What is ‘Self-assembly’?

Self-assembly is the nature’s way of building matter up from the particles and molecules. The rocks on the earth are the crystalline self assemblies of inorganic particles. Biological matter like tissues, organs, plants and animals are the self-assemblies of organic macromolecules. Coatings technology has known the concept of self assembly as exhibited by the formation of micelles by surfactant molecules or the ordered monolayer on the dispersed particles. However, emergence of nanotechnology has brought this concept into prominence as a phenomenon as well as a tool for building newer materials.

Self-assembly is a spontaneous process that converts nanoparticles and macromolecules into a well ordered supramolecular structure. Nanoparticles and macromolecules with high energy on the surface tend to attain a state of low free energy by mutual association through non covalent bonding. The forces responsible for self-assembly are the short range forces namely hydrogen bonding, hydrophobicity, capillarity, electrostatic, magnetic and van der Waal’s forces of different types.

Figure below is a schematic of self-assembly

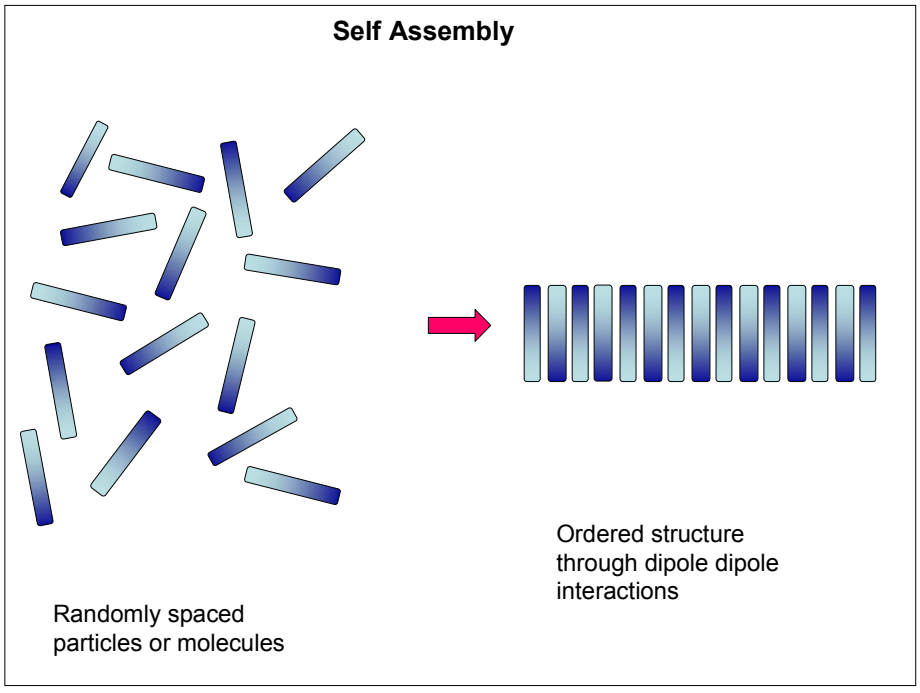

Figure: Self assembly

The process of self assembly has the following characteristics:

1. Assembling units: These are nanoparticles or macromolecules that are generally self-similar with regard to their geometry and physico-chemical characteristics. These individual units must possess mutual affinity in a specific geometrical orientation via corners, edges, poles or flat surfaces. Alternatively, they may exhibit physico-chemical affinity to a foreign surface through a common geometrical feature.
2. Driving force for self assembly: Spatially resolved nanoparticles and polar macromolecules are at a higher level of free energy. This energy drives the process of self assembly under the following conditions:

- The surface of the nanoparticles is not stabilized through adsorption.
- The macromolecular concentration in the system crosses a certain threshold value so that the intermolecular spacing is low enough for them to interact. (e. g. Micelles)
- Spatial separation among nanoparticles is gradually eliminated by a process like evaporation of the solvent.
- Any interface introduced in the system which can attract the nanoparticles or macromolecules on to its surface. This may be in the form of a substrate, another immiscible phase or larger particles.

3. Characteristics of the self assembled structure: The self assembled structure with its lower free energy than the individual units, is thermodynamically stable and is at equilibrium. These structures exhibit long range ordering or patterns as these are formed through a repetitive interaction among the similar nanoparticles or macromolecules. The configuration of the self-assembled structure is determined by the characteristics of the individual assembling units. Further, if these assemblies are temporarily perturbed by an external force, they regain their original configuration.
