Structure and Properties of Materials

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ABSTRACT

This article provides a definition and classification of metals. Elementary crystal lattices. Characteristic features of ferrous metals. Atomic-crystalline structure of metals. Scheme of arrangement of elementary geometric cells in atomic lattices of metals and alloys. Geometric forms of elementary crystal cells.

Keywords: Metal, mechanism, chemical, physics, engineering, element, material, atom, color, anisotropy, scheme.

Metals can be defined in terms of chemistry, physics, and engineering.

In chemistry, metals are chemical elements on the left side of the periodic system of elements by D. Mendeleev, which have a special mechanism of interaction of valence electrons (ions) with the nucleus both in the metals themselves and when entering into chemical reactions with other elements, including metals.

Physics characterizes metals as solids with color, luster, melting (melting) and solidification (crystallization) capabilities, thermal and electrical conductivity, magnetic and other properties.

In engineering, metals are constructional materials with high machinability (malleability, stamping, cutting, soldering, weldability, etc.), strength, hardness, impact toughness and a number of other valuable properties that make them widely used.

Russian scientist M.V. Lomonosov (1711-1765), while examining metals and nonmetals in his work "First principles of metallurgy and ore mining" gave definition to metals: "Metal is called a light body, which can be forged. There are only six such bodies: gold, silver, copper, tin, iron and lead. M.V. Lomonosov gave this definition in 1773, when only six metals were known.

Metals extracted from the earth produce a large group of construction materials used in various industries. In nature, some metals are found in pure, native form, while others are found in the form of oxides (metal compounds with oxygen), nitrides and sulfides, which make up the various ores of these metals.

The most common metals used as construction materials are iron, aluminum, copper, and alloys based on these metals.

Metals include more than 80 elements of the periodic system of Mendeleev. All of these metals are divided into two large groups: ferrous metals and nonferrous metals.

The characteristic features of ferrous metals are their dark gray color, luster, high density and melting point, hardness, strength, ductility and polymorphism (allotropy). According to their physical and chemical properties, ferrous metals are divided into five groups:

- ferrous (iron, cobalt, nickel, manganese);
- refractory (tungsten, rhenium, tantalum, molybdenum, niobium, vanadium, chromium, titanium, etc.);
- Uranium - actinides (uranium, thorium, plutonium, etc.);
- rare-earth - lanthanides (lanthanum, cerium, scandium, etc.);
- alkaline-earth metals (lithium, sodium, potassium, calcium, etc.).

Of these five groups of ferrous metals, the ferrous and refractory metals are particularly widely used in industrial production.

Ferrous metals, except for manganese, are also called ferromagnets. Ferromagnets can magnetize and attract the metals of their group.

Refractory metals are those with a melting point above that of iron (1,539 ° C): titanium - 1,667 ° C, vanadium - 1,902 ° C, chromium - 1,903 ° C, molybdenum - 2,615 ° C,

Niobium - 2 460 °C, tantalum - 2 980 °C, tungsten - 3 410 °C. Refractory metals are mainly used as alloying elements in the production of heat-resistant, heat-resistant, heat-resistant and special alloys, including hard alloys and high-alloy steels.

Metal structure. The atomic-crystalline structure of metals. As we know, all substances consist of atoms, including metals. Each metal (chemical element) can be in gaseous, liquid or solid aggregate states. Each aggregate state will have different characteristics from each other. In a gaseous metal, the distance between the atoms is large, the interaction forces are small and the atoms move chaotically in space; the gas tends to expand toward a larger volume. When temperature and pressure decrease, the substance turns into a liquid state. The properties of liquid matter differ sharply from the properties of gaseous matter. In liquid metal, the atoms retain only the so-called near-order of atoms, i.e. a small number of atoms rather than atoms of the whole volume are placed in the volume. When the temperature drops, the liquid metal changes to a solid state, which has a strict pattern of atom arrangement.

If one draws vertical and horizontal connection lines through the centers of atoms, one sees that in the solid state metals atoms are arranged in a strictly definite order and present numerous repetitive elementary geometric figures--parallelepipeds (Fig. 1.1). The smallest geometric figure is called an elementary cell. Elementary cells located on horizontal and vertical crystallographic planes (Fig. 1.2), form a spatial crystal lattice.

Elementary crystal lattices are characterized by the following basic parameters: the distance between atoms along coordinate axes (along bond lines), angles between bond lines, coordination number - the number of atoms at the closest and most equal distance from any atom in the lattice. The shape of a unit cell is viewed along crystallographic planes in three dimensions.

Thus, any metal can be represented not as a single solid mass, but as a mass composed of a multitude of elementary cells. A block of elementary atomic crystal cells forms an atomic crystal cell (lattice). If we isolate this elementary cell, then depending on metal we get the following types of crystal cells (Fig. 1.3): cube (K), volume-centered cube (VCC), face-centered cube (HCC), hexagonal dense-packed cell (HPC), hexagonal simple cell (G), etc.

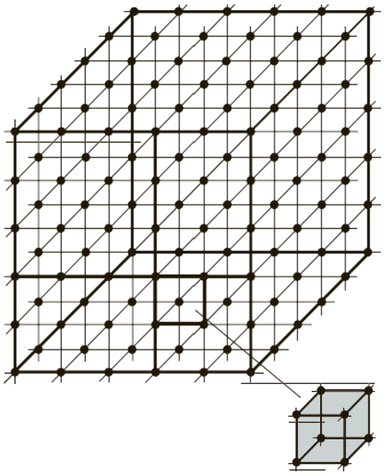

Fig. 1.1. Scheme of arrangement of elementary geometric cells in atomic lattices of metals and alloys

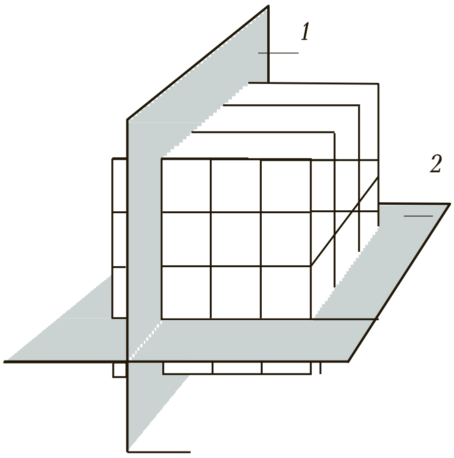

Fig. 1.2. Location of crystallographic planes:
1 and 2 - horizontal and vertical crystallographic planes, respectively

A simple cubic cell (Fig. 1.3, a) is characteristic of nonmetallic The simple cubic cell (Fig. 1.3a) is characteristic of non-metals, which have the highest density and specific gravity, and has eight atoms located in each vertex of the cube.

A cubic centered unit cell (Fig. 1.3b) has eight atoms, one atom at each vertex of the cube and one atom in the center of the cube, equally spaced from the cube facets. Iron, vanadium, tungsten, molybdenum, tantalum, and chromium, i.e. mostly ferrous metals, have this form of atomic crystal cell.

A face-centered cubic cell (Fig. 1.3, c) has 14 atoms - one atom in each vertex of the cube (eight atoms) and one atom in the center of each face (six atoms). The face-centred cubic unit cell has aluminum, iron of Fe-modification, gold, cobalt, copper, nickel, platinum and silver, mainly nonferrous metals and some ferrous metals.

Hexagonal densely packed cell (Fig. 1.3, d) consists of 17 atoms. The shape of the geometric body that these atoms form is a hexagonal prism. There are six atoms in each vertex of the top and bottom bases, one atom in the center of these bases and three atoms in the center of one of the three faces (through the face). Beryllium, cadmium, magnesium, vanadium and tantalum have hexagonal, tightly packed cells.

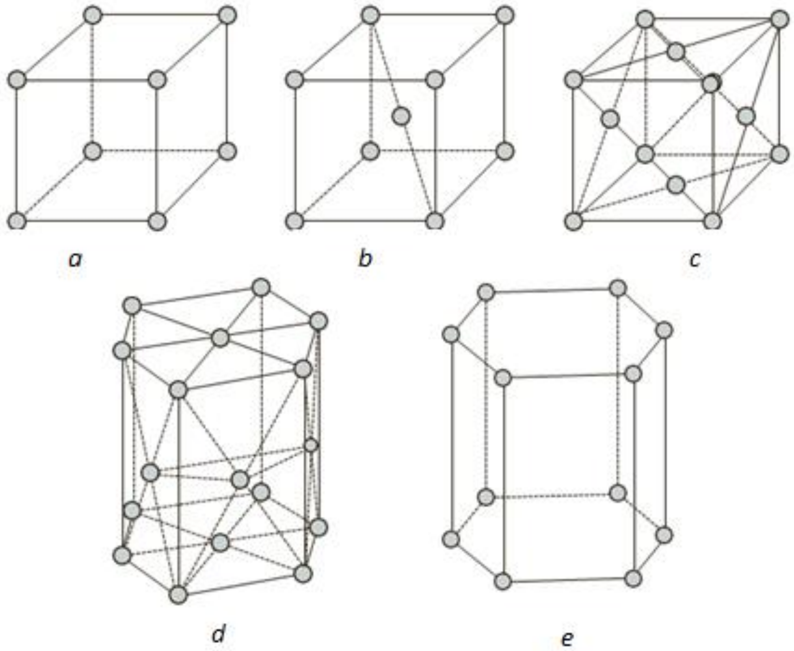

Figure 1.3. Geometric forms of elementary crystal cells:

Fig. 1.3. Geometric forms of elementary crystal cells:
a - cube; b - volume-centered cube; c - face-centered cube; d - hexagonal densely packed cell; e - hexagonal simple cell

A simple hexagonal cell (Fig. 1.3, e) consists of 12 atoms that are located at the tops of the upper and lower bases of a hexagonal prism. Mercury and zinc have such a crystal cell.

The connection between the atoms in the crystal lattice and between the lattices is made by the so-called metallic bonding. The strength of this bond determines the strength and hardness of metals. The higher this bond, the greater the strength and hardness of metals. The mechanism of bonding between atoms in the lattice and between lattices has a complex physical and chemical nature.

In practice, a perfect arrangement of crystal lattices is usually not observed. Crystals formed by crystal lattices have distorted geometric shape and different size.

Anisotropy of metals. Anisotropy (from Gr. anisos - unequal and tropos - direction) is the unequal physical properties of the medium (body) in different directions. Anisotropy implies the dependence of metal properties on the direction along the planes of atomic-crystalline lattice. The more atoms in the plane, the higher the properties of metals. There are more atomic-crystalline lattices in the horizontal planes in any form than in the vertical planes. Consequently, the strength of metals tested in the horizontal direction is higher than in the vertical direction. Anisotropy manifests itself in the processing of structural materials by pressure (rolling, drawing, stamping and other technological methods of producing blanks and products).

In Fig. 1.2, the crystallographic planes coincide with the bond lines passing through the metal atoms. The shape of the unit crystal cell, the distance between the atoms, and the strength of the metal bond determine the physical, mechanical, and technological properties of metals. If the metal under study is viewed along three crystallographic planes, along the lines of bonding between the atoms, it can be seen that the properties along these three dimensions will be different. The number of atoms in these planes is not the same. The metallic bonding between horizontally and vertically arranged atoms is also unequal. This, in turn, leads to different strengths of metals in the longitudinal and transverse directions. For example, the strength of copper in the longitudinal direction will be twice as great as in the transverse direction.

All metals are anisotropic because they are composed of crystals. The crystalline structure of metals determines the plastic deformation, i.e. change of the external shape and dimensions under the action of loads without destruction. The ability of metals and alloys to deform plastically is the basis for forming (rolling, drawing, forging, punching, and extrusion). In pressure treatment, such as rolling (Fig. 1.4, a), one layer of atomic lattices moves over the other in crystallographic planes (Fig. 1.4, b).

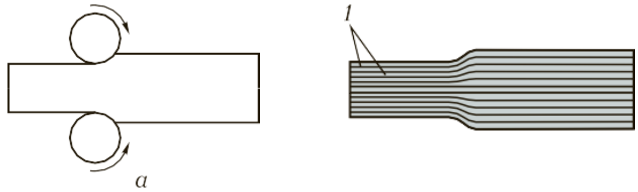

Fig. 1.4. Scheme of deformation of metals and alloys (rolling):
a - deformation; b - sliding of metals on crystallographic planes during deformation; 1 - crystallographic planes

In the process of metal deformation during rolling, not only does the transverse and longitudinal dimensions of the work pieces change, but also the microstructure of the metal changes.

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