Lecture 1

Particles and Nanotechnology

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Course Content

- *Introduction to the subject*
- *Characterization of Solid Particle*
- *Measurement of Particle size*
- *Size Reduction*
- *Crystal Structure*
- *Separation of Particles*
- *Synthesis of Nanomaterials*
- *Applications (Nanofluids & Polymer nano Composites)*
- *Characterization Instruments (1)*
- *Characterization Instruments (2)*

Introduction

Particle technology is a term used to refer to the science and technology related to the handling and processing of particles and powders. Particle technology is also often described as powder technology, particle science and powder science. Particles are commonly referred to as bulk solids, particulate solids and granular solids. Today particle technology includes the study of liquid drops, emulsions and bubbles as well as solid particles.

Measurement of particle size and Particle size distribution

- The three most important characteristics of an individual particle are:

1- Particle Composition.

2- Particle Size.

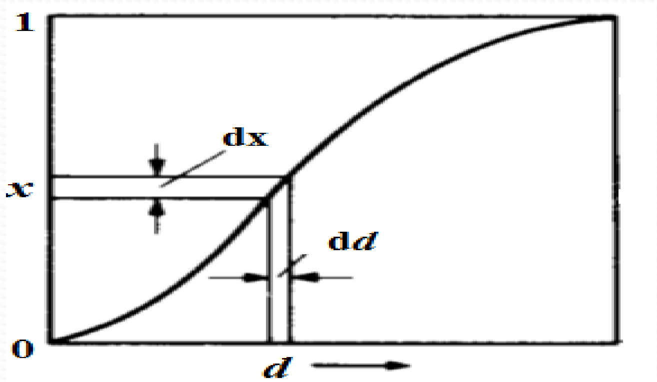
3- Particle Shape.

Particle size distribution

Most particulate systems of practical interest consist of particles of a wide range of sizes
and it is necessary to be able to give a quantitative indication of the mean size and of the
spread of sizes. The results of a size analysis can most conveniently be represented by means of a cumulative mass fraction curve, in which the proportion of particles (x) smaller than a certain size (d) is plotted against that size (d).

Particle size distribution

- This curve rises from zero to unity over the range from the smallest to the largest particle size present. The distribution of particle sizes can be seen more readily by plotting a *size frequency curve*, such as that shown in Figure blow, in which the slope *(*d*x/*d*d)* of the cumulative.



A mean size will describe only one particular characteristic of the powder and it is important to decide what that characteristic is before the mean is calculated. Thus, it may be desirable to define the size of particle such that it's mass or its surface or its length is the mean value for all the particles in the system. In the following discussion it is assumed that each of the particles has the same shape.

Crystal structure

- ***Crystal material*** solid or crystalline is a solid material whose constituents are arranged in a highly ordered microscopic structure, forming a crystal lattice.
- ***Unit cell***: It is smallest group of atoms which by repetition in three dimensions built up the crystal.
- ***Crystal structure*** is a description of the ordered arrangement of atoms, ions or molecules in a crystalline material. Ordered structures occur from the intrinsic nature of the constituent particles to form symmetric patterns that repeat along the principal directions of three-dimensional space in matter. The smallest group of particles in the material that constitutes the repeating pattern is the crystal structure of a material (the arrangement of atoms within a given type of crystal) can be described in terms of its unit cell. The unit cell is a small box containing one or more atoms arranged in 3 dimensions. The unit cells stacked in three-dimensional space describes the bulk arrangement of atoms of the crystal. The unit cell is represented in terms of its lattice parameters, which are the lengths of the cell edges (*a*, *b* and *c*) and the angles between them (alpha, beta and gamma), while the positions of the atoms inside the unit cell are described by the set of atomic positions (x_i, y_i, z_i) measured from a lattice point. Commonly, atomic positions are represented in terms of fractional coordinates, relative to the unit cell lengths.

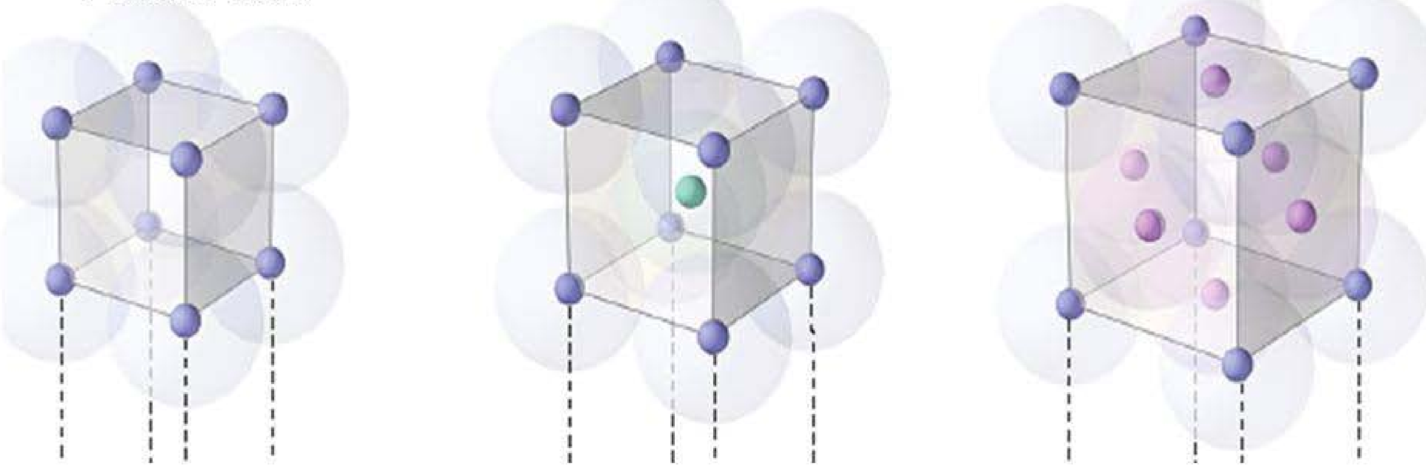
Bravais lattice

Number of Atoms per Unit Cell

Unit Cell Type	Net Number Atoms
SC (Primitive Cubic)	1
BCC	2
FCC	4

Simple cubic — Body-centered cubic — Face-centered cubic

Primitive cubic



Dr. S. M. Condren

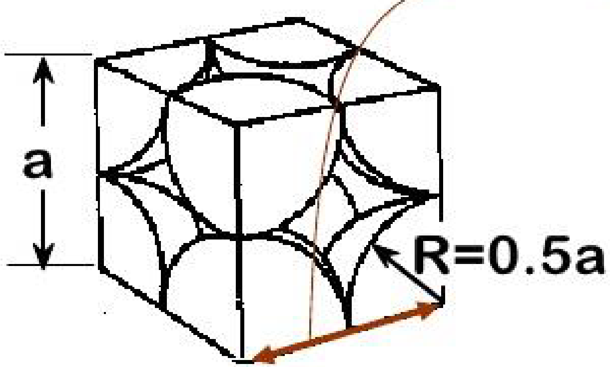
Atomic Packing Factor (APF)

Here's the better way to tell about packing.

ATOMIC PACKING FACTOR (APF)

$$APF = \frac{\text{Volume of atoms* in unit cell}}{\text{Volume of unit cell}}$$

*assume hard spheres



Close-packed direction:

a= 2R

There are 8 of 1/8 atoms.

1 atom/unit cell

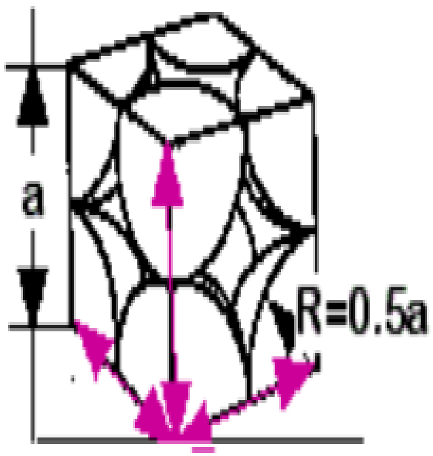
$$APF = \frac{1 \cdot \frac{4}{3}\pi(0.5a)^3}{a^3} = 0.52$$

1 = $\frac{\text{atoms}}{\text{unit cell}}$

$\frac{4}{3}\pi(0.5a)^3$ = $\frac{\text{volume}}{\text{atom}}$

a^3 = $\frac{\text{volume}}{\text{unit cell}}$

APF FOR SIMPLE CUBIC



close-packed directions

contains 8 x 1/8 =
1atom/unit cell

APF = 0.52 for simple cubic

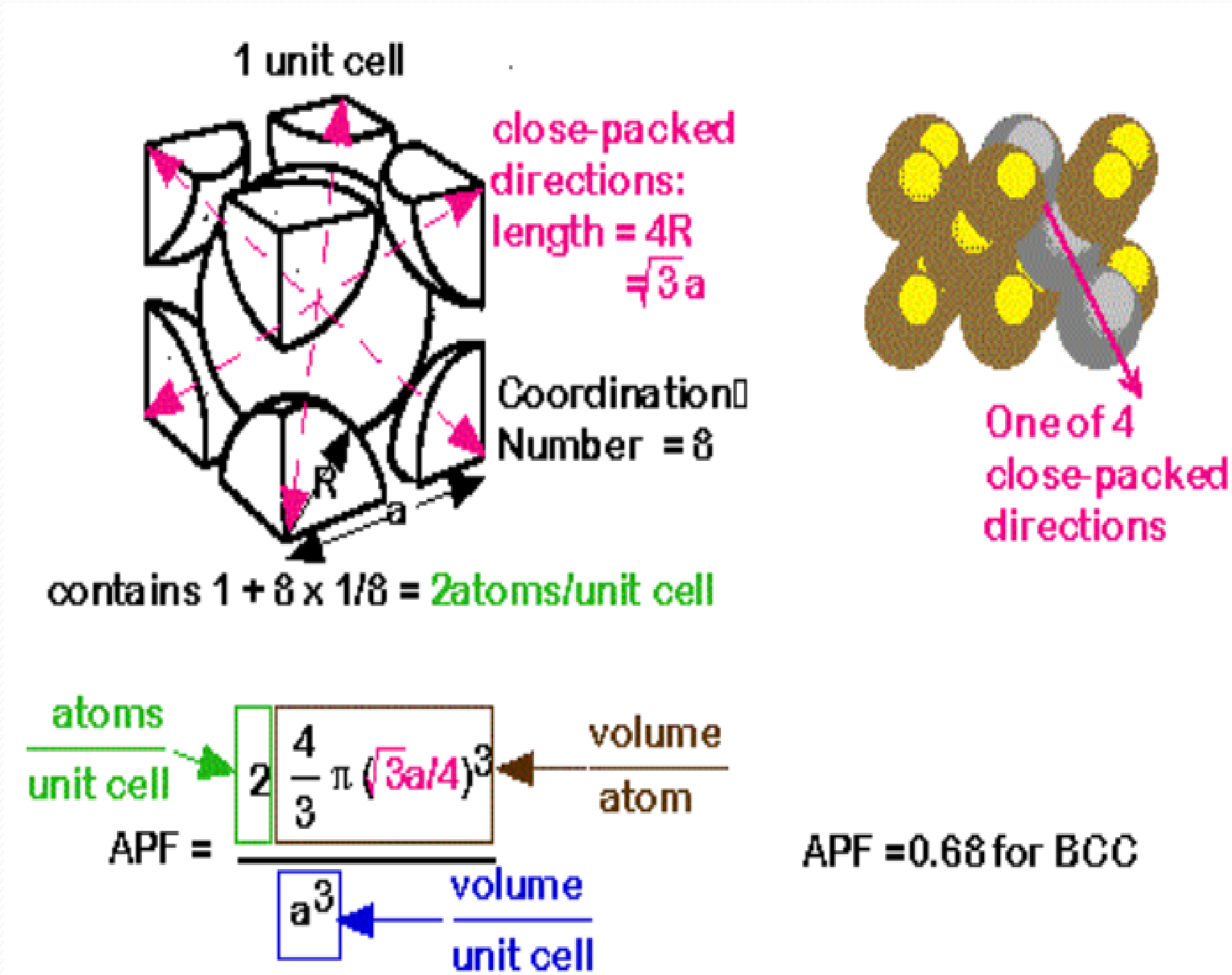
$$APF = \frac{1 \;\; \frac{4}{3}\pi (0.5a)^3}{a^3}$$

$\frac{\text{atom}}{\text{unit cell}}$ → 1

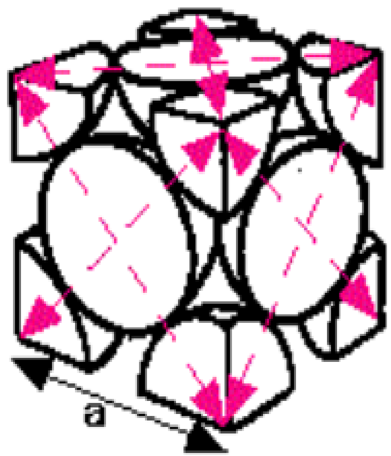
$\frac{\text{volume}}{\text{atom}}$ → $\frac{4}{3}\pi (0.5a)^3$

$\frac{\text{volume}}{\text{unit cell}}$ → a^3

APF FOR BCC / BODY CENTERED CUBIC

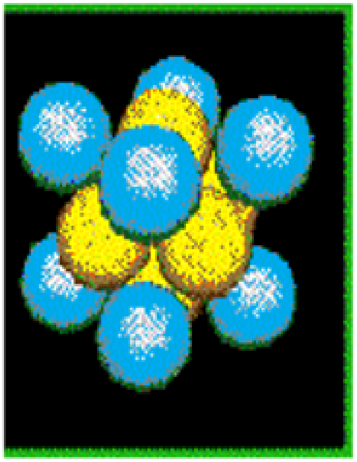


APF FOR Face - Centerd Cubic Structure (FCC)



close-packed directions:
length = 4R
= $\sqrt{2}$a

Coordination Number = 12



Courtesy of Materials Science: A Multimedia Approach, by John C. Russ

contains 6 x 1/2 + 8 x 1/8 = 4atoms/unit cell

$$APF = \frac{4 \; \frac{4}{3}\pi(\sqrt{2}a/4)^3}{a^3}$$

atoms / unit cell → 4

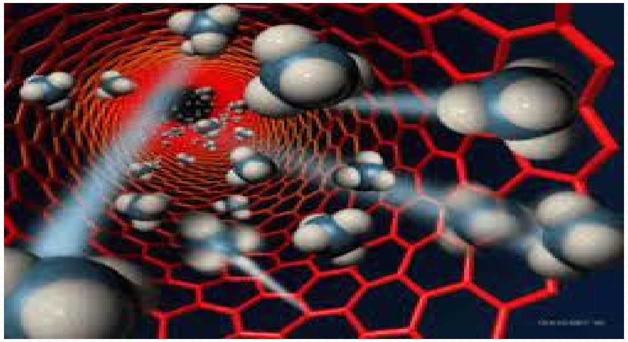
volume / atom → $\frac{4}{3}\pi(\sqrt{2}a/4)^3$

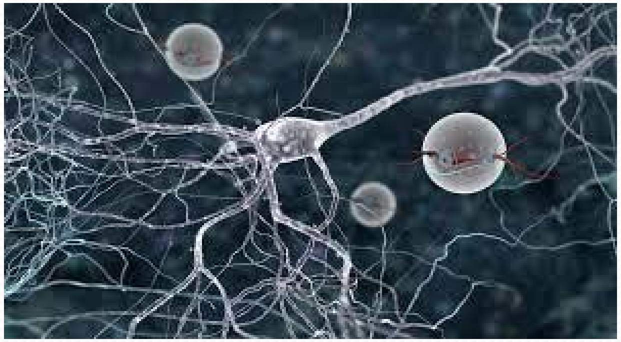
volume / unit cell → a^3

APF =0.74 for FCC

Nano Particles Size and Nanotechnology

What is Nanotechnology?





Nanotechnology is science, engineering, and technology conducted at the nanoscale, which is about 1 to 100 nanometers.

Nanoscience and nanotechnology are the study and application of extremely small things and can be used across all the other science fields, such as chemistry, biology, physics, materials science, and engineering.