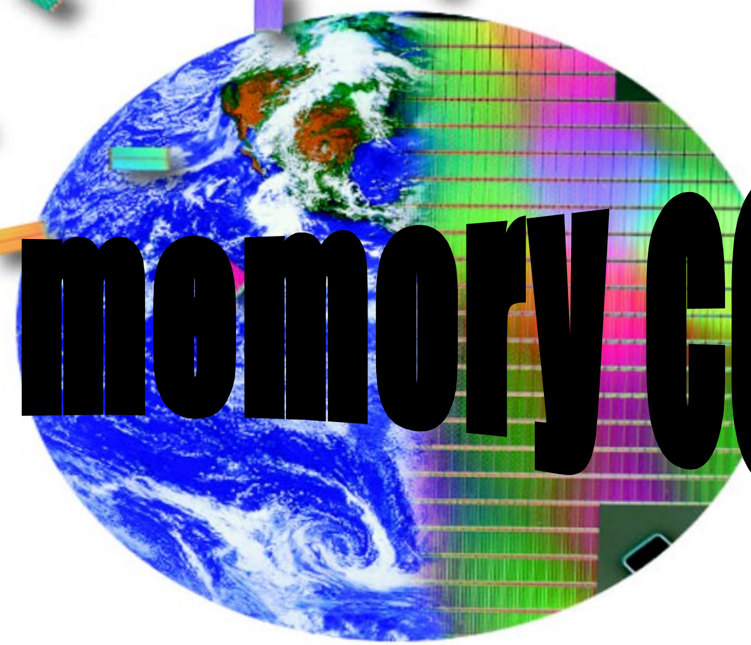
Micron Technology

Building Memory Chips

Rob Miller
Test Engineer

Structure and Function

Of a DRAM memory cell



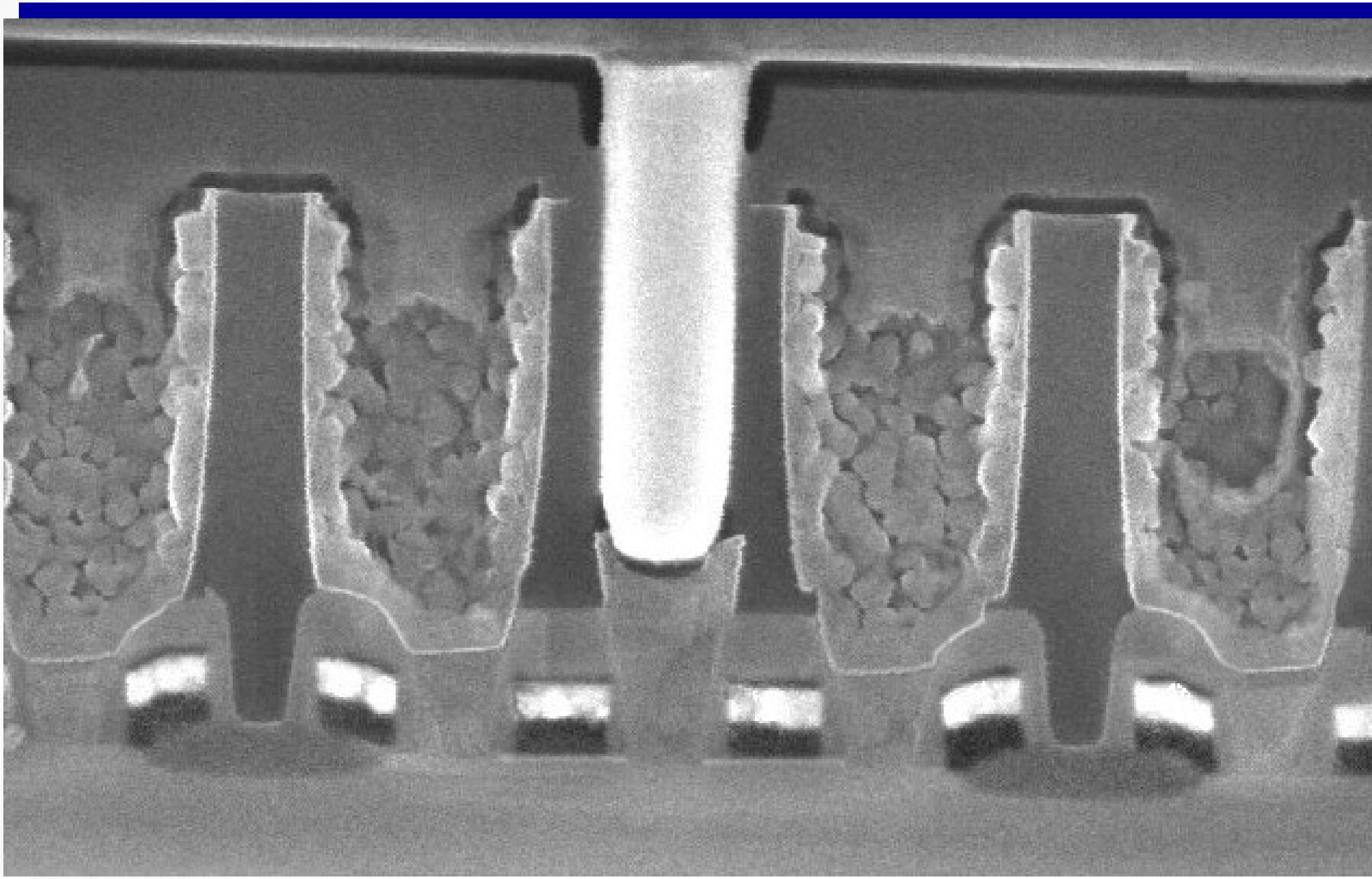
MICRON

Storage and Memory

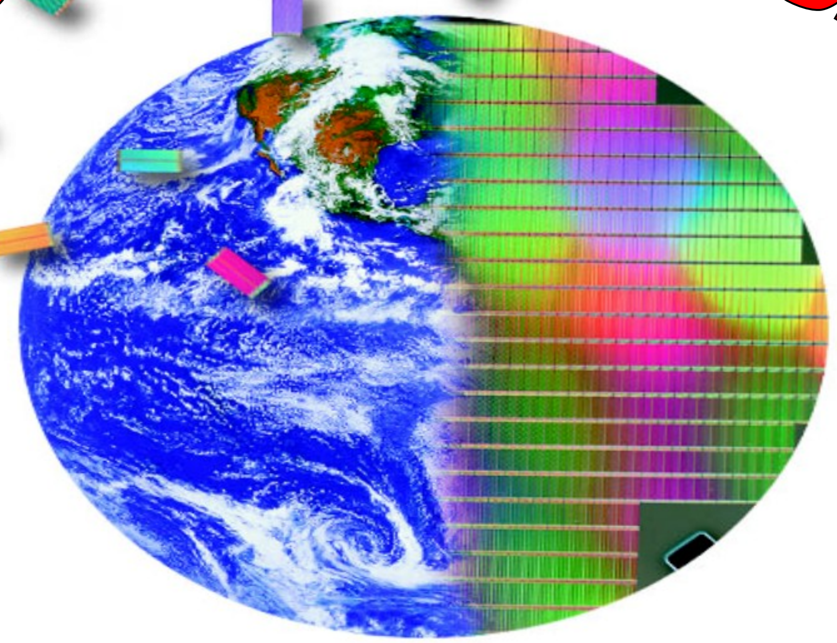
- The most widely used form of electronic memory is Random Access Memory (RAM). RAM memory allows computers to directly store and retrieve bits of information from unique addresses.
- Micron is a major manufacturer of RAM , including DRAM and SRAM. DRAM makes-up 95% of our business.
- DRAM needs to be refreshed
- SRAM does not need to be refreshed

DRAM	SRAM
Leaks	Doesn’t Leak
Needs to be “Refreshed”	“Refresh” is not needed
Simple Design (less cost)	Complex Design (more cost)
1 capacitor, 1 transistor	6 Transistors
More memory 16, 64meg….	Less memory 2, 4meg….

What DRAM Really Looks Like



Semiconductor Chemistry



Elements and Atoms

- ***Elements*** **are the simplest forms of matter encountered in a laboratory. No matter how hard we try, an element cannot be purified into a simpler (stable) substance through chemical means.**

- **An *Atom* is the smallest piece of an element which still retains its original chemical identity. They are often referred to as the "building blocks" of an element.**

The Periodic Table of Elements

x: All isotopes are radioactive.

( ) Indicates mass number of isotope with longest known half-life.

* Number in ( ) heading each column represents the group designation recommended by the ACS Committee on Nomenclature.

1	1.008
H	
Hydrogen	

Atomic Number

Atomic Weight

Aymbol of Element

Name of Element

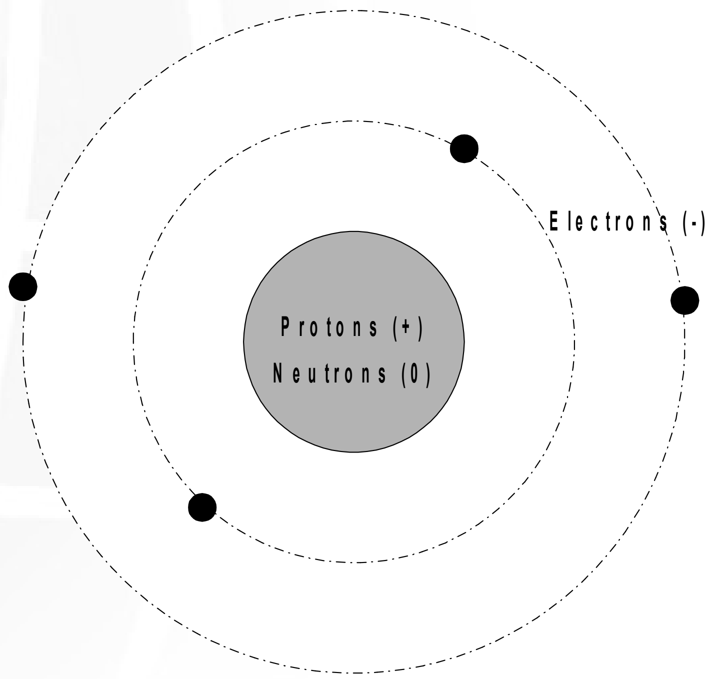
Representative Elements | Transition Elements | Inner-Transition Elements | Noble Gases

Period	(1)* I A	(2) II A	(3) III B	(4) IV B	(5) V B	(6) VI B	(7) VII B	(8)	(9) VIII B	(10)	(11) I B	(12) II B	(13) III A	(14) IV A	(15) V A	(16) VI A	(17) VII A	(18) Noble Gases
1	1 1.008 H Hydrogen																	2 4.003 He Helium
2	3 6.941 Li Lithium	4 9.012 Be Beryllium											5 10.81 B Boron	6 12.01 C Carbon	7 14.01 N Nitrogen	8 16.00 O Oxygen	9 19.00 F Fluorine	10 20.18 Ne Neon
3	11 22.99 Na Sodium	12 24.31 Mg Magnesium											13 26.98 Al Aluminum	14 28.09 Si Silicon	15 30.97 P Phosphorous	16 32.06 S Sulfur	17 35.45 Cl Chlorine	18 39.95 Ar Argon
4	19 39.10 K Potassium	20 40.08 Ca Calcium	21 44.96 Sc Scandium	22 47.90 Ti Titanium	23 50.94 V Vanadium	24 52.00 Cr Chromium	25 54.94 Mn Manganese	26 55.85 Fe Iron	27 58.93 Co Cobalt	28 58.71 Ni Nickel	29 63.55 Cu Copper	30 65.37 Zn Zinc	31 69.72 Ga Gallium	32 72.59 Ge Germanium	33 74.92 As Arsenic	34 78.96 Se Selenium	35 79.90 Br Bromine	36 83.80 Kr Krypton
5	37 85.47 Rb Rubidium	38 1.008 Sr Strontium	39 88.91 Y Yttrium	40 91.22 Zr Zirconium	41 92.91 Nb Niobium	42 95.94 Mo Molybdenum	43 98.91 Tc^x Technetium	44 101.1 Ru Ruthenium	45 102.9 Rh Rhodium	46 106.4 Pd Palladium	47 107.9 Ag Silver	48 112.4 Cd Cadmium	49 114.8 In Indium	50 118.7 Sn Tin	51 121.8 Sb Antimony	52 127.6 Te Tellurium	53 126.0 I Iodine	54 131.1 Xe Xenon
6	55 132.9 Cs Cesium	56 137.3 Ba Barium	57 138.9 La Lanthanum	72 178.5 Hf Hafnium	73 180.9 Ta Tantalium	74 183.9 W Tungsten	75 186.2 Re Rhenium	76 190.2 Os Osmium	77 192.2 Ir Iridium	78 195.1 Pt Platinum	79 197.0 Au Gold	80 200.6 Hg Mercury	81 204.4 Tl Thallium	82 207.2 Pb Lead	83 209.0 Bi Bismuth	84 (210) Po^x Polonium	85 (210) At^x Astatine	86 (222) Rn^x Radon
7	87 (223) Fr^x Francium	88 226.0 Ra^x radium	89 (227) Ac^x Actinium	104 (261) Unq^x	105 (262) Unp^x	106 (263) Unh^x	107 (262) Uns^x	108 (265) Uno^x	109 (266) Une^x									

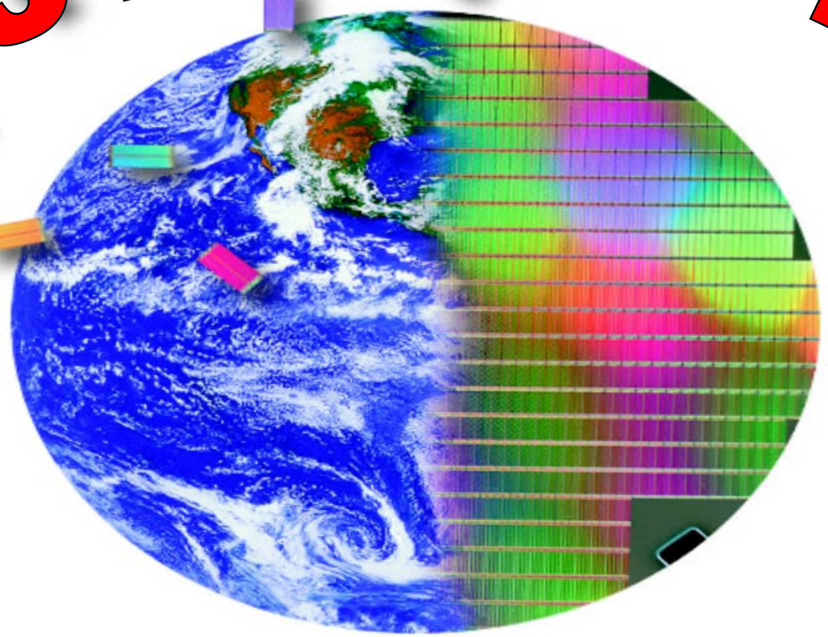
Lanthanides	58 140.1 Ce Cerium	59 140.9 Pr Praseodymium	60 144.2 Nd Neodymium	61 (147) Pm^x Promethium	62 150.4 Sm Samarium	63 152.0 Eu Europium	64 157.3 Gd Gadolinium	65 158.9 Tb Terbium	66 162.5 Dy Dysprosium	67 164.9 Ho Holmium	68 167.3 Er Erbium	69 168.9 Tm Thulium	70 173.0 Yb Ytterbium	71 175.0 Lu Lutetium
Actinides	90 232.0 Th^x Thorium	91 231.0 Pa^x Protactinium	92 238.0 U^x Uranium	93 237.0 Np^x Neptunium	94 (244) Pu^x Plutonium	95 (243) Am^x Americium	96 (247) Cm^x Curium	97 (247) Bk^x Berkelium	98 (251) Cf^x Californium	99 (254) Es^x Einsteinium	100 (257) Fm^x Fermium	101 (258) Md^x Mendelevium	102 (255) No^x Nobelium	103 (256) Lr^x Lawrencium

Protons, Neutrons, and Electrons

- Although the Bohr Model does not completely explain all aspects of chemistry, we can use it to discuss basic chemical rules which govern the reactions of the atoms and elements.



The 5 Atomic Rules



Atomic Rule 1

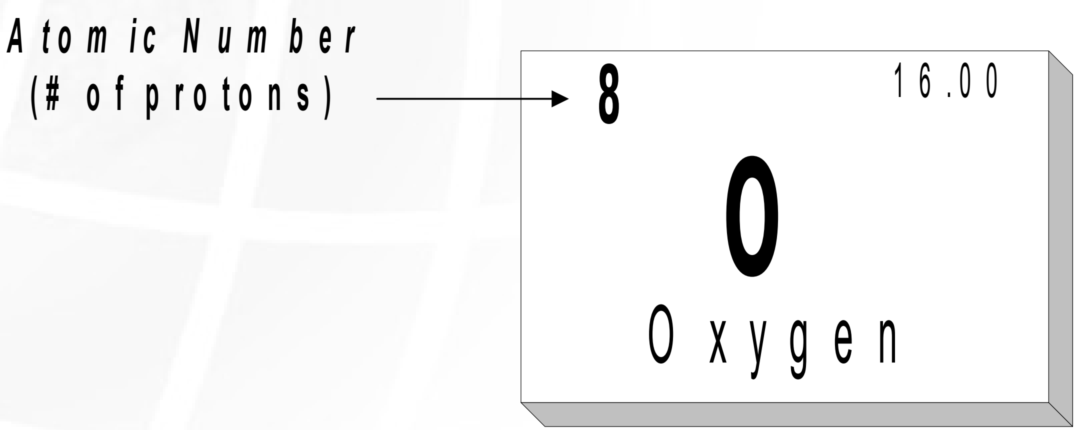
- **Rule 1** *states that in each atom of an element there is an equal number of protons and electrons.*

  If we know that Boron (B) has five protons, then an atom of Boron also has five electrons which makes it neutral. It is possible for an atom to lose or gain an electron, but the protons are confined to the nucleus. If an atom gives up or accepts an electron, then the atom loses its neutrality and becomes an *ion*.

Atomic Rule 2

- **Rule 2** *states that each atom of an element contains a specific number of protons in the nucleus and different elements have a different number of protons.*

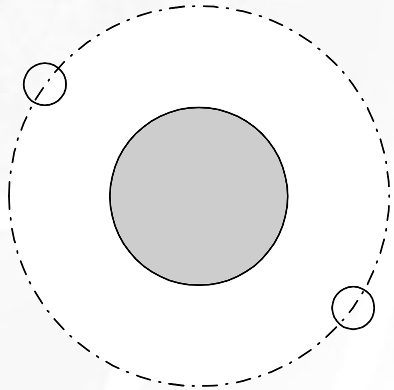
All Oxygen (O) atoms contain eight protons.

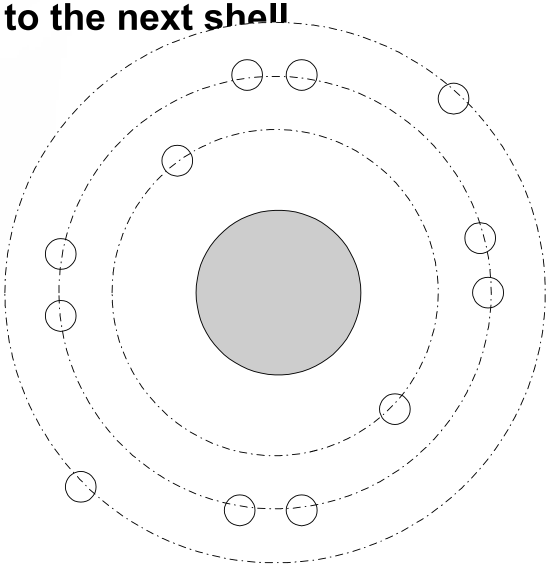


Atomic Rule 3

- **Rule 3** *states that elements with the same number of outer orbital electrons (“**valance**” electrons) have similar properties.*

Electrons are placed in orbits around the nucleus of the atom. The first orbital will take a maximum of two electrons before it repels additional electrons to the next shell. The second orbital will take a maximum of *eight* electrons before forcing the remaining electrons to the next shell.





Atomic Rule 4

- **Rule 4** *states that elements are stable when their atoms have a filled outer orbital.*

  The atoms of elements which appear in the far right column of the Periodic Table (He, Ne, ...) have filled outer orbitals.

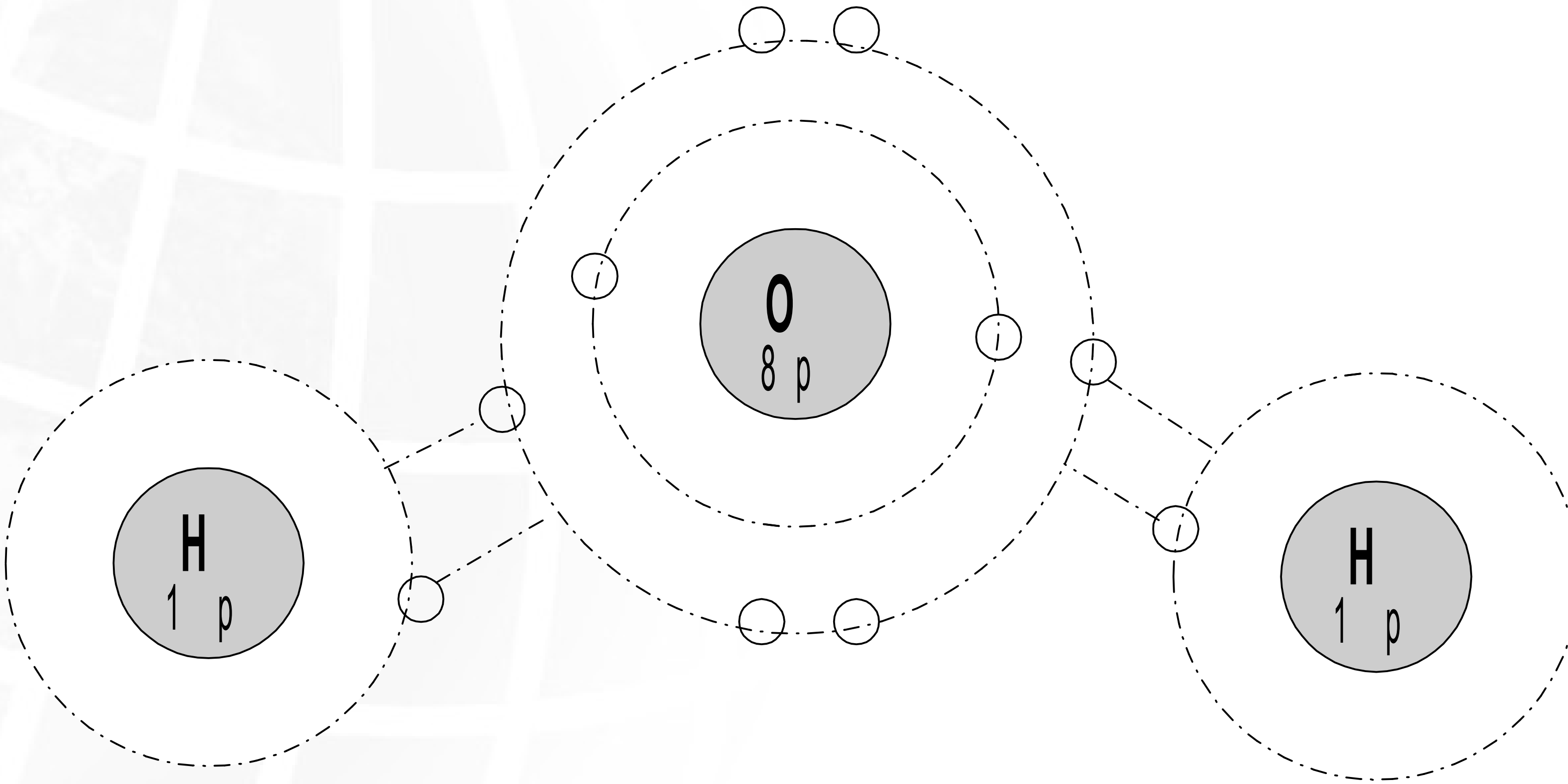
  These stable elements are called “Noble” or “Inert” gases. All other atoms found on the Periodic Table are considered unstable because they do not have filled outer orbitals.

Atomic Rule 5

- **Rule 5** *states that atoms seek to combine with other atoms to create the stable condition of filled orbits through the sharing of electrons* **("*covalent bond*")**.

Rules 4 and 5 help scientists predict the reaction of a particular atom when it is introduced to another atom. Atoms with incomplete outer orbitals can combine with similar atoms or with atoms of different elements.

Atomic Rule 5 Continued



Conductors, Dielectrics and Semiconducors

Conductors

- Electrical conduction takes place in elements and materials where the attractive hold of the electrons by the protons is relatively weak.
- Extent to which materials conduct electricity is measured by a factor known as conductivity.
- This condition exists in most metals because the valence electrons are so far from the nucleus.
- Examples of conductive materials used at Micron include Tungsten (W), Titanium (Ti) and Aluminum/Copper (Al/Cu).

Dielectrics

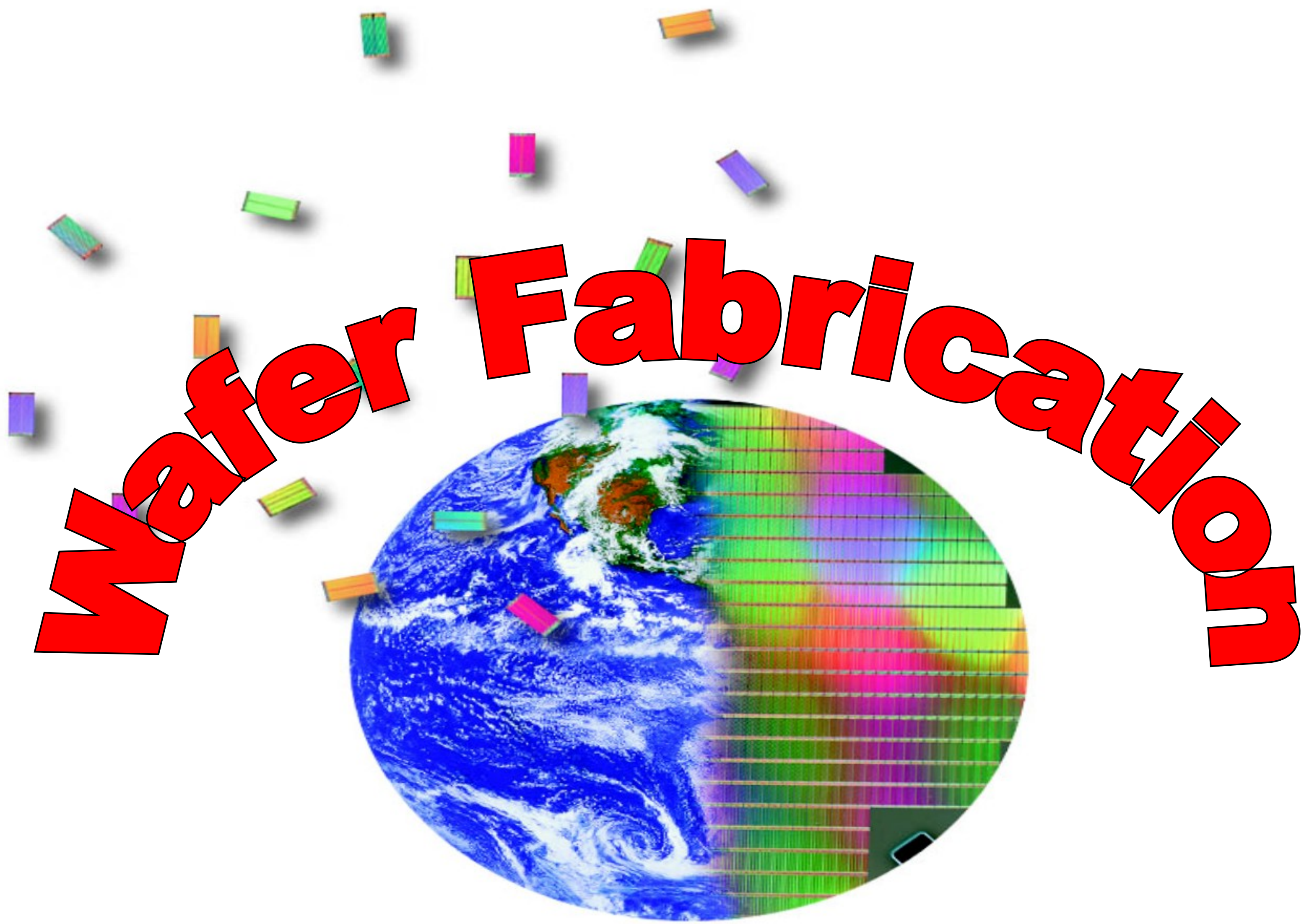
- Resistive materials are known as *dielectrics* (or *insulators*).
- Dielectric materials are used in electric circuits to prevent conduction from passing between two conductive components.
- Two examples of insulators used in the fabrication process include Oxide and Nitride layers.

Semiconductors

- ***Semiconductors*** are materials that exhibit only partial electrical conduction. Their ability to conduct lies somewhere between a metal and an insulator.

- **Silicon** is the mainstream material used in the fabrication of memory devices like transistors and capacitors. This is primarily due to the beneficial characteristics of Silicon. Silicon has a very high melting point compared to other semiconductors (like Germanium).

Wafer Fabrication



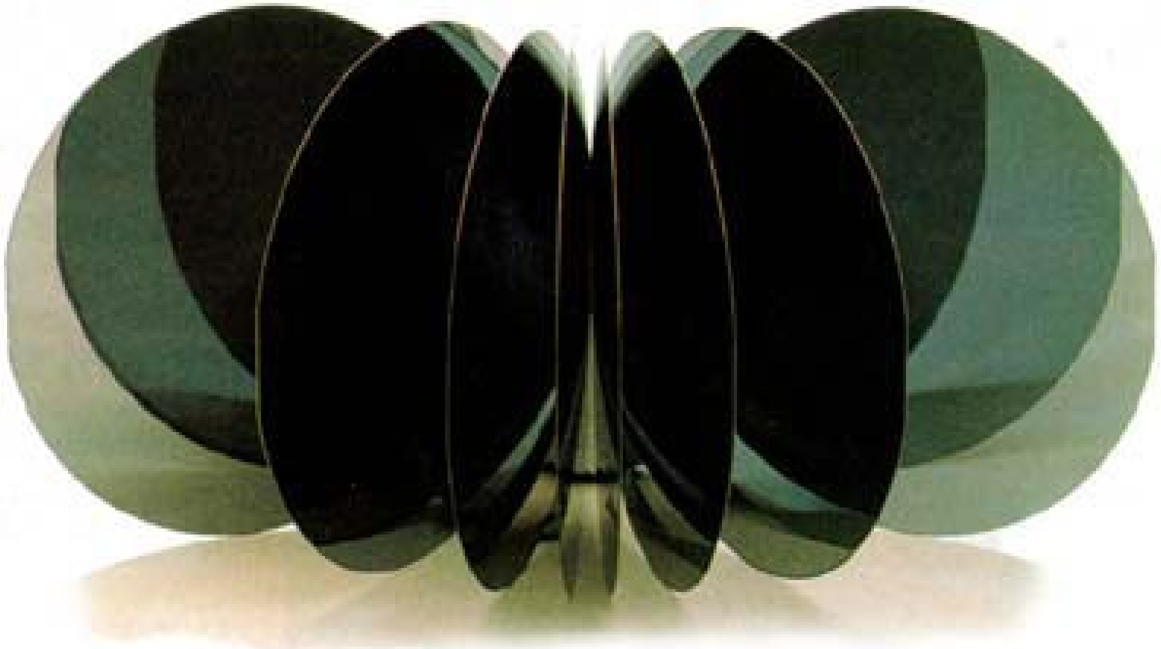
Silicon Chemistry

- Germanium versus
- **Silicon**
  - ***less expensive***
  - ***abundant***
  - ***a higher melting point (1420c vs 990c)***
  - grows a ***more stable and uniform oxide layer***

Silicon Purification

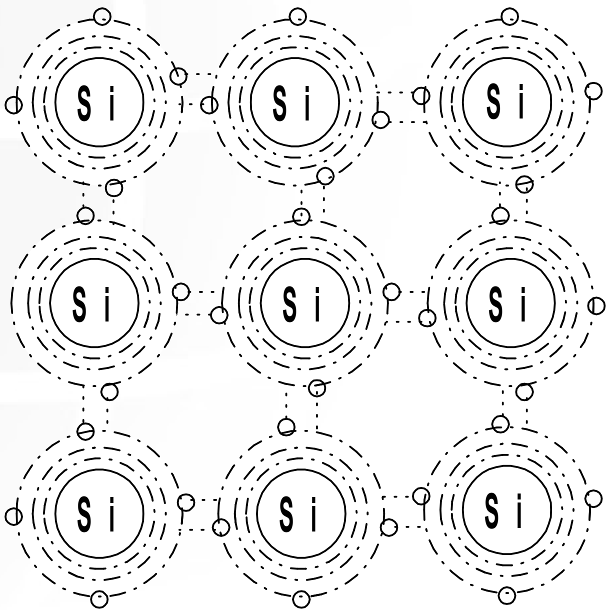
- First stage of wafer fabrication is the chemical purification of Silicon found in common beach sand.
- Although Silicon is the second most abundant element in the earth's crust, it never occurs in nature alone as an element.
- Instead it occurs in the form of ***Silica***, which is a combination of Silicon and different elements.
- **This Silica compound must be processed to yield Silicon that is 99.999999999% pure.**

Silicon Wafers



Intrinsic Silicon

- **Silicon has four valence electrons. When a group of Silicon atoms bond together to produce a pure lattice structure, the material is referred to as Intrinsic Silicon.**

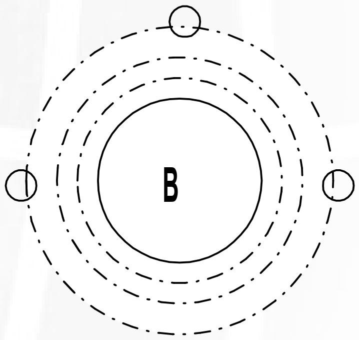


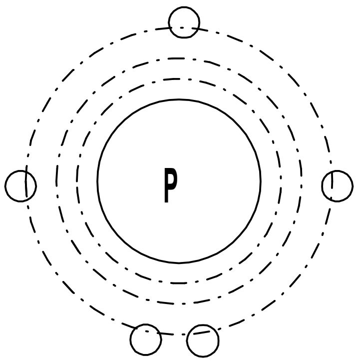
Silicon Doping

- This pure silicon configuration (intrinsic silicon) is a poor conductor because none of its electrons are available to serve as carriers of electric charge.
- The fabrication of integrated circuits requires that the substrate (the wafer surface) be somewhat conductive.
- This process is known as *doping*. Boron (**B**), Phosphorus (**P**), and Arsenic (**As**) are the most common dopant atoms used in the industry.

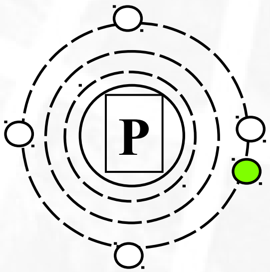
Dopant Chemistry

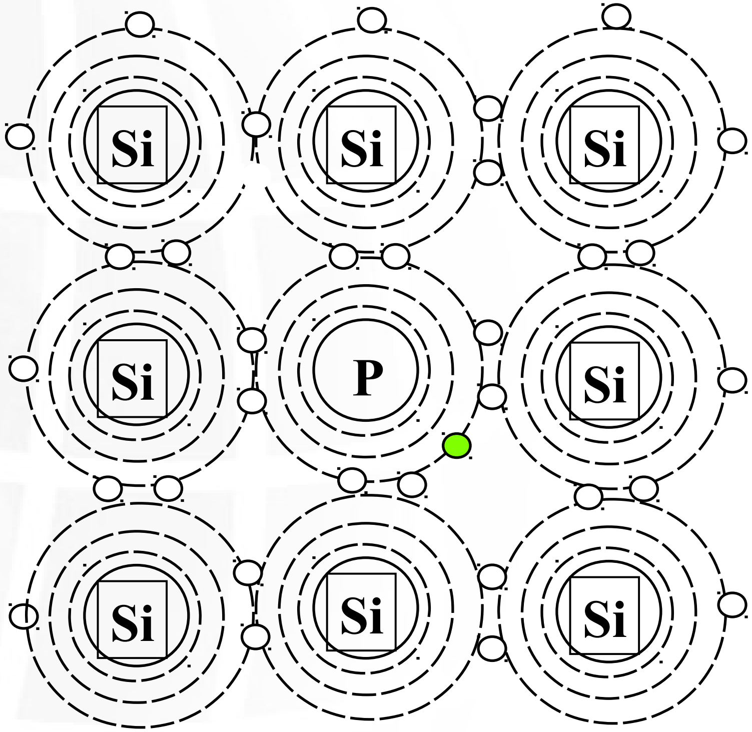
- **By looking at the Periodic Table, we can determine the number of electrons that Boron and Phosphorus have in their outer orbit.**



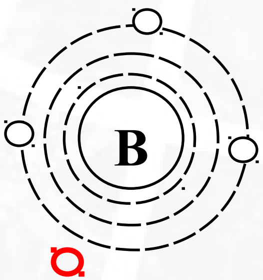


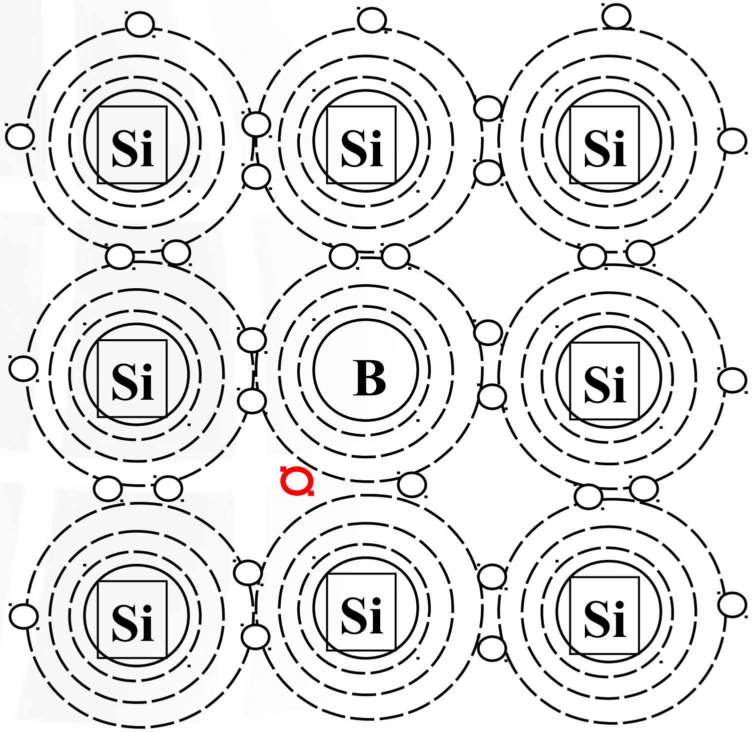
N-Type



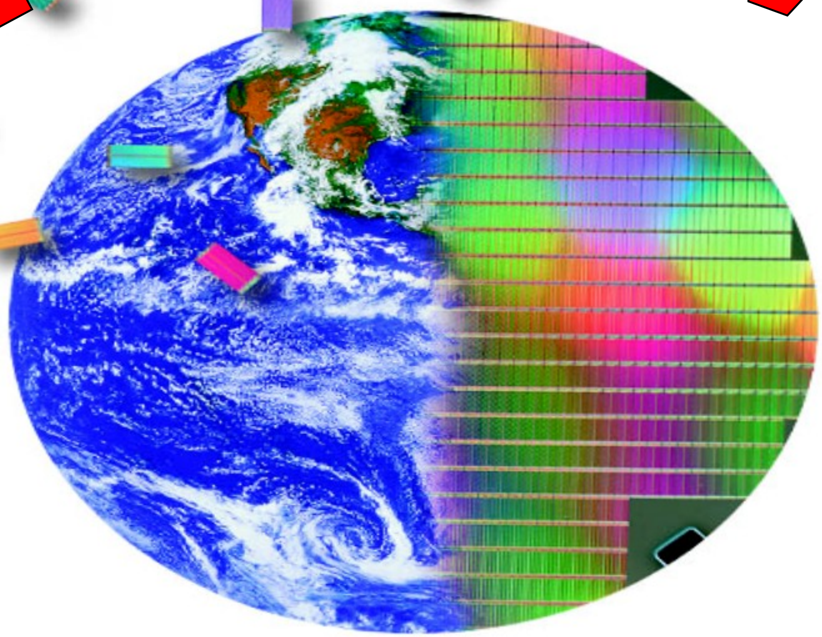


P-Type

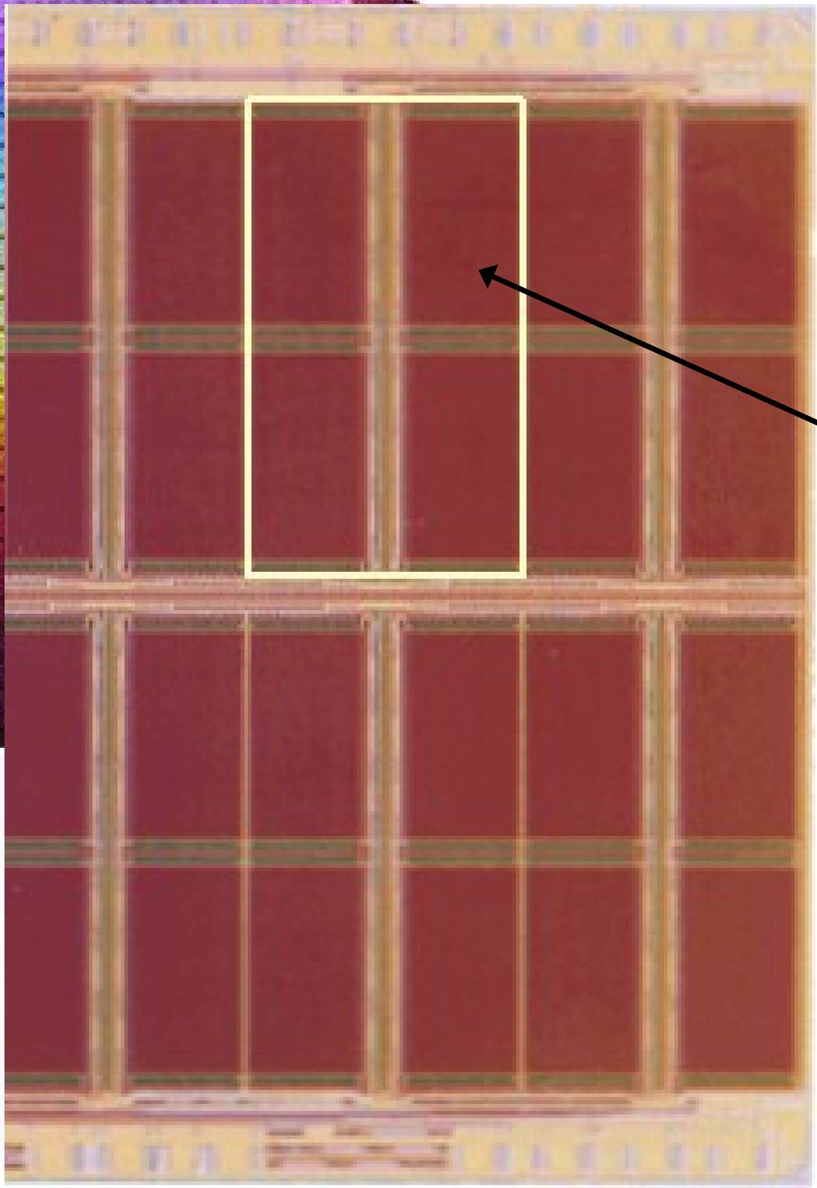




Memory Devices

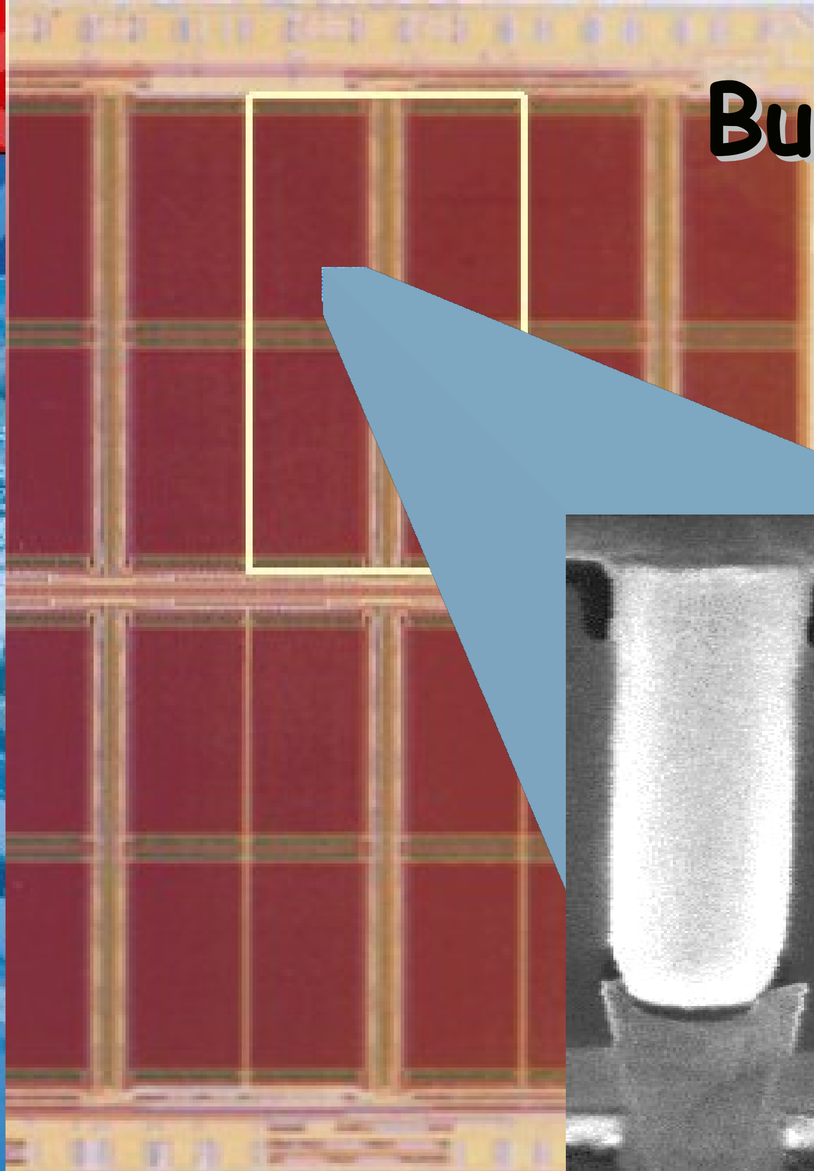


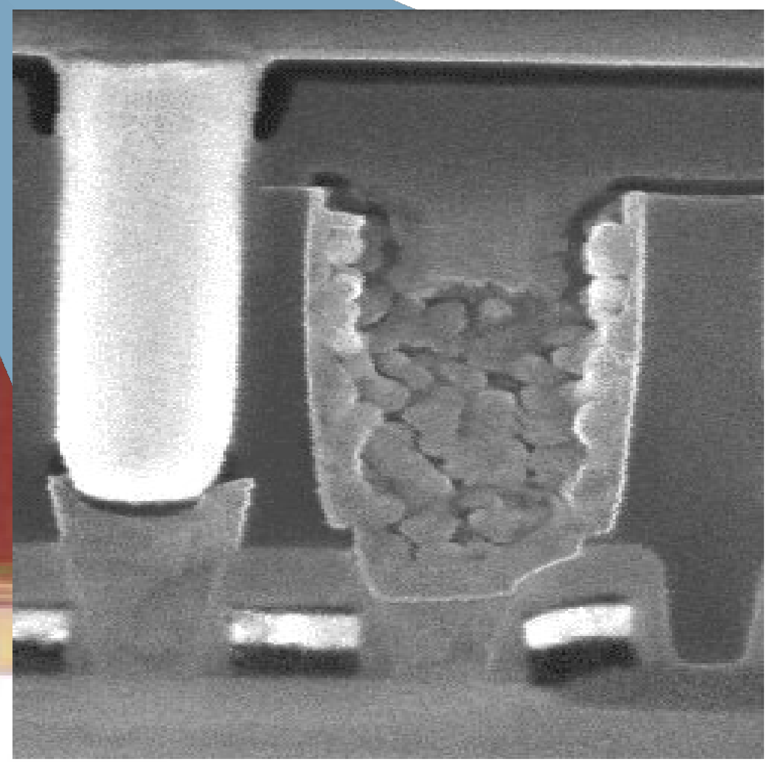
Anatomy of a Memory Chip



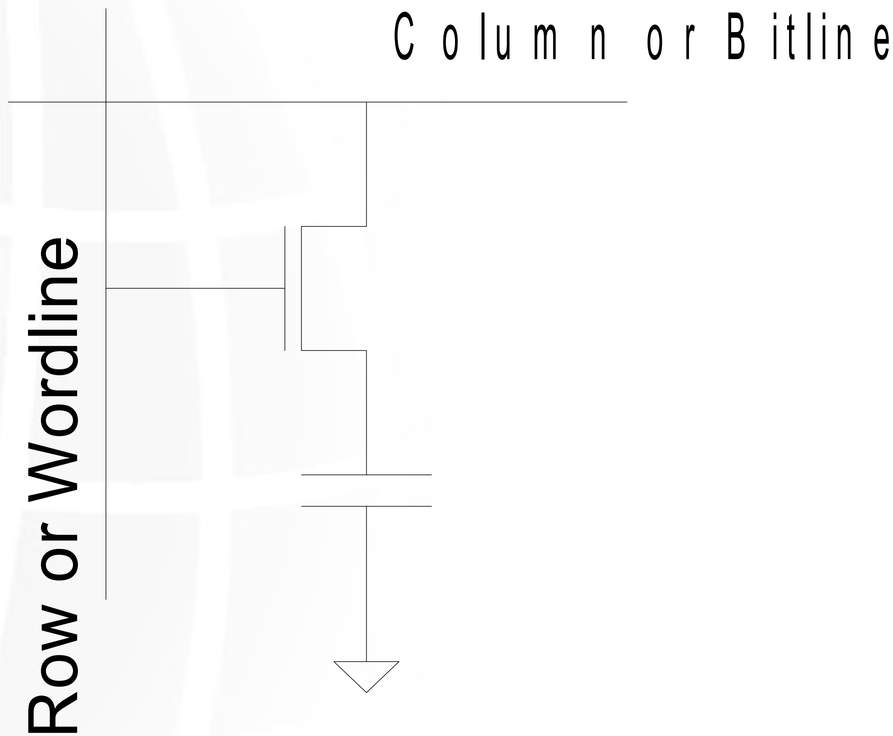
One Die or Chip

Building Blocks of the DRAM memory cell



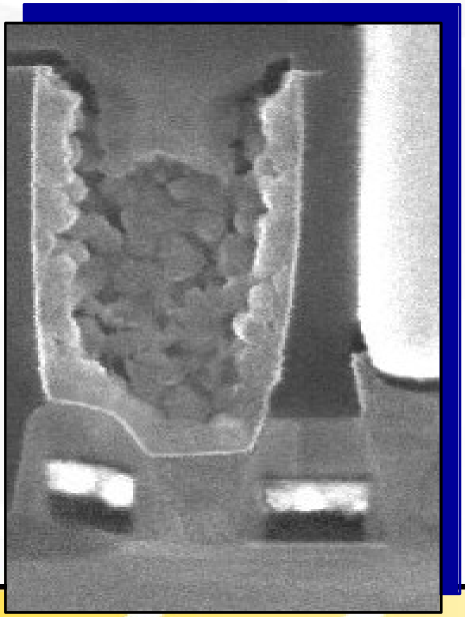


Basic DRAM memory cell - 1T



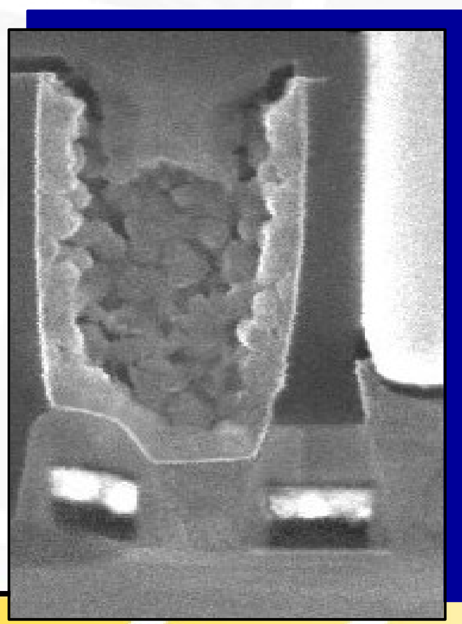
Transistor

- A small electronic device constructed on a semiconductor **(WAFER)** and having a least three electrical contacts **(SOURCE, GATE, AND DRAIN)**, used in a circuit as an amplifier, a detector, or a **SWITCH**.



Capacitor

- An electric circuit element used to temporarily **STORE** a charge, consisting of **TWO CONDUCTIVE** plates separated and insulated from each other by a **DIELECTRIC**.

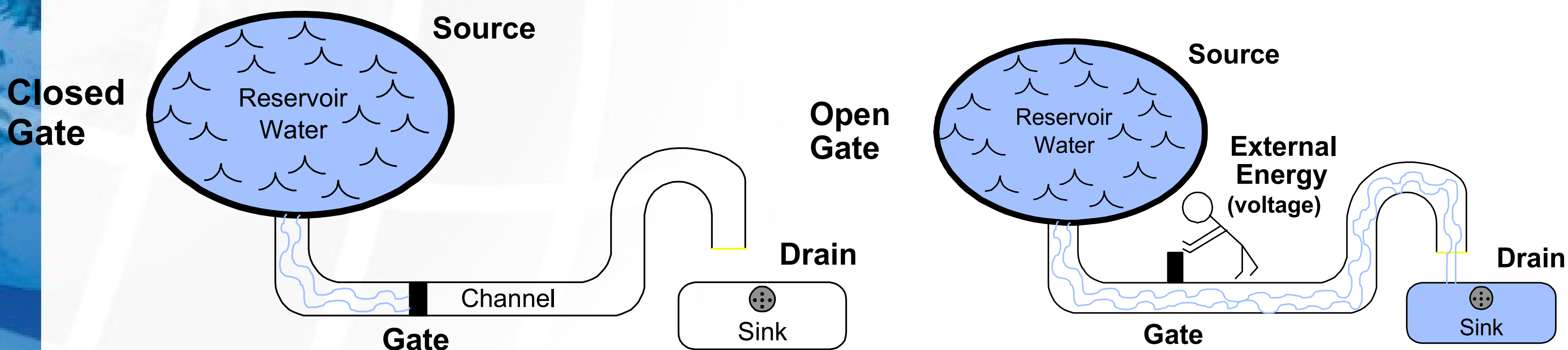


The Transistor

- The first component of the memory cell is a transistor. While the capacitor stores electronic bits of information, the transistor controls the access to that information. Micron uses mostly *Enhancement Mode-N-Channel- Metal-Oxide-Semiconductor-Field-Effect-Transistors (MOSFET).*

The Transistor (continued)

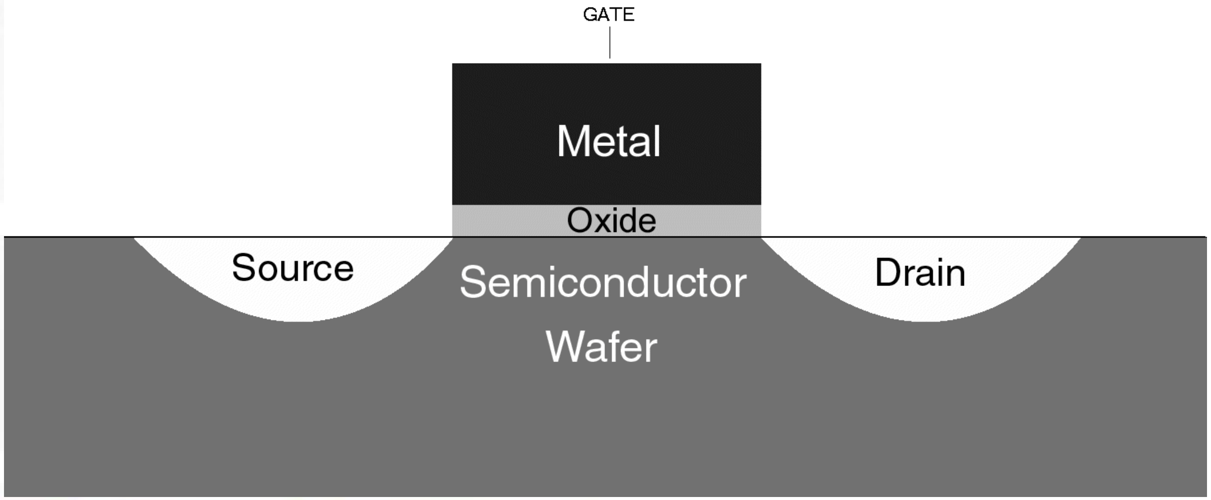
- Doing the dishes requires that we access a ***Source*** (*or reservoir*) of water.
- ***Channel*** (*or pipe*) connects the reservoir to the sink. Don't want a continuous flow of water to our ***drain*** (*or sink*). . .
- Need a ***gate*** (*or valve*) to block the water flow.



MOSFET-Gate, Source, Drain

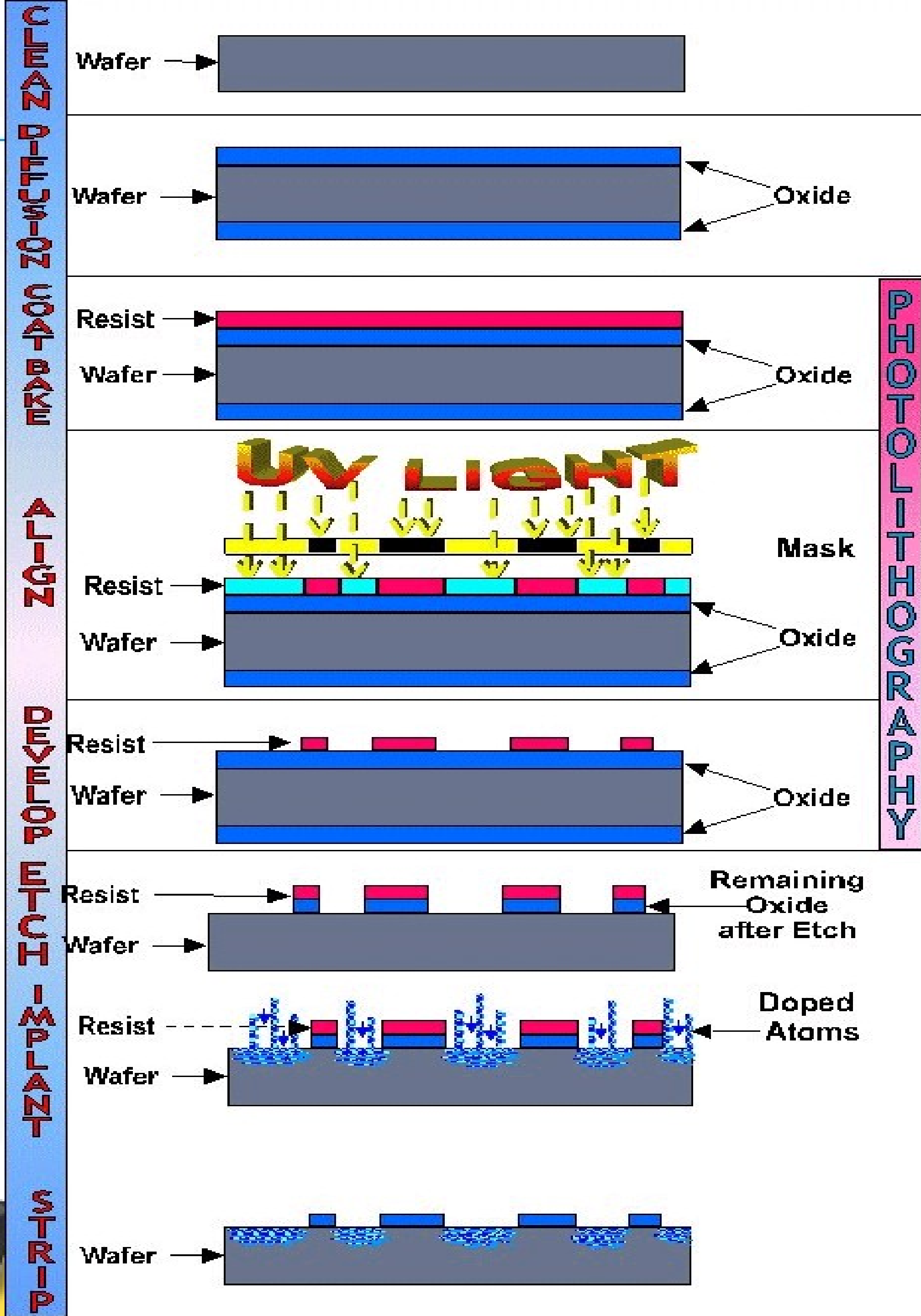
Metal-Oxide-Semiconductor-Field-Effect-Transistors

- A MOSFET is composed of three main components; a ***gate***, a ***source***, and a ***drain***. The ***gate*** is a physical structure built on the wafer surface to control the opening and closing of a source-to-drain ***channel***. To create this structure, a metal and oxide layer are formed on a semiconductor surface (MOS). The ***source*** and ***drain*** regions are just highly doped, shallow pockets in the wafer surface next to the gate.



How is it Built?

How does it Work?



To remove all unwanted contamination from the wafer surface

To grow or deposit material layers like Oxide on the wafer surface.

To apply a layer of UV sensitive photo resist over the Oxide on the wafer surface.

UV light passes through a patterned reticle to alter specified portions of the resist layer.

Resist affected by UV light is removed using a developing solution

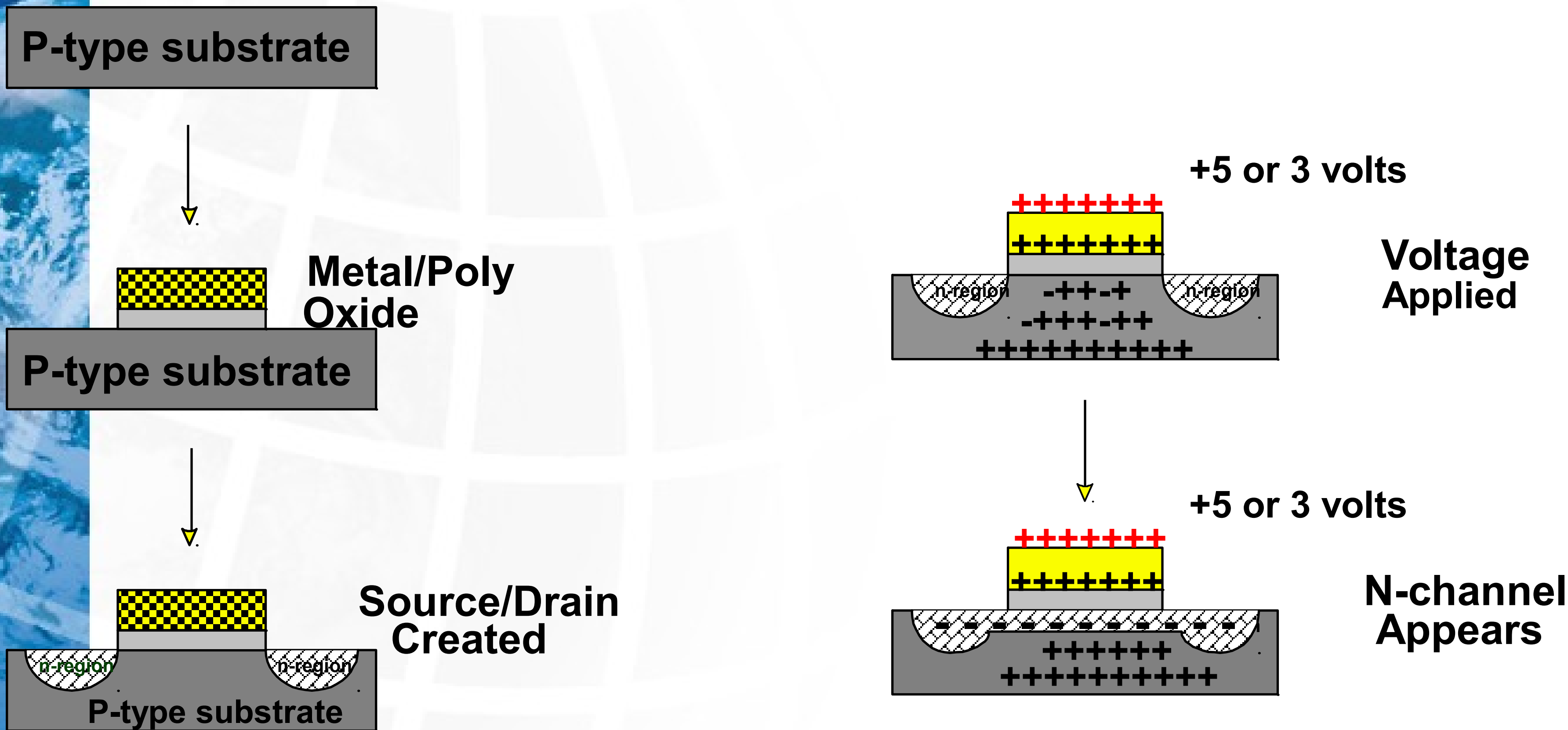
Unprotected portions of the Oxide are removed using a Wet Etch or Dry Etch.

Selected regions of the wafer are implanted with dopant atoms to alter the chemical characteristics of the silicon.

Resist is stripped from the wafer, leaving the patterned Oxide layer on the wafer surface

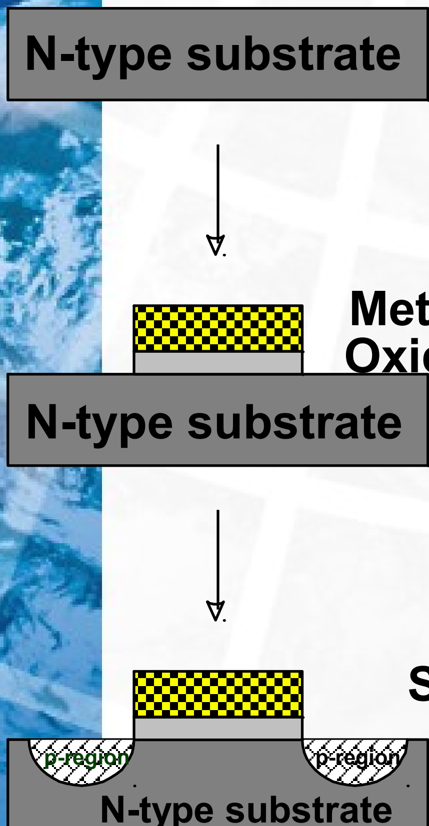
N-Channel MOSFET

Metal-Oxide-Semiconductor-Field-Effect-Transistors



P-Channel MOSFET

Metal-Oxide-Semiconductor-Field-Effect-Transistors

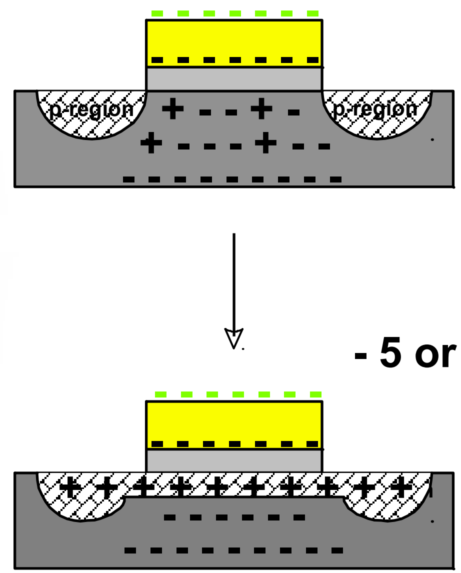


Metal/Poly Oxide

Source/Drain Created

- 5 or 3 volts

Voltage Applied



- 5 or 3 volts

P-channel Appears

Capacitance

$$C = \frac{k\,A}{d}$$

C =

d =

k =

A=

Capacitance

C = *Capacitance*

$$C = \frac{k\,A}{d}$$

The measurement of a capacitor's ability to store a charge

Capacitance

$$C = \frac{k\,A}{d}$$

C = *Capacitance*

d = *Distance betwe*
the cell plates

Capacitance

$$C = \frac{k\,A}{d}$$

C = *Capacitance*

d = *Distance betwe*
the cell plates

k = *Dielectric const*

Capacitance

$$C = k \frac{A}{d}$$

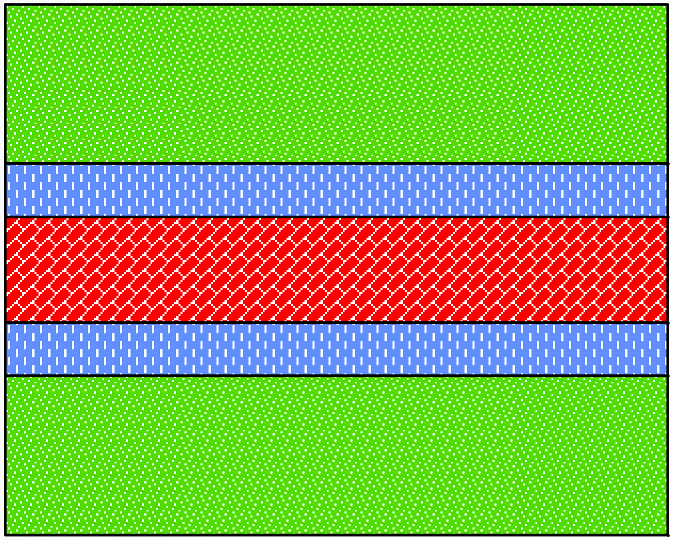
C = *Capacitance*

d = *Distance betwee*
the cell plates

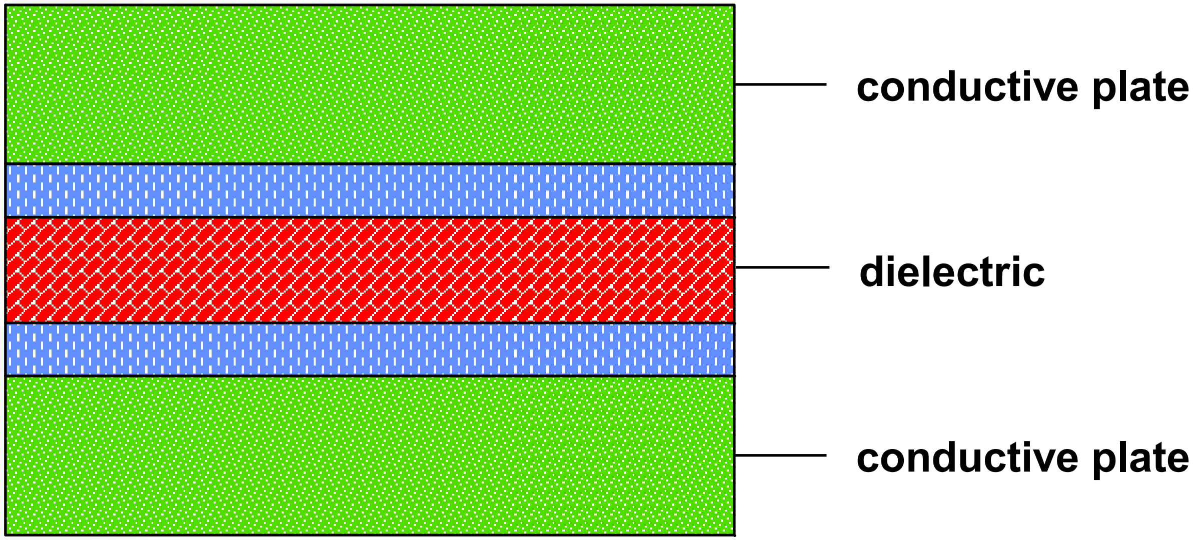
k = *Dielectric consta*

A= *Surface area of c*
plates

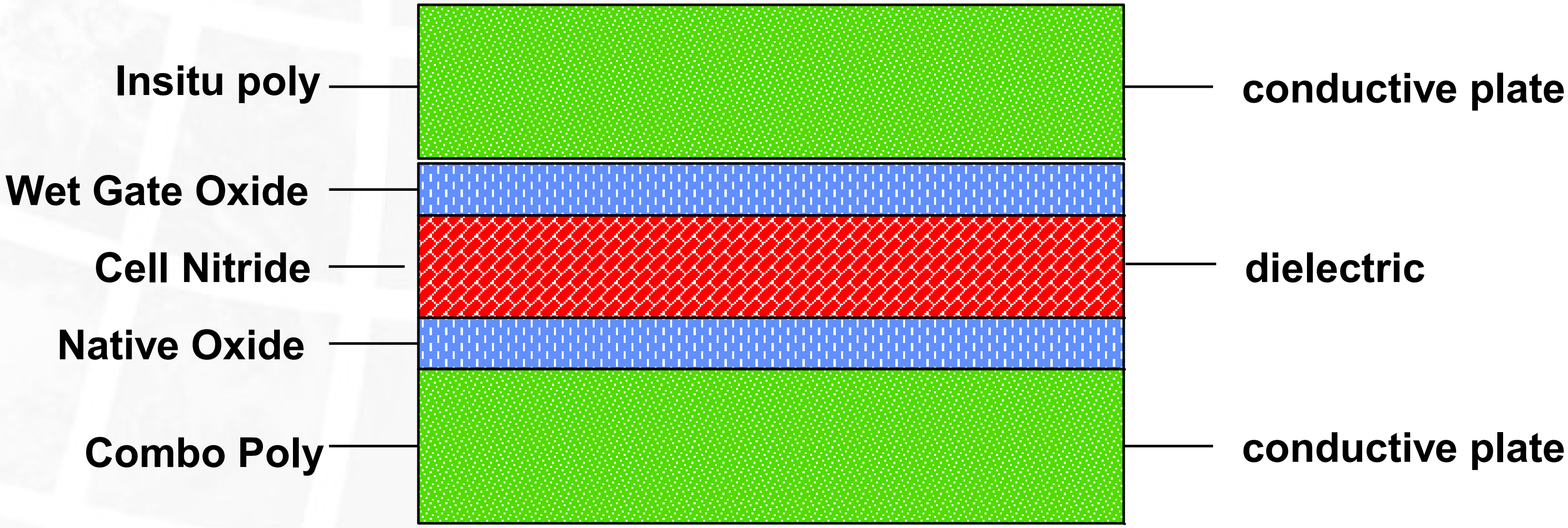
Capacitor



Capacitor



Capacitor


Insitu poly
Wet Gate Oxide
Cell Nitride
Native Oxide
Combo Poly
conductive plate
dielectric
conductive plate

Capacitance

$$C = k\frac{A}{d}$$

C = Capacitance

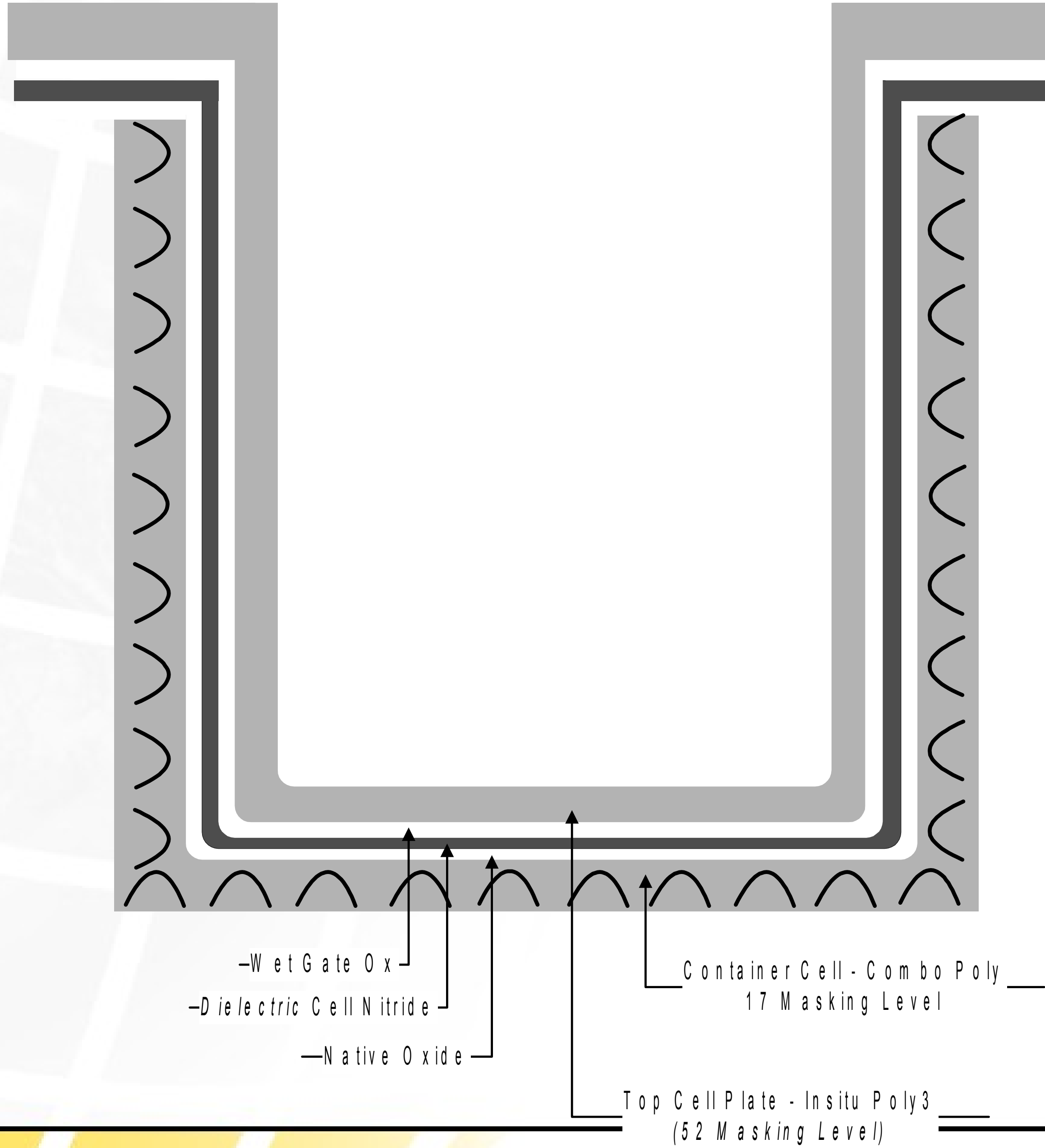
d = Distance between the cell plates

k = Dielectric constant

A= Surface area of cell plates

As the surface area (A) increases, capacitance (C) also increases. If Micron had continued to fabricate planar capacitors, increasing the capacitance in this manner would have greatly increased the size and cost of our microchips. To save valuable wafer real estate, while increasing capacitance, and shrinking our die size, we have moved to "Ministack" and "Container Cell" processing. These structures increase capacitance by stacking the cell plates rather than building them out across the wafer surface.

MICRON


Wet Gate Ox
Dielectric Cell Nitride
Native Oxide
Container Cell - Combo Poly
17 Masking Level
Top Cell Plate - Insitu Poly3
(52 Masking Level)

Capacitance

$$C = \frac{\color{red}{k}\,A}{d}$$

C = Capacitance

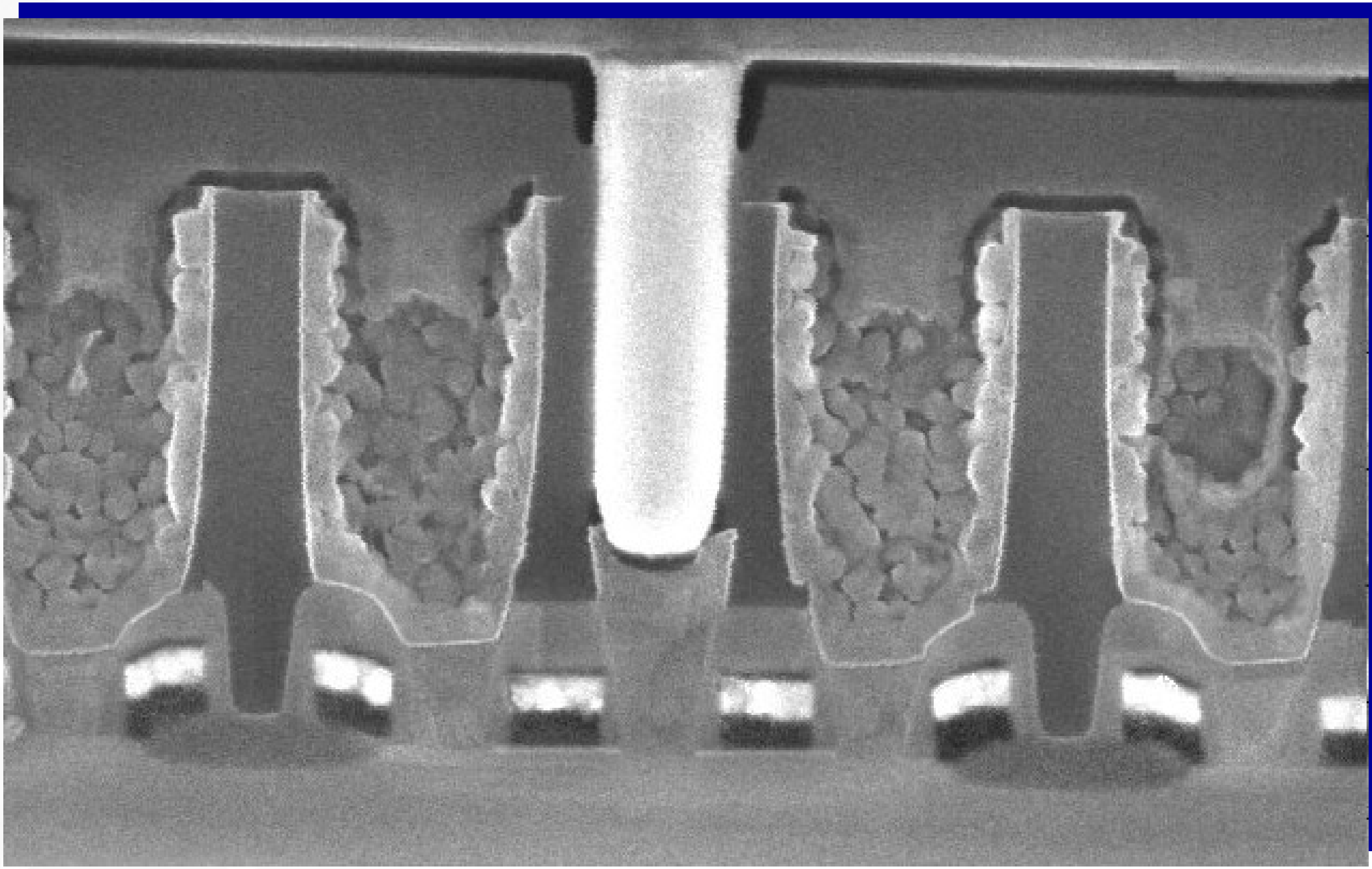
d = Distance between the cell plates

k = Dielectric constant

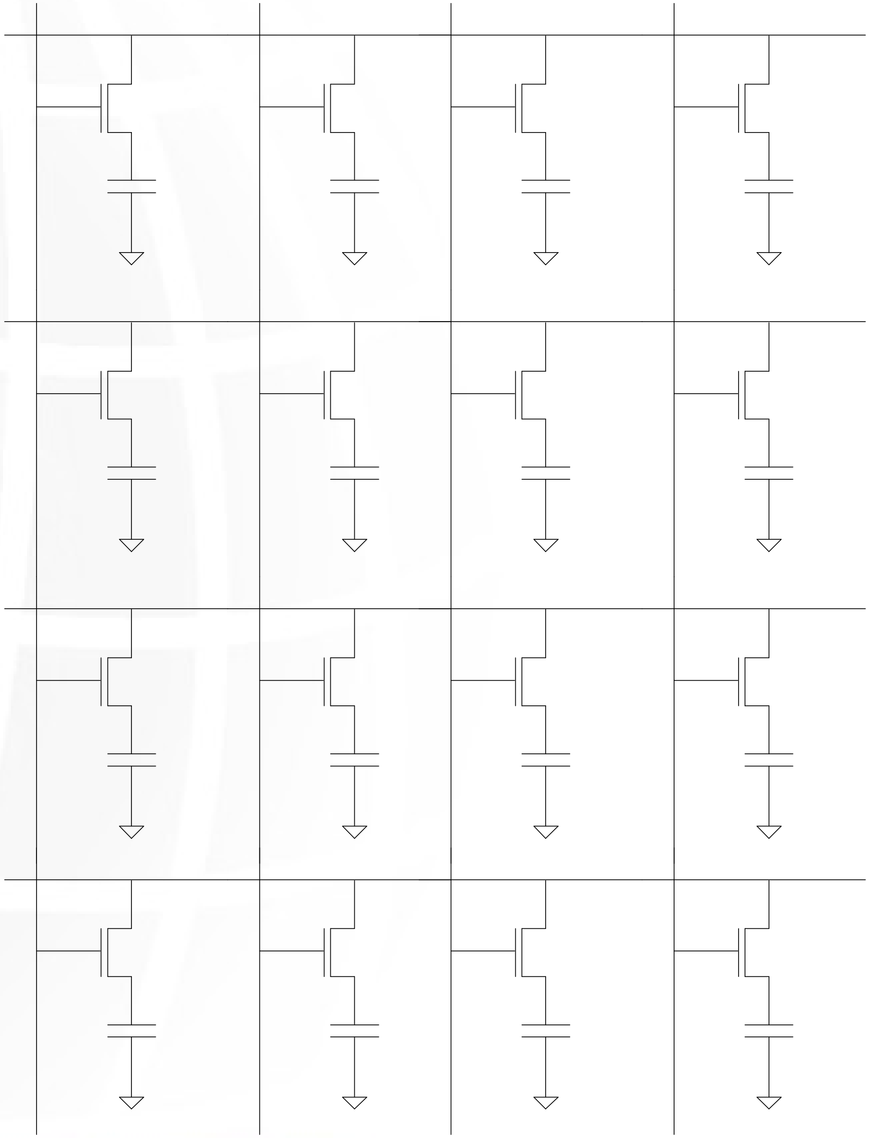
A= Surface area of cell plates

Other efforts to improve memory cell capacitance have included reductions in the dielectric thickness and the selective use of Silicon Nitride rather than Silicon Dioxide as the main dielectric material (k).

What It Really Looks Like

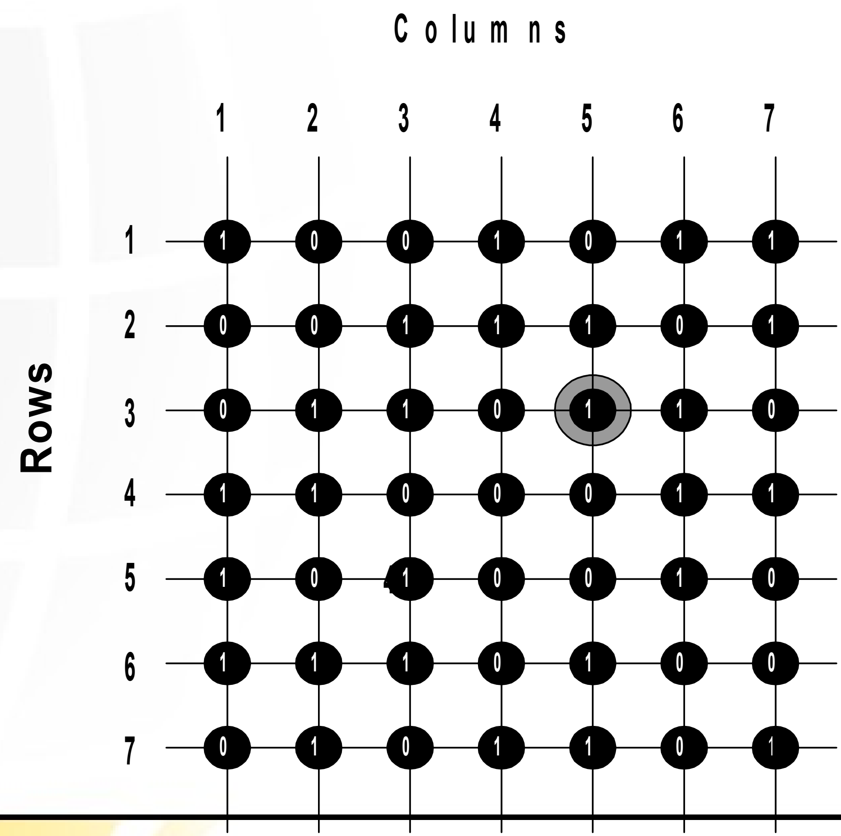


DRAM memory Array



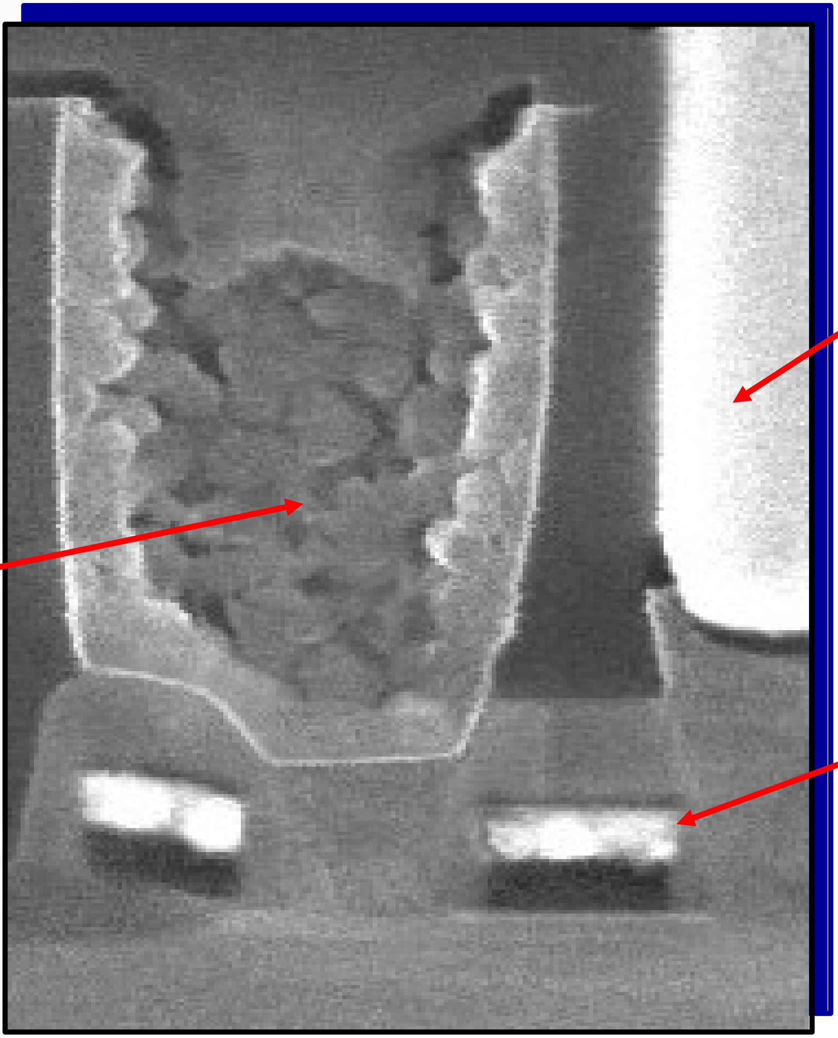
Reading and Writing

- Think of a memory chip as a grid or array of capacitors located at specific rows and columns. If we choose to *read* the memory cell located at row 3, column 5, we will retrieve information from a specific capacitor. Every time we go to row 3, column 5, we will access or address the same capacitor and obtain the same result (1) until the capacitive charge is changed by a write process.



DRAM Memory Cell

1 Bit

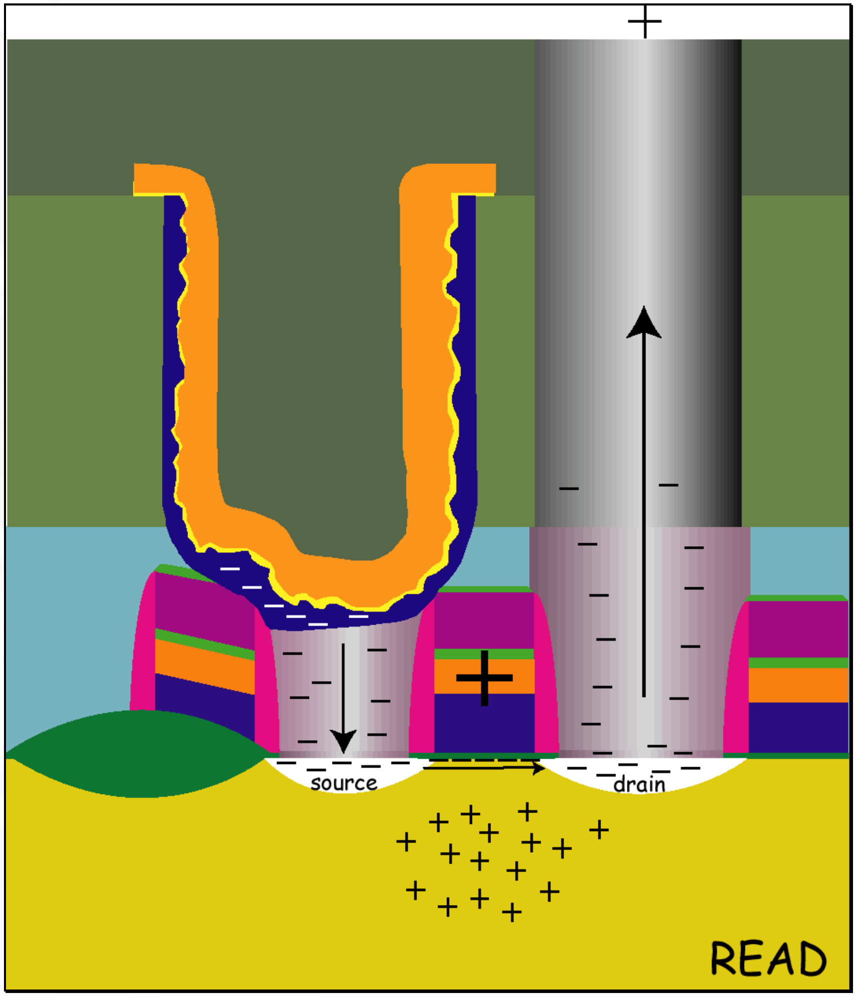


Capacitor

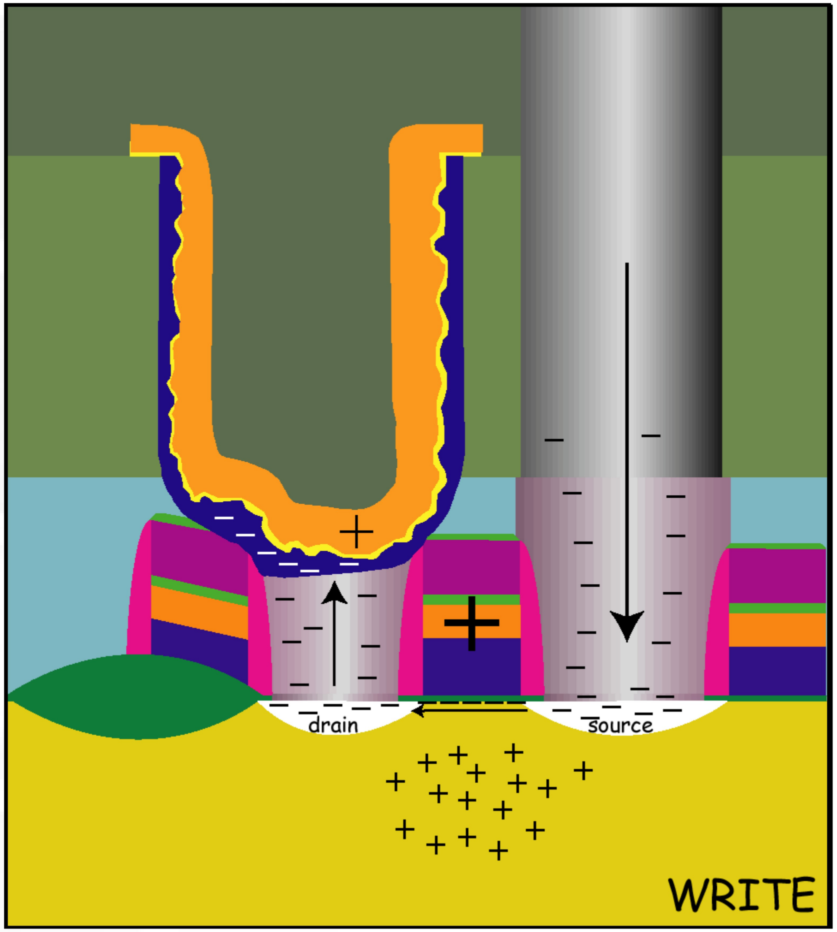
Column Line

Gate or
Row Line

READ



WRITE




the
End.