TOPIC: STUDY OF THE METAL CRYSTALLIZATION PROCESS

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Abstract: The crystallization process of metals is based on physical and chemical laws and plays a crucial role in their transition to a solid state. This process affects the structure, mechanical properties, and operational qualities of metals. The crystallization process includes stages such as nucleation and crystal growth. The crystallization rate of metals depends on cooling conditions, which determine the structure's accuracy and homogeneity. Research indicates that controlling the crystallization process can enhance the strength and durability of metals.

Keywords: metal, crystallization, structure, nucleation, crystal growth, cooling, hardness, plasticity, diffusion, grains, phase transition, homogeneity, amorphous state, strength, heat transfer, alloy, deformation, mechanical properties, operational qualities, metallurgy.

Introduction

Crystallization. The process of obtaining dissolved solid components from solutions in a crystalline state is called crystallization. The reverse process of crystallization is called melting. A crystal refers to a homogeneous solid substance of various shapes, bounded by flat edges. Crystallization is a primary method for obtaining pure solid substances, as it allows for conditions where unwanted substances remain in the solution while only the pure substance crystallizes. The crystallization process is widely used in chemistry, petrochemistry, metallurgy, medicine, pharmaceuticals, food, and other industries. The objectives of crystallization include isolating crystalline phases from solutions, separating impurities in single and multi-stage crystallization processes, obtaining highly purified substances, and growing single crystals. During the crystallization process, crystals of various sizes are formed. Crystals always have characteristic geometric shapes. There are 32 types of crystal symmetry axes, grouped into seven crystallographic categories: cubic, trigonal, tetragonal, hexagonal, orthorhombic, monoclinic, and triclinic.

A chemical substance forming different crystal structures is called polymorphism. Crystals containing water molecules in their structure are called crystal hydrates. For crystallization to occur, the initial solution must be supersaturated. If the concentration of the dissolved substance in the solution exceeds its solubility, the solution is termed supersaturated. Since supersaturated solutions are unstable systems, the excess dissolved substance precipitates, leading to crystallization. Once crystallization ceases, a saturated solution remains. Industrial crystallization processes include three main stages:

1) crystallization, 2) separation of crystals from solutions, and 3) washing and drying of crystals.

Research and methodology

Currently, elements in the periodic table are divided into metals and nonmetals, with metals comprising more than half of all elements and distinguished by their electrical conductivity. Their electrical conductivity depends on temperature and is also a good conductor of heat. Metals can be defined as "substances that increase electrical conductivity with decreasing temperature, are malleable, conduct heat well, and have a shiny appearance." The electrical and thermal conductivity of metals is due to the presence of free electrons in their crystal lattice. X-ray analysis of the internal structure of metals reveals that their atoms are arranged in a specific order, which repeats in space according to specific laws. Therefore, in studying the internal structure of metals, the arrangement of their atoms is represented in a crystal or spatial lattice. Most metals possess three types of crystal lattices:

Body-centered cubic (BCC) lattice. This type of lattice consists of 9 atoms: 8 at the corners of the cubic cell and 1 at the center. This structure is characteristic of Feα, Cr, V, W, Mo, Li, Te, Sn, and others.

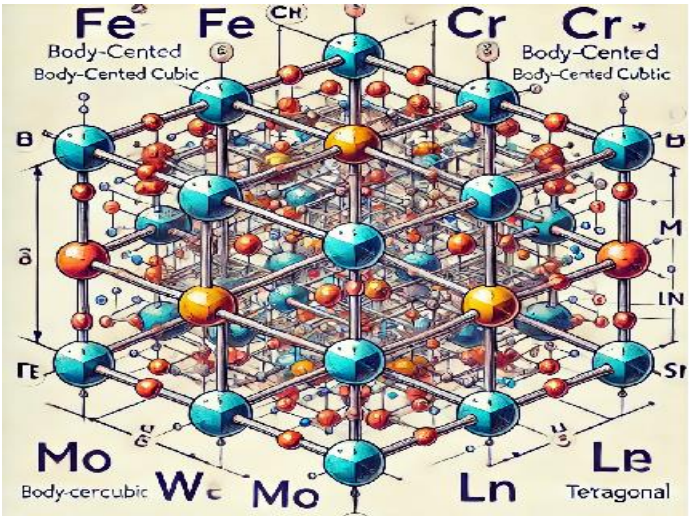

Figure 1.**Body-centered cubic (BCC) lattice.**

Face-centered cubic (FCC) lattice. This lattice consists of 14 atoms: 8 at the cube corners and 6 at the center of the cube's faces. This structure is typical of Feα, Al, Cu, Ni, Co, Pb, Ag, and Au.

Fe (Iron) – Body-centered cubic (BCC)

Al (Aluminum) – Face-centered cubic (FCC)

Cu (Copper) – Face-centered cubic (FCC)

Ni (Nickel) – Face-centered cubic (FCC)

Co (Cobalt) – Hexagonal close-packed (HCP)

Pb (Lead) – Face-centered cubic (FCC)

Ag (Silver) – Face-centered cubic (FCC)

Au (Gold) – Face-centered cubic (FCC)

Hexagonal close-packed (HCP) lattice. This lattice consists of 17 atoms: 12 at the corners of a hexagonal prism, 2 at the centers of the upper and lower faces, and 3 in the middle of the prism. This structure is typical of Zn, Mg, Co, Ti, Ve, and others.

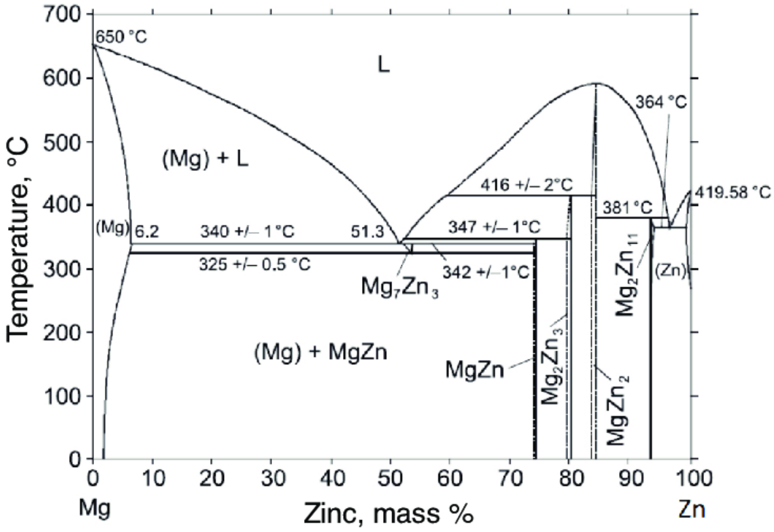

Figure 1.Diagram

Some metals, such as Fe, Sn, Mg, Co, Ti, and others, undergo changes in crystal structure under external conditions (temperature, pressure). This phenomenon is called allotropy or polymorphism. Allotropic modifications of metals are denoted by Greek letters α, β, γ. The lowest-temperature modification is labeled α, while higher-temperature modifications are labeled β, γ, etc. All metals transition to a liquid state when heated to a specific temperature. For example, pure iron melts at 1539°C. When cooled from a liquid state to room temperature, it solidifies. In the solid state, iron exhibits two modifications: α-Fe and γ-Fe

α-Iron (Fe): Exists in two temperature ranges—below 911°C and between 1392°C and 1539°C. Its crystal lattice is a body-centered cubic (BCC) structure.

γ-Iron (Fe): Exists between 911°C and 1392°C, with a face-centered cubic (FCC) crystal lattice.

The transition of metal atoms from a mobile liquid state to an orderly solid state is called crystallization.

In 1878, Russian scientist D.K. Chernov was the first to discover the laws of metal crystallization. He demonstrated that the crystallization process consists of two elementary steps:

3.Results and analysis

Formation of crystallization centers and growth of crystals around these centers. The size of formed crystals depends on the number of crystallization centers (MS) and the growth rate of crystals (KT). It is important to note that undissolved oxides and non-metallic particles in metals can act as crystallization centers. The number of crystallization centers and the crystal growth rate, in turn, depend on the degree of undercooling. Graphical representation of crystal growth rate and the number of centers depending on the degree of undercooling. If the number of crystallization centers is high and the crystal growth rate is low, fine-grained structures form. Conversely, if the number of crystallization centers is low and the crystal growth rate is high, coarse-grained structures form.

4.Conclusion

The crystallization process of metals is a crucial stage in determining their physical and mechanical properties. This process includes nucleation and crystal growth stages and ensures the structural homogeneity and strength of metals depending on cooling conditions. Research shows that controlling the crystallization process can improve metal quality indicators, increasing their strength and operational characteristics. This contributes to increased efficiency in metallurgy and materials science.

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