximately 20 of these people being involved in actual clean room operation, the rest being involved in packaging and other activities at this site. Facility maintenance functions are generally performed after work hours. The work force is not unionized.

The plant is a 97,000 ft^2 area, with approximately 25,000 ft^2 of area devoted to production. The building is of block and brick construction with concrete floors. The facility was built in 1959 or 1960, and has been modified slightly during the last 21 years.

3.2 Chemical Storage

Chemicals of interest used in this facility comprise those frequently encountered in the semiconductor industry. The usual photoresist chemicals are used. A proprietary compound of xylene and benzene is used for chip cleaning, as is Stoddard solvent.

Wet chemical storage areas were not observed during the walk-through survey. An inventory of all wet chemicals used was not collected. Common wet chemicals used in GaAs technology include phosphoric, hydrofluoric, and sulfuric acids, oxidizers such as xylene, benzene, chlorinated hydrocarbons, and Stoddard solvent.

3.3 Gas Handling System

Gases are stored in a closed room which is at a pressure slightly negative to that of the plant interior. Potentially hazardous gases stored in this room are silane, arsine, phosphine, and sulfur dioxide. Liquid nitrogen is not stored in this area but is provided in tanks in the fabrication area. These gases are piped to the diffusion furnaces and epitaxial reactor in welded stainless steel lines. The exhaust from the room is vented through a fan to the environment. Bulk hydrogen is piped to the furnaces and reactor from a tank on a concrete pad outside the building.

3.4 Waste Management

Acid wastes are drained to a plant system. This system is connected to a plant waste treatment system, where the acids are neutralized with flaked NaOH. The wastes are then piped into the local sanitary sewer system.

Organic chemicals are segregated in wheeled containers. These containers are then taken into an outdoor area behind the plant, where they are emptied into drums for disposal. These drums are picked up periodically by a hazardous waste disposal company for ultimate disposal.

This organic waste disposal system has the potential for reducing employee expsure during waste handling. Because all wastes are segregated in wheeled carts, it also provides the opportunity for waste reclamation should Honeywell elect to do so.

3.5 Monitoring System

In the past, individual Matheson gas detectors were used in the gas storage area and in the epitaxial area. These have been replaced with an Airco multipoint monitoring system.

Hoods have indicating differential pressure monitors for measurement of gas velocity through ducts. These monitors provide for a visual warning only of low gas velocity in a duct.

3.6 Ventilation System

The wafer fabrication facility is operated as a clean room, on the order of a Class 1000 facility. Laminar flow hoods are used only in special operations where dirt is a problem. Operations conducted in laminar flow hoods include silicon nitride deposition, etching, and solvent cleaning. Elephant trunks are used to provide local ventilation at saw stations; a complete enclosure is being designed for sawing. Standard air conditioning is used to control the environmental temperature and relative humidity.

Exhaust ducts are taped rather than being welded or soldered.

4.0 PROCESS DESCRIPTION

Honeywell Optoelectronic Division produces GaAs, GaAsP, and GaAsAl chips for use as light emitting diodes. The processes do not vary significantly between these 3 items.

The wafers used are purchased from an outside source. The wafers are cleaned after they are received in a proprietary xylene/benzene solution. The wafers are then etched using a sulfuric acid, hydrogen peroxide, and water mix, a dionized water rinse, and a isopropyl alcohol clean/dry. The wafers are then predoped in a liquid epitaxy step. In this system, a silicon melt containing GaAs is prepared. The wafers are suspended in contact with the melt. The temperature is slowly dropped, and a thin crystal layer is grown on the wafer.

The wafer is then coated with a silicon nitride layer in a chemical vapor deposition furnace. The nitride is formed in a reaction between oxygen, silane, water vapor, and ammonia in the furnace.

Photoresist application is performed by a silk-screening process. The wafer is then baked in a laboratory oven.

Sulfuric, hydrofluoric, and phosphoric acids are used to wet chemical etch the chip. Ammonium hydroxide and hydrogen peroxide are used in a basic etch. Both etching processes are used at Honeywell Optoelectronics.

Zinc diarsenide solid diffusion is performed in vacuum diffusion furnaces. Nitrogen carrier gas is used to sweep the furnace, which is operated below atmospheric pressure.

Gold-zinc sputtering is performed on the wafer to form a backplane. A radio-frequency source is used. Sputtering is performed in a commercial glass bell-jar unit.

Black chrome plating is also performed. No details were obtained on this process.

The dies are cut from the wafer using conventional radial sawing techniques. The dies are encapsulated in purchased plastic housings which are hermetically sealed. The final chips are checked for quality control.

5.0 DESCRIPTION OF PROGRAM

5.1 Industrial Hygiene Program

Honeywell Optoelectronics has no routine industrial hygiene program. Corporate capabilities support this plant on an as-required basis.

5.2 Education and Training Program

There is no formal program for individual job training. Informal individualized training is performed by the supervisor and team leaders. A supervision to employee ratio of 1 supervisor to 8.5 employees allows the supervisor to perform this training.

Procedures to be used for each process step are spelled out in a written operating procedure. Employees are required to follow these procedures on job functions. Quality control specialists monitor 5 procedures, selected on a random basis, each day.

Respirator training is provided to new employees during an orientation briefing. Fire and evacuation training consists of quarterly training and drills conducted by process supervisors. Employees are encouraged to report job hazards through a telephone emergency number. This number is answered 24 hours/day.

5.3 Medical Program

Guards are on call for emergency assistance 24 hours/day. Two Emergency Medical Technicians (EMT's) are on site during operation. Two treatment rooms are available for the EMT's. The rooms are stocked with normal first aid materials, and have bottled O_2 available. A physician is on-call 24 hours/day.

Physicals are not performed on new employees. All employees performing sawing operations have a quarterly urinalysis for As conducted.

5.4 Personnel Protection Program

Smocks, gloves, and safety glasses are required in all fabrication areas. Three types of gloves are available, depending on whether heat, acids, or conventional solvents are being handled. Acid-resistant aprons are worn when handling acids. Safety shoes are required only in shipping areas; no open-toed shoes are allowed in the fabrication areas.

Scott AIR PAK respirators are available in case of an emergency. The respirators are mounted on the walls in the plant. New employees are trained to use these respirators in an initial orientation briefing.

6.0 DESCRIPTION OF CONTROL STRATEGIES FOR PROCESSES OF INTEREST

6.1 Wafer Cleaning

Wafer cleaning is done in a dip process, where a wafer is dipped into a beaker of solvent. This process is performed in a laminar flow hood. Tongs are used for dipping wafers. The wafer is then washed with isopropanol from a wash bottle and allowed to dry. Rinse solutions are collected in a organic liquid waste container.

6.2 Wafer Etching

Wafer etching is performed in a bench top container using a mixture of hydrogen peroxide, sulfuric acid, and water. The wafer is then rinsed by deionized water from a wash bottle, and isopropyl alcohol to dry the water.

6.3 Epitaxial Growth

Epitaxial growth is performed in an enclosed reactor. Wafers and solid epitaxy materials are placed in the reactor. The reactor is then heated, and the wafers are lowered to the surface of the melted epitaxy material. The reactor is slowly cooled, and an epitaxy layer forms on the wafer.

The process vessel is vented through a scrubber which uses waste vacuum pump oils to collect contaminants in the effluent. The gases from both the epitaxy room and the process are then exhausted to the atmosphere. The enclosure is maintained under negative pressure. The enclosure is monitored for As emissions from the reactor.

6.4 Silicon Nitride Deposition

Si_3N_4 is deposited on the wafer in a CVD-type tube furnace. The wafers are placed in a carrier, and inserted into a horizontal tube furnace using a push rod. After deposition of the Si_3N_4 layer, the carrier is removed by pulling it out using the same rod. Wafers are allowed to cool in a rack adjacent to the furnace. Both the rack and the furnace are contained in a laminar flow hood.

After cooling, the wafers are removed from the carrier by an operator wearing gloves.

The furnace is ventilated at the tube end near the operator by variable slots around the tube.

6.5 Photoresist Application

A wafer is placed under a silk screen by the operator. Photoresist material is screened onto the wafer using a squeegee for application. The wafer is then baked in a laboratory oven to fix the resist material.

This process is performed on a bench top. Solvent emissions are controlled only by general ventilation of the process area.

6.6 Chemical Etching

Chemical etching is performed using a mix of sulfuric acid, hydrogen perioxide, and deionized water. Wafers are placed in carriers which are in turn placed in a bath containing the etch solution. Carriers are removed from the bath, and placed in a deionized water bath for rinsing. An isopropyl alcohol rinse of each wafer is used to aid in drying the wafer.

6.7 Metallization

Two metal deposition processes are used by Honeywell in this plant. Black chrome and gold deposition are performed.

Gold deposition is performed in a bell jar. Wafers are loaded manually into the apparatus, and a vacuum is drawn. Exhaust vapors pass through a vacuum pump, and are exhausted to the room. Gold vapor is generated by a radio-frequency source. The equipment is all RF shielded.

The bell jar is cleaned periodically with a vacuum cleaner to remove gold dust. The jar is also periodically wiped with a towelette to remove excess material.

The black chrome processes were not observed during the walk-through survey.

6.8 Wafer Cutting

Dies are cut from wafers using internal radius circular saws. The dust generated is exhausted through elephant trunks and scrubbed in a venturi-type scrubber using waste oil. An enclosure for the cutting process is being designed.

6.9 Encapsulation

Wafer encapsulation is performed using hermetic and plastic encapsulation. These processes were not observed during this survey.

7.0 CONCLUSIONS AND RECOMMENDATIONS

Based on this survey, and comparison to typical silicon wafer production, particulate controls found in this plant are much less stringent than would be found in GaAs microcircuit production. Therefore, a detailed survey is not recommended for this site, because the results could not be correlated to microcircuit production using GaAs technology.

Manual handling of wastes at this site is minimized by using color-coded carts to drop wastes into. These carts are towed to the waste storage area, and pumped into disposal drums. In this manner, wastes are segregated for disposal, and could potentially be recovered to reuse here or in another industry. Further evaluation of this particular concept should be conducted by the electronics industry to benefit both waste recovery and reduce worker exposure.

It is recommended that this plant consider an air monitoring program on the wafer sawing operations. This will allow better evaluation of potential exposure to As than the quarterly urinalysis.

Solvent vapor concentration should be measured at the silk screening and drying station to determine worker exposure to solvents in photoresist chemicals. Local ventilation at these stations will also reduce odors in the work area.

Area sampling and dosimetry for benzene and other solvent compounds should also be initiated for characterizing the potential exposure to these compounds.

Retention of an industrial hygiene consultant to provide a documented industrial hygiene program is recommended.