HOW ARE NANOPARTICLE INTERACTIONS AND ASSEMBLIES DIFFERENT FROM MOLECULAR AND COLLOIDAL ASSEMBLIES

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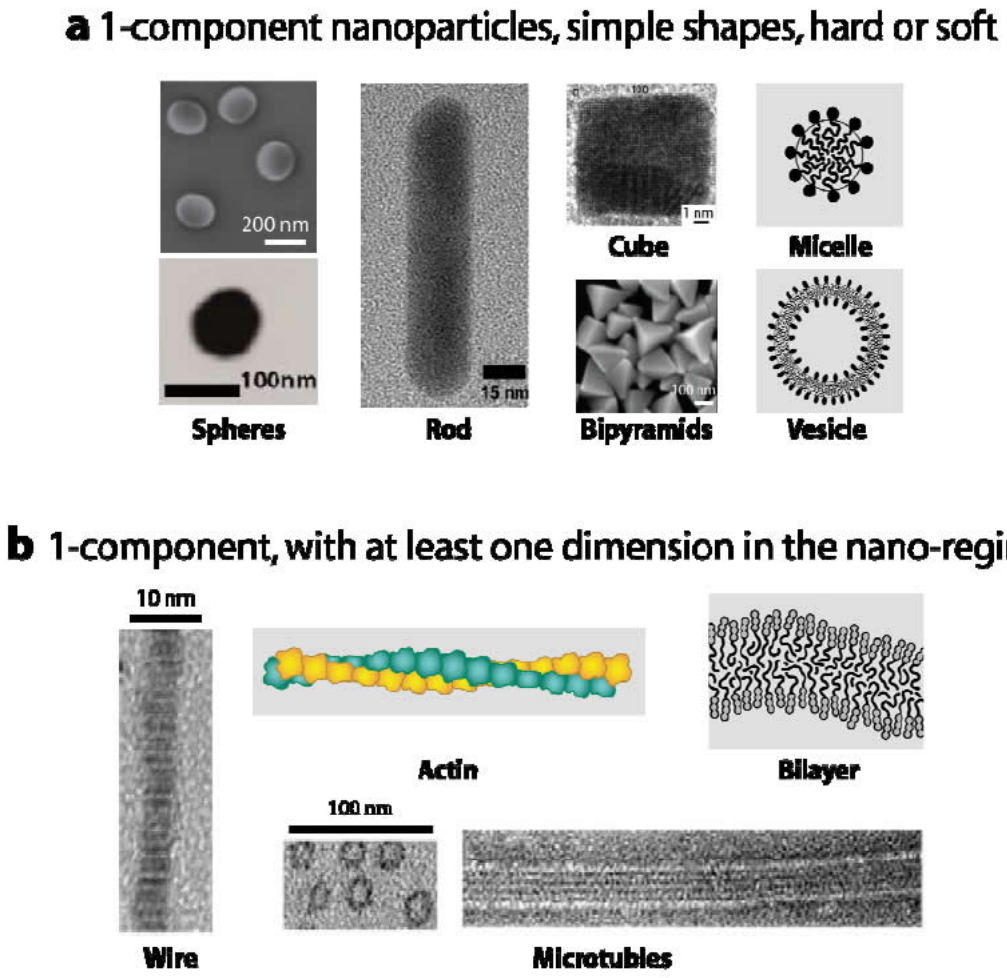
Are nanoparticles and their assembleis fundamentally different from smaller (atomic, molecular) or larger (colloidal) particles and assemblies? For reasons that will be discussed, mos nanoparticles do not spontaneously "self-assemble" into their thermodynamically lowest energy configuration. To do this, or to organize them into a non-equilibrium but stable structure, requires input of energy – a process that is better described as "directed" or "engineered" assembly. A combination of self- and directed-assembly process steps can be employed to obtain desired hierarchical structures, but this requires an understanding of how nanoparticle size, shape, hardness and composition (Fig 1) determine their interaction forces and processing possibilities.



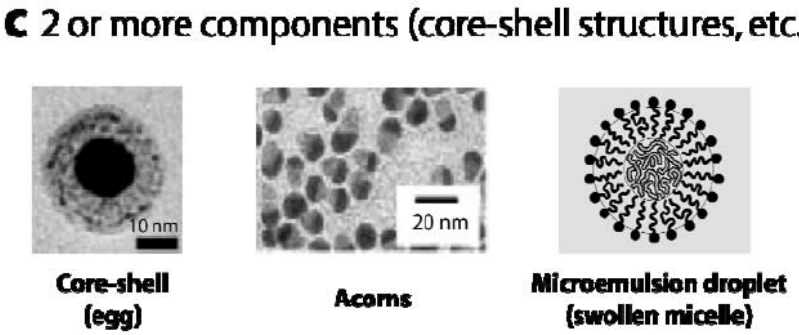


Figure 1. Some typical nanoparticles, here defined as having at least one dimension in the 1-100 nm regime, classified according to their size, shape, hardness and composition. (a) SEM image of main-chain polyether nanoparticle (top of first column) and TEM image of 60 nm gold nanosphere (bottom of first column). TEM image of Au nanorod (second column). HRTEM image of cubic Pt nanocrystal oriented along [001] (top of third column) and SEM image of Ag bipyramids approximately 150 nm in edge length (bottom of third column). Schematic micelle and vesicle are shown in the fourth column. (b) HRTEM image of PbSe nanowire formed in the presence of oleic acid and n-tetradecylphosphonic acid (first column). Schematics of actin and surfactant or lipid bilayer (top of second column). TEM images of microtubules (bottom of second column). (c) TEM image of Au co loid stabilized by sodium citrate and 19 layers of polyelectrolyte (left). HRTEM image of CoPd 'acorns' (middle). Microemulsion droplet (right).

For a variety of thermodynamic and kinetic reasons that will be discussed, most nanoparticle systems are bound to be non-equilibrium ones. Such systems depend on the method of their preparation and can show aging e fects such as slow deformational creep or chemical changes. The complex intermolecular and interparticle forces operating between different types of nanoparticles will be reviewed [1], as will their role in self-assembly and directed-assembly, the latter including the application of external magnetic and electric field forces, pressure confinement, flow, shear and rolling forces, to order nanoparticles. Most of these promising methods have yet to be fully explored.

[1] Younjin Min, Mustafa Akbulut, Kai Kristiansen, Yuval Golan, Jacob Israelachvili, Nature Materials 7, 527-538 (2008).