



Characteristics and Properties of Metals

An Online Continuing Education Course for Engineers

Course Number: MA-5002
Credit: 5 Hours / 5 PDH / 5 CPD

Characteristics and Properties of Metals

STRUCTURE OF METALS

BONDING

Atomic Bonding

Matter, as we know it, exists in three common states. These three states are solid, liquid, and gas. The atomic or molecular interactions that occur within a substance determine its state. In this section, we will deal primarily with solids because solids are of the most concern in engineering applications of materials. Liquids and gases will be mentioned for comparative purposes only.

Solid matter is held together by forces originating between neighboring atoms or molecules. These forces arise because of differences in the electron clouds of atoms. In other words, the valence electrons, or those in the outer shell, of atoms determine their attraction for their neighbors. When physical attraction between molecules or atoms of a material is great, the material is held tightly together. Molecules in solids are bound tightly together. When the attractions are weaker, the substance may be in a liquid form and free to flow. Gases exhibit virtually no attractive forces between atoms or molecules, and their particles are free to move independently of each other.

The types of bonds in a material are determined by the manner in which forces hold matter together.

Figure 1 illustrates several types of bonds and their characteristics are listed below.

- a) Ionic bond - In this type of bond, one or more electrons are wholly transferred from an atom of one element to the atom of the other, and the elements are held together by the force of attraction due to the opposite polarity of the charge.
- b) Covalent bond - A bond formed by shared electrons. Electrons are shared when an atom needs electrons to complete its outer shell and can share those electrons with its neighbor. The electrons are then part of both atoms and both shells are filled.
- c) Metallic bond - In this type of bond, the atoms do not share or exchange electrons to bond together. Instead, many electrons (roughly one for each atom) are more or less free to move throughout the metal, so that each electron can interact with many of the fixed atoms.
- d) Molecular bond - When the electrons of neutral atoms spend more time in one region of their orbit, a temporary weak charge will exist. The molecule will weakly attract other molecules. This is sometimes called the van der Waals or molecular bonds.

- e) Hydrogen bond - This bond is similar to the molecular bond and occurs due to the ease with which hydrogen atoms are willing to give up an electron to atoms of oxygen, fluorine, or nitrogen.

Some examples of materials and their bonds are identified in Table 1.

Material	Bond
Sodium chloride	Ionic
Diamond	Covalent
Sodium	Metallic
Solid H ₂	Molecular
Ice	Hydrogen

The type of bond not only determines how well a material is held together, but also determines what microscopic properties the material possesses. Properties such as the ability to conduct heat or electrical current are determined by the freedom of movement of electrons. This is dependent on the type of bonding present. Knowledge of the microscopic structure of a material allows us to predict how that material will behave under certain conditions. Conversely, a material may be synthetically fabricated with a given microscopic structure to yield properties desirable for certain engineering applications.

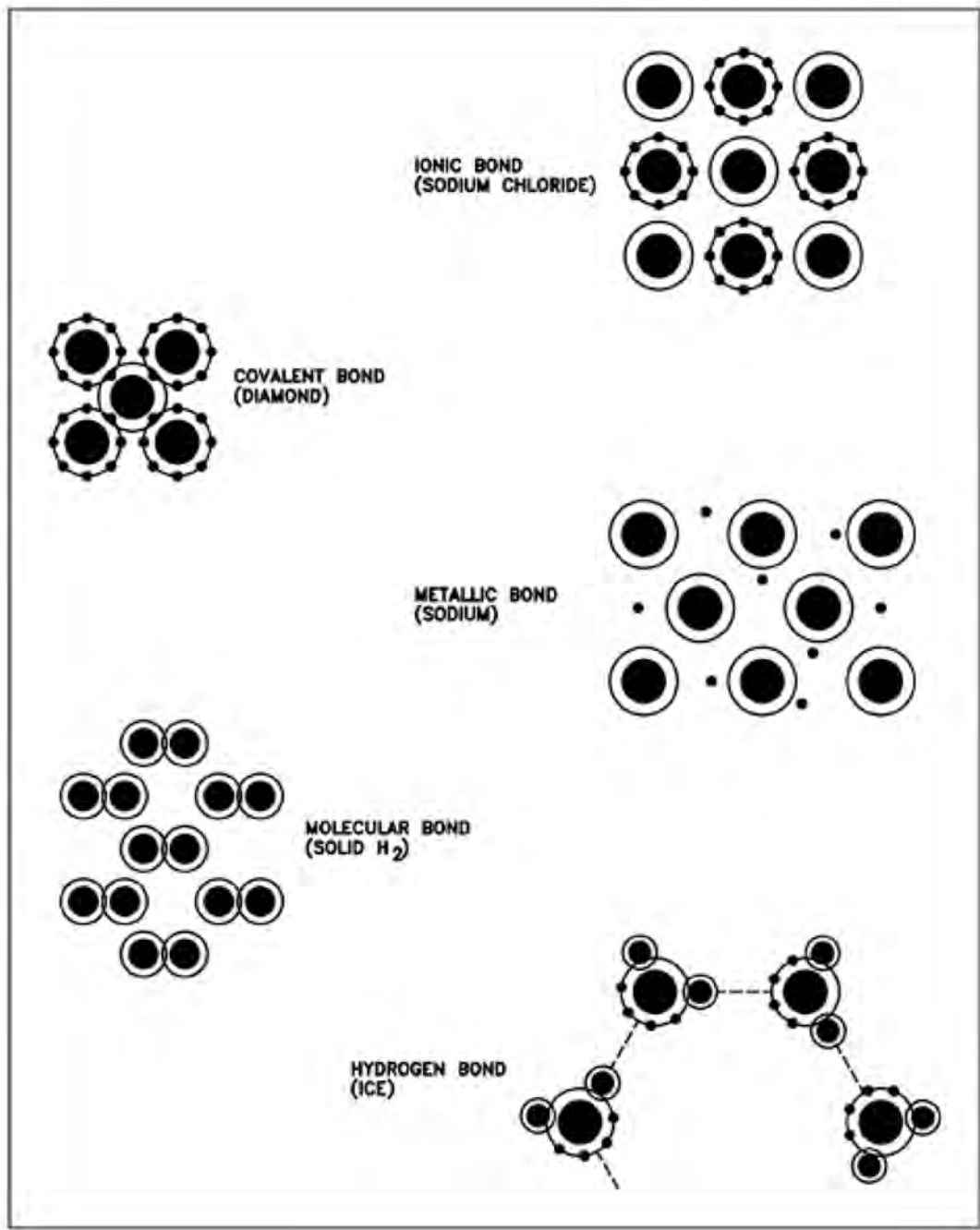


Figure 1. Bonding Types

Order in Microstructures

Solids have greater inter-atomic attractions than liquids and gases. However, there are wide variations in the properties of solid materials used for engineering purposes. The properties of materials depend on their inter-atomic bonds. These same bonds also dictate the space between the configuration of atoms in solids. All solids may be classified as either amorphous or crystalline.

Amorphous

Amorphous materials have no regular arrangement of their molecules. Materials like glass and paraffin are considered amorphous. Amorphous materials have the properties of solids. They have definite shape and volume and diffuse slowly. These materials also lack sharply defined melting points. In many respects, they resemble liquids that flow very slowly at room temperature.

Crystalline

In a crystalline structure, the atoms are arranged in a three-dimensional array called a lattice. The lattice has a regular repeating configuration in all directions. A group of particles from one part of a crystal has exactly the same geometric relationship as a group from any other part of the same crystal.

Types of Bonds and Their Characteristics

- Ionic bond – An atom with one or more electrons are wholly transferred from one element to another, and the elements are held together by the force of attraction due to the opposite polarity of the charge.
- Covalent bond – An atom that needs electrons to complete its outer shell shares those electrons with its neighbor.
- Metallic bond – The atoms do not share or exchange electrons to bond together. Instead, many electrons (roughly one for each atom) are more or less free to move throughout the metal, so that each electron can interact with many of the fixed atoms.
- Molecular bond – When neutral atoms undergo shifting in centers of their charge, they can weakly attract other atoms with displaced charges. This is sometimes called the van der Waals bond.
- Hydrogen bond – This bond is similar to the molecular bond and occurs due to the ease with which hydrogen atoms displace their charge.

Order in Microstructures

- Amorphous microstructures lack sharply defined melting points and do not have an orderly arrangement of particles.
- Crystalline microstructures are arranged in three-dimensional arrays called lattices.

COMMON LATTICE TYPES

Common Crystal Structures

In metals, and in many other solids, the atoms are arranged in regular arrays called crystals. A *crystal structure* consists of atoms arranged in a pattern that repeats periodically in a three-dimensional geometric lattice. The forces of attraction between atoms cause this repetition. It is this repeated pattern which controls many of the properties of metals, such as density, conductivity (property of conducting or trans

In general, the three most common crystal structures used with metals are: (a) the body-centered cubic structure, (b) the face-centered cubic structure, and (c) the hexagonal close-packed. Figure 2 shows these three pa

To view the remainder of the course material and to take the quiz for PDH credit, you must purchase the course.

Close this window and click "Add to cart" on the product page.