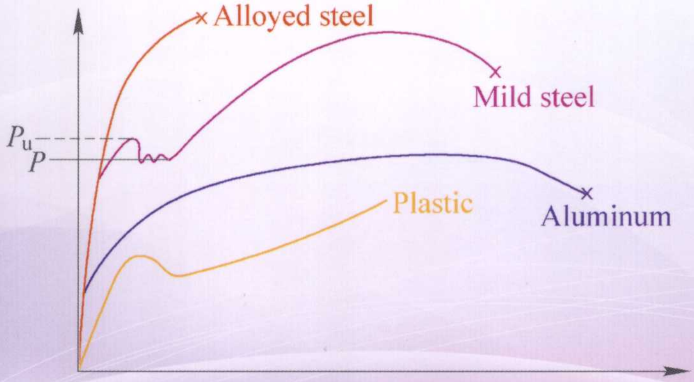
普通高等教育“十二五”规划教材

PUTONG GAODENG JIAOYU "12·5" GUIHUA JIAOCAI

Special English for Material Processing Engineering

材料加工工程科技英语

王快社　刘 环　张 郑　编著



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内 容 提 要

本书是材料成形与控制工程专业学生用以掌握本专业英语词汇，阅读、翻译及写作相关英文文章的基础教程。本书的主要内容包括相与结构、材料检测方法、金属材料热处理、轧制理论及工艺、挤压与拉拔、铸造、锻造及焊接工艺、CAD/CAM 等，另外选用了12篇阅读材料加以补充。

本书主要作为高等院校相关专业学生的教材，也可供从事金属材料加工工作的工程技术人员参考。

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前言

本书是为材料成形与控制工程专业高年级学生在学完基础英语之后而设置的以专业内容为主体的英语教材。主要目的是使学生巩固英语基本词汇，扩展专业词汇，掌握本专业的基本英语术语；提高对专业英语语法结构的综合分析能力和文章的阅读能力，培养学生的翻译能力与写作技巧。全书共分8章，包括相与结构、材料检测方法、金属材料热处理、轧制理论及工艺、挤压与拉拔、铸造、锻造及焊接工艺、CAD/CAM。此外，为了提高同学的阅读能力和保证教材内容上的完整性，选用了12篇阅读材料。每篇课文后都附有生词和专业技术词汇表以及思考题，以利于学生阅读和理解课文，记忆和掌握专业词汇。

本书是针对材料成形与控制专业编写的，也适合于从事金属材料加工的工程技术人员扩展专业英语词汇，巩固专业英语水平之用。该书是按60学时编写的，由西安建筑科技大学王快社同志负责统稿并担任主编，刘环、张郑任副主编，王文也参与了部分阅读材料的编写工作，在编写过程中，西安建筑科技大学冶金学院材料加工研究所的全体教师提出了许多宝贵意见，本书的出版也得到西安建筑科技大学材料加工工程省级重点学科的支持，在此一并表示感谢。

由于编者水平所限，书中不足之处在所难免，诚望读者批评指正。

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1 Phase and Structures

The goal of this chapter is to describe the underlying physical concepts related to the structure of materials. You will learn that the structure of atoms affects the types of bonds that hold materials together. These different types of bonds directly affect suitability of materials for real-world engineering applications. Arrangements of atoms and ions play an important role in determining the microstructure and properties of materials. A phase can be defined as any portion, including the whole of a system which is physically homogeneous within itself and bounded by a surface so that it is mechanically separable from any other portions. A phase diagram shows the phases and their composition at any combination of temperature and alloy composition. The iron-carbon phase diagram is a wonderful tool for looking at the effect of carbon in changing the allotropic transformation temperatures of pure iron. As a side benefit and of equal importance, the diagram allows the metallurgist to predict the microstructure resulting from heating and/or cooling various iron-carbon alloys. A basic understanding of the influence carbon on the behavior of iron is essential in understanding the heat treating of carbon and alloy steel.

1.1 Lattice Structures

As we have seen, atoms are the building blocks of all materials. They are put together in a great variety of ways and bonded or "held together" by cohesive forces in a manner characteristic of a particular material.

In the liquid state, the atoms of a metal are said to be in somewhat random arrangement, having short-range order. At times, several unlike atoms will arrange themselves in the characteristic pattern of a particular metal. However, this is a probability event. Since the forces are weak and there is much activity taking place, they soon separate and reform again. This phenomenon of random grouping, scattering and regrouping for short periods of time is characteristic of the liquid state. As the random grouping mechanism becomes less frequent and the atomic movement of unlike atoms becomes more agitated, the material may become gas.

As the energy input decreases, the random movement of the unlike atoms becomes less frequent, the bonding becomes stronger, and ordered arrays of atoms form lattices. These lattice form crystals, and many crystals form a pattern, which we call the solid material.

Amorphous materials are those that retain their random disorder even when cooled into the solid state. Glass is such a material and is referred to as a supercooled liquid.

In all instances, all matter tends toward the equilibrium state, which is the lowest energy state. As is the case with sodium chloride, the neutral sodium atom has two electrons in its first shell, eight in its second shell, and one loosely bound electron in its third shell, whereas neutral chlorine has two electrons in its first shell, eight in its second shell, and seven electrons in its third shell. Since each atom attempts to complete its shells to either 2, 8, 18, 32, etc., the neutral sodium gives up its one electron, which immediately migrates into the vacant seven-electron third shell of the chlorine atom. Thus the sodium atom by virtue of having lost one negative charge becomes a positive ion, because its nucleus still retains the same number of charges. The chlorine, on the other hand, has picked up this extra negative charge without changing the net positive configuration of its nucleus. Because of this extra electron, the atom becomes a negative ion.

The positive and negative ions attract each other, as shown in Fig.1-1a. Six chlorine ions surround each sodium ion; likewise, the chlorine ion is surrounded by six sodium ions. The forces are, therefore, equal in all directions. The bonding mechanism, referred to as ionic bonding, takes place in many nonmetallic materials.

In Fig.1-1b, one oxygen atom is shown with six (black dots) of its outer electrons. Each electron (small circles) from the hydrogen atoms is shown completing the eight-electron shell and thus binding both hydrogen atoms to the oxygen to form a water molecule. This type of union is known as covalent bonding. The Van der Waals forces are the third system of binding forces. These forces are generated at the instant that an electron cloud density occurs at one side of an atom during the electron flight about the nucleus. This creates a dipole wherein one side of the atom becomes electrically charged negative and the other side has a deficiency of electrons and is considerably charge positive. The atom is distorted as shown in Fig.1-1c.

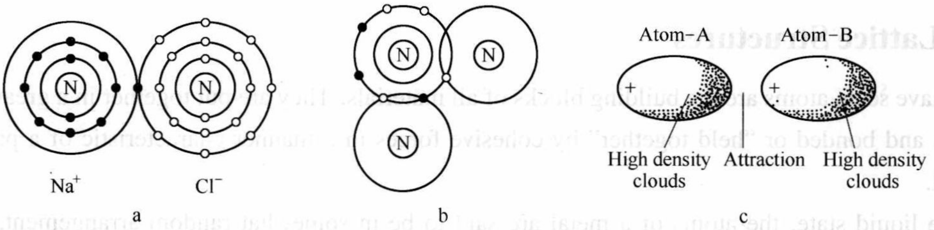

Fig.1-1 The types of bonds of materials

a—Ionic bonding; b—Covalent bonding; c—The Van der Waals forces

If this atomic dipole approaches or is near another atomic dipole, they will attract each other if they are synchronized. These attracting forces may be considerable if the atoms are close together or if there are a greater number of electrons per molecule. One dipole atom may also cause a "spherical" atom to instantaneously become a dipole and generate a "chain" reaction of dipoles.

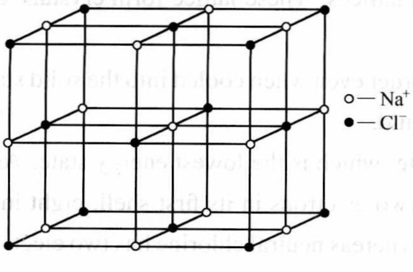

Fig.1-2 The sodium chloride structure

The fourth system of forces results in metallic bonding. If we consider the sodium chloride structure in Fig.1-2, a careful examination shows that the center ion of sodium is surrounded by six oppositely charged chlorine ions. The forces between these six chlorine ions and the sodium ion are forces of attraction. They put the imaginary connecting "links" in tension. The other sodium ions repel the center sodium ion and therefore put these imaginary connecting links (not shown) into compression. That is, the Na^+ ion is pulling on all six Cl^- ions and pushing on all other Na^+ ions. The system is thus held together by these ionic forces.

Another system of forces operating in this metallic substance is free-electron constraint. This is due to the resonating of many covalent electrons shared by atoms. The comparatively free motion between atoms forms a negative cloud—almost a matrix—about the positive ions created by this movement of electrons. The vibration requires energy. Therefore, the energy level of the system is reduced, thus the increasing the attraction forces between the atoms. The random vibration of the "free" electrons, constrained by the "cloud" within the structure, also makes the material electrically conducting. This is the case with metal.

In addition, the electron-filled outer shells of the metallic ions repel each other. This force results from the repulsion forces of the negative shells and is referred to as electron interference.

Many metals are bonded by combination of the force systems just discussed.

The forces of attraction due to free-electron constraint and those of repulsion, which result from electron interference, together with the atomic repulsion-attraction make up the system of forces, referred to as metallic binding, which are called rigidity. A pattern of atomic structure such as that is shown in Fig.1-2 results.

The system, as indicated, is one in which the atoms vibrate about a central equilibrium point. They are not static, even though the system is said to be rigid. They are said to be in dynamic equilibrium. As the energy of the system increases, the vibration of the atoms increases and the material expands, because the lattice parameters increase and the density of the crystal decrease.

If the atoms are considered solid spheres, then two atoms will approach each other until the forces of attraction balance those of repulsion. This point is taken to be the diameter of the atom (see Fig.1-3a). At this point, the net energy of the system will be a minimum (Fig.1-3b). The force required to push the atoms closer together or pull them farther apart increases.

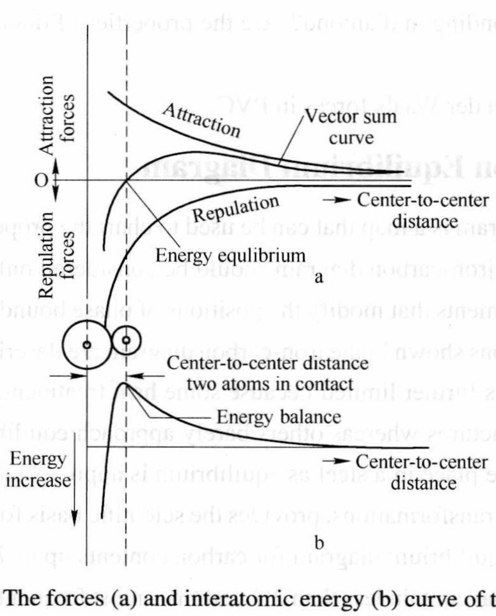

Fig.1-3 The forces (a) and interatomic energy (b) curve of two atoms

The distance between atoms is different from different materials, since it is related to the number of shells populated by electrons and the number of valence electrons present. Thus the greater the number of shells, the greater the distance between the centers of the atoms that "touch" is. The greater the number of valence electrons present, the shorter the center-to-center distance between the atoms.

New words and vocabulary

lattice [ˈlætis] n. 晶格
cohesive forces [kəuˈhi:siv] 内聚力
short-range order 短程有序
scatter [ˈskætə] v. 分散, 散开
array [əˈrei] n. 点阵
crystal [ˈkristəl] n. 晶体, 晶粒
amorphous [əˈmɔ:fəs] a. 非晶的
supercooled liquid 过冷液体
covalent [kəuˈveilənt] a. 共价的
Van der Waals forces 范德华力
dipole [ˈdaipəul] n. 偶极子
matrix [ˈmeitriks] n. 基体, 母体
sodium chloride 氯化钠
sodium [ˈsəudiəm] n. [化] 钠
chloride [ˈklɔ:raid] n. [化] 氯化物
dynamic [daiˈnæmik] a. 动力的, 动态的, 有力的
equilibrium [ˌi:kwiˈlibriəm] n. 平衡, 平衡图, 平衡曲线
shell [ʃel] n. 电子层
chlorine [ˈklɔ:ri:n] n. [化] 氯

Questions

(1) Define Amorphous material.

(2) State briefly how the Na^+ ion and Cl^- ion create in NaCl.

(3) How many kinds of force system present in materials? What are they?

(4) Explain how a dipole creates.

(5) Why is the distance between atoms different from different materials.

(6) What is the type of bonding in diamond? Are the properties of diamond commensurate with the nature of bonding?

(7) Explain the role of Van der Waals forces in PVC.

1.2 The Iron-carbon Equilibrium Diagram

The iron-carbon (Fe-C) diagram is a map that can be used to chart the proper sequence of operations for a given heat treatment. The iron-carbon diagram should be considered only a guide, however, because most steels contain other elements that modify the positions of phase boundaries. The effects of alloying elements on the phase relations shown in the iron-carbon diagram are described later in this chapter. Use of the iron-carbon diagram is further limited because some heat treatments are specifically intended to produce nonequilibrium structures whereas others barely approach equilibrium. Nevertheless, knowledge of the changes that take place in a steel as equilibrium is approached in a given phase field, or of those that result from phase transformations, provides the scientific basis for the heat treatment of steels.

Fig.1-4 shows the Fe-C equilibrium diagram for carbon contents up to 7%. Steels are alloys of iron, carbon and other elements that contain less than 2% carbon—most frequently 1% or less. Therefore, the portion of the diagram below 2% carbon is of primary interest for steel heat treatment. Alloys containing more than 2% carbon are classified as cast iron. Actually, two diagrams are shown in Fig.1-4: the solid lines show the equilibrium between Fe_3C and the several phases of iron, whereas the dashed lines show the equilibrium between graphite and the other phases. Graphite is a more stable form of carbon than Fe_3C and, given very long periods of time, Fe_3C will decompose to graphite. Graphitization, however, rarely occurs in steels, and thus the Fe-Fe_3C diagram is the more pertinent for understanding the heat treatment of steel. In cast iron, high carbon content and the usual high silicon additions promote graphite formation, and accordingly cast iron technology is based much more on the Fe-graphite diagram.

The diagram in Fig.1-4 is strictly valid only at a pressure of one atmosphere. At very high pressure, the boundaries shift and new phases appear. For example, in pure iron a close-packed hexagonal crystal form of iron, epsilon iron, has been produced at high pressure. The triple point in pure iron between alpha iron, gamma iron and epsilon iron occurs at 770K and 110 kbars (11GPa).

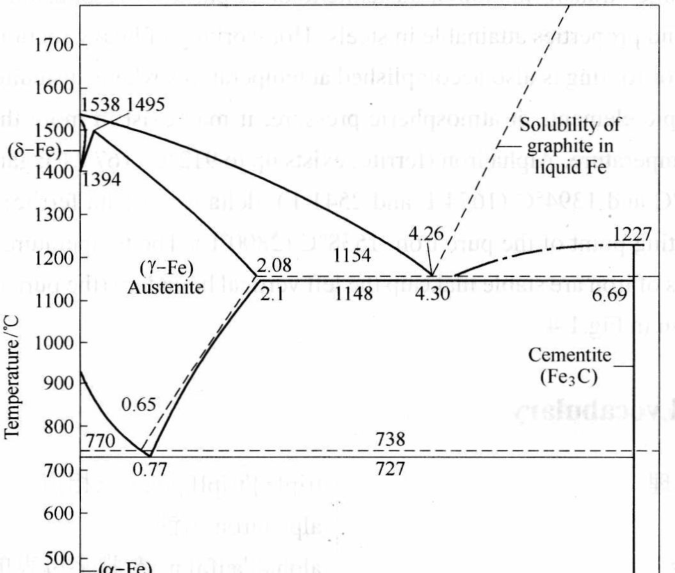

Fig.1-4 The Fe-C equilibrium diagram up to 7% carbon
(Solid lines indicate Fe-Fe_3C diagram, dashed lines indicate Fe-graphite diagram)

Compositions of the Fe-C alloys and phases represented by the Fe-C diagram are conventionally given in weight percent. The percent symbol (%), unless otherwise identified, is understood to represent weight percent, a convention that is followed in this text. Sometimes it is useful to determine compositions in atomic percent. Conversion from weight percent to atomic percent carbon in the Fe-C alloy is accomplished by the following equations:

$$x(\mathrm{C}) = \frac{w(\mathrm{C})}{w(\mathrm{C}) - w(\mathrm{Fe})} \times 100\% \tag{1-1}$$

$$x(\mathrm{C}) = \frac{\dfrac{w(\mathrm{C})}{12}}{\dfrac{w(\mathrm{C})}{12} - \dfrac{w(\mathrm{Fe})}{56}} \times 100\% \tag{1-2}$$

Application of this calculation to Fe-0.4C alloys shows that 0.4% carbon is equivalent to 1.8 atomic percent carbon, a reflection of the much lighter atomic weight of carbon (12) compared with that of iron (56). Conversion to atomic percent for steels containing elements other than Fe and C requires an additional term in the denominator of formula 1-1 or 1-2 for each of the other elements present.

The art and science of steel heat treatment is based on the existence of the austenite phase field in the Fe-C system. Controlled transformation of austenite to other phases is responsible for the great variety of microstructures and properties attainable in steels. Hot working of heavy sections into useful shapes and sizes by rolling or forging is also accomplished at temperatures where austenite is the stable phase.

Iron is an allotropic element: at atmospheric pressure, it may exist in more than one crystal form depending on the temperature. Alpha iron (ferrite) exists up to 912°C (1674°F); gamma iron (austenite) exists between 912°C and 1394°C (1674°F and 2541°F); delta iron (delta ferrite) exists from 1394°C (2541°F) to the melting point of the pure iron, 1538°C (2800°F). The temperature ranges in which the various crystal forms of iron are stable make up the left vertical boundary (the pure iron end) of the Fe-C phase diagram shown in Fig.1-4.

New words and vocabulary

heat treatment 热处理
phase [feiz] n. 相
alloy ['ælɔi] n. 合金
interest ['intrist] n. 重要性, 重要, 重大
cast iron 铸铁
solid lines 实线
dashed lines 虚线
graphite ['græfait] n. 石墨
graphitization [ˌgræfitai'zeiʃən] n. 石墨化
silicon ['silikən] n. [化] 硅
close-packed hexagonal crystal 密排六方晶体
hexagonal [hek'sægənəl] a. 六角形的, 六边形的
epsilon iron η-铁
epsilon [ep'sailən, 'epsilən] n. 希腊语字母的第五个字母
triple ['tripl] point 三相点
alpha iron α-铁
alpha ['ælfə] n. 希腊字母表的第一个字母
gamma ['gæmə] n. 希腊字母表的第三个字母
gamma iron γ-铁
austenite ['ɔ:stəˌnait] n. 奥氏体
rolling ['rəuliŋ] n. 轧制
forging ['fɔ:dʒiŋ] n. 锻造, 锻件, 锻造方法, 锻压
allotropic [ˌæləu'trɔpik] a. [化] 同素异晶的, 同素异形的
allotrophy n. 同素异形体
ferrite ['ferait] n. [化] (冶) 铁素体
delta ferrite δ 铁素体
delta ['deltə] n. 德耳塔 (希腊字母表的第四个

字母)

stable phase 稳定相

denominator [di'nɔmineitə] n.(分数的) 分母

heavy section 大型型钢, 大型材

The difficult sentence

Nevertheless, knowledge of the changes that take place in a steel as equilibrium is approached in a given phase field, or of those that result from phase transformations, provides the scientific basis for the heat treatment of steels.

注释：knowledge of the changes that take place in a steel as equilibrium is approached in a given phase field, or of those that result from phase transformations 为主语，provides 为谓语，the scientific basis for the heat treatment of steels 为宾语。

"or of those···" or 和 of 之间省略了 knowledge，those 指代 changes。

译文：然而，在一个给定相区内，接近平衡时钢中发生变化的理论知识，或由于相变造成的变化的理论知识，为钢的热处理提供了理论依据。

Questions

(1) What is a phase diagram? Explain the effects of carbon contents and other alloying elements on the phase relations in Fe-C equilibrium diagram.

(2) What is homogenization? What types of segregation can it remove?

(3) What do A_1, A_3 and A_{cm} temperatures refer to? Are these temperatures constant?

(4) Translate the following paragraph into Chinese:

Austenite is not a stable phase in this system over the whole range of temperature. As the temperature falls, the solubility of carbon in solid iron diminishes, and cementite separates as a second phase, the change being represented by the line *SE*. At 700°C the limit of saturation of austenite is only 0.81 per cent. The temperature of transformation of γ-iron into α-iron is depressed by the presence of carbon in solid solution, as shown by the line *GS*. It intersects the cementite line at 0.81% C and 700°C. This is the eutectoid point, and the intimate mixture of α-iron and cementite is known as pearlite. Blow this temperature austenite is no longer stable, and the rearrangement to α-iron and cementite persists on further cooling.

1.3 Crystal Structures of Iron

The crystal structure of ferrite is characterized by the unit cell shown in Fig.1-5. In this figure, A2 is structure symbol, and W is prototype metal with bcc structure. Ferrite in steel is bcc. Ferrite belongs to the cubic crystal system—all three axes of the unit cell are of the same length and are mutually perpendicular. The space lattice of ferrite is body-centered cubic (bcc). There are total of two atoms per unit cell——the body-centered atom with coordinates ($a/2$, $a/2$, $a/2$), and the atom at the origin of the unit cell with coordinates (0,0,0). The latter atom represents all of the equivalent corner atoms of the unit cell, each of which is shared by eight unit cells that come together at a corner. The one-eighth atom per corner times the eight corners of the unit cell therefore accounts for one of the two atoms in a bcc unit cell.

The lattice parameter of alpha iron at room temperature is 2.86Å, or 0.286nm. The body diagonals of the unit cell, corresponding to ⟨111⟩ directions, are the directions in which the iron atoms are in contact in the bcc structure. Fig.1-5 shows that the body-centered atom has eight nearest neighbor atoms at a center-to-center distance of one-half a body diagonal, or $a\sqrt{3}/2$.

Crystal structures in which the atoms are packed as closely together as possible have twelve nearest neighbor atoms, and therefore the bcc form of iron is a more open or less dense structure than the gamma iron structure described below. The difference in atomic packing between alpha and gamma is responsible for the volume expansion that occurs when the higher density gamma iron transforms to alpha iron on cooling.

The unit cell of gamma iron or austenite is shown in Fig.1-6. In this figure, A1 is structure symbol, and Cu is prototype metal with fcc structure. Austenite in steel is fcc. Austenite also belongs to the cubic crystal system, but has a face-centered cubic lattice. There are a total of four atoms per unit cell with coordinates (0,0,0), (0, $a/2$, $a/2$), ($a/2$, $a/2$, 0), ($a/2$, 0, $a/2$), corresponding to a corner atom and an atom in the center of each face of the unit cell. Each face atom is shared by two adjacent unit cells: the six faces of the cubic cell thus contribute three atoms. As described above for the bcc cell, the eight corners together contribute only one atom.

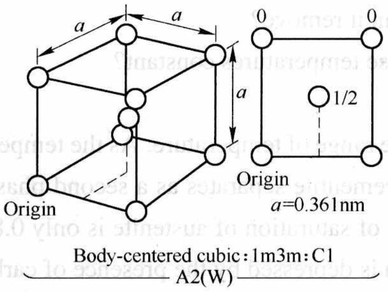

Fig.1-5 Body-centered cubic(bcc) crystal structure

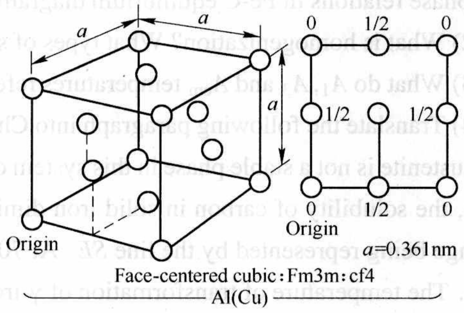

Fig.1-6 Face-centered cubic(fcc) crystal structure

The lattice parameter of austenite, about 3.56 Å (0.356nm), is larger than that of ferrite. However, the close-packed structure and the 4 atoms per unit cell make the density of austenite greater than that of ferrite. The face diagonals, corresponding to ⟨110⟩ directions, are the close-packed directions in the fcc structure, and establish the center-to-center atom spacing of the 12 nearest neighbor atoms as $a\sqrt{2}/2$.

Austenite also may be characterized as a structure made up of planes of closest atomic packing, stacked in a sequence that repeats every three layers. The orientation of the close-packed {111} planes relative to the unit cell may be readily identified because each {111} plane is defined by three face diagonals of the unit cell. The close-packed planes in austenite are extremely important; the dislocation motion that makes mechanical deformation of austenite possible occurs on {111} planes, and microstructural features within grains known as twins have {111} plans as boundaries. Twins are characterized by mirror symmetry of atoms across the planes separating the twins and the adjacent matrix. In austenite twins frequently form as a result of growth accidents in the stacking of {111} planes—accidents caused