Lec5\ Nanomaterial Properties

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Electronic properties of solids are altered with great small in particle size :

Quantum confinement
Quantization of Energy Level مستوى الطاقة
Chemical properties خصائص كيميائية
Mechanical properties خصائص ميكانيكية
Optical properties خصائص بصرية

Some properties at nanoscale enabling unique applications.

opaque substances become transparent المواد المعتمه الى شفافة
inert materials become catalysts المواد الخامله الى سفافه
stable materials turn combustible المواد المستقرة الى مواد غير مستقرة
solids turn into liquids at room temperature المواد الصلبة الى سائلة
insulators become conductors المواد العازلة الى مواد موصله

Melting Point Depression انخفاض درجة الانصهار

When heating a solid to a certain point, there will be enough energy to break the bonds holding the material together.

Since the atoms on the surface are bonded to fewer atoms, they are easier to pull apart.

At the nanoscale, Surface Area to Volume ratio increases, and thus melting requires **less energy**

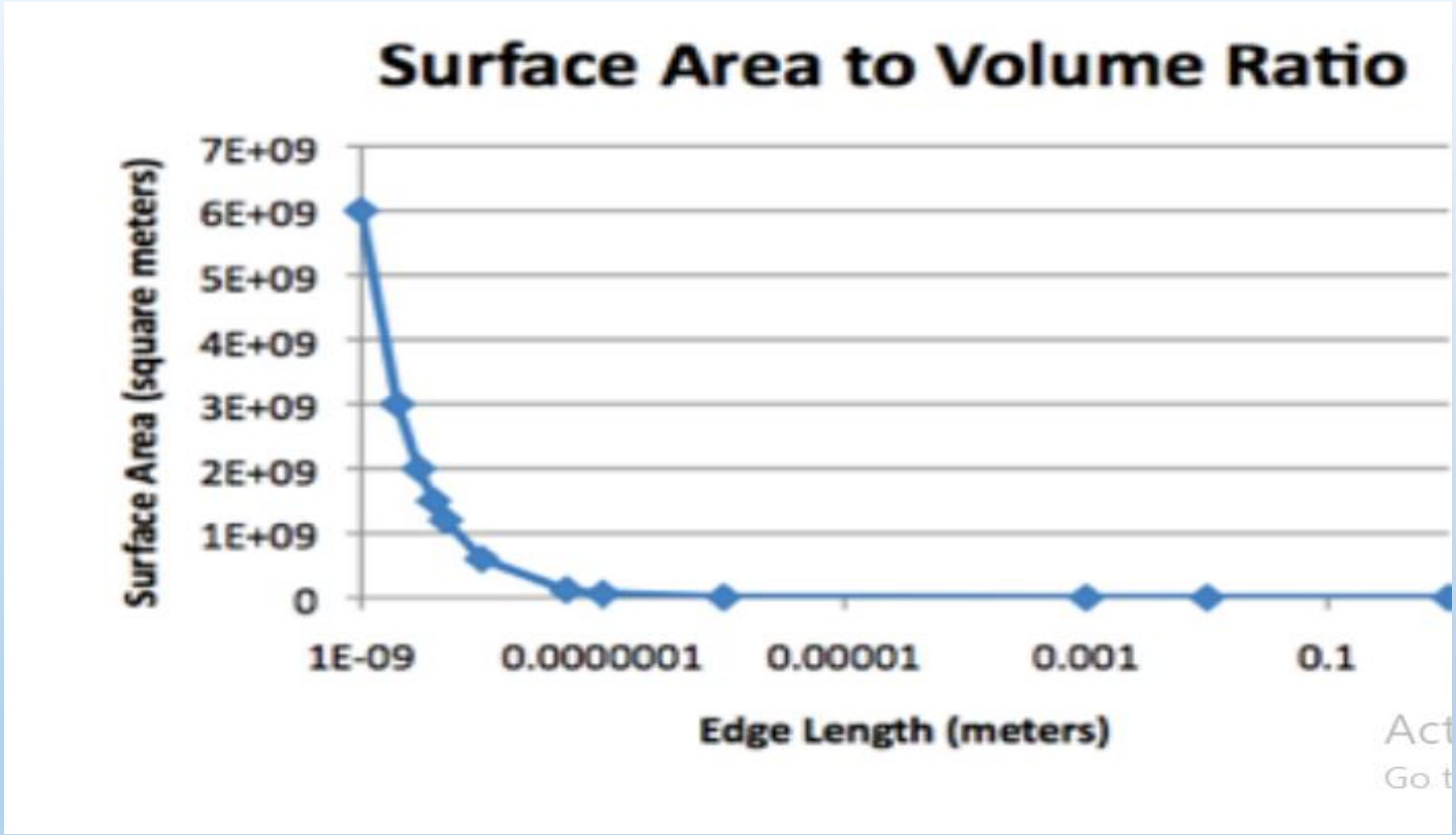
Effects of Surface Area to Volume ratio تاثيرات مساحة السطح الى الحجم

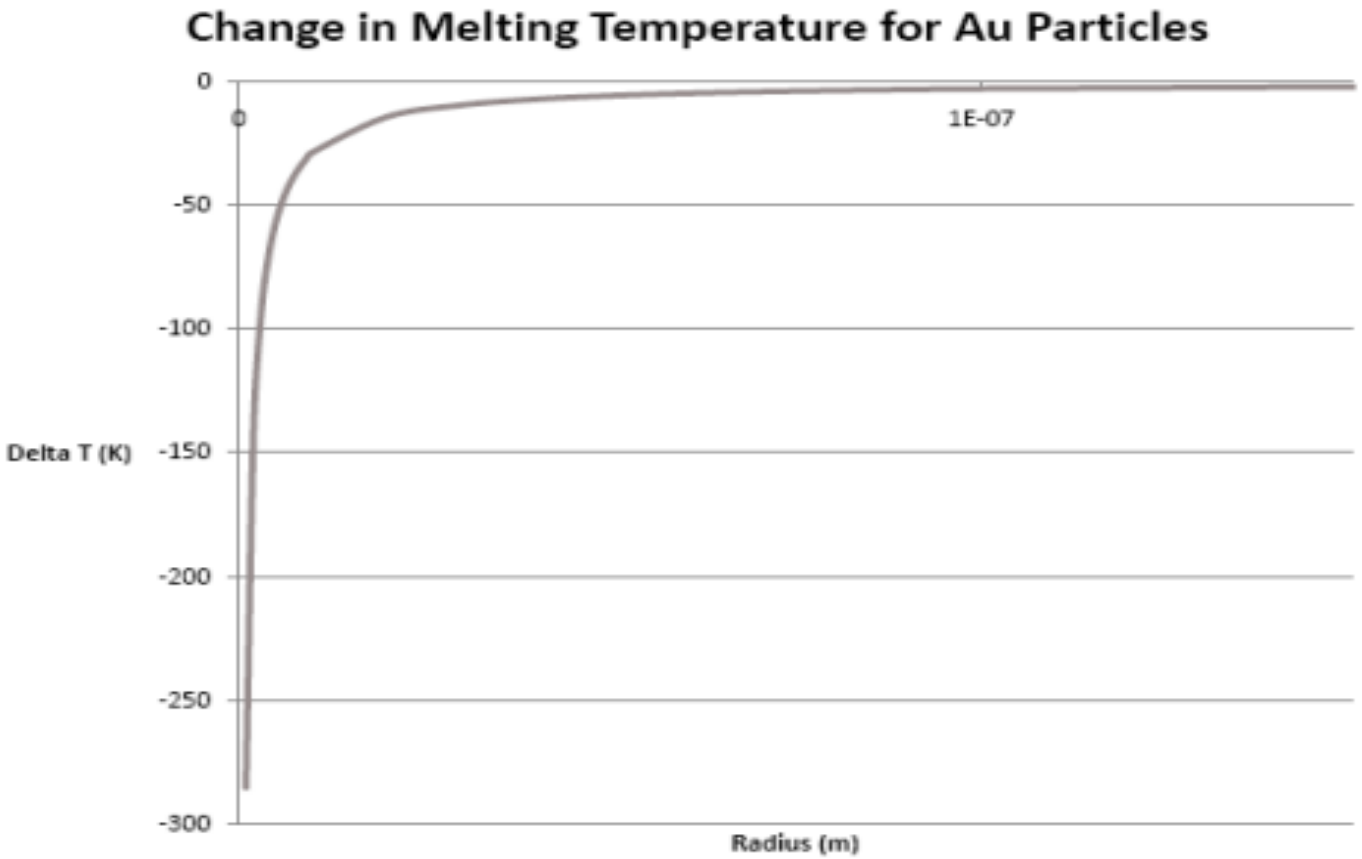
The Surface Area to Volume ratio is the surface area of a shape divided by its volume

More surface for interaction مساحة سطحية للتفاعل اكبر

More surface energy than bulk material طاقة سطحية اكبر

Melting point depression انخفاض درجة الانصهار


Surface Area to Volume Ratio
Surface Area (square meters)
7E+09
6E+09
5E+09
4E+09
3E+09
2E+09
1E+09
0
1E-09
0.0000001
0.00001
0.001
0.1
Edge Length (meters)


Change in Melting Temperature for Au Particles
0
-50
-100
-150
-200
-250
-300
Delta T (K)
0
1E-07
Radius (m)

What is Melting point

Melting point of a solid is the temperature at which it changes state from solid to liquid.

At the melting point the solid and liquid phase exist in equilibrium depends (usually slightly) on pressure and is usually specified at standard atmospheric pressure.

the reverse change from liquid to solid, it is referred to as the freezing point

In theory, the melting point of a solid **should be the same** as the freezing point of the liquid.

In practice, small **differences** between these quantities can be observed.

Phase Transition المرحلة الانتقالية

Involves a thermodynamic parameter called free energy (or Gibbs free energy), G.

is a function of thermodynamic parameters

1. Enthalpy, H (the internal energy of the system) الانثالبي
2. Entropy S (is a measurement of the randomness or disorder of the atoms or molecules) الانتروبية

With respect to phase transformations, an important thermodynamic parameter is the change in free energy G.

There are two contributions to the total free energy change that accompany a

Melting/solidification transition

Hundred years of thermodynamic model

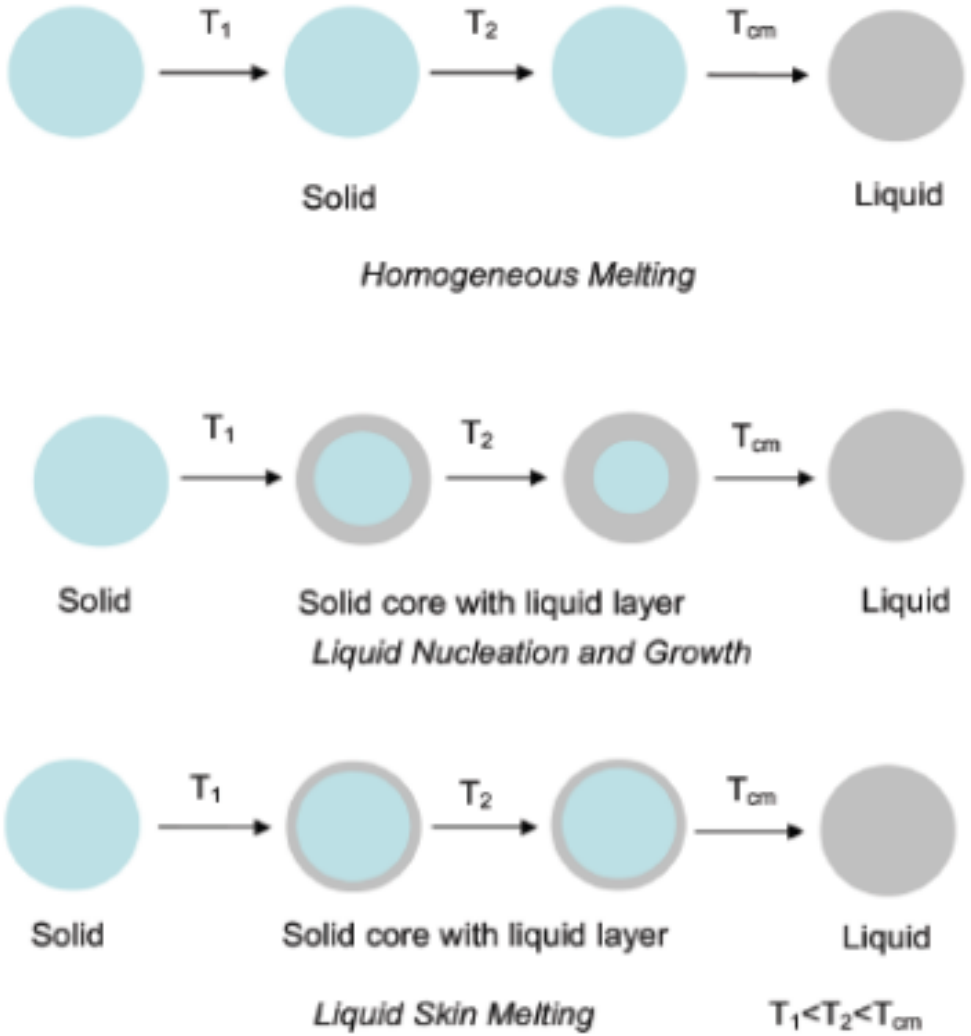


Figure 1. Three different melting hypotheses for nanoparticles.

Nanoparticles can be synthesized through homogeneous nucleation in three medium

1.Liquid

2. Gas

3. Solid

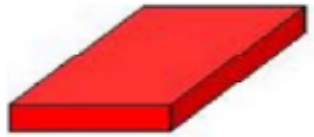
Fundamentals of nucleation and subsequent growth are essentially same

Quantum Size Effect تاثير الحجم الكمي

Can be classified by Dimension

Dimensions in the orthogonal directions X,Y,Z .i. e., Lx, y, z If the Nanoscopic Limit is Lo (comparable to de Broglie wave length)

Lx, y, z > Lo	No Nanomaterials	No confinement	BULK
Lx, y > Lo > L z	2 –D Nanostructures	One dimensional confinement	Quantum wells
Lx > Lo > L y, z	1 –D Nanostructures	Two dimensional confinement	Quantum wires
Lo > L x, y, z	0 –D Nanostructures	Three dimensional confinement	Quantum dots



Chemical Physics of atomic and molecular clusters

Important physical and chemical properties of bulk materials:

Structure

Melting

Conduction of electricity

Solubility

Magnetism

Chemistry

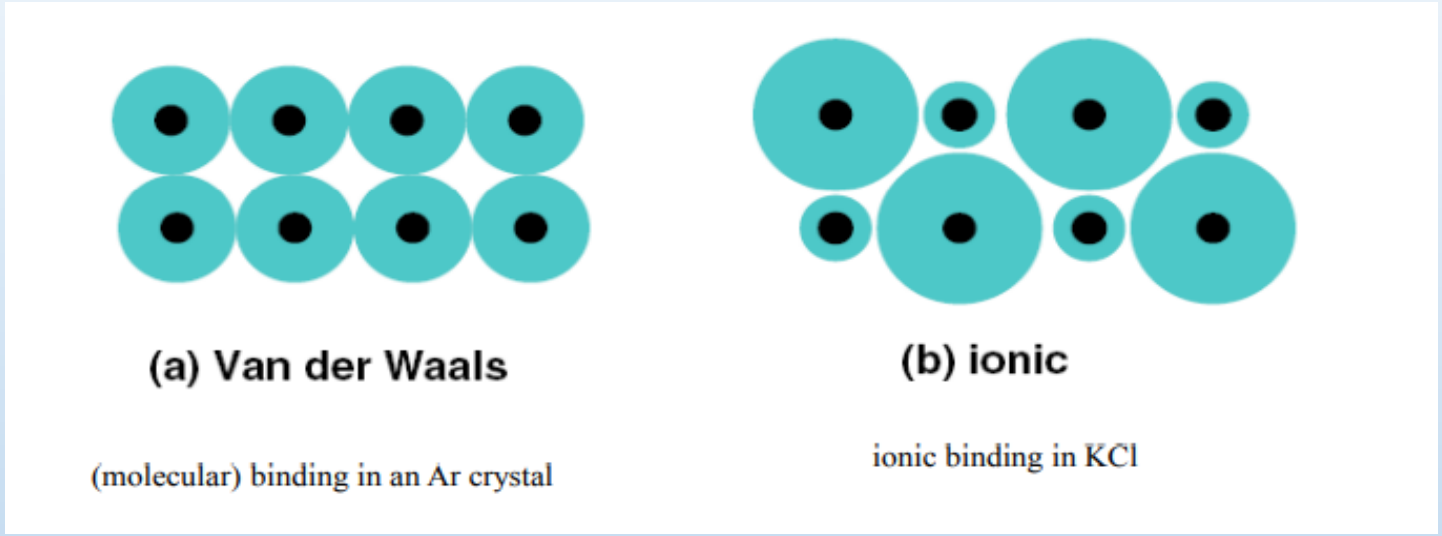
Bond types in solids Nanotechnology

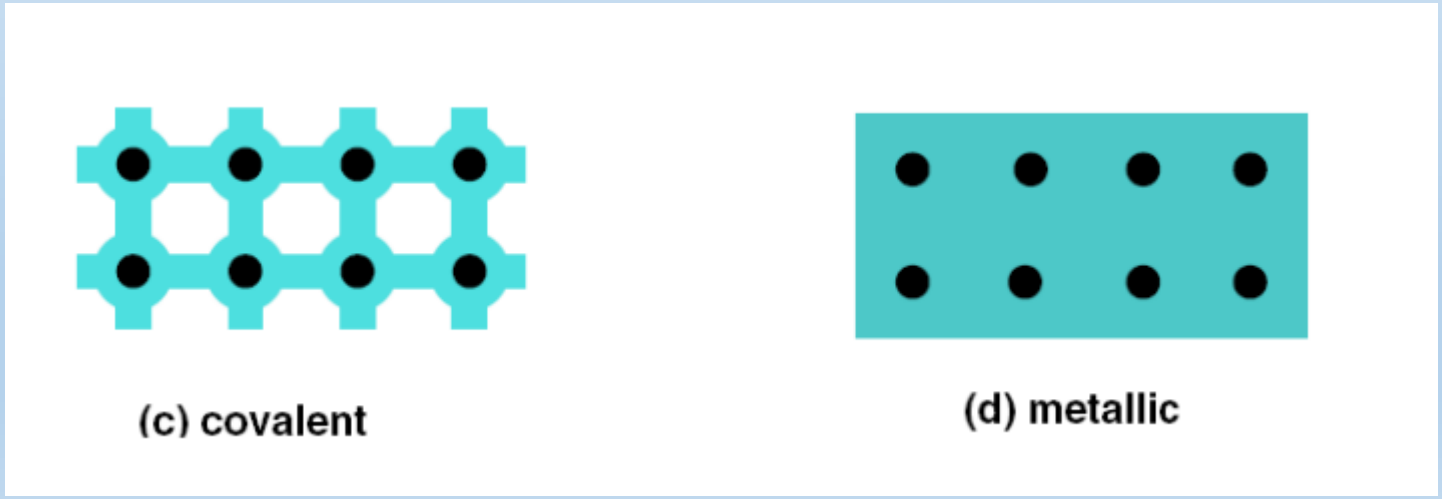
Bond Van der waals

Bond Ionic

Bond covalent

Bond Metal.





Bond types in solids Nanotechnology

The small (filled) circles represent the ionic cores

The shaded areas represent an appreciable amount of the electron

Density

Note that the electronic density is not uniform.

Van der Waals or covalent bonding in many metals, particularly in noble metals where loosely bound d electrons participate in the bonding.

Bond types in solids Nanotechnology

In covalent crystals, one faces a set of semi-localized electrons, which gather along the lines joining atoms together. The typical example of such a binding is the case of diamond.

In metals the valence electrons of each atom are fully delocalized, so that they form a nearly free uniform gas of electrons

Each electron thus loses any direct contact with the atom it was originally bound to.