Ch. 12.1: Bonding in solids

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Crystalline solids

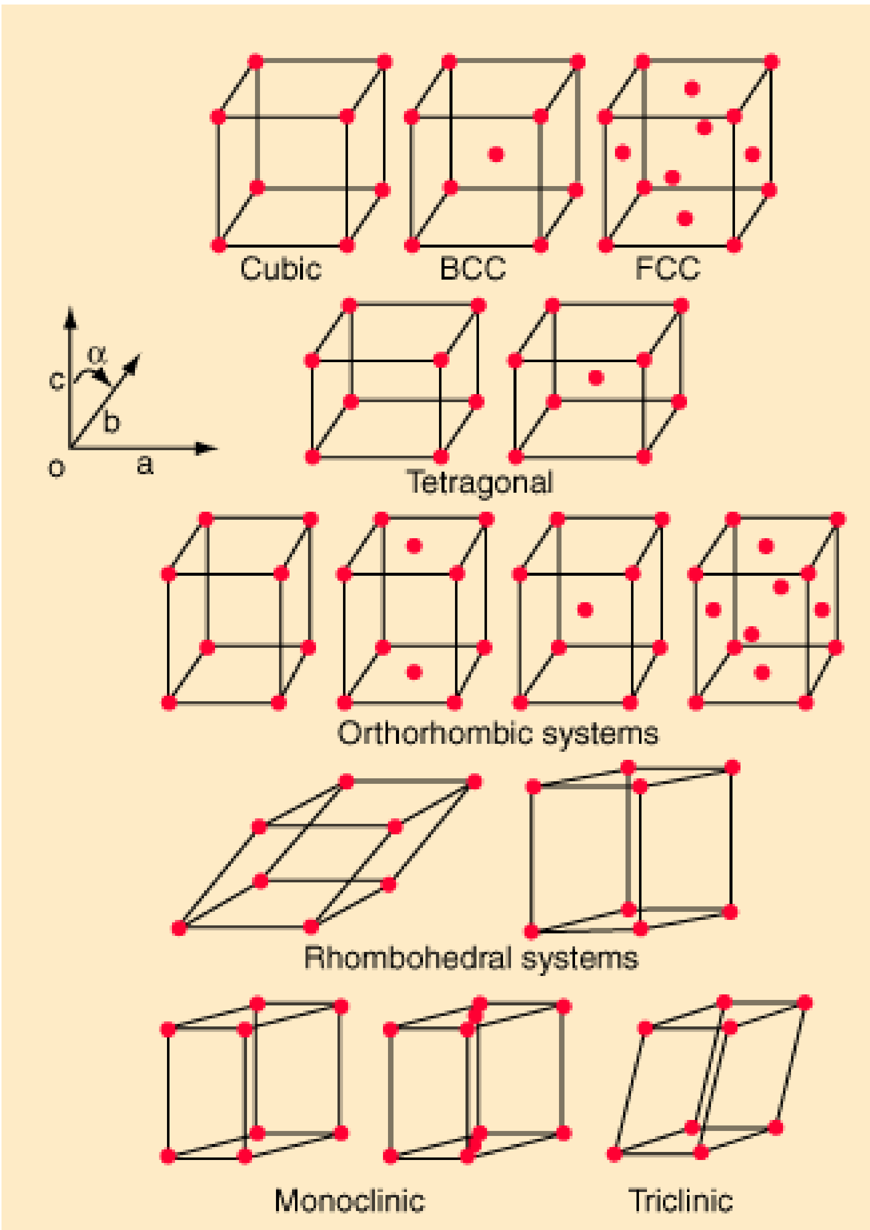
A large number of atoms arranged in a regular array, forming a periodic structure.

The number of possible lattice types is limited by the geometry of 3-dimensional space. These are known as the *Bravais lattices.*

Ordinary objects usually made of many tiny crystals. Details of defects and crystal domains affect strength of metals.

The various bonding mechanisms discussed previously apply to bonding in the solid state.

The Bravais lattices



from `http://hyperphysics.phy-astr.gsu.edu/hbase/solids/bravais.html`

Ionic solids

Dominant mechanism is Coulomb interaction between ions.

Net effect is a potential between atoms made of attractive coulombic part and a repulsion due to inner electron electrostatic repulsion and exclusion principle:

$$U_{\text{total}} = -\alpha k \frac{e^2}{r} + \frac{B}{r^m}.$$

α is the **Madelung constant,** depending on the crystal lattice, and $m \sim 10$.

The potential minumum at $r = r_0$, the equilibrium separation, is

$$U_0 = -\alpha k \frac{e^2}{r_0}\left(1 - \frac{1}{m}\right)$$

and $|U_0|$ is the **ionic cohesive energy**, the energy required to pull the solid apart into isolated ions. $|U_0|$ per atom, the **atomic cohesive energy** can be used to compare the strengths of bonding in solids.

Ionic crystal properties

- Stable and hard crystals.
- Poor electrical conductors (no free e^-)
- High melting and boiling points because high $|U_0|$.
- Transparent to visible light, absorb at IR.
- Generally soluble in polar liquids: dipole moment of solvent breaks ionic bonds.

Covalent solids

Crystals made of covalently bonded atoms in a lattice, a “giant molecule.”

Covalent bond is quite strong—diamond, for example.

- Very hard, high bond energies, melting points.

- Good insulators, tightly bound electrons interact less with light—many transparent.

Metallic solids

Metallic bonds are weaker, but still strong enough to make strong solids. Valence electrons are free to move about—think of metal as ions in a lattice surrounded by electron gas.

Visible light reacts strongly with free electrons which can move in phase, interacting to reflect light.

Nondirectionality of metallic bond allows mixtures of metal types—**alloys,** which can have varying strength, ductility, corrosion resistance, etc.

Molecular crystals

No electrons to bond—form due to van der Waal's type forces. Those with strong dipole moments form hydrogen bonds, such as H_2O.

Lower melting and boiling points, etc.

Amorphous solids

Have local order—approximate same bond length, etc. but no long-range order. Classic example is glass.

Slow cooling favors large crystal formation—long range order. Extremely rapid cooling can make amorphous solids of many materials.

See fig. 12.6 on melt spinning.