

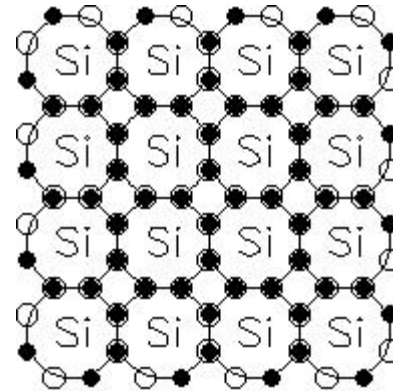
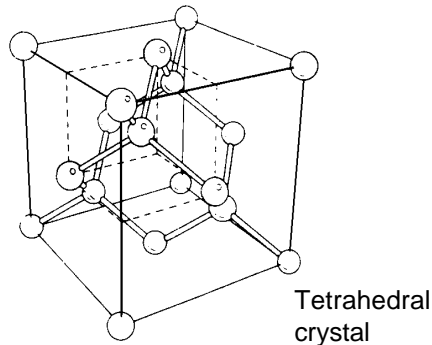
## Silicon atoms

Silicon atoms each have 4 valence electrons (electrons in their outermost shell). That leaves 4 spaces in the outer shell of 8. This makes silicon a very reactive chemical, like carbon, which has the same valence configuration.



## Silicon crystals

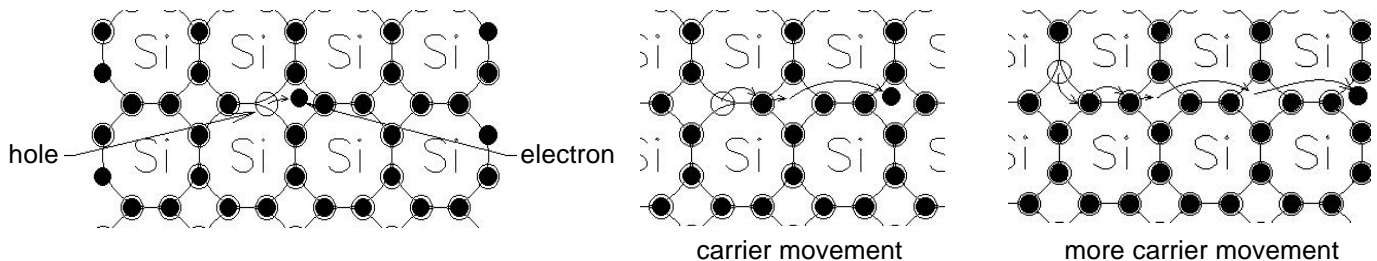
Each atom covalently bonds with four neighboring atoms to form a tetrahedral crystal, which we'll represent in 2D.



2-dimensional representation

In the pure, "intrinsic" crystal, practically all the electrons are used in bonds and all the spaces are filled, which leaves almost no electrons free to move and thus no way to make current flow.

By the effects of heat, light and/or large electric fields, a few electrons do break free of the bonds and become "free" carriers. That is, they're free to move about crystal and "carry" an electrical current.



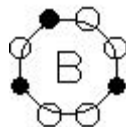
Interestingly, the space that was vacated by the electron also acts like a carrier. This pseudo-carrier is called a "hole" and it acts like a positively charged carrier.

Unless there's a lot of heat or light, the intrinsic silicon is still a very bad conductor. Silicon is considered a semiconductor.

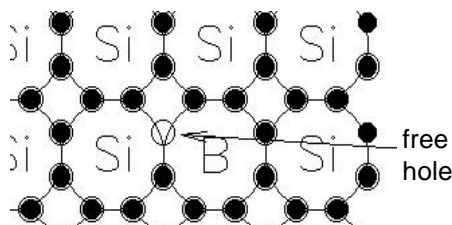
## Doping

### p-type

Some atoms, like boron and aluminum naturally have 3 valence electrons in their outer shells.

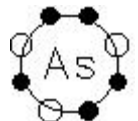


If you replace some of the silicon atoms in a crystal with boron there won't be quite enough electrons to fill the crystalline bond structure and unfilled spaces will act just like free holes. This "doped" silicon crystal is now called an p-type semiconductor. The p refers to the "extra" "positive" carriers.

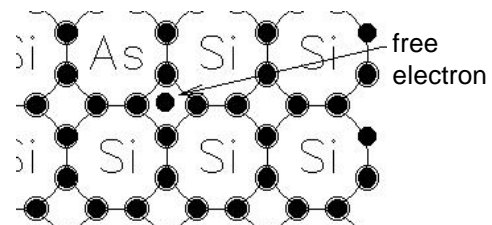


### n-type

Some atoms, like arsenic and phosphorus naturally have 5 valence electrons in their outer shells.

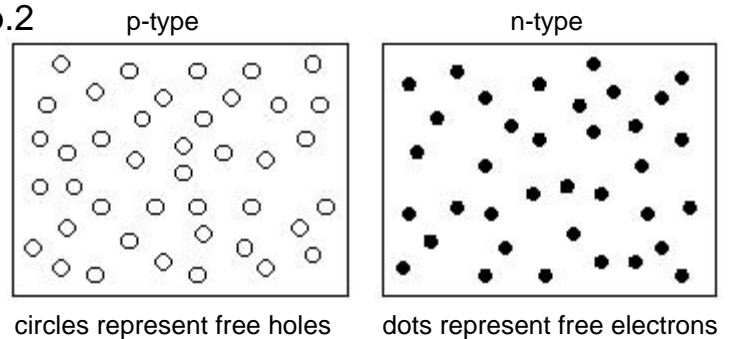


If you replace some of the silicon atoms in a crystal with arsenic the 5th electron doesn't fit into the crystalline bond structure and is therefore free to roam about and be a carrier. This "doped" silicon crystal is now called an n-type semiconductor. The n refers to the "extra" negative carriers.



## Diode Physics (The simple version) p.2

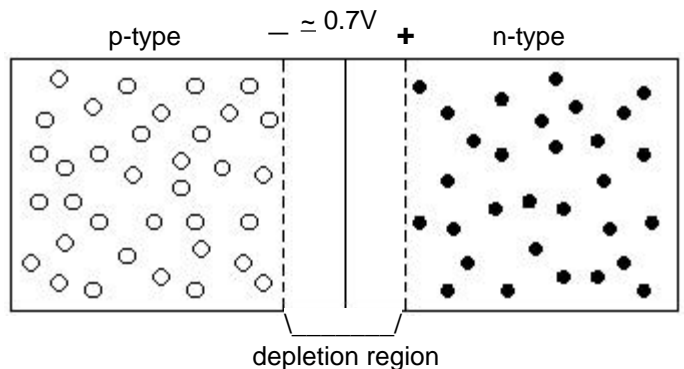
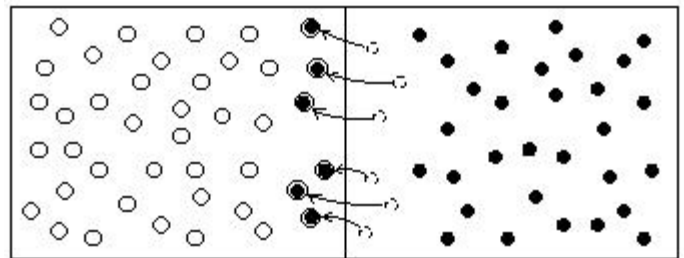
It turns out that the free carriers are the most important things in the semiconductor crystals, so we can simplify the drawings to show only these free carriers.



### PN Junction

When a p-type semiconductor is created next to an n-type, some of the free electrons from the n side will cross over and fill some of the free holes on the p side. This makes the p side negatively charged and leaves the n side positively charged. When the voltage across the junction reaches about 0.7 V the electrons find it too difficult to move against the charge and the process stops.

A region near the junction is now depleted of carriers and (surprise) is called the depletion region.

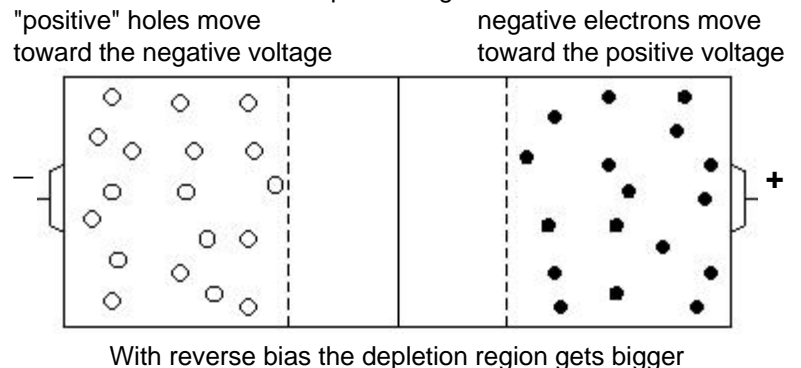


### Reverse bias

This pn junction is now a diode. If you place an external voltage across the diode in the reverse bias direction, the depletion region gets bigger and no current flows.

This reverse bias region can be used as a heat or light sensor since the only current flow should be due to a few carriers produced by these effects.

The reverse biased diode can also be used as a voltage variable capacitor since it is essentially an insulator (the depletion region) sandwiched between two conducting regions.



### Forward bias

If you place an external voltage across the diode in the forward bias direction, the depletion region shrinks until your external voltage reaches about 0.7V. After that the diode conducts freely..

