

Class 4: Semiconductor Doping and N-MOS



An integrated circuit on an Intel chip

PRIME Modules
Project-based Resources for Introduction to Materials Engineering

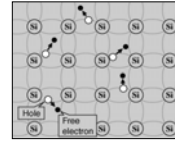
[www.intel.com/research]

Conduction in a semiconductor is controlled by doping, which is adding other atoms to the silicon

Heating up a semiconductor will increase its conductivity all over

But microelectronics need localized areas where the conductivity changes

Doping replaces Si atoms with atoms with a different electron configuration



Intrinsic (pure) semiconductor



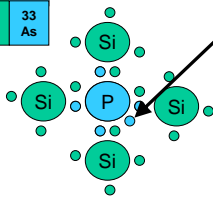
Extrinsic (doped) semiconductor

[hyperphysics.phy-astr.gsu.edu]

Silicon doped with electron donors is known as an **n** type semiconductor

III	IV	V
5 B	6 C	7 N
13 Al	14 Si	15 P
31 Ga	32 Ge	33 As

Replace Si with an atom from column V (P, As)



Now there is one extra electron

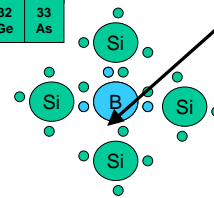
The dopant is called a donor

Si doped with donors is known as n-type

Silicon doped with electron acceptors is known as a **p** type semiconductor

III	IV	V
5 B	6 C	7 N
13 Al	14 Si	15 P
31 Ga	32 Ge	33 As

Si is replaced with an atom from column III (B)

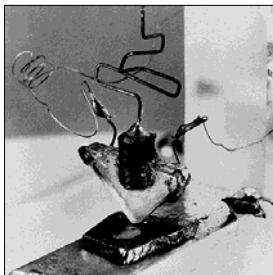


Now there is a missing electron called a hole

The dopant is called an acceptor

Si doped with acceptors is known as p-type

The first transistor was invented in 1947



"Brattain and Bardeen's pnp point-contact germanium transistor operated as a speech amplifier with a power gain of 18 on December 23, 1947"

[http://www.bell-labs.com/history]

There are many kinds of transistors and many different uses

The word transistor comes from transfer resistance

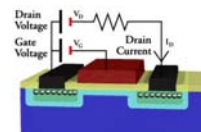
To operate, the conductivity of certain regions are manipulated

There many kinds of transistors: MOSFETs, BJTs, JFETs, MeSFETs

And many different uses: switches, binary logic, amplifiers, etc.



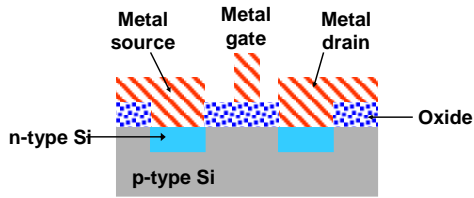
Family of transistors



MOSFET

[www.mtmi.vu.it]

MOSFETs are used as switches

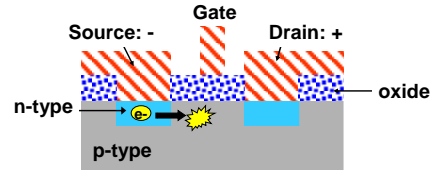


An N-MOSFET has n-type source and drains in a p-type bulk

The N MOS is Normally Off and does not conduct

The NMOS has a - voltage applied to the source and a + applied to the drain

Electrons will want to flow from the source to the drain



However, the p-type bulk has a lot of missing electrons

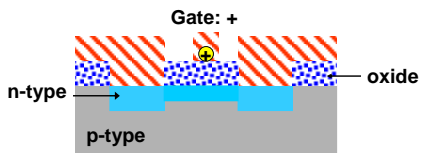
Electrons from the source get annihilated and never make it to the drain

Applying a positive voltage to the gate will turn the transistor on

Applying a + voltage to the gate builds a + charge because the oxide can't conduct (it's an insulator)

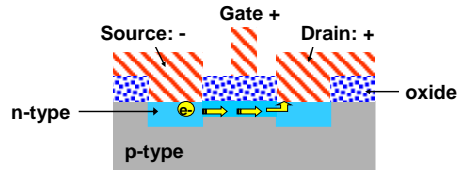
Electrons in the silicon will sense the positive force above (that's the field effect) and accumulate just below the oxide

If enough electrons build up, the silicon below the gate is converted from p-type to n-type



An N MOS in the "On" state has a positive voltage applied to the gate

An NMOS in the on-state has - voltage applied to the source, + applied to the drain, and + to the gate



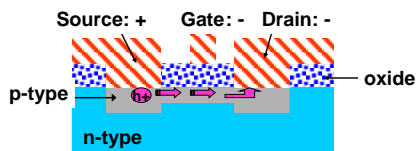
An n-type channel is created from the source to the drain for electrons to flow through

The P MOS is the opposite of an N MOS

The PMOS has p-type source and drain in an n-type bulk

The PMOS has + voltage applied to the source and - applied to the drain

To turn on, - is applied to the gate

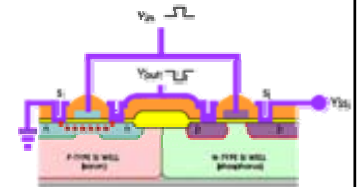


A CMOS is a P- MOS and an N MOS connected side by side

CMOS stands for Complementary MOSFET

An NMOS and a PMOS are fabricated side by side

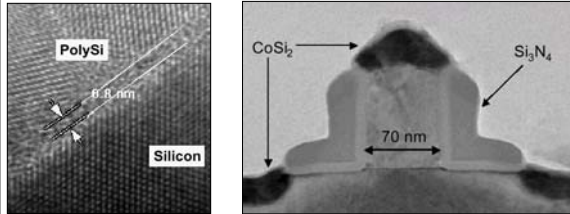
Opposite applied polarities will turn them on



http://www.eece.unm.edu/faculty/hersee/fbp_eece_576.html

Check out the original, which is animated

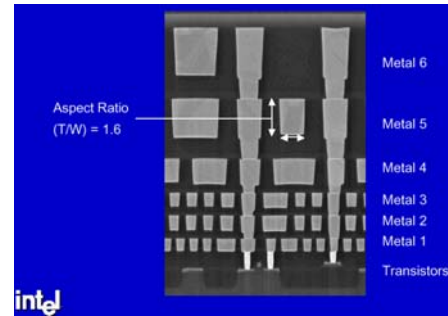
Real transistors are 1000 times smaller than a strand of human hair



The length of the gate on Intel's transistors is 30 nm

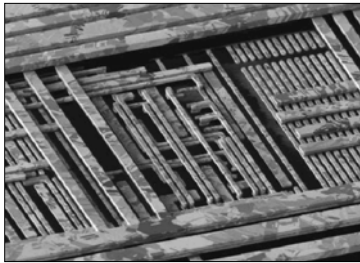
[http://www.intel.com/research]

An electron microscope shows the cross section of a transistor



[http://www.intel.com/research]

This top view shows many layers of wires needed to connect the millions of transistors that are on a microprocessor



[http://www.intel.com/research]

In summary, conduction in a semiconductor is controlled by doping

