**Characteristics of ceramic Powder**

**1- PURITY:**

Crystal Modification by Impurities, these changes in crystal habit caused by kinetic factors are drastically effected by the presence of impurities that adsorb specifically to one or another face of a growing crystal.

Ex: NaCl: changing the crystallization from cubic to octahedral.

Because crystal growth is a surface phenomena, it is not surprising that impurities that concentrate at crystal faces will affect the growth rate of those faces and hence the crystal shape. With some surface active impurities, small traces, about 0.01%, are all that is required to change crystal habit during crystallization. These impurities can:

1. Reduce the supply of material to the crystal face,
2. Reduce the specific surface energy,
3. Block surface sites and pin the steps of the growing crystal.

The impurities that modify crystal habit fall into four categories:

1. Ions, either anions or cations;
2. Ionic surfactants, either anionic or cationic;
3. Nonionic surfactants like polymers;
4. Chemical binding complexes

Fractional surface coverage, \( b(=K/\alpha l) \) is related to the distribution coefficient \( K \) and the activity of the solvent \( \alpha l \) and can also be written as:

\[
b = b' \exp(\Delta H/R.T)
\]

where \( \Delta H \) is the enthalpy of adsorption.

*Test: Chemical analysis*
Influence of impurity adsorption on the crystal habit

2- CRYSTALLIZATION

Crystallization phenomena usually include nucleation and growth of crystals.

Nucleation

The formation of crystal nuclei can be classified into primary and the secondary nucleation categories,

Primary nucleation refers to the spontaneous formation of crystals from clear supersaturated solutions and is further classified into homogeneous and the heterogeneous nucleation.
The secondary nucleation predominates in practical crystallizers where a large number of crystal particles are present in the solution.

**Crystal Growth**

Crystal particles grow with the driving force of solution supersaturation. The rate processes involved in crystal growth kinetics are the mass transfer of crystallizing component(s) from the bulk to the surface in the solution, the surface integration in which the crystallizing components are incorporated into the crystal lattice, and, finally, the heat transfer of the latent heat of crystallization. The first two processes occur in series, whereas the last parallels them.

*Test: XRD, XRF analysis*

### 3- PARTICLE SHAPE

*When a particle's surface is not uniformly smooth like that of a sphere but has a texture like that of broccoli or cauliflower, the particle is said to be fractal*
Imagine an irregularly shaped particle like that shown in Figure, For this particle, an infinite number of statistical diameters radiating from the center of gravity of the particle exist.
\[
\bar{d}_R = \int_0^{2\pi} r \frac{d\theta}{\pi}
\]

**Fig 2** Multitude of particle diameters.

**Fig 3** Different particle diameters.
The sieve diameter is the length of a side of the minimum square aperture through which a particle will pass. An irregularly shaped particle will pass through the smallest possible mesh only if it is presented in the optimum orientation. Sieving times for elongated particles approach infinity because only two orientations will allow the particle to pass the smallest sieve. Long sieving times can cause problems since some amount
of particle breakage will inevitably result during this time. A common solution to this dilemma is to sieve for a specific period of time with all samples of the same type and live with the error and breakage that result.

![Diagram of particle pass through the sieve](image)

**Fig. 4 particle pass through the sieve**

### 2-Mean particle size

<table>
<thead>
<tr>
<th>Mean Diameter Type</th>
<th>Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length mean diameter</td>
<td>( d_{NL} = d_{av} = \frac{\sum N_i \cdot d_i}{\sum N_i} ).</td>
</tr>
<tr>
<td>Geometric mean diameter</td>
<td>( d_{GN} = a \log_{10} \left( \frac{\sum N_i \cdot \log_{10} d_i}{\sum N_i} \right) ).</td>
</tr>
<tr>
<td>Surface mean diameter</td>
<td>( d_{NS} = \left( \frac{\sum N_i \cdot d_i^2}{\sum N_i} \right)^{1/2} ).</td>
</tr>
<tr>
<td>Volume mean diameter</td>
<td>( d_{NV} = \left( \frac{\sum N_i \cdot d_i^3}{\sum N_i} \right)^{1/3} ).</td>
</tr>
</tbody>
</table>
5-PARTICLE SIZE DISTRIBUTION

With sizing techniques that count the particles, it is desirable to know the accuracy of the size distribution after counting a given number of particles. Figure 5 gives the number of particles to be counted to give a specific accuracy.
<table>
<thead>
<tr>
<th>Method</th>
<th>Dimension measured</th>
</tr>
</thead>
<tbody>
<tr>
<td>Microscopy</td>
<td>Projected Area diameter</td>
</tr>
<tr>
<td></td>
<td>Feret’s diameter</td>
</tr>
<tr>
<td></td>
<td>Martin’s diameter</td>
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<tr>
<td></td>
<td>Perimeter diameter</td>
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<tr>
<td></td>
<td>Unrolled diameter</td>
</tr>
<tr>
<td>Sieve</td>
<td>Sieve diameter</td>
</tr>
<tr>
<td>Settling</td>
<td>Stokes’s diameter</td>
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<tr>
<td></td>
<td>Drag diameter</td>
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<tr>
<td></td>
<td>Free-fall diameter</td>
</tr>
<tr>
<td>Gas absorption</td>
<td>Surface to volume diameter</td>
</tr>
<tr>
<td>Coulter counter (Electro-zone)</td>
<td>Volume diameter</td>
</tr>
<tr>
<td>Inertial separation</td>
<td>Stokes’s diameter</td>
</tr>
<tr>
<td>Light scattering</td>
<td>Scattering diameter</td>
</tr>
<tr>
<td>Photon correlation spectroscopy</td>
<td>Sixth moment diameter</td>
</tr>
<tr>
<td>Permeability</td>
<td>Surface to volume diameter</td>
</tr>
</tbody>
</table>

Fig. 5 Particle size Distribution
Histograms of particle size distributions  5 nm, 10 nm, 20 nm, 30 nm, 40 nm, and 60 nm
6-INTERNAL POROSITY

Porosity within a particle is a manifestation of the shape of a particle. Fractal particles will have internal porosity as a result of their shapes.

Fractal particles with large fractal dimensions greater than small dimensions, will have narrower pore size distributions with most of the pores are open space in the particle structure.

The method used to measure the pore size distribution in a powder: is mercury, by principle: capillary rise.

A non wetting liquid requires an excess pressure to rise in a narrow capillary. The pressure difference across the interface.

The measurement of porosity are using mercury that gives moisturizing angle between 112 ° and 142 °, and such a fluid penetrates the pores only when pressing.
\[ P = -\frac{2S \cos \theta}{r} \]

\[ \theta = 130^\circ \]

**7- SURFACE AREA**

The specific surface area of a ceramic powder can be measured by gas adsorption or Permeability.

The theoretical equation relating the quantity of gas adsorbed to the equilibrium pressure.

Using the kinetic theory of gases,

\[ \frac{V}{V_m} = \theta = \frac{bP}{1 + bP} \]

\[ b = \frac{\tau_0}{\sqrt{2\pi mkT}} \exp \left( \frac{Q}{RT} \right) \]

P : gas pressure , \( V_m \) is the monolayer capacity, \( V \): volume adsorbed

\( \Theta \): is the fractional surface

where \( \tau_0 \) is the molecular vibration time, \( m \) is the molecular mass, \( k \): is Boltzmann's constant, \( T \) is temperature, and \( Q \) is the energy evolved when a gas is adsorbed.
8-POWDER DENSITY

The weight of a powder divided by the volume it occupies is its bulk density. The bulk density of a powder is often much less than the density of the individual grains that make up the powder.

The true density of the individual grain is determined by pycnometry, a mass of powder is placed in a vessel with a calibrated volume.