Physical & Thermal Properties

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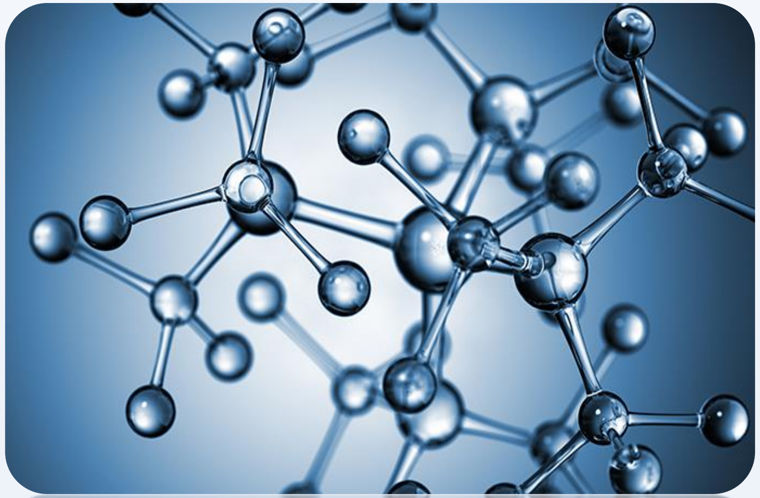


Lecture Objectives

A. Physical Properties

1. Atomic Arrangements
2. Density
3. Dimensional Stability
4. Absorption of Oral Fluids
5. Solubility & Disintegration
6. Bonding
7. Adhesion & Cohesion
8. Surface Energy
9. Hydrophilicity and Hydrophobicity

C. Thermal Properties

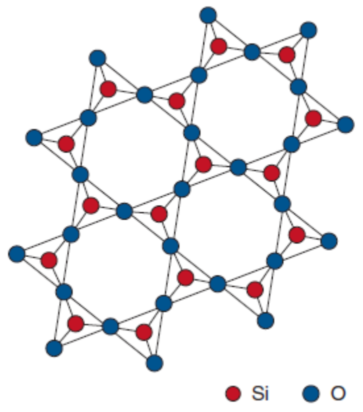
1. Thermal Conductivity
2. Thermal Diffusivity
3. Coefficient of Thermal Expansion & Contraction

A. Physical Properties

1. Physical Properties

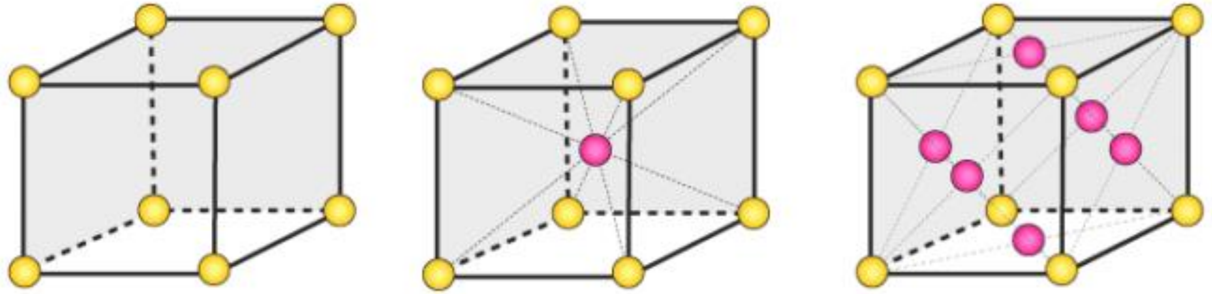
1. Atomic Arrangement

- Material can be crystalline or non-crystalline (amorphous) structure.



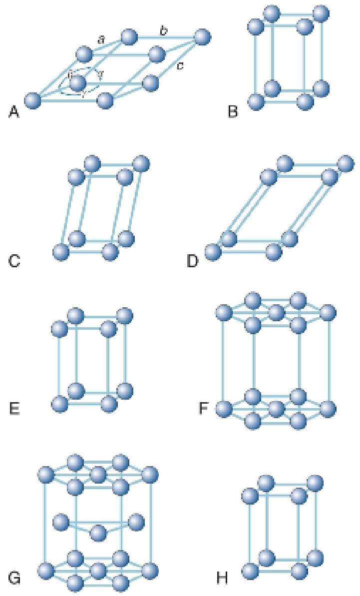
A. Crystalline

- Regularly spaced configuration (repetitive space lattice) known as a crystal.
- Type of space lattice is defined by the length of each of the 3-unit cell edges (called the axes) & the angles between the edges.
- Examples:
    - Metallic-based dental materials & ceramics (alumina & zirconia)



Simple cubic | Body-centred Cubic Unit Cell (BCC) | Face-centred Cubic Unit Cell (FCC)

1. Physical Properties



1. Atomic Arrangement

B. Non-Crystalline (Amorphous)

- Structures where irregularly spaced configurations in the solid state.
- Its atoms are arranged in non-repeating units.
- Examples: Waxes, glass, polymeric-based materials (eg. acrylic resin) used in dentistry

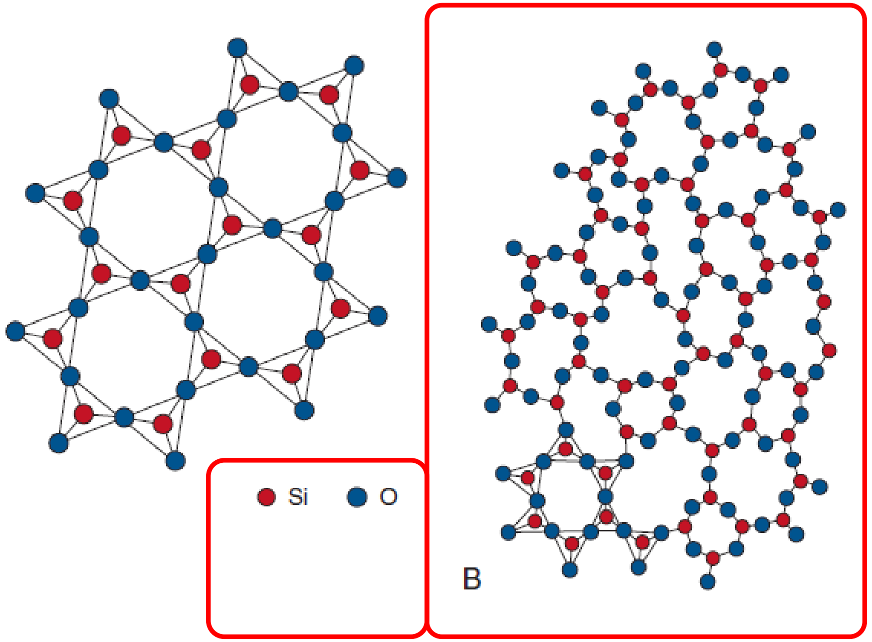
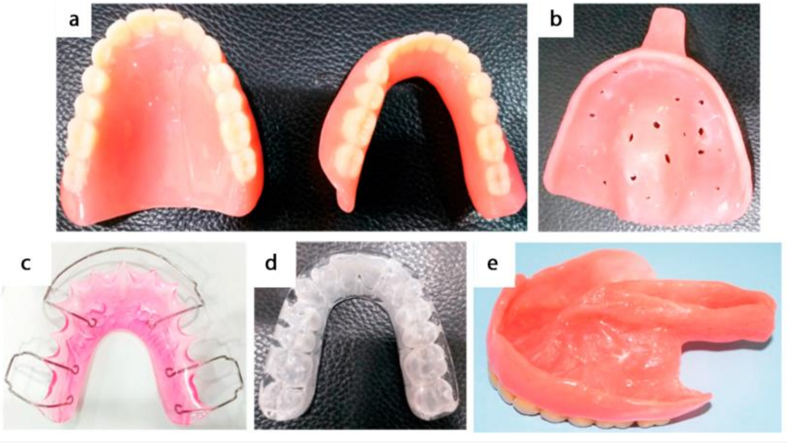


FIGURE 2-9 Two-dimensional illustration of crystalline (*left*) and noncrystalline (*right*) forms of SiO_2.

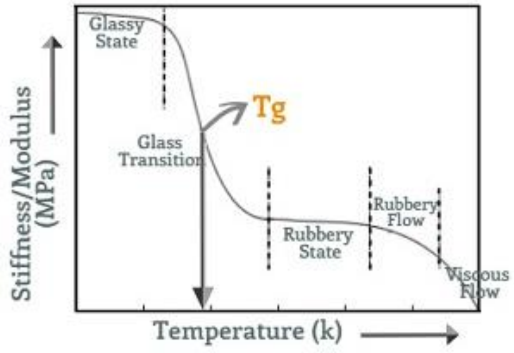


1. Physical Properties

1. Atomic Arrangement

Material can be crystalline or non-crystalline (amorphous) structure.

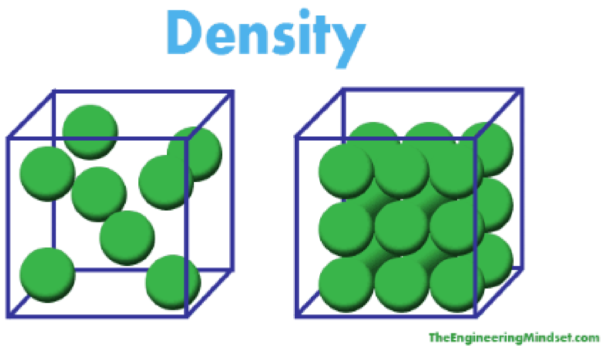
Properties	*Crystalline solid*	*Amorphous solid*
1. Structure	The constituent particles, atoms, ions or molecules are arranged in regular and definite three dimensional pattern. e.g. sodium chloride, diamond, sugar etc.	The constituent particles are arranged in irregular three dimensional pattern.
2. Compressibility	Rigid and incompressible.	Usually rigid and can not be compressed to any appreciable extent.
3. Melting point	They have sharp and definite melting point.	Melting point is not definite. Melt over a range of temperature.
4. Heat of fusion	Definite	Not definite
5. Physical properties	These are **anisotropic** i.e. their physical properties are not identical in all directions	These are **isotropic** i.e. their physical properties are identical in all directions



1. Physical Properties

2. Density

- Density is the measurement of how tightly a material is packed together
- Lightness is nearly always an advantage in restorative materials, but sometimes tin or lead is used inside a full lower denture to make it heavy to control its mobility.
- **Density:**
  - Gold = 14 gm/cm
  - Acrylic = 1.2 gm/cm
  - Chromium/cobalt = 8.3 gm/cm
  - Water = 1 gm/cm



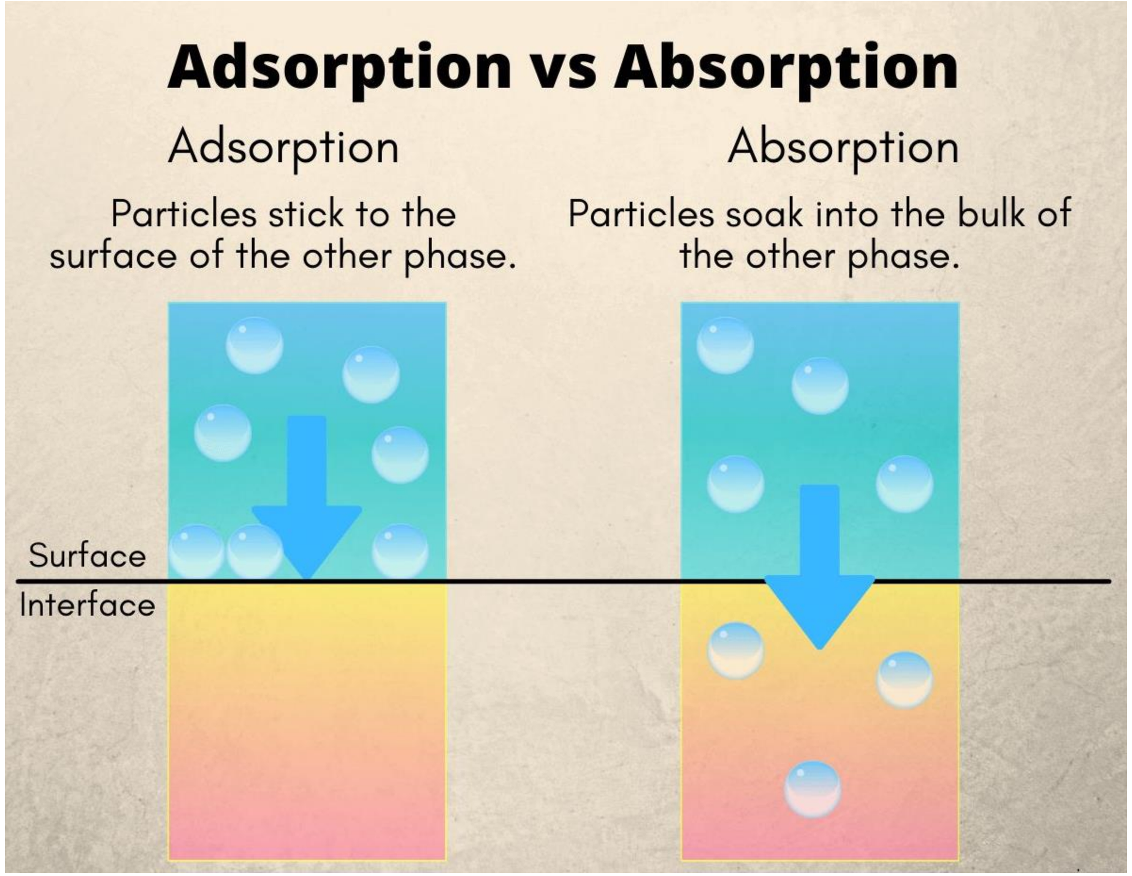
1. Physical Properties

3. Dimensional Stability

- Many materials change shape when they set or harden.
- Dental materials should have no dimensional changes when set.
- Example:
  - Silicone impression is more stable than Alginate impression

1. Physical Properties

4. Absorption of oral fluids



- Some materials will absorb water or other fluids.
- Long absorption of water can result in serious dimensional changes
- Acrylic absorbs water for a day & stops after that.

1. Physical Properties

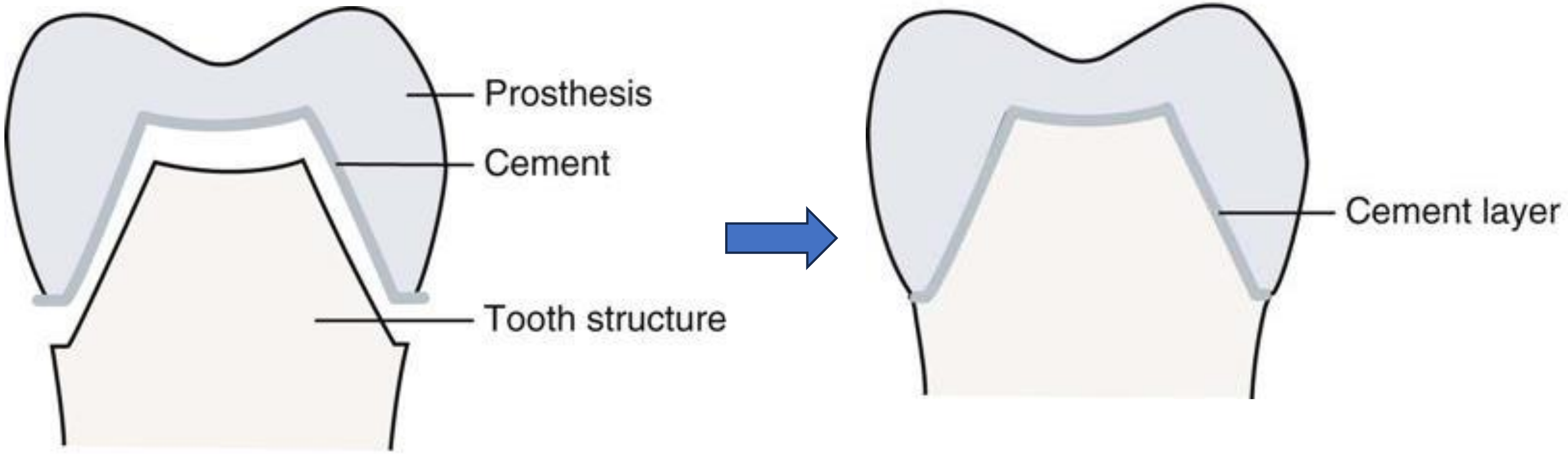
5. Solubility & Disintegration

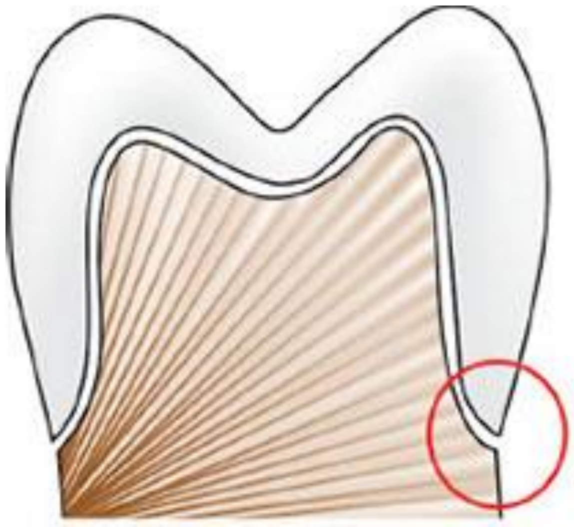
- Restorative materials (cement, composite, amalgam) should not dissolve in the mouth, & if they dissolve, they should not release toxic substances.
- Solubility
  - Silicate cement = 0.7-1.6%
  - Composite = 0.01%

1. Physical Properties

5. Solubility & Disintegration

- They are important property as they can determine the long-term survivability of restorations.
- Most cements exhibit varying degrees of solubility.
- Cements in the oral environment are continually exposed to a variety of acids produced by microorganisms or consumed in foods and drinks.

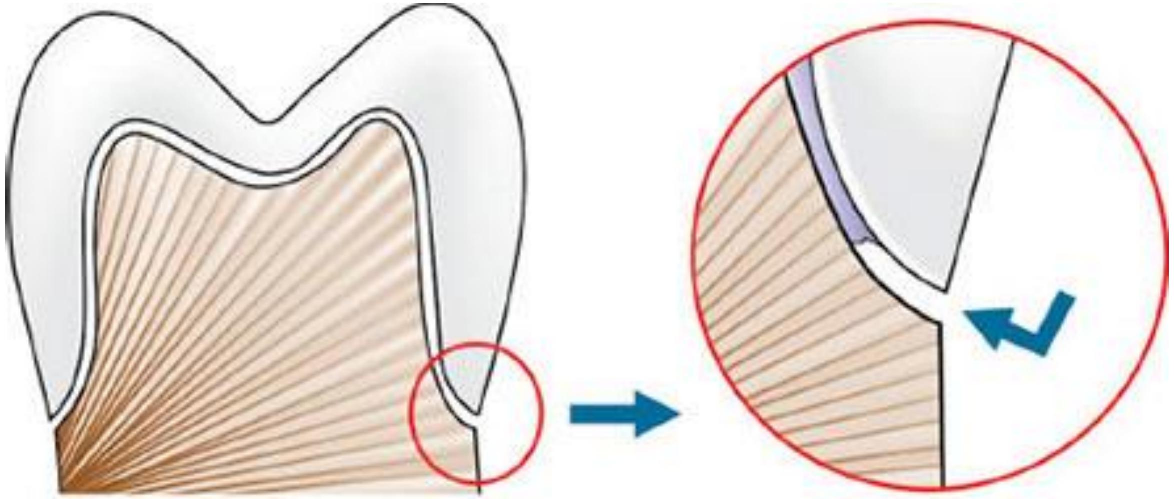




1. Physical Properties

5. Solubility & Disintegration

- Solubility & disintegration of the cement at the margins can eventually lead to problems like inflammation, caries, sensitivity, etc.
- Solubility & disintegration can be reduced by
  - proper manipulation
  - minimizing the exposure of the cement to the oral environment, &
  - protecting of the cement during setting and the initial 24-hour period.



6. Bonding

- Atom is relatively stable if it has eight electrons in its outer valence shell (except for helium, which has only two electrons).
- Other atoms must lose, acquire, or share electrons with yet other atoms to achieve a stable configuration—that is, eight electrons in the outer shell.
- These processes produce various bonding.
    - Primary Bonding
    - Secondary Bonding

Callister 2010.

1. Physical Properties

6. Bonding

A. Primary Bonds

- The formation of primary bonds depends on the atomic structures & their tendency to assume a stable configuration.
- The strength of these bonds determines the physical properties of a material.
- Primary atomic bonds, also called chemical bonds, may be of 3 different types:

  a. Ionic,

  b. Covalent, &

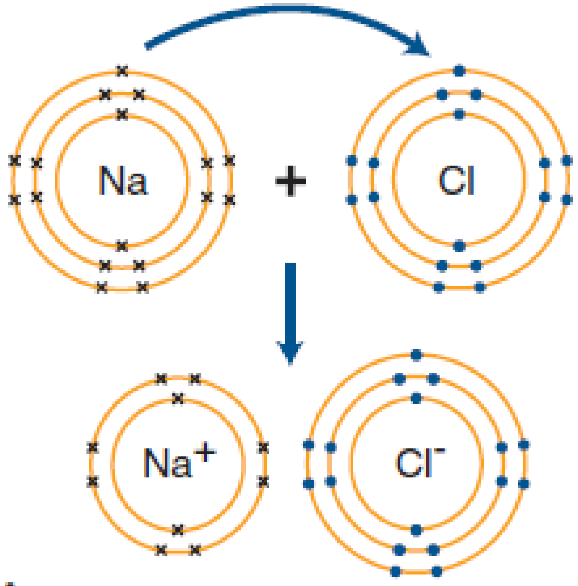
  c. Metallic.

1. Physical Properties

6. Bonding: A. Primary Bonds: a. Ionic Bonds

- Transfer of electrons to become stable.
- Example of ionic bonding is the bond between the Na^+ & Cl^- of sodium chloride.
  - Sodium atom contains 1 valence electron in its outer shell & chlorine atom has 7 electrons in its outer shell, the transfer of the sodium valence electron to the chlorine atom results in the stable compound $Na^+ Cl^-$.

- In dentistry, ionic bonding exists in some dental materials, such as in gypsum structures & phosphate-based cements.



A Ionic bond

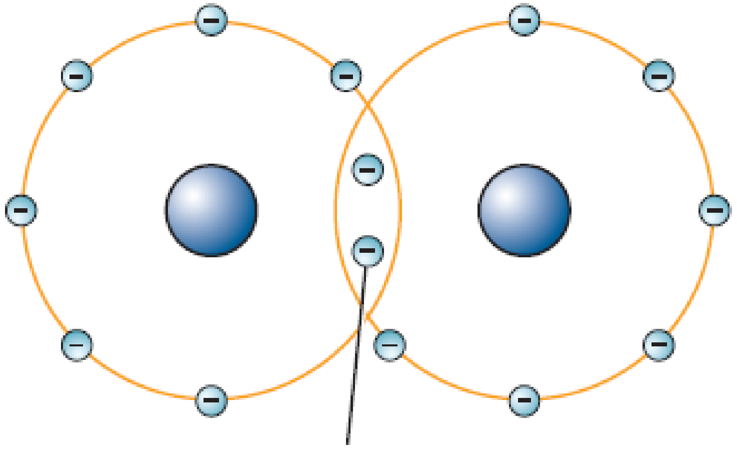
Callister 2010.

1. Physical Properties

6. Bonding: A. Primary Bonds: b. Covalent Bonds

- Two valence electrons are shared by adjacent atoms.
- By sharing electrons, the 2 atoms are held together by covalent bonds to form a molecule that is sufficiently stable, & electrically neutral in a definite arrangement.

- Hydrogen molecule, H_2, exemplifies covalent bonding.
  - The single valence electron in each hydrogen atom is shared with that of the other combining atom, & the valence shells become stable.
- Covalent bonding occurs in many organic compounds, such as in dental resins, where they link to form the backbone structure of hydrocarbon chains.



B

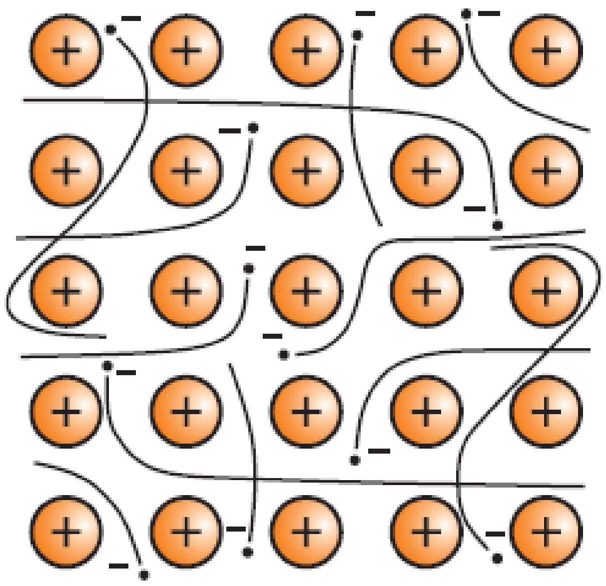
Callister 2010.

1. Physical Properties

6. Bonding: A. Primary Bonds: c. Metallic Bonds

- Outer valence electrons are removed easily from metallic atoms & form positive ions.
- Free valence electrons can move about in the metal space lattice to form what is sometimes described as an electron “cloud” or “gas.”
- Electrostatic attraction between the electron cloud & the positive ions in the lattice provides the force that bonds the metal atoms together as a solid.

- Free electrons give the metal its high thermal & electrical conductivity. These electrons absorb light energy so that all metals are opaque to light.
- The metallic bonds are also responsible for the ability of metals to deform plastically.



C

1. Physical Properties

6. Bonding: B. Secondary Bonds Weaker than primary bonds

- In contrast with primary bonds, secondary bonds do not share electrons.
- Instead, charge variations among atomic groups of the molecule induce dipole forces that attract adjacent molecules or parts of a large molecule.
- Seconday atomic bonds, also called physical bonds, may be of 2 different types:
  - a. van der Waals Forces
  - b. Hydrogen bonding

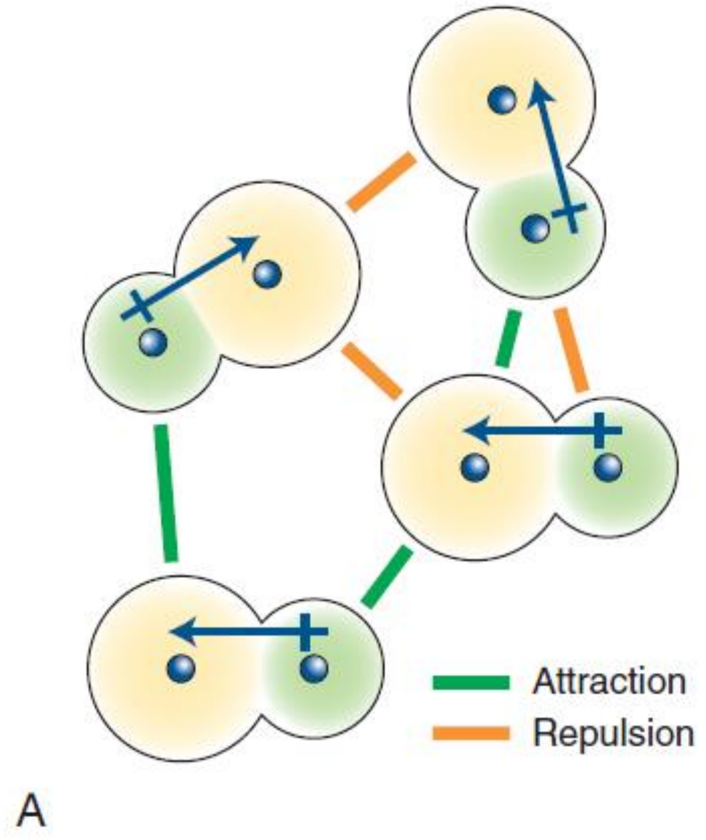
Callister 2010.

1. Physical Properties

6. Bonding: B. Secondary Bonds: a. van der Waals Force

- These van der Waals forces of attraction arise from dipole attractions.
- **In the case of polar molecules**, dipoles are induced by an unequal sharing of electrons.

Attraction & repulsion between molecules are induced by a permanent dipole moment resulting from asymmetrical electron distribution within the molecule.

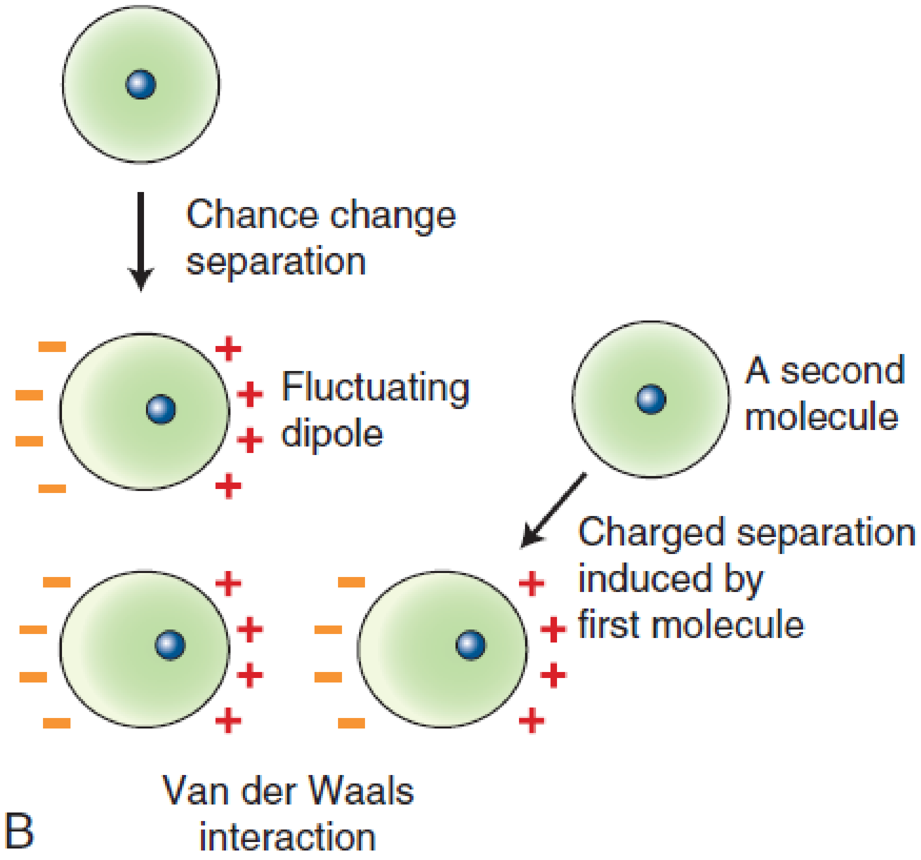


1. Physical Properties

6. Bonding: B. Secondary Bonds: a. van der Waals Force

- **In the case of nonpolar molecules**, random movement of electrons within the molecule creates fluctuating dipoles.
- Dipoles generated within these molecules will attract other similar dipoles.

A temporary dipole (fluctuating dipole) occurs when the symmetrical distribution of electrons in a molecule becomes asymmetrical temporarily; it then attracts the dipole to adjacent molecules, resulting in the eventual interaction.



1. Physical Properties

6. Bonding: B. Secondary Bonds: b. Hydrogen bonding

- Hydrogen bond is a special case of dipole attraction of polar compounds.

- Example: water molecule.
- Attached to the oxygen atom are 2 hydrogen atoms.
- As a consequence, the protons of the hydrogen atoms pointing away from the oxygen atom are not shielded efficiently by the electrons. They become positively charged.
- Positive hydrogen nucleus is attracted to the unshared electrons of neighboring water molecules.
- This type of bond is called a hydrogen bridge.

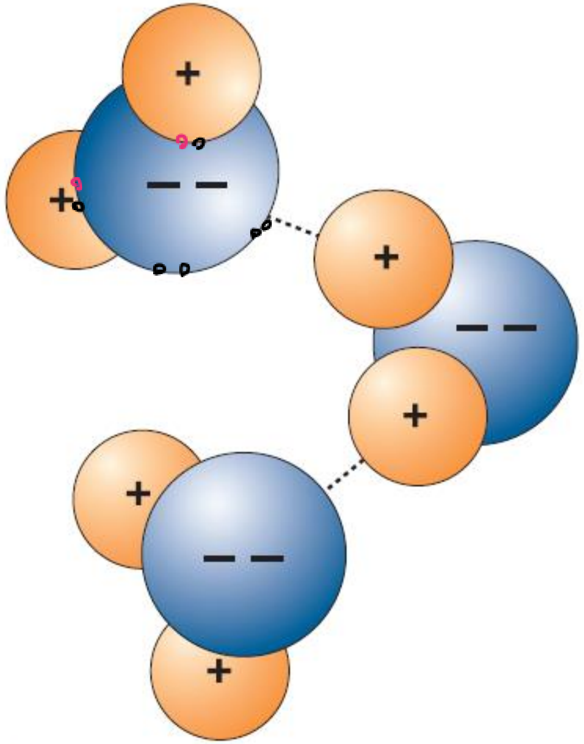


FIGURE 2-5 Hydrogen bond formation between water molecules. The polar water molecule bonds to adjacent water molecules via an H (*orange*) O (*blue*) interaction between molecules.

1. Physical Properties

6. Bonding

- Bonding energies, which generally range between 600 & 1500 kJ/mol (3 & 8 eV/atom), are relatively large, as reflected in high melting temperatures.

Table 2.3 Bonding Energies and Melting Temperatures for Various Substances

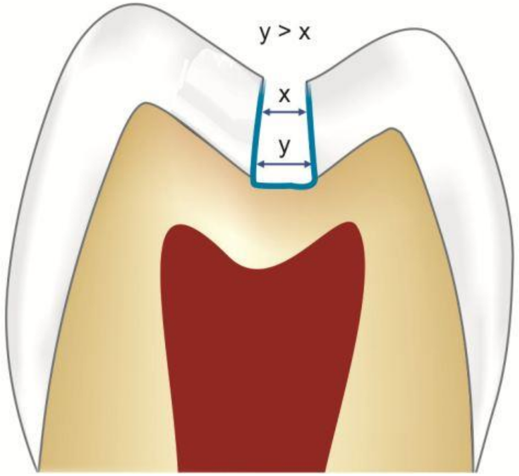
		Bonding Energy		
Bonding Type	*Substance*	*kJ/mol*	*eV/Atom, Ion, Molecule*	*Melting Temperature (°C)*
Ionic	NaCl	640	3.3	801
	MgO	1000	5.2	2800
Covalent	Si	450	4.7	1410
	C (diamond)	713	7.4	>3550
Metallic	Hg	68	0.7	−39
	Al	324	3.4	660
	Fe	406	4.2	1538
	W	849	8.8	3410
van der Waals	Ar	7.7	0.08	−189
	Cl_2	31	0.32	−101
Hydrogen	NH_3	35	0.36	−78
	H_2O	51	0.52	0

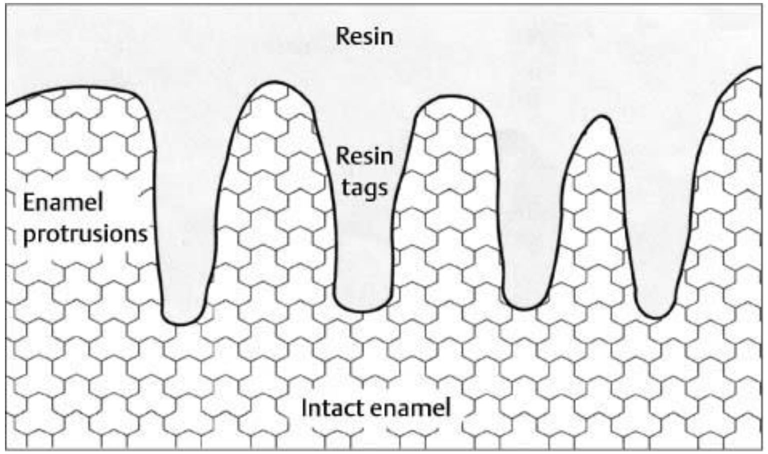
1. Physical Properties

6. Bonding

- Bonding in Amalgam vs Composite resin Restorations.

Amalgam	Composite resin
Mechanical (Macromechanical)	Micromechanical bonding

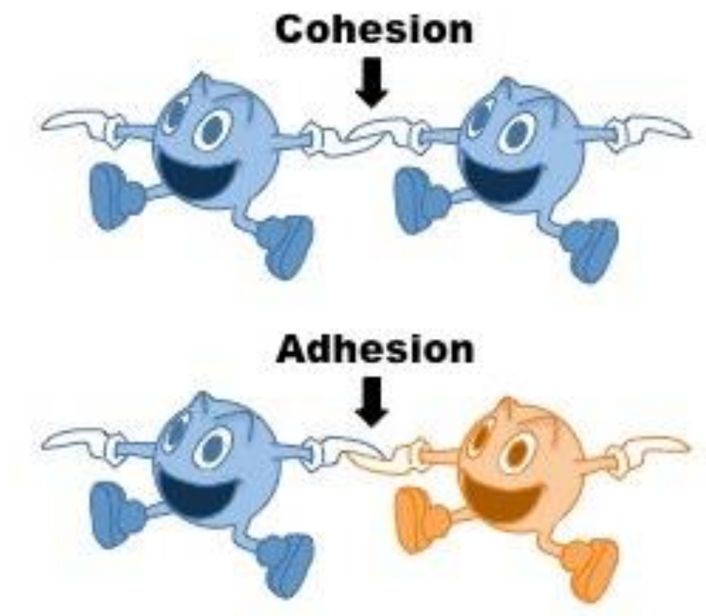


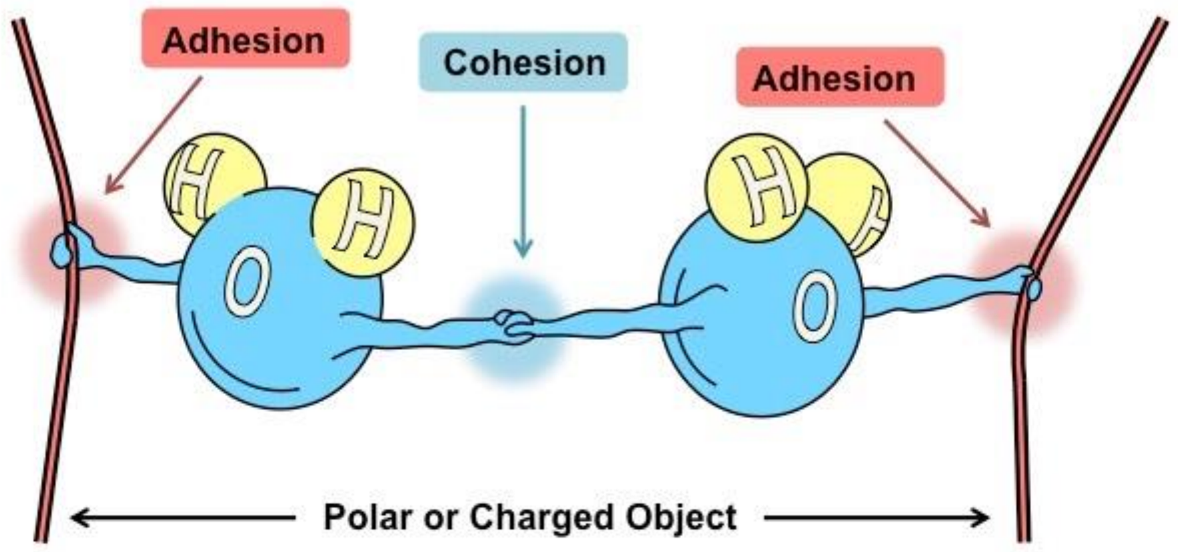


1. Physical Properties

7. Adhesion & Cohesion

- When the molecules of one substrate adhere or are attracted to molecules of the other substrate, the force of attraction is called **adhesion** when unlike molecules are attracted & **cohesion** when the molecules involved are of the same kind.





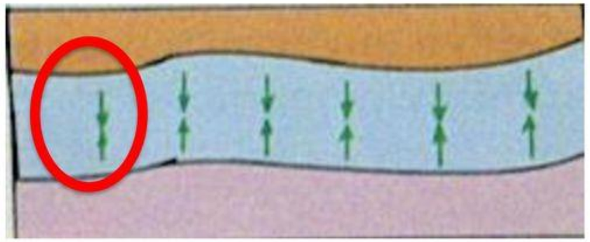
1. Physical Properties

7. Adhesion & Cohesion

- A denture stays attached to the soft tissue when saliva is present.

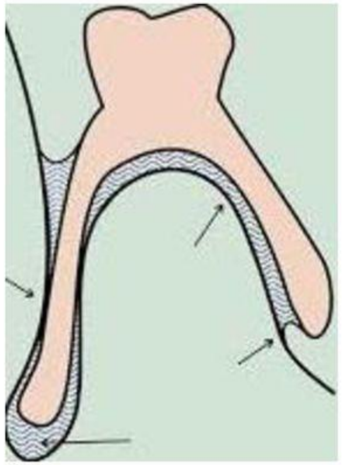
Cohesion:

- It is the physical attraction of like molecules to each other ...molecules of the same substance together .



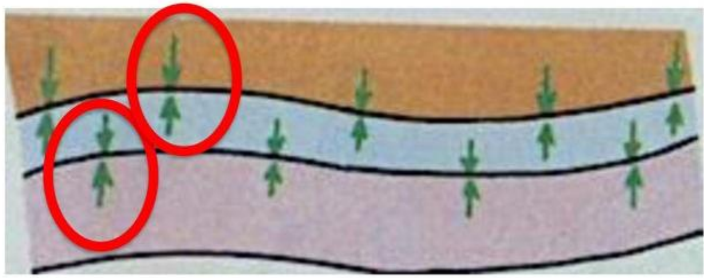
In complete denture :

- Saliva needs to be cohesive



Adhesion:

- Is the physical force involved in the attraction between two unlike molecules.



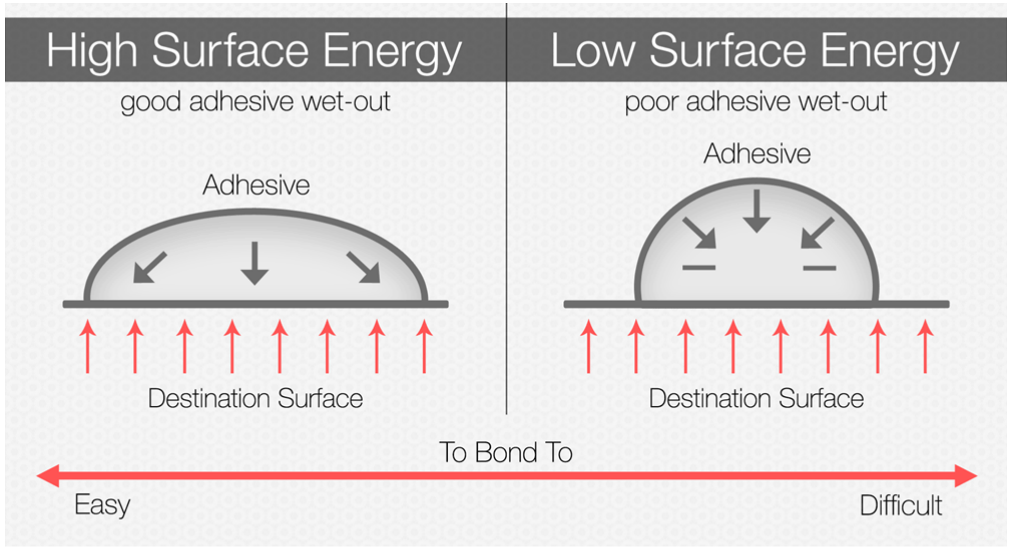
In case of denture

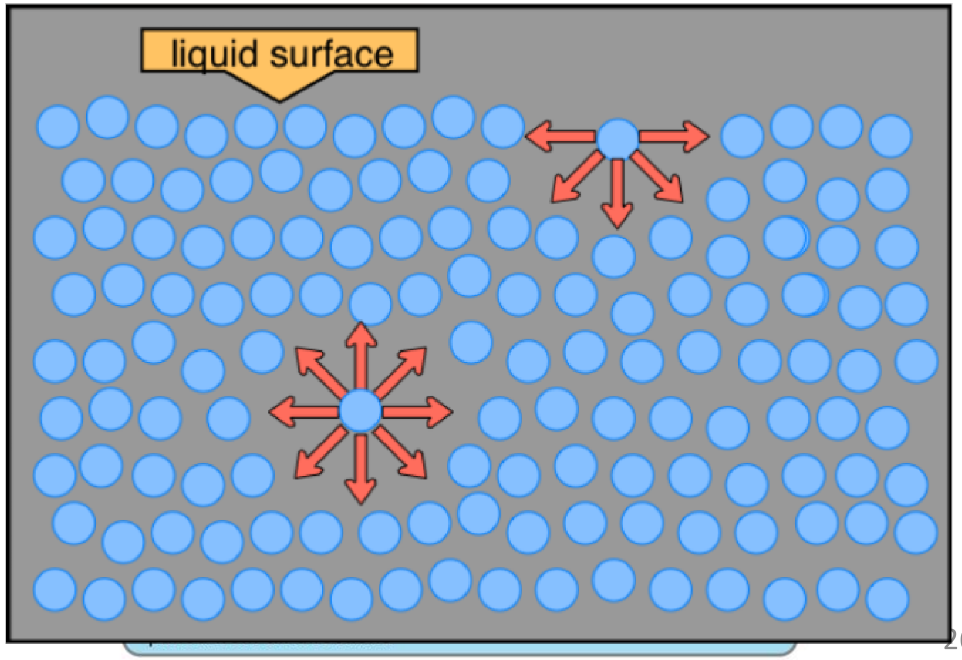
- It is the attraction between the denture and saliva and between saliva and oral mucosa.

1. Physical Properties

8. Surface Energy and surface tension

- Energy at the surface of a solid is greater than in its interior.
- The greater the surface energy, the greater the adhesion.
- The increase in energy per unit area of surface is referred to as surface energy or surface tension.
- **Surface tension** is the energy required to increase the surface area of a liquid due to intermolecular forces.



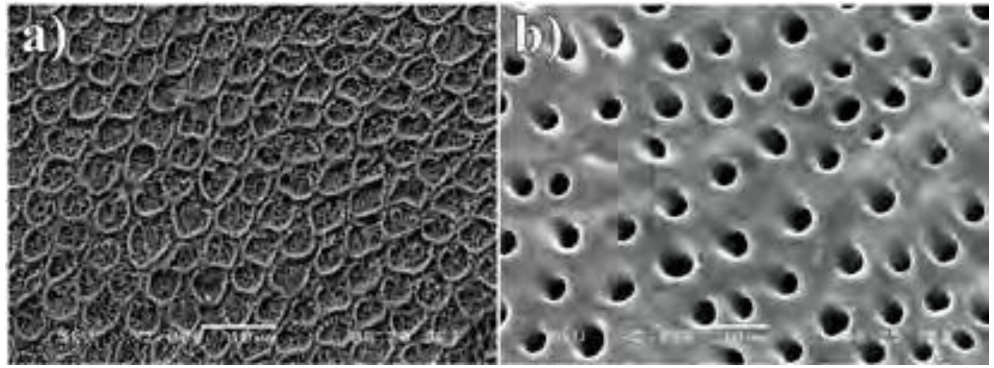


1. Physical Properties

8. Surface Energy

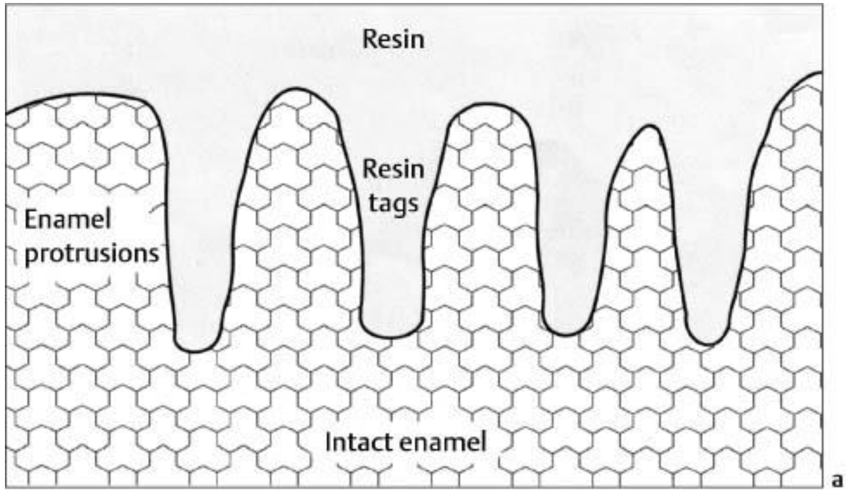
- Etched enamel has a high surface energy, allowing the resin to wet the tooth surface better & penetrate into the microporosities.

Enamel Dentin



- When polymerized, it forms resin 'tags' which forms a mechanical bond to the enamel.

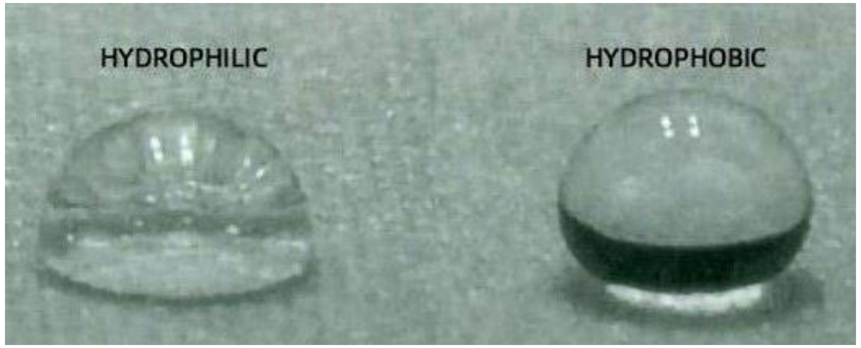
	Tooth substance	Surface energy (N/m)
Untreated	Enamel	0.028–0.032
	Dentin	0.042–0.045
Etched	Enamel	0.072
	Dentin	0.027–0.030



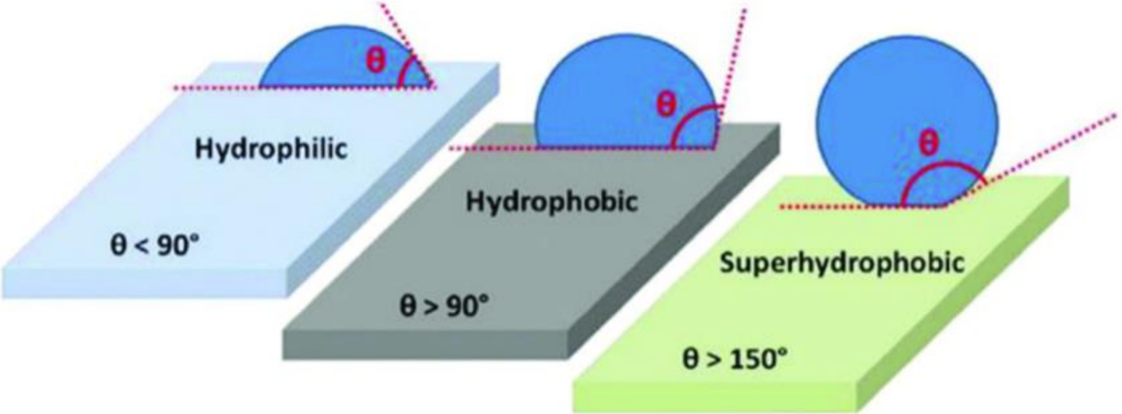
1. Physical Properties

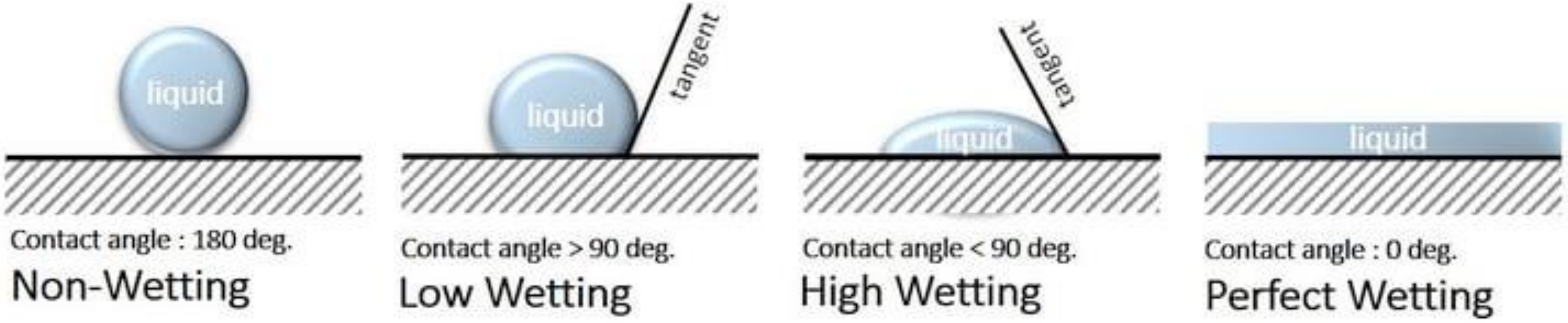
9. Hydrophilicity and Hydrophobicity

- Hydrophilic property to attract water (water lover)
- Hydrophobic property to resist water (water hater)
- Contact angle: Angle between a liquid surface & a solid surface where they meet.



- **Wetting:** the ability of a liquid to maintain contact with a solid surface, resulting from intermolecular interactions when the two are brought together





C. Thermal Properties

Thermal Properties

Three important thermal properties of dental materials are:

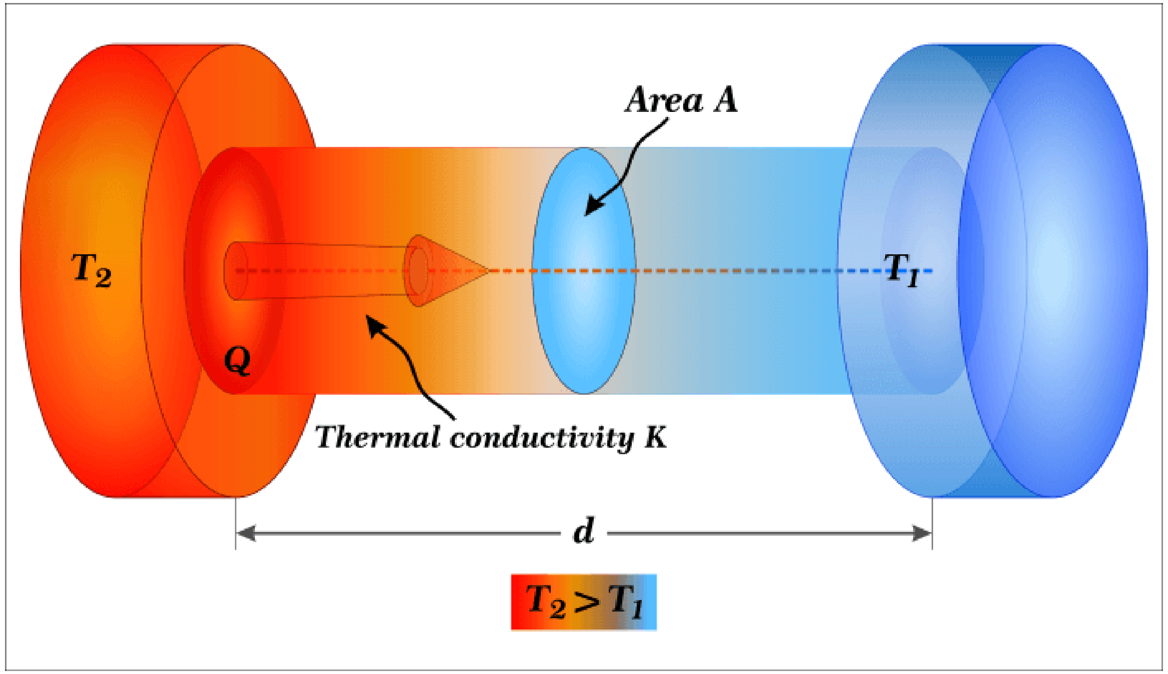
1. Thermal Conductivity
2. Thermal Diffusivity
3. Coefficient of Thermal Expansion & Contraction

Anusavice 2012.

Thermal Properties

1. Thermal Conductivity

- Thermal conductivity refers to the ability of a given material to conduct/transfer heat.
- It is generally denoted by the symbol ‘λ’ & ‘K’.
- The reciprocal of this quantity is known as thermal resistivity.



Thermal Properties

1. Thermal Conductivity

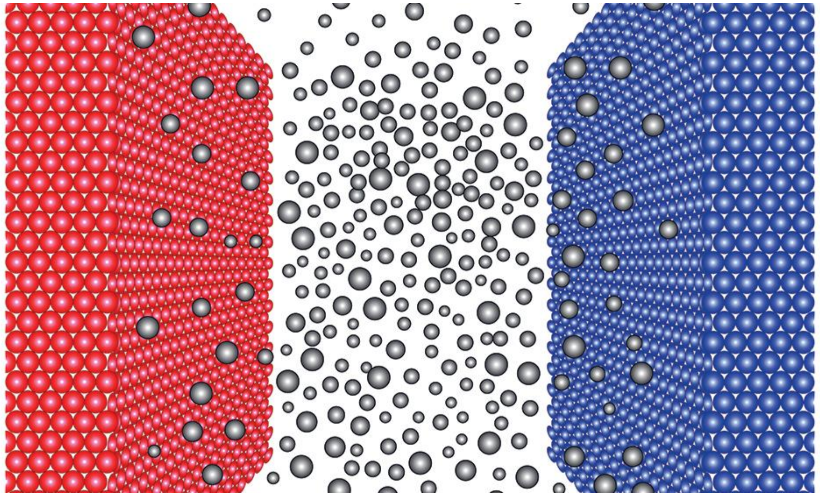
- Low thermal conductivity of enamel & dentin aids in reducing thermal shock & pulpal pain when hot or cold foods are taken into the mouth.

Material	Thermal Diffusivity (in 10^{-4} cm^2 /sec)
Pure Gold	11,800
Amalgam	960
Composite	19 to 73
Water	14
Glass Ionomer	22
Dentin	18 to 26
Enamel	47
Zinc Phosphate	30

Thermal Properties

2. Thermal Diffusivity

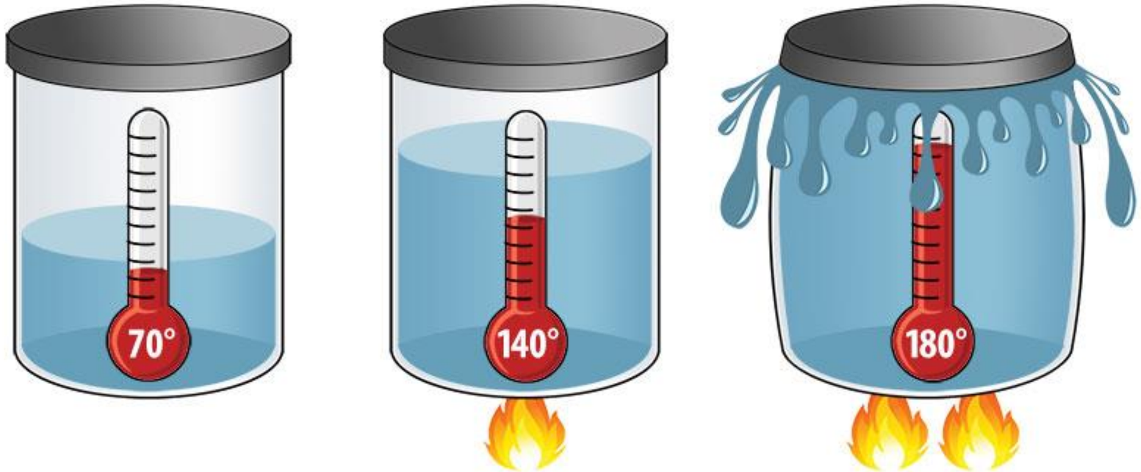
- It is a measure of the rate at which a body with no uniform temperature reaches a state of thermal equilibrium.
- Thermal conductivity of Zinc oxide-eugenol cement is slightly less than that of dentin, its thermal diffusivity is also less.



Thermal Properties

3. Coefficient of Thermal Expansion & Contraction

- It measures the fractional change in size per degree change in temperature.
- As the temperature rises, a solid material will expand & on cooling it will contract, this is measured by the linear coefficient of thermal expansion & contraction which is the change in length per unit length of a material for a 1°C change in temperature.



Thermal Properties

3. Coefficient of Thermal Expansion & Contraction

- Hard tooth structure has the smallest coefficient, metals are intermediate, and polymers have the largest.
- Tooth = $11*10^{-6}$ cm/cm.
- Gold = $14*10^{-6}$ cm/cm
- Impression compound = $250*10^{-6}$ cm/cm

Thermal Properties

3. Coefficient of Thermal Expansion & Contraction

- Filling material should have the same coefficient as the tooth, otherwise it will press too hard against the cavity wall on expansion & may cause pressure on the pulp or pull away from the wall when chilled by cold water.
  - These can cause leakage and further carries.

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THANK YOU
FOR
YOUR
ATTENTION
ANY QUESTIONS?