University of Anbar
College of Science
Department of Physics

فيزياء المواد

Physics of Materials

المرحلة الثالثة

الكورس الاول

اعداد
م.د. قيس عبدالله عباس

8. Polymer:

The term '**polymer**' comes from two Latin words: poly متعدد means many and mer means part جزء or unit وحدة. The word polymer is defined تعرف as very great molecules جزيئات كبيرة that possess great molecular mass كتلة جزيئية كبيرة. The recurrence structural parts الاجزاء الهيكلية المتكررة are resultant تنتج from some reactive and simple molecules الجزيئات المتفاعلة والبسيطة known as (monomers) مونومير and are connected وترتبط to each other مع بعضها البعض by covalent bonds باواصر تساهمية. The method طريقة of formation تشكيل of polymers from monomers مونومير is called polymerization البلمرة.

Polymerization:

[Monomers ⟶ Polymers]

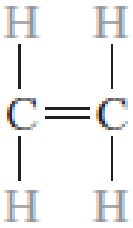
Most polymers are organic عضوي in origin في الاصل, the basic concepts المفاهيم الاساسية relating to ب علاقة ذات the structure of their molecules.

Monomers المونيمرات are simple recurrent units هي وحدات بسيطة متكررة which linked والتي ترتبط together مع بعضها in great numbers بعدد كبير which give rise to a polymer. Many organic materials المواد العضوية are hydrocarbons هايدروكاربونات; that is, they are composed تتكون من of hydrogen هيدروجين and carbon كاربون.

The intramolecular bonds are covalent الاواصر الداخلية الجزيئية تساهمية. Each carbon atom has four electrons اربع الكترونات that may participate تشارك in covalent bonding اصرة تساهمية, whereas every hydrogen atom has only one bonding electron الكترون رابط واحد. A single covalent bond اصرة تساهمية مفردة exists توجد when each of the two bonding atoms contributes one electron.

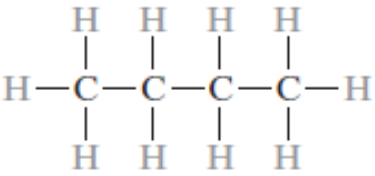
تساهم كل من الذرتين المترابطتين بإلكترون واحد.

Example, **ethylene**, which has the chemical formula C_2H_4, the two carbon atoms are doubly ثنائية bonded together ترتبط معا, and each is also singly bonded وارتباط منفرد to two hydrogen atoms, as represented by the structural formula

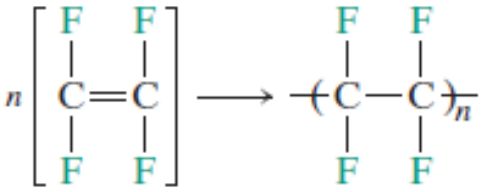


An example of a **triple bond** is found in acetylene, C_2H_2:

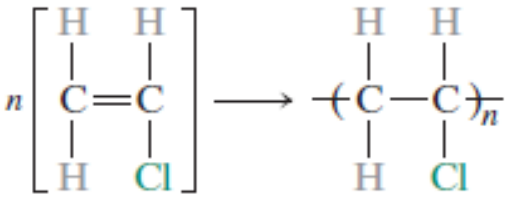
Hydrocarbon compounds with the same composition نفس التركيب may have different atomic arrangements, a phenomenon ظاهره termed تسمى isomerism. For example, there are two isomers for butane بوتان; normal butane has the structure

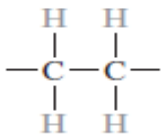
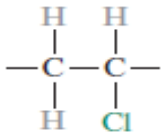
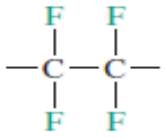
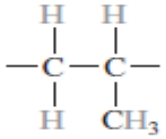
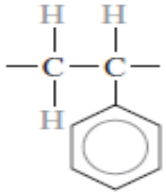
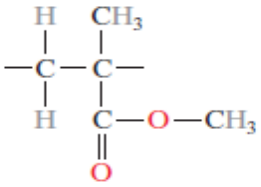
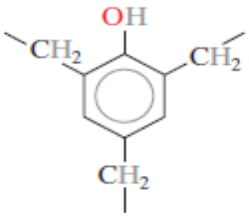
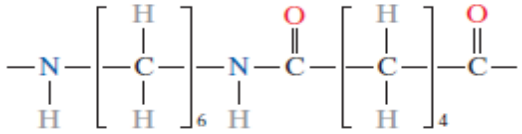
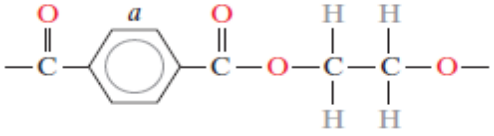
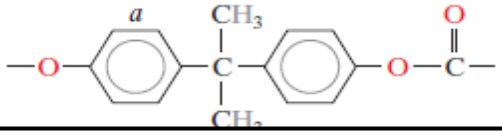


The **tetrafluoroethylene** monomer, CF_2 CF_2 can polymerize to form **polytetrafluoroethylene** (PTFE) as follows:



The **vinyl chloride** monomer (CH_2 CHCl) is a slight variant مختلف قليلا of that for **ethylene**, in which one of the four H atoms is replaced with a Cl atom. Its polymerization is represented as



Polymer	Repeat Unit
Polyethylene (PE)	
Poly(vinyl chloride) (PVC)	
Polytetrafluoroethylene (PTFE)	
Polypropylene (PP)	
Polystyrene (PS)	
Poly(methyl methacrylate) (PMMA)	
Phenol-formaldehyde (Bakelite)	
Poly(hexamethylene adipamide) (nylon 6,6)	
Poly(ethylene terephthalate) (PET, a polyester)	
Polycarbonate (PC)	

8.1 Molecular Weight

Large molecular weights الاوزان الجزيئية الكبيرة are observed توجد in polymers with very long chains سلاسل طويلة جدا. During the polymerization process عملية البلمرة, not all ليس كل polymer chains السلاسل البوليمرية will grow تنمو to the same length نفس الطول; this results in هذا ينتج في a distribution توزيع of chain lengths or molecular weights.

The number-average molecular weigh $\overline{M_n}$ is expressed as

$$\overline{M}_n = \Sigma x_i M_i$$

where *Mi* represents the mean (middle) molecular weight of size range *i*, and *xi* is the fraction of the total number of chains within the corresponding size range.

A weight-average molecular weight is based on the weight fraction الكسر الوزني of molecules within the various size ranges. It is calculated according to

$$\overline{M}_w = \Sigma w_i M_i$$

where, *Mi* is the mean molecular weight within a size range, whereas *wi* denotes the weight fraction of molecules within the same size.

An alternate way بطريقة اخرى of expressing التعبير average chain size of a polymer is as the **degree of polymerization درجة البلمرة**, *DP*, which represents يمثل the average number of repeat units الوحدات المتكررة in a chain. *DP* is related to the number-average molecular weight $\overline{M_n}$ by the equation.

$$DP = \frac{\overline{M}_n}{m}$$

where m is the repeat unit molecular weight.

8.2 Types of polymers

8.2.1 Linear Polymers البوليمرات الخطية

Linear polymers are those in which the repeat units الوحدات المتكررة are joined together تتصل مع بعضها end to end نهاية بنهاية in single chains في السلسلة المنفردة. These long chains are flexible مرنة and may be thought يمكن اعتبارها of as a mass كتلة من of spaghetti السباكتي, as represented schematically in Figure 8.1 a, where each circle represents كل دائرة تمثل a repeat unit وحدة متكررة. For linear polymers, there may be extensive van der Waals قوى فاندرفالس and hydrogen bonding اواصر هيدروجينية between the chains. Some of the common polymers بعض البوليمرات الشائعة that form with linear structures تراكيب خطية are **polyethylene**, **poly(vinyl chloride)**, **polystyrene, poly(methyl methacrylate), nylon, and the fluorocarbons.**

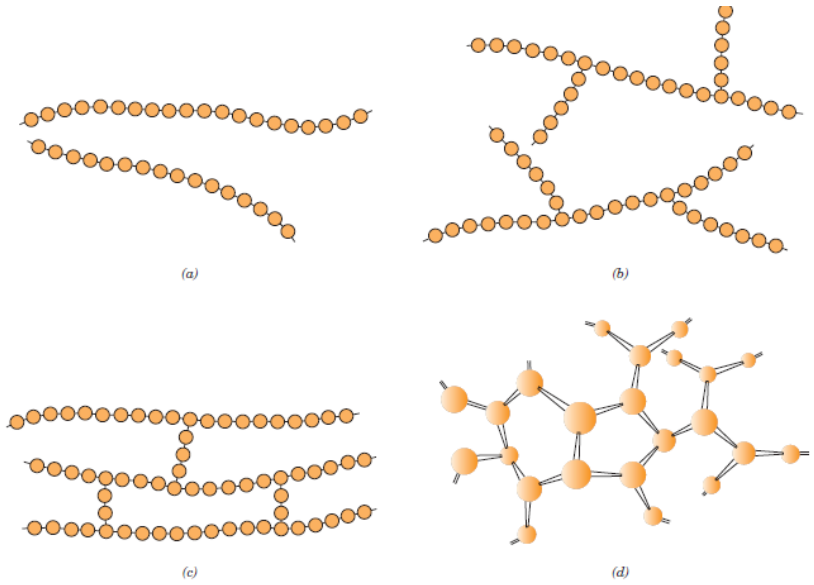


Figure 8.1 Schematic representations of (a) linear, (b) branched, (c) crosslinked, and (d) network (three-dimensional) molecular structures. Circles designate individual repeat units.

8.2.2 Branched Polymers البوليمرات المتفرعة

Polymers may be synthesized يمكن ان تصنع in which side-branch chains سلاسل فرعية جانبية are connected وتتصل to the main ones بالاساسية, as indicated schematically in Figure 8.1 b; The branches, considered to be part of the main-chain molecule, may result from side reactions تفاعلات جانبية that occur تحدث during the synthesis تصنيع of the polymer. The chain packing efficiency كفاءة تعبئة السلسلة is

reduced تقل with the formation تشكل of side branches, which results in a lowering of the polymer density. For example low-density polyethylene (LDPE) contains short chain branches.

8.2.3 Crosslinked Polymers البوليمرات المتسابكة

In crosslinked polymers, adjacent linear chains السلاسل الخطية المتجاورة are joined تتصل one to another الواحد بالاخر at various positions باماكن مخلفة by covalent bonds, as represented in Figure 8.1 c. The process of crosslinking التشابك is achieved تنجز either during synthesis or by a nonreversible chemical reaction تفاعل كيميائي غير عكسي. Many of the rubber elastic materials are crosslinked;

8.2.4 Network Polymers بوليمرات الشبكة

Multifunctional متعدد الوظائف monomers مونيمرات forming تشكل three or more active covalent bonds اواصر تساهمية فعالة make three-dimensional networks تصنع شبكة ثلاثية الابعاد (Figure 8.1 d) and are termed وتسمى **network polymers**. These materials have distinctive مميزة mechanical and thermal properties; the **epoxies, polyurethanes, and phenol-formaldehyde.**

8.3 Properties of Polymers: خصائص البوليمرات

Polymeric materials are very important and have many uses for their properties, most polymers have the following general properties: خصائص بصورة عامة

- Low coefficient of friction.
- Weak density is relative to ceramics and metals.
- Good mould ability.
- Can be obtained a good surface.
- High erosion resistance.مقاومة عالية للتآكل .
- Can be produced in different colours or transparent
- Economical.
- Low temperature resistance.
- Low tensile strength.
- Very resistant to chemicals materials.

▪ Low electrical and thermal conductivity.

▪ Good strength-to-weight ratios for some polymers.

▪ Low mechanical properties, which can be improved by fiber reinforcement of plastics.

▪ Low modulus of elasticity

8.4 Copolymers بوليمرات ثنائية

Consider a copolymer that is composed يتكون من of two repeat units وحدتين متكررة as represented by and in Figure 8.2 . Depending اعتمادا على on the polymerization process and the relative fractions الكسر النسبي of these repeat unit types, different sequencing arrangements ترتيبات مختلفة along the polymer chains are possible.
When calculating the degree of polymerization for a copolymer, the value *m* in equation is replaced with the average value that is determined from

$$\overline{m} = \Sigma f_j m_j$$

In this expression, f_j and m_j are, respectively, the mole fraction and molecular weight of repeat unit j in the polymer chain.

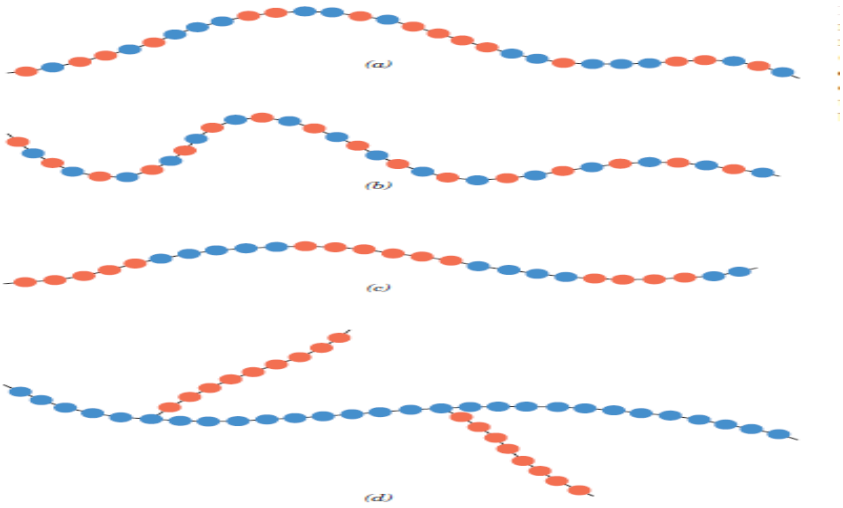


Figure 8.2 Schematic representations of (a) random, (b) alternating, (c) block, and (d) graft copolymers. The two different repeat unit types are designated by blue and red circles.

8.5 Classification of Polymers According to Heat Effect:
تصنيف البوليمرات اعتمادا على تاثير الحرارة

The response استجابة of a polymer to mechanical forces at elevated temperatures is related to its dominant molecular structure. In fact, one classification scheme for these materials is according to behavior سلوكها with rising temperature مع زيادة الحرارة. Thermoplastic polymers and thermosetting polymers) are the two subdivisions تقسيمات.

- **Thermoplastics** soften تلين when heated تسخن (and eventually liquefy وتصبح سائلة) and harden وتتصلب when cooled—processes في عمليات التبريد. Examples of common thermoplastic polymers include **polyethylene, polystyrene, poly(ethylene terephthalate), and poly(vinyl chloride).**
- **Thermosetting** polymers are network polymers. They become تصبح permanently hard صلبة بشكل دائم during خلال their formation تشكيلها and do not soften upon heating لا تلين عند التسخين . Most of the crosslinked and network polymers, which include **vulcanized rubbers, epoxies, and phenolics and some polyester resins**, are thermosetting.

Thermoplastic polymers have linear and branched structures; they soften when heated and harden when cooled.

Thermosetting polymers, once they have hardened, will not soften upon heating; their structures are crosslinked and network.

8.6 Mechanical Behavior of Polymers (Stress–Strain Behavior)
الخواص الميكانيكية للبوليمرات (سلوك اجهاد مطاوعة)

The mechanical properties الخواص الميكانيكية of polymers are specified محدد with many of the same parameters معملات that are used for metals—that is, **modulus of elasticity معاملات المرونة** and **yield and tensile strengths قوة الشد**. For many polymeric materials, the simple stress–strain test, figure 8.3, is used to characterize some of these mechanical parameters.

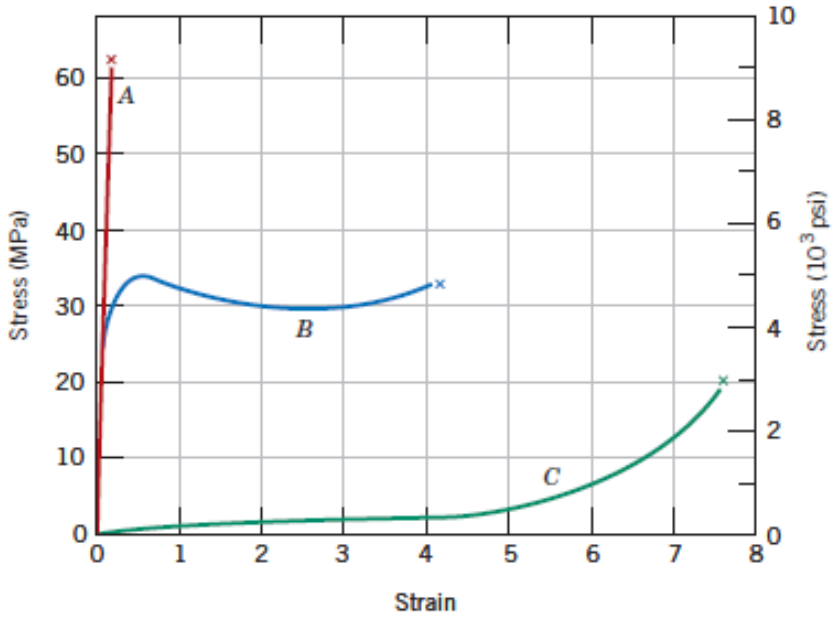


Figure 8.3 stress–strain behavior of different types of polymers.

Three typically different types ثلاث انواع من of stress–strain behavior are found وجدت for polymeric materials, as represented in Figure 8.3. **Curve A** illustrates يمثل the stress–strain اجهاد مطاوعة character خاصية for a brittle polymer البوليمرات الهشة, inasmuch بقدر ما as it fractures تنكسر while بيمنا deforming elastically تشوه مرننا. The behavior السلوك for a plastic material المواد البلاستيكية, **curve B**, is similar مشابه to that for many metallic materials للمواد المعدنية; the initial deformation التشوه البدائي is elastic يكون مرن, which is followed ويتبع بعدها by yielding and a region of plastic deformation تشوه بالاستيكي. Finally واخيرا, the deformation displayed التشوه الحاصل by **curve C** is totally elastic مرن كليا; this rubberlike elasticity مرونه شبيهة بالمطاط (large recoverable قابلة للاسترداد strains produced تنتج at low stress levels مستويات اجهاد منخفظة) is displayed تعرض by بواسطة a class صنف of polymers termed the elastomers تسمى اللدائن .

References المصادر

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