What is 'Surface Chemical Potential' and its significance for nanoparticles?

Chemical potential is a thermodynamic quantity which expresses the incremental energy content of a system per unit particulate mass. Higher chemical potential indicates higher chemical reactivity and a spontaneous reaction. Energy associated with a chemical reaction is equal to the net difference between the chemical potential of the reactants and the products. In bulk phases, the contribution of the surface energy to total energy content is inconsequential and surface chemical potential hardly comes into play. However at nanoscale, the surface energy forms a major part of the total energy and has to be included in the calculation of chemical potential. Hence the term 'surface chemical potential.' It can be looked upon as surface or interfacial energy per unit particulate mass. Thus higher surface chemical potential means higher surface energy (which in turn indicates higher surface tension).

This effect is governed by Gibbs –Thomson Equation which states that the surface chemical potential is inversely proportional to the radius of curvature of the particle:

$$\mu(r) - \mu(\infty) = 2K\Omega/r$$

$\mu(r)$ = Surface chemical potential at radius of curvature 'r'
$\mu(\infty)$ = Surface chemical potential of flat surface
K = Surface free energy
Ω= Molecular volume
r = Particle radius

Following Figure 7 depicts how decreasing particle size increases the chemical potential through increase of curvature of the surface. Nanophase particles with very small radii have enormous surface chemical potential (μs). This leads to very high reactivity of nanoparticles which can be beneficially used for catalysis or stabilization through chemisorption of the surrounding matrix.

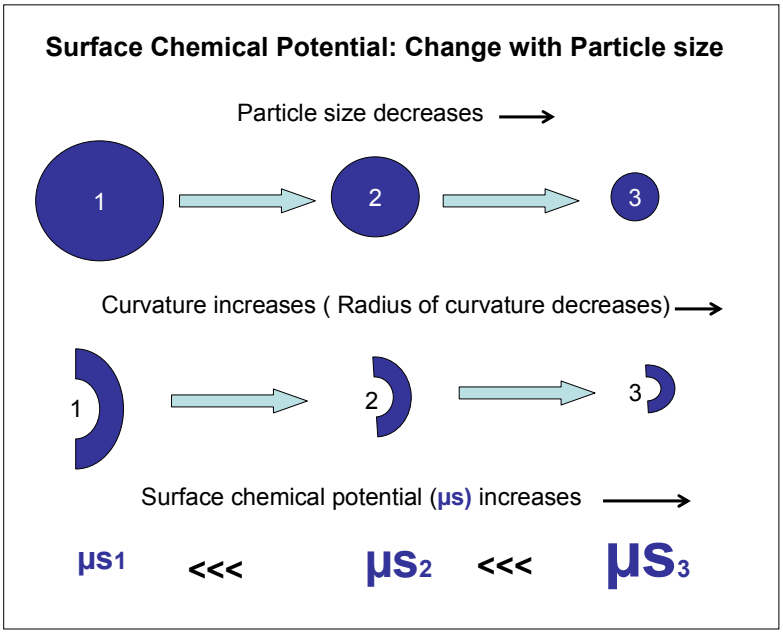

Figure: Surface Chemical Potential: Variation with particle size

Sharp increase in the surface chemical potential at nano particle sizes can have following implications in the context of coating technology:

- Nanodispersions of pigments and extenders in a resin medium can be spontaneously stabilized by chemisorption of polymeric species from the resin /solvent matrix.
- In case of particles with high aspect ratio, the surface chemical potential will be unevenly distributed over the surface area of the particles, thereby providing anisotropic properties in the matrix.
- Nano polymer emulsions will require very high amount of surfactants for stabilization.
- Higher chemical potential of nano pigments and extenders will lead to their dissolution/ bleeding in the medium.
- Saturation concentration of the material increases with increasing chemical potential of the nanoparticles.

_____