CHEMISTRY OF NANO MATERIALS

NANO MATERIALS

Nano materials describe, in principle, materials of which a single unit small sized between 1 and 100 nm. Nano materials research takes a materials science-based approach to nanotechnology, leveraging advances in materials metrology and synthesis which have been developed in support of micro fabrication research. In Nanotechnology, a particle is a small object that behaves as a unit with respect to its transport and properties. The properties can change at Nano scale. All properties including Reactivity, Size, Magnetism, Thermal, Mechanical and Optical properties would change.

For example, Carbon in the form of graphite (i.e. pencil lead) is soft, at the Nano-scale, can be stronger than steel and is six times lighter (CNT). Nano-scale copper is highly elastic metal at room temperature, stretching to 50 times its original length without break. Shiny orange yellow Gold changes its color to brownish black on reducing the size.

There are unique properties of nanoparticles which are dependent on their size. Nano particles have tremendous driving force for diffusion. Nano particles also exhibit Super paramagnetism. Superparamagnetism is a form of magnetism which appears in small ferromagnetic or ferrimagnetic nanoparticles. In sufficiently small nanoparticles, magnetization can randomly flip direction under the influence of temperature. Nano particles also exhibit an effect known as Quantum confinement. Quantum confinement effects describe electrons in terms of energy levels, potential wells, valence bands, conduction bands, and electron energy band gaps. The quantum confinement effect is observed when the size of the particle is too small to be comparable to the wavelength of the electron.

HISTORY OF NANO MATERIALS/NANOTECHNOLOGY

The Father of Nano technology is the 1965 Nobel Laureate, Richard Feynman. There's Plenty of Room at the Bottom: An Invitation to Enter a New Field of Physics" was a lecture given by physicist Richard Feynman at the annual American Physical Society meeting at Caltech on

December 29, 1959 and predicted that one day we will be making things at the atomic level. And since these small things will build upwards we will be able to make them more precisely and control what we want them to do. This prediction became true at the turn of the century with the onset of Nano science and technology. Physicist Norio Taniguchi, coined the term "Nanotechnology" (1974). Invention of the scanning tunneling microscope in 1981 and the discovery of fullerene (C60) in 1985 lead to the emergence of nanotechnology. In 1985 Robert F. Curl, Jr., Harold W. Kroto, and Richard E. Smalley discovered the first fullerene, the third known form of pure carbon (after diamond and graphite). They named their discovery buckminsterfullerene ("buckyball") for its resemblance to the geodesic domes promoted by the American architect R. Buckminster Fuller. Technically called C_{60} for the 60 carbon atoms that form their hollow spherical structure, buckyballs resemble a football one nanometer in diameter. In 1991 Sumio Iijima of NEC Corporation in Japan discovered carbon nanotubes, in which the carbon ring like structures are extended from spheres into long tubes of varying diameter. The scanning tunneling microscope not only allowed for the imaging of atoms by scanning a sharp probe tip over a surface, but it also allowed atoms to be "pushed" around on the surface. With a slight bias voltage applied to the probe tip, certain atoms could be made to adhere to the tip used for imaging and then to be released from it. Thus, in 1990 Donald Eigler spelled out the letters of his company's logo, IBM, by moving 35 xenon atoms into place on a nickel surface. This demonstration caught the public's attention because it showed the precision of the emerging Nano scale too. In 1993, a lab solely devoted to nanotechnology was formed in the US. In 2000, the national nanotechnology initiative was started and a lot of advancements have been made in Nano medicines and other technologies in the last two decades. In 2009, in vivo study was done using Nano particles to deliver drug to cancer tissues. The advancements in this field is clear from the amount of research and patents filed in this area.

NANO MATERIALS USED IN THE HISTORY

- When a laser or other beam of light is shown through a colloid, the light will scatter and the beam will be visible in the mixture. The nanoparticles in colloids are larger than those in solutions (1-1000 nm) and will scatter light (Tyndall effect). This effect is shown by Nano particles and this

property was knowingly or unknowingly made use of multiple times in the history. Medieval artisans were the first nanotechnologists. They made stained glass by mixing gold chloride into molten glass. They created tiny gold spheres which absorbed and reflected sunlight in a way that produced a variety of colors. They knew that by putting varying, tiny amounts of gold and silver in the glass, they could produce the effects found in stained-glass windows.

- Lycurgus cup is a 4th-century Roman glass cage cup made of a dichroic glass shows a different color depending on whether or not light is passing through it. It shows red color when lit from behind and green when lit from in front and depicts King Lycurgus ensnared in a tangle of grapevines, presumably for evil acts committed against Dionysus, the Greek god of wine. It was found that the dichroism (two colors) is observed due to the presence of nanoparticles, silver 66.2%, 31.2% gold, and 2.6% copper, up to 100 nm in size, dispersed in a glass matrix. The red color observed is a result of the absorption of light (~520 nm) by the gold particles. The purple color results due to the absorption by the larger particles while the green color is attributed to the light scattering by colloidal dispersions of silver particles with size >40 nm.
- In the 15^{TH} and 16^{th} century – pottery of Deruta, Italy – Glazes containing copper and silver Nano particles were made.
- In the seventeenth century, beautiful glass which came to be known as 'ruby glass' from its color, was first made in Potsdam in Germany. The recipe for making the coloring pigment or stain was published in 1685 by Andreas Cassius, and ever since then the color has been called Purple of Cassius. The recipe was costly, for it involved dissolving fine gold powder in aqua regia, adding water, and then adding a piece of pure tin. After an hour or two, a brilliant purple precipitate formed, Purple of Cassius.

FARADAY'S DIVIDED METAL

The existence of metallic nanoparticles in solution was first recognized by Faraday in 1857 and a quantitative explanation of their color was given by Mie in 1908. In 1857 Michael Faraday reported a systematic study of the synthesis and colors of colloidal gold. Faraday prepared his colloidal dispersions of gold by a two-phase preparation, reducing an aqueous solution of a gold salt, such as sodium tetrachloroaurate ($Na[AuCl_4]$), with a solution of phosphorus in carbon disulfide, since phosphorus was regarded as "a very favorable agent". The reduction proceeds rapidly at room temperature and the bright yellow color of the $Na[AuCl_4]$ solution is replaced within minutes of

mixing by the deep ruby coloration characteristic of colloidal gold. Faraday concluded that the gold was dispersed in the liquid in a very finely divided form, the presence of which could be detected by the reddish opalescence when a narrow intense beam of light is passed through the liquid. He thus said that "the gold is reduced in exceedingly fine particles, which becoming diffused, produce a beautiful ruby fluid … the various preparations of gold, whether ruby, green, violet or blue in color, … consist of that substance in a metallic divided state."

NANO MATERIALS IN NATURE

1. LOTUS EFFECT

   When rain falls on lotus leaves water beads up with a high contact angle. The water drops promptly roll off the leaves, collecting dirt along the way. This self-cleaning ability is called lotus effect. The lotus leaf's ability to shed water is due to its multi-levelled roughness. The combination of the micro scale mounds and the Nano-scale hair-like structures causes falling water to bead up and roll off the leaf. By altering the surface structure of the leaves while keeping their chemical composition approximately the same the researchers were able to confirm the importance of the lotus leaf's Nano scale hair-like structure on its self-cleaning ability. They did this by heating the leaf until the Nano-scale hair-like structures melted, at 150°C, coating the leaf surface. This heating process, while keeping the chemical composition of the surface approximately the same, alters the roughness such that the contact angle is decreased and water droplets no longer roll off the leaf.

2. SPIDER SILK

   Spider silk is a protein fiber spun by spiders. Spiders use their silk to make webs or other structures, which function as sticky nets to catch other animals, or as nests or cocoons to protect their offspring, or to wrap up prey. They can also use their silk to suspend themselves, to float through the air, or to glide away from predators. It has been shown that Nano fibrils are at the origin of their mechanical performance. For spider silk, Nano fibrils have been widely speculated to play an important role, however, so far without satisfying experimental support. In vitro spider silk is further able to self-assemble into small Nano fibrils upon incubation in potassium phosphate buffer for several days at room temperature

3. SERPENT SEA STAR

   The serpent sea star is a dish-shaped shellfish. It has five tentacles and no eyes. It can accurately sense potential natural enemies in the distance and retract the tentacles into the shell in time. The

serpent sea star body is actually covered with “eyes”, that is, tens of thousands of perfect miniature lenses. In this way, the entire furry body constitutes the starfish’s eyes. Studies also show that the number of such lenses on a serpent sea star is about 50,000 to 100,000, and they are composed of calcium carbonate Nano crystals; this perfect light-sensitive micro-lens system is the result of Nano-crystallization on the surface of the starfish’s body growth. In order to prevent unnecessary color fringing, a proper amount of magnesium is also absorbed in the lens during crystallization, which can not only help starfish filter the light more effectively but also correct the “spherical aberration” of the lens. This improves the efficiency of finding natural enemies

4. GECKO EFFECT

   Geckos have the largest mass and have developed the most complex hairy attachment structures among climbing animals that are capable of smart adhesion – the ability to cling to different smooth and rough surfaces and detach at will. These animals make use of about three million micro scale hairs (setae) (about 14,000/mm^2) that branch off into Nano scale spatulae, about three billion spatulae on two feet. The so-called division of contacts provides high dry adhesion. Multiple-level hierarchically structured surface construction provides the gecko with the compliance and adaptability to create a large real area of contact with a variety of surfaces.

5. OTHER OCCURENCES

- Magneto tactic bacteria belong to a group of bacteria that synthesize iron oxide nanoparticles covered by biological material that are called magnetosomes. These bacteria use the magnetosomes as a compass to navigate in the direction of the earth's magnetic field.
- Butterflies have nanostructures for other purposes too, like making their wings super water repellent and self-cleaning. Hydrophobicity is important for butterfly wings because it allows them to weather a rainstorm, where any moisture sticking to its wings could weigh down a butterfly and make it difficult to fly.
- DNA, RNA, enzymes all are Nano sized materials

GOLD NANO PARTICLES IN TRADITIONAL MEDICINE

Traditional Indian Ayurveda medicines- gold is used in several preparations. Saraswatharishtham prescribed for memory enhancement. Swarnabhasma which has been used as a therapeutic agent for several clinical disorders including bronchial asthma, rheumatoid arthritis, diabetes mellitus,

nervous diseases, etc. Medicinal preparation for babies in order to enhance their mental capability. Over 5000 years ago, the Egyptians used gold in dentistry. In Alexandria, alchemists a powerful colloidal elixir known as liquid gold to restore youth. The great alchemist and founder of modern medicine, Paracelsus, developed many highly successful treatments from metallic including gold. Francisci Antonii – philosopher and doctor in 1618 book mentioned gold sols as medicine. In middle ages it was used to cure heart diseases, epilepsy, tumors and even to detect syphilis