NET, IAS, State-SET (KSET, WBSET, MPSET, etc.), GATE, CUET, Olympiads etc.: Science and Technology Nanotechnology

Nanotechnology

What is Nanotechnology?

1. Definitions of nanotechnology are as diverse as its applications. Basically, it is the ability to design and control the structure of an object at all length scales from the atom up to the macro scale.
2. One nanometer is one-billionth of a meter, roughly the width of three of four atoms.
3. Materials reduced to the nanoscale can suddenly show very different properties compared to what they exhibit on a macroscale, enabling unique applications.
4. For instance, opaque substances like copper become transparent, inert materials like platinum become catalysts, stable materials like aluminium turn combustible, solids like gold turn into liquids at room temperature and even loses conductivity, and insulators such as silicon become conductors. Much of the fascination with nanotechnology stems from these unique quantum and surface phenomena that matter exhibits at the nanoscale.

Building Blocks of Nanotechnology

1. Particles that show the wonders at the nanoscale are known as nanoparticles. The transition from microparticles to nanoparticles can lead to a number of changes in physical properties. Two of the major factors in this are the increase in the ratio of surface area to volume, and the size of the particle moving in to the realm where quantum effects predominate.
2. High surface area is a critical factor in the performance of catalysis and structures such as electrodes, allowing improvement in performance of such technologies such as fuel cells and batteries.

Application of Nanotech

Health and Medicine

1. Medical science will be able to create devices small enough to enter the body's bloodstream to repair damage and treat diseases at the cellular level.

2. Nanotechnology can help to reproduce or repaid damaged tissue. This so-called tissue engineering might replace today's conventional treatments, e. g. Transplantation of organs or artificial implants.
3. To get rid of wound infections there is an antimicrobial dressing covered with nanocrystalline silver. The nanocrystalline coating of silver rapidly kills a broad spectrum of bacteria in as little as 30 minutes.

Wastewater Treatment

1. Nanotechnology has strong influence on wastewater treatment and is currently utilized in many parts of the world. Magnetic nanoparticles offer an effective and reliable method to remove heavy metal contaminants from wastewater by making use of magnetic separation techniques. Using nanoscale particles increases the efficiency to absorb the contaminants and is comparatively inexpensive compared to traditional precipitation and filtration methods.

Energy and Environmental Crisis

1. A reduction of energy consumption can be reached by better insulation systems, by the use of more efficient lighting of combustion systems, and by use of lighter and stronger materials in the transportation sector. Currently used light bulbs only convert approximately 5% of the electrical energy into light. Nanotechnological approaches like light-emitting diodes (LEDs) or Quantum Coged Atoms (QCAs) could lead to a strong reduction of energy consumption for illumination.

Computing and Data Storage

1. In the coming decades we'll have to build molecular computers to keep the computer hardware revolution on track. Nanotechnology will let us build computers that are incredibly powerful. The critical length scale of integrated circuits is already at the nanoscale (50 mm and below) regarding the gate length of transistors in CPUs of DRAM devices.

Information and Communication

1. The production of displays with low energy consumption could be accomplished using carbon nanotubes. Carbon nanotubes can be electrically conductive and due to their small diameter to several nanometers, they can be used as field emitters with extremely high efficiency for field emission displays (FED) .
2. Nanocrystals are ideal light harvesters in photovoltaic devices. They absorb sunlight more strongly than dye molecules or bulk semiconductor materials; therefore, high optical densities can be achieved while maintaining the requirement of thin films.

Food Production and Distribution

1. Nanotechnology also has applications in the food sector. Many vitamins and their precursors, such as carotenoids, are insoluble in water. However, when skilfully

produced and formulated as nanoparticles, these substances can easily be mixed with cold water, and their bioavailability in the human body also increases.

2. Nanotechnology can be applied in the production, processing, safety and packaging of food. A nanocomposite coating process could improve food packaging by placing anti-microbial agents directly on the surface of the coated film.

Space Mission

1. By application of nanotechnology a new era of robotic exploration of the solar system is in the coming among other technologies through the development of small economical spacecrafts with high autonomy and improved capabilities. Furthermore, nanotechnological diagnostics and therapy procedures will improve life support systems and an autonomous medical supply of astronauts, which will pave the way for long-term and more complex manned space missions.
2. Momentum toward this nanotechnology future is building as researchers, private companies and government agencies all over the world rush to be the leaders in this very exciting race.
3. The future is small, but it promises to benefit us all.

Nanotechnology in Medicine

1. Bioavailability refers to the presence of drug molecules where they are needed in the body and where they will do the most good. Targeted drug delivery results in maximizing bioavailability to concerous tissues in the body and prolonged over a period of time.

Nanodevices

Nanodevices that have already been proved are:

1. Cantilevers: These are tiny levers anchored at one end. They can be designed such that they bind to molecules that represent a deviation from normally, such as altered DNA sequences or proteins present in infected cell. When these molecules bind to the cantilevers, surface tension changes causing the cantilever to bend. By monitoring this bending, scientists can identify the type of molecule that has caused the bending. This may help in identifying infecting cells even if they are present in very low concentrations.
2. Nanopores: These are tiny holes that allow the DNA molecule to pass through one strand at a time. By monitoring the shape and electrical properties or each base or letter on the strand of DNA, scientists can decipher the encoded information on DNA. This is possible because shape and electrical properties are unique for each of the four bases that make up the genetic code. Errors in the genetic code associated with a particular disease can also be located.
3. Nanotubes: Carbon rods, about half the diameter of a molecule of DNA, can detect the presence of altered genes and also pinpoint the exact location of those changes

(mutations) .

4. Quantum Dots: Nanoparticles of cadmium selenide (quantum dots) glow when exposed to ultraviolet light. The wavelength or the colour of the light depends on the size of the dot. When injected, they seep into cancer tomours. The surgeon can see the glowing tumour, and use it as a guide for more precise cutting of tomours. Quantum dots demonstrate the nanoscale property that colour is size-dependent. By combining different sized quantum dots within a single bead, scientists can create probes that release distinct colours and intensities of light. When the crystals are hit by UV light, each latex bead emits light that serves as a sort of spectral bar code, identifying a particular region of DNA, which is associated with a particular type of cancer. We know that most cancers arise from multiple mutations within DNA. Thus several quantum dots can be designed to show several cancer-associated regions of DNA simultaneously. This can potentially eliminate the need for surgical biopsy (removal of tissue for histopathological examination under microscope) .
5. Nanoshells: These are miniscule beads coated with gold that absorb specific wavelengths of light. These shells then get heated up and kill the surrounding cell. By engineering the nanoshells to selectively link with the antibodies associated with a diseased cell, we can ensure that the nanoshells seep only into the tumour and destroy if, leaving the neighbouring normal cell intact. This has already been done using near-infrared light on animal cancer cell line cultures.
6. Dendrimer: This molecule has over a hundred hooks on it that provide a large surface area and hence allow it to teach to cells in the body for a variety of purposes like identification, diagnosis or therapy. For example, scientists have attached folic-acid to a few of the hooks (folic-acid being a vitamin is received by cells in the body) . Cancer cells have more vitamin receptors than normal cells, so these vitamin-laden dendrimers were absorbed by the cancer cell. To the rest of the hooks on the dendrimer, anti-cancer drugs were placed and these were absorbed with the dendrimer into the cancer cell, thereby delivering the cancer drug to the cancer cell and nowhere else.
7. BioMEMS (Biological Micro-Electro-Mechanical Systems) : These are tiny working machines that usually consists of several microsensors coupled with a microprocessor, the processing unit of the device. BioMEMS can be used in the detection of DNA, viruses, proteins and other biologically derived molecules.

Nanomedicine has already crossed the threshold of laboratory animals and entered the portals of clinical practice. The coming decade will establish the existing nanotechnology devices and discover new ones, which may take us from blunderbuss treatment to target-specific and efficient therapy of incurable cancers and life-threatening multi drug-resistant bacterial infections.

Courtesy: Science Reporter