EE407 Introduction to Microfabrication

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Text: Jaeger: Introduction to Microelectronic Fabrication

Course Objectives

- Introduce the student to cleanroom protocol
- Inform the student of hazards in the cleanroom
- Introduce the student to the techniques and equipment used in the microfabrication process
- Fabricate working transistors

Graded Material

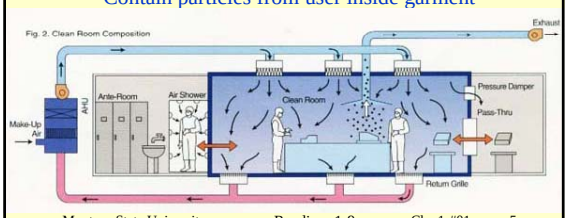
- Homework (25%)
- Laboratory Journal (25%)
  - Cleanroom Notebooks can be purchased in the EE stockroom
  - Each student will need to purchase tweezers from the EE stockroom
  - CMOS Lab Manual
- Midterms (25%)
- Laboratory Report: IEEE Journal Format (25%)
  - Summarize your results
  - Postulate what went wrong
  - Discuss improvement options

Lectures and Lab

- Typical week will include
  - Lecture on laboratory process step and equipment use
  - Lecture on theory of the process step
  - Laboratory
    - Scheduled for 2 hours but can take longer for some process steps
    - Schedule other sections (8 students➔3 sections)
      - T 10am (4)
      - T 1pm (3)
      - Θ 10am (0) empty
      - Θ 1pm (2) Can these 2 students move to either Tuesday section?

Clean room

- Clean filtered air in
- Dirty air out
- Minimize particle generation inside
- Contain particles from user inside garment



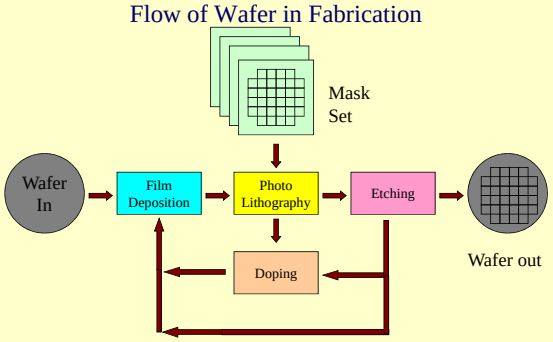
Clean room Apparel

- Designed to minimize particle shedding
- Our apparel is a subset of shown in Cobleigh
  - Hair Cover (Bouffant)
  - Frock
  - Gloves
  - Blue Booties
  - Shoe Cover

Lab Journal Notebook

- Clean room paper notebook
- A **complete** record of the work done for this class
  - Print out the CMOS Lab Manual
    - Record **all** steps and results
    - Date and sign your lab manual before you leave.

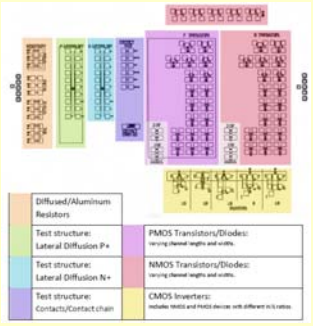
Flow of Wafer in Fabrication



Devices in Mask Set

- Transistors of various sizes
  - p-type
  - n-type
- Contacts
  - Metal to semiconductor
- Inverters
  - Balanced
  - Unbalanced
- Lateral Diffusion Tests
- Resistors of various sizes
  - n+
  - p+
  - Metal
  - n-well

Die Layout



interesting sites

- http://www.dbanks.demon.co.uk/ueng/
- http://jas.eng.buffalo.edu/
- www.icknowledge.com
- http://www.ee.byu.edu/cleanroom/index.phtml

References

- Jaeger, R. C., *Introduction to Microelectronic Fabrication 2e*, Prentice Hall, 2002.
- Wolf, S., *Microchip Manufacturing*, Lattice Press, 2004.
- Runyan, W. R., Bean, K. E., *Semiconductor Integrated Circuit Processing Technology*, Addison Wesley, 1990.
- Plummer, J. D., Deal, M. D., Griffin, P. B., *Silicon VLSI Technology*, Prentice Hall, 2000.
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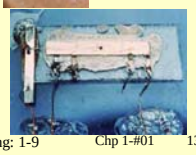
- Campbell, *Fabrication Engineering at the micro and nano scales*, Oxford, 2008.

History of the IC

- 1945 point contact transistor invented

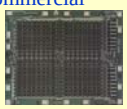
- 1951 junction transistor
- 1958 integrated circuit
  - 5 component oscillator



History Continued

- 1959 Planar technology

- 1970 First commercial DRAM (1K)

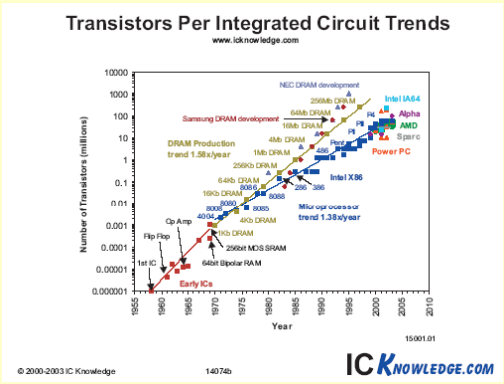


- 1971 first microprocessor Intel 4004

Scaling

- Wafer size going up → more surface area
- Feature size going down → smaller devices
- Net results → price reduction

	1990	1995	2000
DRAM's	4MB	64MB	1GB
Feature size	0.8µ	0.35µ	0.15µ
Wafer Diameter	6"	8"	12"
Cost/MB	$6.50	$3.14	$0.10



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Chemical Safety

Hazardous Materials Identification System

Color Coding

- Blue – Health
- Red – Flammability
- Yellow – Reactivity
- White – Personal Protection

Degree of Hazard

- 4 Extreme
  - Very short exposure could cause death or major residual injury even with prompt medical attention
- 3 Serious
  - May cause serious temporary or residual injury even with prompt medical attention
- 2 Moderate
  - Intense or continuous exposure could cause temporary incapacitation or possible residual injury unless prompt medical attention is given
- 1 Slight
  - May cause irritation but only minor residual injury even without treatment
- 0 Minimal
  - No chemical is without some degree of toxicity

Flammability Ratings

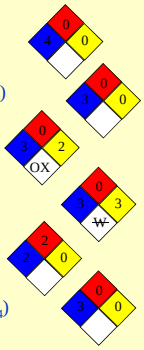
- 4 Extreme
  - Extremely flammable with flashpoint below 73ºF (22.8ºC)
- 3 Serious
  - Flashpoint between 73-100ºF (22.8-37.8ºC)
- 2 Moderate
  - Flashpoint between 100-200ºF (37.8-93.4ºC)
- 1 Slight
  - Flashpoint above 200ºF (93.4ºC)
- 0 Minimal
  - 1500 ºF (815.5ºC) for five minutes

Reactivity Ratings

- 4 Extreme
  - Can explode or decompose violently at room temperature and pressure
- 3 Serious
  - Can detonate or explode but requires a strong initiating force or confined heating
- 2 Moderate
  - Normally unstable and readily undergoes violent change but does not detonate
- 1 Slight
  - Normally stable material but becomes unstable at elevated temperature or pressure
- 0 Minimal
  - Normally stable and not reactive with water

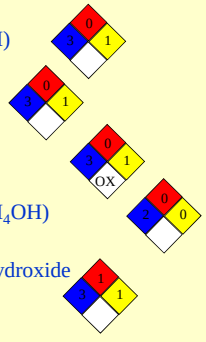
Acids

- Hydrofluoric Acid (HF)
- Hydrochloric Acid (HCl)
- Nitric Acid (HNO_3)
- Sulfuric Acid (H_2SO_4)
- Acetic Acid ($C_2H_4O_2$)
- Phosphoric Acid (H_3PO_4)



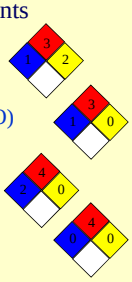
Bases

- Potassium Hydroxide (KOH)
- Sodium Hydroxide (NaOH)
- Hydrogen Peroxide (H_2O_2)
- Ammonium Hydroxide (NH_4OH)
- Tetramethyl Ammonium Hydroxide
  - (TMAH) $(CH_3)_4NOH$



Solvents

- Acetone (C_3H_6O)
  - $(CH_3)_2CO$
- Isopropyl Alcohol (C_3H_8O)
  - $CH_3CHOHCH_3$
- Methanol (CH_4O)
  - (CH_3OH)
- Ethanol (C_2H_6O)



Hydrofluoric Acid

- Extremely dangerous liquid and vapor
- Causes severe burns which may not be immediately painful or visible
- Reaction with some metals causes release of hydrogen gas (always use under fume hood)
- Main active ingredient in BOE (Buffered Oxide Etch) used to etch silicon dioxide

HF dermal exposure

- Highly corrosive
- Readily penetrates skin
- Causes deep tissue destruction
- Severity of symptoms depend on:
  - Concentration
  - Duration of exposure
  - Penetrability of the exposed tissue
- Pain may be delayed

HF concentration

- Less than 20%
  - Erythema (redness) and pain maybe delayed 2-24 hours
  - Often not reported until tissue damage is extreme
- 20%-50%
  - Erythema (redness) and pain maybe delayed 1-8 hours
  - Often not reported until tissue damage is extreme
- Greater than 50%
  - Produces immediate erythema, pain and tissue damage

Mechanism of HF toxicity

- Upon penetration into the body, HF dissociates into a hydrogen ion and fluoride ion
- The fluoride ion affects tissue by:
  - Liquefaction Necrosis (kills the tissue by turning liquid)
  - Decalcification (removes calcium, Hypocalcemia)
    - Precipition of CaF_2 in the blood
    - Quickly fatal- important for cardiac muscles
  - Destruction of bone
    - Loss of calcium from bone as body tries to equilibrate serum calcium
  - Produces insoluble salts

HF Decontamination

- Remove all exposed clothing taking necessary precautions to prevent self exposure
- Immediately wash all exposed areas with copious amounts of water (15 minutes)
- Apply calcium gluconate or calcium carbonate gel
  - Know where the calcium gluconate tube is kept
  - If on hand place in clean room glove with generous amounts of gel
  - If other areas rub generous amounts into burned area
  - Only use on dermal areas
- All HF exposure requires a medical follow up

HF properties

- Never put HF in a glass container it is used to etch silicon dioxide (glass) in semiconductor fabrication
- HF will also etch concrete giving off a dangerous gas, if spilled on the floor, evacuate and call the MSU police x-2121 or call 911 and state the nature of the emergency
  - Give them your name, location: (Cobleigh 523 extension x-3140 or EPS 107 extension x-3470)

Nitric Acid

- Inhalation
  - Damage to the mucus membranes and upper respiratory tracts
  - Irritation of the nose and throat, labored breathing, pulmonary edema (watery swelling of the lungs)
  - Pulmonary Edema → Delayed Effects
    - Onset can be several hours after exposure
    - Initial symptoms – sore throat & coughing
    - Characterized by frothy pink sputum
    - Fatal if untreated
  - Exposure that causes coughing should have follow up with physician

Solvents/Organics (Use under hood)

- Includes Photoresists and Resist removers
- Exposure Symptoms:
  - Headache, Dizziness, Nausea, Fatigue
  - Over exposure leads to Sleepiness, Coma, Death
- Mechanism
  - Asphyxiation by replacing O_2 and reducing the blood's ability to carry O_2
  - Central nervous system: Body "forgets" to breathe
- Long term exposure
  - Effects liver and kidneys, blood forming tissue, and nervous system
  - Some solvents are known carcinogens (cancer causing)
  - Birth Defects

Others (not currently in our clean room)

- Dimethyl sulfoxide (DMSO) in some resist removers
  - Used as a carrier for experimental drugs
  - Penetrates skin and latex, "carrying" whatever it contacts into the bloodstream
- Cyclohexanone in negative resist
  - Contains proprietary "sensitizers" that can cause immune reactions and asthma
- Potassium Cyanide in some gold etches
  - Cyanide poisoning
- Silane (SiH_4) used for polysilicon deposition
  - $SiH_4 \rightarrow Si+2H_2$
  - Pyrophoric gas→ usually ignites upon contact with air

Piranha

- Used to remove organic materials from substrate
- Acid Piranha
  - 3:1 Sulfuric Acid: Hydrogen peroxide
  - Self starting exothermic reaction (gives off heat and hydrogen gas)
  - Can accelerate out of control (burn, explode)
- Base Piranha
  - 3:1 Ammonium Hydroxide: Hydrogen peroxide
  - Heat to 60ºC to start reaction
  - Can accelerate out of control with sufficient fuel (PR)
- Piranha Safety Equipment:
  - Face shield, acid gloves, acid apron
- Allow to open container to cool before disposal

Safety First

- Wear long pants, no shorts or skirts
- Wear closed toe shoes, no sandals
- Avoid wearing contacts in clean room
- Label every container used with
  - Chemical
  - Time and Date
  - Name
- Clean up after yourself
- No food or drink in the lab
- Know the position of
  - Emergency shower
  - Eye wash
  - Calcium cream
- Report any chemical spills
- Know the emergency number- 911

Acid Safety

- Always wear safety glasses and chemical resistant gloves.
- Always Add Acid to water (AAA). Pour acids in slowly. Unwanted reactions may occur if mixed incorrectly.
- Don't inhale any fumes in the lab. Always use chemicals under a fume hood.
- After mixing acid solutions make sure they are cooled to room temperature before capping. This is to avoid pressure build up in the bottle.
- Make sure acid bottles are always capped.
- Acids and solvents have to be disposed of in their respective disposal bottle.
- If any acid is spilled on your person, rise thoroughly with large quantities of water. **Report the occurrence to the lab instructor immediately.**
- When using HF always use plastic. Don't use any glass. The glass will be etched then unusable.

Solvent Safety

- **DO NOT MIX ACIDS AND SOLVENTS.** Mixing them can cause highly explosive solutions, or other unwanted reactions.
- Solvents are not to be poured down the sink. The Lab instructor will show you the proper way to dispose of them. They go into the solvent waste bottle if there is not a specific bottle for it.
- Always use solvents in a fume hood. Most of the solvents fumes have some sort of toxic property.
- Don't get solvents on your skin. Most are readily absorbed through your skin and some are carcinogenic.
- Photoresist contains these solvents so handle photoresist with the utmost care.
- In general solvents are flammable. So be very careful around ignition sources.
- Do not allow solvent fumes to come near an ignition source.
- Always wash gloves after handling solvents, so that if the gloves come in contact with acids there in not chemical reaction.
- Don't use the same gloves for handling solvents and acids.

Clean Room Emergency

- Vacate the room
- Call the professionals