Particle Contamination: human beings in cleanrooms

- All exposed parts of our body and cloths carry contaminants
  - Skin
  - Exhalation

  } **Fats, salts, bacteria & fungi**
  - Hair
  - Apparel
  - Costumes

  } **Hair, particles & fibers**
- Wear lint free bunny suits, hair nets, goggles, hand gloves – do not expose any part of your body in clean rooms
- In a specific order – cover up starting from the head down
- Reduce the presence of human beings in clean rooms – more automation

Wafer cleaning

- Clean wafers of various contaminants which are introduced during processing or storage or both
  - Ionic, example: Potassium from CMP slurry, Sodium from handling
  - Non ionic, example: polishing agents in CMP slurry, materials used in filtration
  - Organic, example photo resist
- Should remove contaminants but should not attack films which are already on the wafer
  - Strongly acidic and basic solutions are used in Silicon processing. However they would attack metals used for making contacts and interconnects. Organic solvents are used for cleaning after metals are introduced.
- Should not introduce contaminants

Clean water

- Used for cleaning of wafers
  - diluent of acids and bases
  - removal of acids and bases from wafer surfaces
- Should remove other chemicals quickly
- Should not introduce contaminants on its own
- Ultra high purity water is an excellent solvent => can dissolve material from piping, can dissolve gases from air etc
- 99.5 % by volume of all liquid chemicals used in semiconductor manufacturing
- Contaminants in supply water
  - Ionic
  - Non ionic
  - Organic
  - Bacteria
  - Dissolved gas

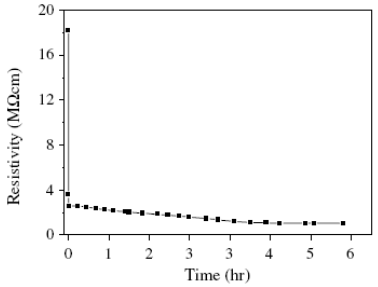
Deionized Water – Specifications

Parameter	Specification
Resistivity at 25 C	> 18 M Ω. cm
Total organic carbon	< 5 ppb
Silica (dissolved)	3 ppb
Particles (> 100nm)	< 100 particles per liter
Bacteria	< 5 per liter
Cations (Na^+, K^+, Ca^{2+}, Mg^{2+}, NH_4^+)	< 0.1 ppb (each ion)
Anions (F^-, Cl^-, SO_4^{2-}, NO_3^-, Br^-, PO_4^{3-})	< 0.1 ppb (each ion)

W. Whyte (ed.), Cleanroom Design, IInd edition, Wiley, 1991

High purity water for VLSI

- De-ionized (DI) water
  - Exposure to air causes dissolution of ions and gas molecules from air
    - Cannot be stored and hence should be used fresh



D. K. Chung et al., J. Micromech. Microeng., 17(2007), 867-874

25

Example wafer cleaning procedure – RCA clean

Step 1: H_2SO_4/H_2O_2, 1:1 to 1:4 at 120℃ to 150℃ for 10 min
Strips organics especially photoresist
Step 2: H_2O/HF, 10:1 to 50:1, RT, 1min
Strips chemical oxide
Step 3: DI water rinse, RT
Step 4: $NH_4OH/H_2O_2/H_2O$, 1:1:5 to 0.05:1:5, 80℃ – 90℃, 10 min
Strips organics, metals and particles
Step 5: DI water rinse, RT
Step 6: $HCl/H_2O_2/H_2O$, 1:1:6, 80℃ – 90℃, 10 min
Strips alkali ions and metals
Step 7: DI water rinse to 18 MΩ.cm
Step 8: (optional) H_2O/HF, 50:1 dip

26

Gas purity – common contaminants in gases

- Gases are used as
  - Reactants and sputter gases
  - Reactant carriers
  - Wafer cleaning and drying
  - Purging and cooling
  - Operation of pneumatic valves
- All gases should meet low particle contamination levels for VLSI processing
- Should be free of other gases which can adversely impact the target process
- Common gaseous contaminants
  - Oxygen – CVD processes involving SiH_4 would form SiO_2 dust
  - Moisture – Same as above & problems controlling oxidation
  - Hydrocarbons – carbon incorporation in dielectric films and cause poor breakdown voltages

27

Gas purity – Specifications & examples

- Gas purity is specified as 5N, 6N etc. 5N purity means the gas is 99.999% pure, 6N means 99.9999% pure

	SiH4 (ULSI 6N)	CF4 (ULSI 5N)
purity	99.9999	99.999
O2 + Ar	≤ 0.06 ppmv	
N2	≤ 0.5 ppmv	
CO2	≤ 0.05 ppmv	(+CO) ≤ ppmv
CO	≤ 0.08 ppmv	
H2	≤ 20 ppmv	
H2O	≤ 0.5 ppmv	≤ 2ppmv
He	≤ 1.0 ppmv	
CH4	≤ 0.04 ppmv	
THC	≤ 0.1 ppmv	≤ 2ppmv
Total Cholosilanes	≤ 0.1 ppmv	
Si2H6	≤ 0.5 ppmv	
Disiloxane	≤ 0.05 ppmv	
Air		≤ 5ppmv
SF6		≤ 1ppmv
HF		≤ 1ppmv
Resistivity, N-type (ohm-cm)	>10000	

http://www.mathesontrigas.com

28

Exercise

On the previous slide, the purity of two gases used in silicon device manufacturing are given. Briefly discuss why using a 99.9999% CF does not make sense, while using 99.9999% pure SiH_4 makes eminent sense, for the applications discussed in the lecture.

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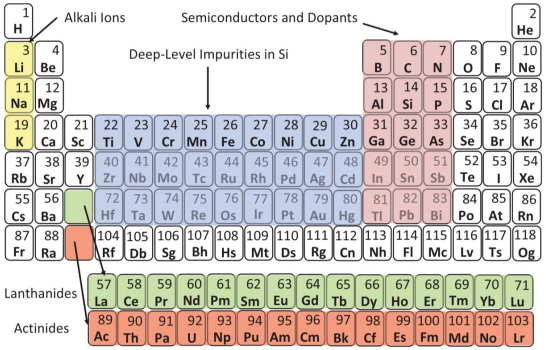
29

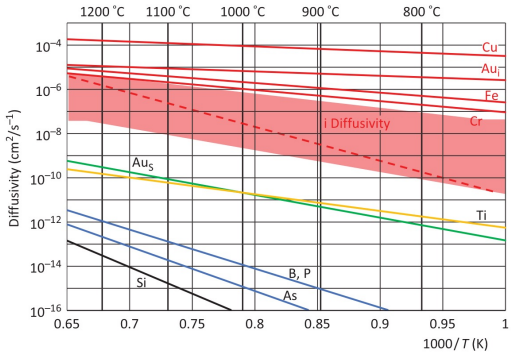
Impurity Gettering

Gettering is a means of collecting harmful elements in regions of the chip where they cause minimal harm.



30

Impurity Gettering (2)

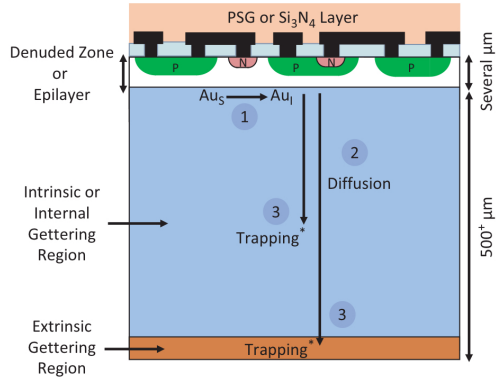


$$Au_S + I \leftrightarrow Au_i$$

$$Au_S \leftrightarrow Au_i + V$$

31

Impurity Gettering (3)



32

Bibliography

- S. M. Sze and K. K. Ng, Physics of Semiconductor Devices, 3rd edition, John Wiley and Sons, 2007.
- P. Würfel, Physics of Solar Cells, Wiley-Vch, 2005.
- W. Whyte (ed.), Cleanroom Design, IInd edition, Wiley, 1991
- International Standard Organization, Clean Room Standards, ISO-14644
- International Technology Roadmap for Semiconductors, http://www.itrs.net
- W. Kern and D. A. Puotinen, "Cleaning Solutions Based on Hydrogen Peroxide for Use in Silicon Semiconductor Technology, RCA Review vol. 31, pp. 187-206, 1970, available at http://garfield.library.upenn.edu/classics1983/A1983QD90200001.pdf
- M. M. Heyns et al., "Cost Effective Cleaning and High-Quality Thin Gate Oxides", IBM Journal of Research and Development, vol. 43, no.3, pp. 339-350, 3 May 1999.
- D. K. Jung et al., "Micro electrical discharge milling using deionized water as a dielectric fluid", Journal of Micromechanics and Microengineering, vol. 17, pp. 867-874.
- E. R. Weber, "Transition metals in Silicon", Applied Physics, vol. A30, pp. 1-23, 1983.