



UNIVERSITI PUTRA MALAYSIA

**OCCUPATIONAL SAFETY AND HEALTH OF WOMEN WORKERS IN
SEMICONDUCTOR ASSEMBLY IN RELATION TO CHEMICAL
EXPOSURE**

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By

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**Thesis Submitted in Fulfilment of the Requirement for the Degree of Master of
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Abstract of thesis submitted to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science.

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Chairperson: Associate Professor Chee Heng Leng, Ph.D.

Faculty: Medicine and Health Sciences

Semiconductor assembly is a chemical intensive industry. Some of the chemicals involved in the assembly of chips have been reported to cause health problems to the workers. This study was carried out to examine the health problems of the workers in relation to the chemicals that they used. The study was carried out in 12 semiconductor factories in the Bayan Lepas Free Trade Zone, Penang. The study comprised of four stages, (i) management survey, (ii) factory walk-through, (iii) worker survey using structured questionnaire and (iv) an interview with the safety and health officer on chemical safety management. A total of 655 women workers participated in the study. Results showed that the used of chemicals by respondents was associated with work sections ($X^2 = 94.05$, $p < 0.001$), with middle of line (68.3%) having relatively higher number of respondents who use chemicals compared to front of line (37.9%) and end of line (21.4%). Results also showed that skin itchiness (31.5%, $n=222$) was the most common general health complaint, followed by eye problem (20.3%) and breathing difficulty (19.4%). In terms of reproductive health complaints, spontaneous abortion



(11.8%, n=296) was the most common complaint, followed by premature birth (5.4%) and low birth weight (5.1%). The only health complaints that were significantly associated with work sections were skin itchiness, eye problem, breathing difficulty, chest pain and nausea/vomitting. The three most commonly cited chemicals for skin itchiness, isopropyl alcohol, mold and acid (plating), showed significant association with skin itchiness ($p < 0.001$). However, spontaneous abortion showed no association with the use of chemicals. Given that skin itchiness was the most common health problem in this industry, a good chemical management policy is required. Although spontaneous abortion was not significantly associated with the use of chemicals, it does not rule out the possibility of the inherent reproductive hazards of some of the chemicals.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi sebahagian daripada keperluan untuk mendapatkan ijazah Master Sains

KESELAMATAN DAN KESIHATAN PEKERJA WANITA DI KILANG SEMIKONDUKTOR BERKAITAN DENGAN PENDEDAHAN KEPADA BAHAN KIMIA

Oleh

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Kilang semikonduktor merupakan salah satu jenis kilang yang intensif dalam penggunaan bahan kimia. Sebahagian daripada bahan kimia dalam pemasangan chip dilaporkan sebagai penyebab masalah kesihatan kepada pekerja. Kajian ini dijalankan untuk mengkaji perhubungan di antara bahan kimia yang digunakan dan jenis masalah kesihatan pekerjaan. Ia dijalankan di kawasan Zon Bebas Cukai Bayan Lepas, Pulau Pinang. Kajian ini meliputi empat tahap, iaitu (i) survei personel pengurusan, (ii) “*walk-through*” kilang, (iii) survei pekerja dan (iv) temuduga dengan pegawai keselamatan dan kesihatan pekerjaan. Seramai 655 pekerja wanita terlibat dalam survei ini. Keputusan menunjukkan penggunaan bahan kimia oleh pekerja adalah berhubung secara signifikan dengan bahagian kerja ($X^2=94.05$, $p<0.001$), dengan bahagian *middle of line* (68.3%) melaporkan jumlah yang paling besar berbanding dengan *front of line* (37.9%) atau *end of line* (21.4%). Keputusan juga menunjukkan bahawa kegatalan kulit (31.5%, $n=222$) merupakan masalah kesihatan yang utama bagi kategori masalah kesihatan am, diikuti oleh masalah mata (20.3%) dan kesukaran pernafasan (19.4%). Bagi kategori masalah



kesihatan reproduktif, keguguran spontan (11.8%, n=296) merupakan masalah kesihatan yang utama diikuti oleh *premature birth* (5.4%) dan *low birth weight* (5.1%). Masalah kesihatan yang menunjukkan perhubungan yang signifikan dengan bahagian kerja ialah kegatalan kulit, masalah mata, kesukaran pernafasan, kesakitan dada dan pening/muntah. Tiga bahan kimia yang biasa dilaporkan untuk kegatalan kulit, *isopropyl alkohol*, *mold* and *asid (plating)* menunjukkan perhubungan yang signifikan dengan kegatalan kulit ($p < 0.001$). Di samping itu, keguguran spontan tidak menunjukkan sebarang perhubungan dengan penggunaan bahan kimia di tempat kerja. Disebabkan kegatalan kulit merupakan satu penyakit yang biasa di jenis kilang ini, satu program pengurusan bahan kimia yang sempurna adalah perlu. Walau keguguran spontan didapati tidak berkaitan dengan penggunaan bahan kimia, ini tidak mengabaikan kemungkinan risiko reproduktif yang terdapat dalam sesetengah bahan kimia.

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*Concern for man himself and his fate must always form
the chief interest of all technical endeavour.
Never forget this in the midst of your diagrams
and equations (Albert Einstein).*

Ng Wei Kiang
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GLOSSARY OF TERMS

Active components Electronic components, such as transistors, diodes, etc., which can modify the current supply to it through rectification, amplification or switching operations.

Assembly The step in semiconductor manufacturing in which the device is encased in a plastic, ceramic, or other package. In some cases, the chip is assembled directly on a printed circuit board.

Ball grid array package For very high speed integrated circuit, a package embodying a rather novel technology in which solder-contact pads are not just around the package periphery (as with chip carrier), but cover the entire bottom surface in checkerboard fashion. Also known as pad array carrier (PAC), pad array package, land grid array, or pad-grid array package.

CERDIP Acronym for Ceramic Dual In-Line Package. The package is composed of a ceramic header and lid, a stamped-metal lead frame, and a frit glass that is used to secure the structure

Chip carrier An integrated circuit package, usually square, which may have a cavity for the chip in the center. Its connections are usually on all four sides

Chemical exposure The contact of a person with the chemicals through inhalation, ingestion, absorption or injection during the time of work.

Chip Also called a die. Popular term describing a section of a wafer that contains a discrete component or an integrated circuit. Many chips are made on a single wafer, then separated into dice and packaged individually.

Chip On Board (COB) COB is an advanced Direct Chip Attach (DCA) process. This process incorporates the use of bare silicon die without the associated package, and attached the bare die directly to Printed Circuit Board (PCB). The bare die is electrically connected to the PCB by using either wire bonding technique or Flip Chip technique. Also called Chip-on-Substrate (COS).

Company ownership A company is deemed to be non-resident controlled where a) 50% or more of its paid-up capital is held by non-residents, b) It is a branch of a company incorporated outside Malaysia e.g. multinational corporation, c) The majority shareholding is held by residents, but the ultimate right of control is held by non-residents.

Cure To change the physical properties of a material (usually from a liquid to a solid) by chemical reaction or by the action of heat and catalysts, alone or in combination, with or without pressure.

Curing agent Agent used to form crosslinking or catalyzing the formation of a thermoset plastic.

Die bond Mechanical attachment of the silicon die or chip to the substrate usually by solder, epoxy, or gold-silicon eutectic. The die bond is made to the back (inactive) side of the chip with the circuit side (face) up.

Dual-in-Line package (DIP) A package having two straight, parallel rows of leads extending at right angles from the base and having standard spacings between leads and between rows of leads.

Electronics A branch of physics and technology concerned with the behavior and movement of electrons in a vacuum, gas, semiconductor, etc. It is also refer to circuits that used this technology.

Encapsulate Sealing or covering an element or circuit for mechanical and environment protection. Typical encapsulating materials are potting, glob top and molding compound.

Fine leak test A test to establish the integrity of a given device package by measuring the leak rate of the package under specified conditions. It usually employs a tracer gas as the test medium.

Flip chip A chip that has bumped terminations spaced around the device and is intended for facedown mounting.

Flip-chip attachment A method of attaching a device to a substrate in which the device is flipped so that the connecting conductor pads on the surface of the device are set on mirror-image pads on the substrate and bonded by reflowing the solder.

Hermetic Sealed so that the object is gas tight. A plastic encapsulation cannot be hermetic as it allows permeation by gases.

Integrated circuit (IC) A microcircuit consisting of interconnected elements inseparably associated and formed in situ on or within a single substrate to perform an electronic circuit function.

Large Scale Integrated (LSI) chip This term used to describe semiconductor chips with more than 1000 circuit.

Lead frame The metallic portion of the device package that completes the electrical connection path from the die or dice and from ancillary hybrid circuit elements to the outside world.

Malaysia Industrial Classification (MIC) A list coding industrial work into a series of numbered categories. Also called Standard Industrial Classification (SIC).

MSDSs (Material Safety Data Sheets) Also called chemical safety data sheets (CSDSs). Pamphlets required by the hazard communication standard that lists the identity of chemicals, hazard information, and information about the manufacturer.

Multinational Corporation A company that has two or more offshore subsidiaries.

Occupational injury This refers to any injury such as cut, fracture, sprain, strain, amputation, etc., which results from a work event or from a single *instantaneous* in the work environment.

Occupational illness This refers to any abnormal condition or disorder, other than one resulting from an occupational injury, caused by exposure to factors associated with employment. It includes acute and chronic illnesses or disease, which may be caused by inhalation, absorption, ingestion, or direct contact of health hazards.

Output growth The increment (or changes) in the amount produced in a particular time, normally in a year.

Package In the electronics/microelectronics industry, an enclosure for a single element, an integrated circuit, or a hybrid circuit. It provides hermetic or nonhermetic protection, determines the form factor, and serve as the first level interconnection externally for the device by means of package terminals. A package generally consists of a bottom part, called the case or header, and a top part, called the cover or lid. These are sealed into one unit. Passive parts may be enclosed in an encapsulant or molded package.

Package delay Time delays associated with the interconnections between components in circuit that make up a logical function.

Passive components (elements) An electronic circuit element that displays no gain or control, such as a resistor, inductor, or capacitor.

Plastic A polymeric material, either organic, such as epoxy and polyimide, or inorganic, such as silicone, used for conformal coating, encapsulation, or overcoating.

Plating The process of the chemical or electrochemical deposition of metal on a surface.

Quad in-line package (QUIP) A diplike plastic package with leads coming out in two rows. Half of the leads are bent close to the body and the other half projected out for additional 1.27 mm before being bent down.

Reflow soldering A process for joining parts by tinning the mating surfaces, placing them together, heating until the solder fuses, and allowing them to cool in the joined position.

Resin An organic polymer that cross-links to form a thermosetting plastic when mixed with a curing agent.

Risk phrases Phrases that describe the risks of a substance. Risk phrases are divided into physico-chemical risk phrases, environmental risk phrases and health effect risk phrases.

Semiconductor A class of materials, such as silicon and germanium, whose electrical properties lie between those of conductors (such as copper and aluminum) and insulators (such as glass and rubber). A material that exhibits relatively high resistance in a pure state and much lower resistance when it contains small amounts of certain impurities. The term is also used to denote electronic devices made from semiconductor materials.

Single chip module (SCM) A package supporting one chip, as opposed to a multichip which supports several.

Small Outline Package (SOP) Also called SOIC (small outline integrated circuit package). A plastic molded lead frame package with leads on two sides similar to a dual-in-line package but smaller with leads on 1.27, 1.0 or 0.85 mm spacing. It is meant for surface mounting.

Solder A low melting point alloy, usually of lead (Pb)-tin (Sn), that can wet copper, conduct current, and mechanically join conductors and so on.

Solder bumps The round solder balls bonded to a transistor contact area and used to make connection to a conductor by face-down bonding techniques.

Substrate In the hybrid industry, that which is used as a base material, usually aluminium oxide (alumina).

Surface Mount Technology (SMT) A method of electrically and mechanically connecting components to the surface of a conductive pattern (e.g. as on a printed circuit board) without using through holes.

Value added This refers to an increment in value at each state in the production of a good which means the value of output minus value of the inputs.

Very large scale integrated (VLSI) chip Referring to a single semiconductor chip with more than 10,000 transistors. The upper boundary is not well defined.

Wave soldering A process in which printed boards are brought in contact with the surface of continuously flowing and circulating solder. Also called mass soldering.

Yield The ratio of the number of acceptable items produced in a production run to the total number that were attempted to be produced (i.e., started in the production run).

Sources:

Gedney RW (1995).

Harper CA & Miller MB (1993).

Mohd Nazari Ismail (1998).

McCurdy SA *et al.* (1991).

David CR (1997).

DOSH (1997a).

DOSH (1997b).

DOSH (1997c).

List of Chemicals Found in Semiconductor Assembly

a. Cleaning Solvents

- Alcohol (isopropyl alcohol)
- Chlorinated hydrocarbons (tetrachloroethane)
- Ketones (acetone)
- Halogenated hydrocarbons (freon)

b. Electroplating

- Acid (nitric acid, hydrochloric acid)
- Alkali (ammonia)
- Lead
- Tin

c. Bonding

- Uncured resins (formaldehyde)
- Epoxy resin fillers (asbestos, fiberglass)
- Resin modifiers and thinner (aromatic hydrocarbon, ketone)
- Curing agents (amines, anhydrides, phenol compound)

d. Encapsulation

- Ceramics (aluminum silicates)
- Plastic (polyvinyl chloride)
- Fillers (asbestos)
- Epoxy resin
- Paints/Inks (dyes, solvent)

e. Soldering

- Tin
- Lead
- Non-corrosive flux
- Corrosive flux (organic acids, corrosive acids and alkalis)

Sources:

Gassert (1985).

NIOSH USA (1985).

List of Chemicals Prohibited in Malaysia

(Prohibited under the prohibition order issued by Director General of Department of Occupational Safety & Health (DOSH), Malaysia on 2 August 1999).

Name of Substance	Scope of Prohibition
4-Aminodiphenyl, Benzidine, 2-Naphthylamine, 4-Nitrodiphenyl; their salts and any substance containing any of these compounds, in any other substance in a total concentration exceeding 0.1 percent	Manufacture and use for all purposes including any manufacturing process in which any of the substances described above is formed, except for research and analytical purposes
White Phosphorus	Use in the manufacturing of matches
Benzene	Cleaning and degreasing purposes
Carbon disulphide, Carbon tetrachloride and n-Hexane	Cleaning and degreasing purposes
Crocidolite	All purposes except for research or analytical purposes

Source:

Occupational Safety and Health (Prohibition of Use of Substance) Order 1999.

List of Chemical Risk Phrases

R1:	Explosive when dry.
R2:	Risk of explosion by shock, friction, fire or other sources of ignition.
R3:	Extreme risk of explosion by shock, friction, fire or other sources of ignition.
R4:	Forms very sensitive explosive metallic compounds.
R5:	Heating may cause an explosion.
R6:	Explosive with or without contact with air.
R7:	May cause fire.
R8:	Contact with combustible material may cause fire.
R9:	Explosive when mixed with combustible material.
R10:	Flammable
R11:	Highly flammable
R12:	Extremely flammable
R14:	Reacts violently with water.
R15:	Contact with water liberates extremely flammable gases.
R16:	Explosive when mixed with oxidizing substances.
R17:	Spontaneously flammable in air.
R18:	In use, may form flammable/explosive vapor-air mixture.
R19:	May form explosive peroxides.
R20:	Harmful by inhalation.
R21:	Harmful in contact with skin.
R22:	Harmful if swallowed.
R23:	Toxic by inhalation.
R24:	Toxic in contact with skin.
R25:	Toxic if swallowed.
R26:	Very toxic by inhalation.
R27:	Very toxic in contact with skin
R28:	Very toxic if swallowed.
R29:	Contact with water liberates toxic gas.
R30:	Can become highly flammable in use.
R31:	Contact with acids liberates toxic gas.
R32:	Contact with acids liberates very toxic gas.
R33:	Danger of cumulative effects.
R34:	Causes burns.
R35:	Causes severe burns.
R36:	Irritating to eyes.
R37:	Irritating to respiratory system.
R38:	Irritating to skin.
R39:	Danger of very serious irreversible effects.
R40:	Possible risks of irreversible effects.
R41:	Risk of serious damage to eyes.
R42:	May cause sensitization by inhalation.
R43:	May cause sensitization by skin contact.
R44:	Risk of explosion if heated under confinement.
R45:	May cause cancer.
R46:	May cause heritable genetic damage.
R48:	Danger of serious damage to health by prolonged exposure.
R49:	May cause cancer by inhalation.
R50:	Very toxic to aquatic organisms.
R51:	Toxic to aquatic organisms.
R52:	Harmful to aquatic organisms.
R53:	May cause long-term adverse effects in the aquatic environment.
