Fundamentals of Metals

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TERMINAL OBJECTIVE

1.0 Without references, **DESCRIBE** the bonding and patterns that effect the structure of a metal.

ENABLING OBJECTIVES

1.1 **STATE** the five types of bonding that occur in materials and their characteristics.

1.2 **DEFINE** the following terms:

a. Crystal structure
b. Body-centered cubic structure
c. Face-centered cubic structure
d. Hexagonal close-packed structure

1.3 **STATE** the three lattice-type structures in metals.

1.4 Given a description or drawing, **DISTINGUISH** between the three most common types of crystalline structures.

1.5 **IDENTIFY** the crystalline structure possessed by a metal.

1.6 **DEFINE** the following terms:

a. Grain
b. Grain structure
c. Grain boundary
d. Creep

1.7 **DEFINE** the term polymorphism.

1.8 **IDENTIFY** the ranges and names for the polymorphism phases associated with uranium metal.

1.9 **IDENTIFY** the polymorphism phase that prevents pure uranium from being used as fuel.

ENABLING OBJECTIVES (Cont.)

1.10 **DEFINE** the term alloy.

1.11 **DESCRIBE** an alloy as to the three possible microstructures and the two general characteristics as compared to pure metals.

1.12 **IDENTIFY** the two desirable properties of type 304 stainless steel.

1.13 **IDENTIFY** the three types of microscopic imperfections found in crystalline structures.

1.14 **STATE** how slip occurs in crystals.

1.15 **IDENTIFY** the four types of bulk defects.

BONDING

The arrangement of atoms in a material determines the behavior and properties of that material. Most of the materials used in the construction of a nuclear reactor facility are metals. In this chapter, we will discuss the various types of bonding that occurs in material selected for use in a reactor facility.

EO 1.1 STATE the five types of bonding that occur in materials and their characteristics.

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 chapter, 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.

TABLE 1

Examples of Materials and Their Bonds

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.

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