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فيزياء المواد

Physics of Materials

المرحلة الثالثة
الكورس الاول

اعداد
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Physics of materials:

Physics of material is a science which involves investigating the relationships that exist between the structures and properties of materials. Almost, all important properties of solid materials may be grouped into five different categories: mechanical, electrical, thermal, magnetic, and optical.

Classification Of Materials:

Materials have been conveniently grouped into six basic classifications: metals, ceramics, polymers, composite, semiconductors, and biomaterials.

1- Metals

Materials in this group are composed of one or more metallic elements (such as iron, aluminium, copper, titanium, gold, and nickel), and often also nonmetallic elements (for example, carbon, nitrogen, and oxygen).

2- Ceramics

Ceramics are compounds between metallic and nonmetallic elements; they are most frequently oxides, nitrides, and carbides. For example, some of the common ceramic materials include aluminum oxide (or *alumina*, Al_2O_3), silicon dioxide (or *silica*, SiO_2), silicon carbide (SiC), silicon nitride (Si_3N_4), and, in addition, what some refer to as the *traditional ceramics*—those composed of clay minerals (i.e., porcelain), as well as cement and glass. With regard to mechanical behavior, ceramic materials are relatively stiff and strong—stiffnesses and strengths are comparable to those of the metals. ceramics are typically very hard. On the other hand, they are extremely brittle (lack ductility) and are highly susceptible

3- Polymers

Polymers include the familiar plastic and rubber materials. Many of them are organic compounds that are chemically based on carbon, hydrogen, and other nonmetallic elements (viz. O, N, and Si). Furthermore, they have very large molecular structures, often chain-like in nature with a backbone of carbon atoms. Some of the common and familiar polymers are polyethylene (PE), nylon, poly (vinyl chloride) (PVC), polycarbonate (PC), polystyrene (PS), and silicone rubber. These materials typically have low densitieswhereas their mechanical characteristics are generally dissimilar to the metallic and ceramic materials—they are not as stiff nor as strong as these other material types

4- Composites

A composite is composed of two (or more) individual materials, which come from metals, ceramics, and polymers. The design goal of a composite is to achieve a combination of properties that is not displayed by any single material, and also to incorporate the best characteristics of each of the component materials. A large number of composite types exist that are represented by different combinations of metals, ceramics, and polymers. Furthermore, some naturally-occurring materials are also considered to be composites—for example, wood and bone. However, most of those we consider in our discussions are synthetic (or man-made) composites.

One of the most common and familiar composites is fiberglass, in which small glass fibers are embedded within a polymeric material (normally an epoxy or polyester).4 The glass fibers are relatively strong and stiff (but also brittle), whereasthe polymer is ductile (but also weak and flexible). Thus, the resulting fiberglass is relatively stiff, strong,

5- Semiconductors

Semiconductors have electrical properties that are intermediate between the electrical conductors (viz. metals and metal alloys) and insulators (viz. ceramics and polymers)—Figure 1.7. Furthermore, the electrical characteristics of these materials are extremely sensitive to the presence of minute concentrations of impurity atoms, for which the concentrations may be controlled over very small spatial regions. Semiconductors have made possible the advent of integrated circuitry that has totally revolutionized the electronics and computer industries (not to mention our lives) over the past three decades.

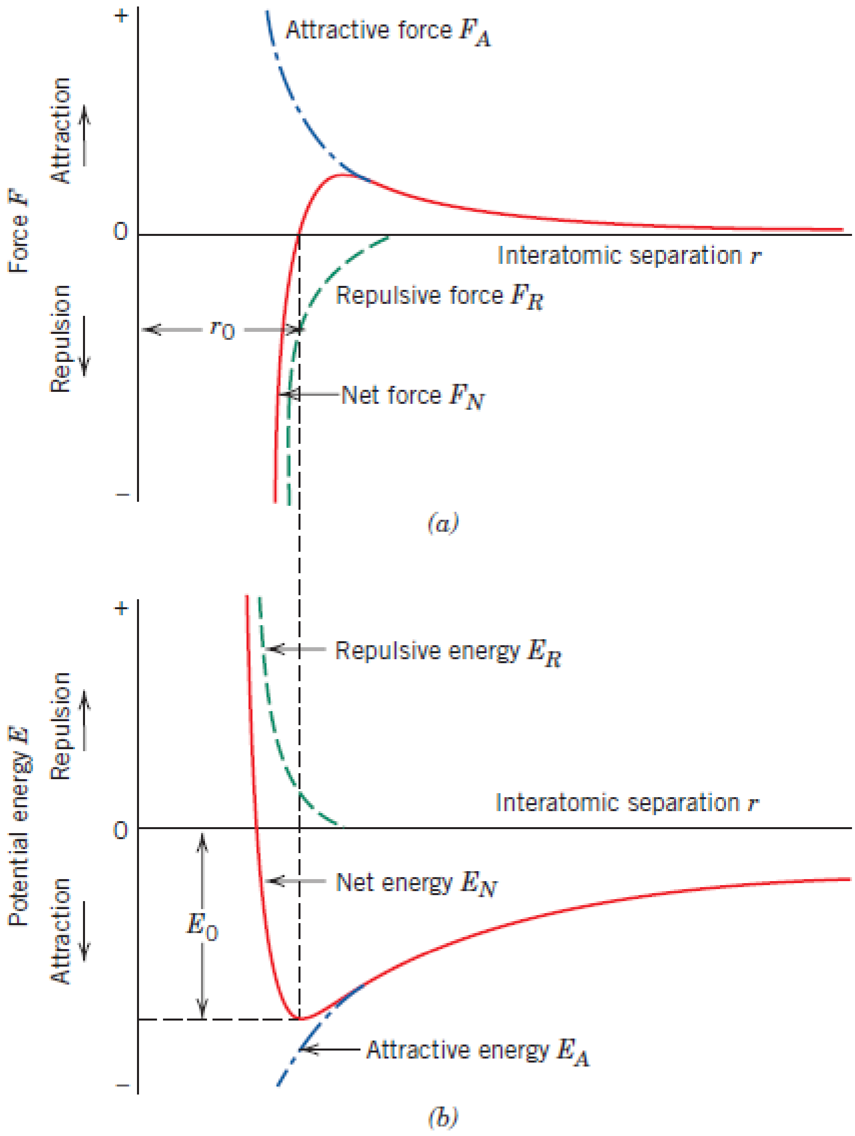
6- Biomaterials

Biomaterials are employed in components implanted into the human body for replacement of diseased or damaged body parts. These materials must not produce toxic substances and must be compatible with body tissues (i.e., must not cause adverse biological reactions). All of the above materials—metals, ceramics, polymers, composites, and semiconductors—may be used as biomaterials. For example, some of the biomaterials that are utilized in artificial hip replacements.

Atomic Bonding in Solids:

BONDING FORCES AND ENERGIES

An understanding of many of the physical properties of materials is predicated on a knowledge of the interatomic forces that bind the atoms together. Perhaps the principles of atomic bonding are best illustrated by considering the interaction between two isolated atoms as they are brought into close proximity from an infinite separation. At large distances, the interactions are negligible, but as the atoms approach, each exerts forces on the other. These forces are of two types, attractive and repulsive, and the magnitude of each is a function of the separation or interatomic distance. The origin of an attractive force *FA* depends on the particular type of bonding that



exists between the two atoms. The magnitude of the attractive force varies with the distance, as represented schematically in Figure. Ultimately, the outer electron shells of the two atoms begin to overlap, and a strong repulsive force F_R comes into play. The net force F_N between the two atoms is just the sum of both attractive and repulsive components; that is,

$$F_N = F_A + F_R$$

which is also a function of the interatomic separation, as also plotted in Figure a When F_A and F_R balance, or become equal, there is no net force; that is,

$$F_A + F_R = 0$$

Sometimes it is more convenient to work with the potential energies between two atoms instead of forces. Mathematically, energy (E) and force (F) are related as

$$E = \int F\, dr$$

or, for atomic systems,

$$E_N = \int_{\infty}^{r} F_N\, dr$$

$$= \int_{\infty}^{r} F_A\, dr + \int_{\infty}^{r} F_R\, dr$$

$$= E_A + E_R$$

in which EN, EA, and ER are respectively the net, attractive, and repulsive energies for two isolated and adjacent atoms. Figure 2.8b plots attractive, repulsive, and net potential energies as a function of interatomic separation for two atoms. The net curve, which is again the sum of the other two, has a potential energy trough or well around its minimum

PRIMARY INTERATOMIC BONDS

1- **Ionic bonding** is perhaps the easiest to describe and visualize. It is always found in compounds that are composed of both metallic and nonmetallic elements, elements that are situated at the horizontal extremities of the periodic table.Atomsof a metallic element easily give up their valence electrons to the nonmetallic atoms. In the process all the atoms acquire stable or inert gas configurations and, in addition, an electrical charge; that is, they become ions. Sodium chloride (NaCl) is the classic ionic material.

2- **Covalent Bonding:** In covalent bonding**,** stable electron configurations are assumed by the sharing of electrons between adjacent atoms. Two atoms that are covalently bonded will each contribute at least one electron to the bond, and the shared electrons may be considered to belong to both atoms. Covalent bonding is schematically illustrated in Figure 2.10 for a molecule of methane (CH4). The carbon atom has four valence electrons, whereas each of the four hydrogen atoms has a single valence electron. Each hydrogen atom can acquire a helium electron configuration (two 1*s* valence electrons) when the carbon atom shares with it one electron.
3- **Metallic bonding,** the final primary bonding type, is found in metals and their alloys. A relatively simple model has been proposed that very nearly approximates the bonding scheme. Metallic materials have one, two, or at most, three valence electrons. With this model, these valence electrons are not bound to any particular atom in the solid and are more or less free to drift throughout the entire metal.

References

1- Fundamentals of Materials Science and Engineering, William D. Callister, Jr. David G. Rethwisch
2- Materials _Science_ and _Engineering_9th . William D. Callister, Jr. David G. Rethwisch