Nanotechnology as an Integral Part of Electronics: A Review

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ABSTRACT

Nanotechnology is highly interdisciplinary and includes the full range of physics, chemistry, biology, materials science and engineering. The term nanotechnology is widely used as an abbreviation for both science and technology in this new field. In a narrow sense, nanoscience involves a basic understanding of atoms and their physical, chemical, and biological properties. Nanotechnology in the narrow sense employs controlled manipulation of these properties to create materials and functional systems with unique capabilities.

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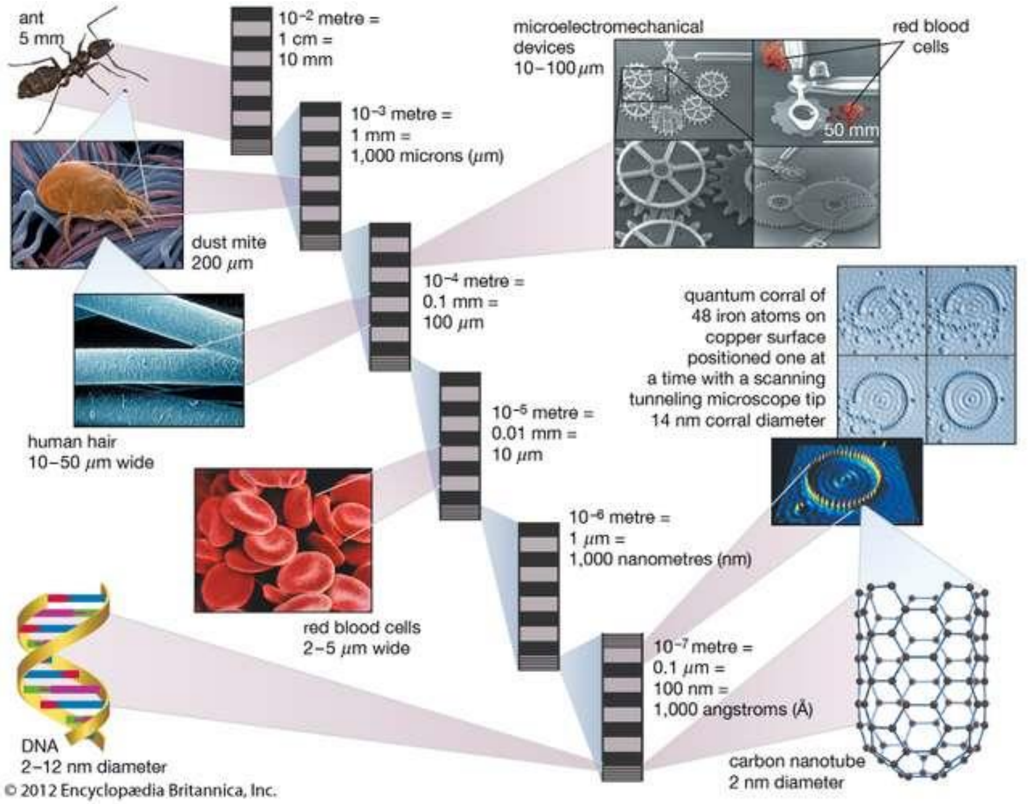
INTRODUCTION

Manufacture and manufacturer of devices and materials on the scale of small groups of atoms or atoms. "Nanoscale" is usually measured at nanometers or one billionth of a meter (nanoscale, the Greek word for "dwarf", which is the source of the prefix), and materials constructed at this scale are for quanta. Mechanical effects that often exhibit unique physical and chemical properties. Although such small usable devices may be decades away (see Micro Electromechanical Systems), the technology of working at the nanoscale has become an integral part of electronics, and nanoengineering materials have become consumer products. It is starting to appear. Zinc oxide nanocrystals have been used to create invisible sunscreens that block UV light. Silver nanocrystals are embedded in bandages to kill bacteria and prevent infection.

OVERVIEW OF NANOTECHNOLOGY

In contrast to recent engineering efforts, nature has developed "nanotechnology" for billions of years, using enzymes and catalysts to organize different types of atoms and molecules into complex fine structures. Made life possible. These natural products are constructed very efficiently, using the power to harvest solar energy, the power to convert minerals and water into living cells, the large array of nerve cells to store large amounts of data and it has excellent functions such as processing power and perfect replication power.



Nanotechnology……

There are two main reasons for qualitative differences in the behavior of materials at the nanoscale (previously defined as less than 100 nanometers). First, quantum mechanical effects work in very small dimensions, leading to new physics and chemistry. Second, a distinct nanoscale feature is the very large surface-to-volume ratio of these structures.

This means that there are no atoms very far from the surface or interface, and the behavior of atoms at these high energy sites has a significant impact on the properties of the material. For example, the reactivity of metal-catalyzed particles generally increases significantly with smaller sizes. Macroscopic gold is chemically inert, but at the nanoscale, gold is highly reactive, catalytic, and melts at low temperatures (Donepudi, 2017b). Therefore, in nanoscale dimensions, the properties of the material depend on size, composition and structure and vary.

NANOTECHNOLOGY RESEARCH

Nanomaterials

Material properties, electrical, optical, magnetic, mechanical, or chemical, depend on the exact dimensions. This paves the way for the development of new and improved materials through the manipulation of nanostructures.

Introducing of new engineering materials, such as polymer clay Nano composites, that are not only stronger and stronger than traditional reinforced plastics, but also lightweight and easy to recycle.

Such improvements in structural materials are especially important for the transportation industry, where weight reduction directly leads to improved fuel economy. Other improvements can improve safety and reduce the environmental impact of manufacturing and recycling. Further advances, such as truly smart materials that can indicate an imminent failure or even self-repair defects, may be possible with future composites.

Sensors are at the heart of almost all modern control systems. For example, automobiles use multiple sensors for a variety of tasks such as engine management, emissions control, security, safety, comfort, vehicle monitoring, and diagnostics. Due to their small size, nanosensors exhibit unprecedented speed and sensitivity, sometimes even detecting single molecules. For example, nanowires made of carbon nanotubes, silicon, or other semiconductor materials show exceptional sensitivity to chemical species and biological agents. The current flowing through the nanowires can be changed by attaching molecules that locally disturb the electron band structure to the surface (Taher-Uz-Zaman et al., 2014). The nanowire surface coated with sensor molecules that selectively attach specific species allows the presence of those species to be detected using charge-induced changes in current. This same strategy is used in many classes of sensing systems. New types of sensors with ultra-sensitivity and specificity have many uses. For example, if a cancerous tumor is composed of only a few cells, a sensor that can detect them would be a huge step forward.

Nanomaterials are also excellent filters for capturing heavy metals and other pollutants from industrial wastewater. One of the greatest potential impacts of nanotechnology on the lives of the vast majority of people on the planet lies in the area of economical water desalination and purification (Nau, 2009). Nanomaterials are very likely to find important applications in fuel cells, biotransformation of energy, food bioprocessing, waste repair, and pollution control systems.

A recent concern about nanoparticles is whether their small size and new properties can pose significant health or environmental risks. In general, ultrafine particles such as copier toner and carbon in combustion engines and factory soot have a negative effect on humans and animals in the respiratory and cardiovascular systems. Nanomaterials that are currently attracting attention from health authorities include carbon nanotubes, buckyballs, and cadmium selenide quantum dots. Studies on the absorption of titanium oxide nanoparticles (used for sunscreen) through the skin are also planned. No more extensive research has been done on the toxicity, transport, and overall fate of nanoparticles in ecosystems and the environment. Some early animal studies, including the introduction of very high levels of nanoparticles that resulted in the rapid death of many subjects, are highly controversial.

Possibilities in Future

Nanotechnology requires less energy to supply than traditional materials, requires less waste than traditional manufacturing, and promises improved fuel efficiency in land transportation, ships, aircraft, and spacecraft, lighter and more It has the potential to enable the production of strong, programmable materials. Nanocoatings on both opaque and translucent surfaces can provide resistance to corrosion, scratches, and radiation. Nanoscale electronic, magnetic, and mechanical devices and systems with unprecedented levels of data processing, also as chemical, photochemical, and biological sensors for cover, health care, manufacturing, and therefore the environment are often manufactured. A new photoelectric material that enables the production of cost-effective solar energy panels. Molecular-semiconductor hybrid devices that could be the engine of the next revolution in the information age. The potential for improved health, safety, quality of life and environmental protection is enormous.

At the same time, key challenges must be overcome to realize the benefits of nanotechnology. Scientists need to learn how to reliably manipulate and characterize individual atoms and small groups of atoms. Controlling material properties and structure at the nanoscale requires new and improved tools. To understand this area, it is essential to significantly improve computer simulation of atomic and molecular structures. Next, new tools and approaches are needed to assemble atoms and molecules into nanoscale systems, and to further assemble smaller systems into more complex objects. In addition, nanotechnology products need to offer cost savings as well as improved performance. Finally, without integrating nanoscale objects with microscale and macroscale (ie, one millionth of a meter to millimeter scale) systems, it is very difficult to take advantage of the many unique properties found in nanoscale. It is difficult.

Pioneers

Many important technical milestones have been achieved by working as pioneers. Invented by Alfred Cho and John Arthur at Bell Labs in 1968 and developed in the 1970s, molecular beam epitaxy enabled controlled deposition of single atomic layers. This tool provided Nano structuring in one dimension as atomic layers grew one after another. Since then, it has become important in the field of compound semiconductor device manufacturing. For example, sandwiching a 1-nanometer-thick layer of non-magnetic sensor material between the magnetic layers of a computer disk drive will significantly increase storage capacity, and using nanostructures as well, for use in compact disc players. We have obtained an energy-efficient semiconductor laser for this purpose.

PROPERTIES OF NANOSCALE

Electronic and photonic behavior

Quantum mechanical properties for confining electrons in one dimension have long been used in solid-state electronics. Because semiconductor devices grow in thin layers of different compositions, electrons (or "holes" if electron charges are missing) can be confined to specific regions of the structure (called quantum wells). A thin layer with a larger energy bandgap can act as a barrier that limits the flow of charge to specific conditions that can "tunnel" these barriers, which are the basis of resonant tunneling diodes. A superlattice may be a periodic structure of repeating wells that sets up a replacement set of selection rules that affect the conditions under which charges flow through the structure. Superlattices have been used in cascade lasers to achieve far-infrared wavelengths. Modern telecommunications is based on semiconductor lasers that take advantage of the unique properties of quantum wells to achieve specific wavelengths and high efficiencies.

As the size and periodicity of the transient structure approaches the wavelength of visible light (400-800 nanometers), photon propagation changes dramatically. When photons propagate through a cyclically changing permittivity (for example, a semiconductor post surrounded by air), quantum mechanical rules define and limit the propagation of photons consistent with their energy (wavelength). This new behavior is similar to the quantum mechanical rules that define the motion of electrons through a crystal, giving the semiconductor a bandgap. . In one dimension, compound semiconductor superlattices are often epitaxially grown in alternating layers with different permittivity, thus providing a highly reflective mirror for specific wavelengths determined by the repetition distance of the layers within the superlattice. To do. These structures are used to provide "built-in" mirrors for vertical resonator type surface emitting lasers used in communications applications. In 2D and 3D, a periodic structure called a photonic crystal gives you more control over photon propagation.

Photonic crystals have been investigated in a variety of materials and cycles, including 2D hexagonal arrays of posts made of compound semiconductors and log arrays with stacked 3D silicon bars. The dimensions of these structures depend on the wavelength of the light being propagated and are typically in the range of hundreds of nanometers at visible and near-infrared wavelengths (Kuykendall, 1999). Photonic crystal properties based on nanostructured materials have the potential to confine, steer, and separate light at each wavelength on an unprecedented scale, and lasers that require very low currents to initiate laser oscillation (It offers the possibility to create new devices (called lasers with almost no threshold). These structures are being extensively investigated as tools for nanostructured materials are making steady progress. Researchers are particularly interested in infrared wavelengths. Infrared wavelengths aren't as rigorous because the shorter visible wavelengths, and optical communications and chemical sensing provide motivation for potential new applications.

Magnetic, mechanical, and chemical behavior

Nanoscale materials even have size-dependent magnetic behavior, mechanical properties, and chemical reactivity. At very small sizes (several nanometers), magnetic nanoclusters have one magnetic domain, and therefore the tightly bound magnetic spins of every atom combine to supply particles with one "giant" spin. I will. For example, the giant spins of ferromagnetic iron particles spin freely at room temperature with a diameter of less than about 16 nanometers. This is an effect called superparamagnetism. The mechanical properties of nanostructured materials can reach extraordinary strength. As a specific example, introducing a 2 nanometer aluminum oxide precipitate into a thin film of pure nickel increases the yield strength from 0.15 gigapascals to 5 gigapascals. This is more than twice that of hard steel. Another example of extraordinary mechanical properties on the nanoscale is carbon nanotubes, which show great strength and stiffness along their vertical axis.

Surface dominance is the main reason for changes in material behavior at the nanoscale. Since up to half of all atoms in nanoparticles are surface atoms, properties such as electrical transport are no longer determined by the solid bulk phenomenon. Similarly, nanostructured atoms have a higher average energy than larger structured atoms due to the large proportion of surface atoms (Donepudi, 2016). For example, catalyst materials reduce the size of the catalyst on a nanoscale, resulting in higher chemical activity per atom on the exposed surface. Defects and impurities can be attracted to surfaces and interfaces, and the interaction between particles at these small dimensions can depend on the structure and nature of the chemical bonds on the surface. Molecular monolayers can be used to modify or control surface properties and mediate interactions between nanoparticles.

The interaction of a surface with its molecular structure is the basis of all biology. The intersection of nanotechnology and biotechnology offers the potential to realize new functions and properties on the surface of nanostructures. during this surface-interface-dominated regime, biology does the exquisite task of selectively controlling function through a mixture of structure and chemical forces. Transcription of data stored in genes and selectivity of biochemical reactions supported chemical recognition of complex molecules are samples of interfaces playing a crucial role in establishing nanoscale behavior. At these dimensions, atomic power and chemical bonds dominate, but macroscopic effects like convection, turbulence, and momentum (inertial force) have little effect.

BIOMEDICINE AND HEALTH CARE

Drug Delivery

Nanotechnology promises to impact healthcare in a variety of ways. First, advances in nanoscale particle design and manufacturing offer new options for drug delivery and drug therapy. Delivery is difficult because more than half of the new drugs developed each year are not water-soluble. However, in the form of nano-sized particles, these drugs are easily transported to their destination and can be delivered in conventional form of pills.

More importantly, nanotechnology has the potential to deliver drugs to the exact correct location in the body and to release drug doses on a timely schedule for optimal treatment. A common approach is to attach the drug to a nano-sized carrier that releases the drug in the body over a long period of time, or when specially triggered to do so. In addition, the surfaces of these nanoscale carriers can be treated to seek out and localize disease sites, for example, by attaching to cancerous tumors. One type of molecule of particular interest in these applications is the organic dendrimer. Dendrimers are a special class of macromolecular molecules that enter and exit the hollow central region. These spherical "fuzzballs" are about the same size as a typical protein, but cannot be expanded like a protein. Interest in dendrimers stems from the ability to adjust the size and chemistry of cavities to hold a variety of therapeutic agents. Researchers want to design a variety of dendrimers that can swell and release drugs when exposed to specially recognized molecules that indicate the target of the disease. This same general approach to drug delivery directed to nanoparticles has been investigated for other types of nanoparticles as well.

Another approach involves a gold-coated nanoshell that can be sized to absorb light energy of different wavelengths. In particular, infrared rays pass through a few centimeters of body tissue and delicately and accurately heat such capsules to release therapeutic substances. In addition, antibodies can be attached to the outer gold surface of the shell to specifically bind them to specific tumor cells, thereby reducing damage to surrounding healthy cells.

Assistive devices and tissue engineering

Other biomedical applications of nanotechnology include assistive devices for people who have lost or lack certain natural abilities. For example, researchers want to design retinal implants for people with visual impairments. The concept is to implant a chip with a photodetector array to send a signal from the retina to the brain via the optic nerve. Meaningful spatial information is very useful for the visually impaired, even at a rudimentary level. Such research presents a tremendous challenge in designing hybrid systems that work in the interface between inorganic devices and biological systems.

Closely related studies include implanting nanoscale neural probes in brain tissue to activate and control motor function. This requires effective and stable "wiring" of many electrodes to neurons. It's exciting because control of people with movement disorders can be restored. Studies that employ nerve stimulation of the injured spinal cord with electrical signals have shown some motor recovery. Researchers are also looking for ways to help regenerate and heal bone, skin, and cartilage. For example, the development of synthetic biocompatible or biodegradable structures with nano-sized voids that serve as templates for regenerating specific tissues while supplying chemicals to support the repair process. At a more sophisticated level, researchers hope that one day they will build nanoscale or microscale machines that can repair, support, or replace more complex organs.

INFORMATION TECHNOLOGY

Semiconductor experts say that the continuous contraction of "traditional" electronic devices is inevitably based on quantum effects such as "tunneling," in which electrons jump out of a given circuit path and cause atomic-scale interference between devices. I agree to reach the limit. At that point, a radical new approach to data storage and information processing will be needed for further progress. For example, a radically new system based on quantum computing and biomolecular computing is envisioned.

Molecular electronics

The use of molecules in electronic devices was proposed by Mark Ratner of Northwestern University and Avi Aviram of IBM as early because the 1970s,but suitable nanotechnology tools were not available until the turn of the 21st century. Wiring molecules about 0.5 nanometers wide and several nanometers long remains a major challenge, and the understanding of electrical transport through a single molecule is still in its infancy. Many groups were able to demonstrate molecular switches. For example, it could be used in computer memory or logic arrays. Current research areas include mechanisms that guide the choice of molecules, architectures for assembling molecules into nanoscale gates, and 3-terminal molecules for transistor-like behavior. More radical approaches include DNA computing, where single-stranded DNA on a silicon chip encodes all possible variable values and complementary strand interactions are used in a parallel processing approach to find solutions. I will. The field related to molecular electronics is the field of organic thin film transistors and illuminants, promising new applications such as wallpaper and video displays that can be deployed like flexible electronic newspapers.

Nanotubes and nanowires

Carbon nanotubes have amazing electronic, mechanical, and chemical properties. Depending on their particular diameter and the bond arrangement of their carbon atoms, nanotubes behave as either metals or semiconductors. The electrical conductivity within the perfect nanotube is ballistic (scattering is negligible) and there is little heat dissipation. As a result, wires made from nanotubes, or nanowires, can carry much more current than regular metal wires of comparable size. Nanotubes with a diameter of 1.4 nanometers are about one-hundredth the gate width of silicon semiconductor devices. In addition to conducting nanowires, transistors, diodes, and simple logic circuits have been demonstrated by combining metal and semiconductor carbon nanotubes. Similarly, silicon nanowires are wont to build experimental devices like field effect transistors, bipolar transistors, inverters, light emitting diodes, sensors, and even simple memories. As with molecular electronics, the main challenge for nanowire circuits is to connect these devices and integrate them into a viable, high-density architecture. Ideally, the structure grows and is assembled in place. The crossbar architecture, which combines the functionality of wires and devices, is of particular interest.

Carbon Nanotubes

Size	0.6 to 1.8 nanometer in diameter	Electron beam lithography can create lines 50 nm wide, a few nm thick
Density	1.33 to 1.40 grams per cubic centimeter	Aluminium has a density of 2.7g/cm3
Tensile Strength	45 billion pascals	High-strength steel alloys break at about 2 billion Pa
Resilience	Can be bent at large angles and restraightened without damage	Metals and carbon fibers fracture at grain boundaries
Current Carrying Capacity	Estimated at 1 billion amps per square centimeter	Copper wires burn out at about 1 million A/cm2
Field Emission	Can activate phosphors at 1 to 3 volts if electrodes are spaced 1 micron apart	Molybdenum tips require fields of 50 to 100 V/µm and have very limited lifetimes
Heat Transmission	Predicted to be as high as 6,000 watts per meter per kelvin at room temperature	Nearly pure diamond transmits 3,320 W/m.K
Temperature Stability	Stable up to 2,800 degrees Celsius in vacuum, 750 degrees C in air	Metalwires in microchips melt at 600 to 1,000 degrees C

Single-electron transistors

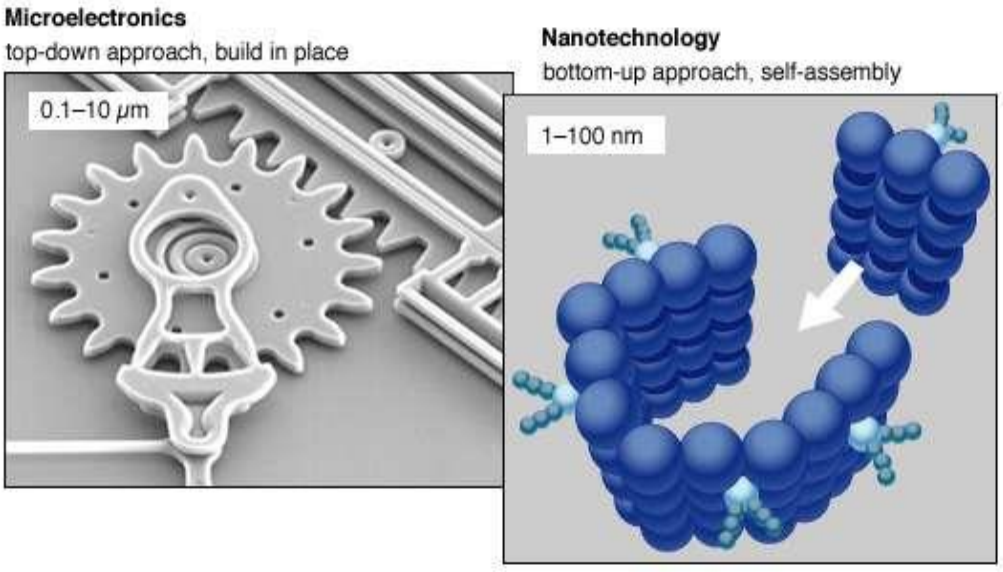
In nanoscale dimensions, the energy required to add an electron to a "small island" (isolated physical region), for example through a tunnel barrier, is important. This change in energy provides the basis for devising a single electron transistor. At low temperatures, where thermal fluctuations are small, nanostructures of various single-electron devices can be easily realized, and extensive research has been conducted on structures with restricted electron flow. However, for room temperature applications, the size should be significantly reduced to the 1 nanometer range for stable operation. For large applications with millions of devices, as seen in today's integrated circuits, the need for very uniform sized structures to maintain uniform device characteristics is a major challenge. I am. Also, for this and many new nanodevices being sought, the lack of gain is a significant drawback that limits implementation in large electronic circuits.

Spintronics

Spintronics are electronic devices that perform logical operations based not only on the carrier charge, but also on its spin. For example, information can be transferred or stored via electron spin-up or spin-down states. This is a new field of study, and issues include injection of spin-polarized carriers, their transport, and their detection. The role of the nanoscale structure and electronic properties of the ferromagnetic-semiconductor interface within the spin injection process, the expansion of latest ferromagnetic semiconductors with nanoscale control, and the possibility of using nanostructured features to manipulate spins are all interesting Thing.

NANOFABRICATION

Two very different paths are pursued. One is a top-down strategy to miniaturize current technology, and the other is a bottom-up strategy to build more complex molecular devices atom by atom. The top-down approach is suitable for generating long-range ordered structures and creating macroscopic connections, while the bottom-up approach is ideal for assembling in nanoscale dimensions and establishing short-range order. The integration of top-down and bottom-up technologies is expected to ultimately provide the best combination of tools for nanofabrication. Nanotechnology requires new tools for manufacturing and measurement.



Top-down approach

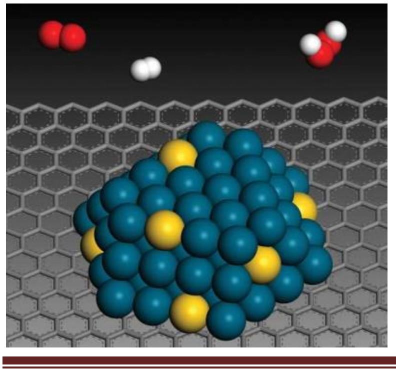
The most common top-down approach to manufacturing includes lithography patterning techniques using short wavelength light sources. The main advantage of the top-down approach developed in the manufacture of integrated circuits is that the parts are patterned and in place, eliminating the need for assembly steps. Short-wavelength optical lithography technology is just below 100 nanometers (the traditional definition of nanoscale thresholds).

Has reached. Short-wavelength light sources such as extreme ultraviolet and X-rays have been developed, enabling lithographic printing technology to reach dimensions of 10 to 100 nanometers. Scanning beam technologies such as electron beam lithography offer patterns up to approximately 20 nanometers. Here, the pattern is written by sweeping a finely focused electron beam over the entire surface. Focused ion beams have a slightly lower resolution than electron beam lithography, but are also used for direct wafer processing and patterning. Smaller features can be obtained by depositing or removing thin layers using a scanning probe.

Mechanical printing techniques such as nanoscale imprinting, stamping, and molding have been extended to surprisingly small dimensions of approximately 20-40 nanometers. In one variation, the surface of the stamp is coated with a very thin layer of material ("ink") that can be deposited directly on the surface ("ink") to reproduce the pattern of the stamp. For example, controlled patterning of molecular monolayers on a surface can be achieved by stamping an ink of thiol-functionalized organic molecules directly onto a gold-coated surface (a molecule containing a sulfur-terminated group called a thiol). Strongly binds to gold). Another approach is to use the stamp mechanically to push the pattern into a thin layer of material. This surface layer is typically a polymeric material that has been softened for the molding process by being heated during the stamping procedure. Plasma etching can then be used to remove a thin layer of masking material under the stamped area. Therefore, all residual polymers are removed, leaving a nanoscale lithography pattern on the surface. Yet another variation is to create a relief pattern from a photoresist on a silicon wafer by optical or electron beam lithography, then pour a liquid precursor (eg, polydimethylsiloxane in the form of silicone) onto the pattern, and then it is to cure it. The result is a rubbery solid that can be peeled off and used as a stamp. These stamps can be printed with ink as described above or pressed against the surface to capillaries the liquid polymer into the raised areas of the mask. It can be poured into and cured in place. The difference between this latter approaches is that the stamps are flexible and can be used to print nanoscale features on curved surfaces.

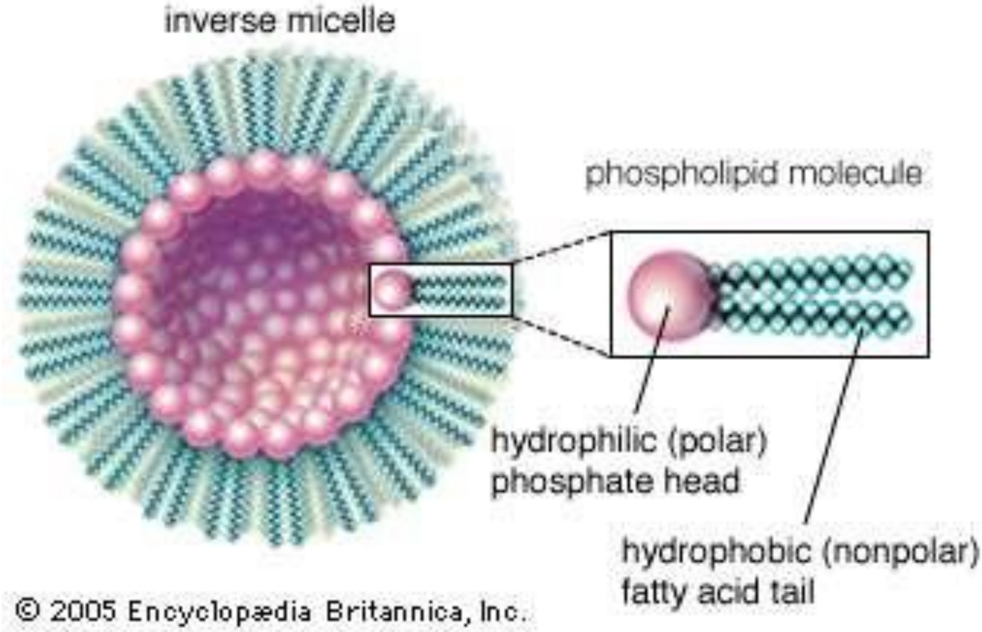
Bottom-up approach

Bottom-up or self-organizing approaches to nanofabrication use chemical or physical forces acting on the nanoscale to assemble basic units into larger structures. As components become smaller in nanofabrication, the bottom-up approach complements top-down technology more and more importantly (Donepudi, 2015). The inspiration for the bottom-up approach comes from the biological system in which nature uses chemical forces to create essentially all the structures needed for life. Researchers want to recreate the natural ability to generate small clusters of certain atoms. This makes it self-organizing and more complex.



Nanoparticles: hydrogen peroxide

An example of self-organization that achieves a limited degree of control over both formation and organization is the growth of quantum dots. Indium gallium arsenide (InGaAs) dots can be formed by growing a thin layer of InGaAs on GaAs, and the repulsive force caused by the compressive strain of the InGaAs layer forms isolated quantum dots. After growing a pair of layers, a fairly uniform spacing of dots can be achieved. Another example of self-assembly of complex structures is the formation of carbon nanotubes under appropriate chemical and temperature conditions.



Structure of an inverted or reverse micelle

DNA-assisted assemblies may provide a way to integrate hybrid heterogeneous parts into a single device. Biology does this very well, combining self-organization and self-organization in a fluid environment where weak electrochemical forces play an important role. By using DNA-like recognition, molecules on the surface may be able to direct attachments between objects in a fluid. In this approach, polymers made of complementary DNA strands are used as intelligent "adhesive tapes" that adhere between the polymers only in the presence of proper pairing. The DNA-assisted approach has several advantages. DNA molecules can be sequenced and replicated in large numbers, DNA sequences act as codes that can be used to recognize complementary DNA strands, hybridized DNA strands form strong bonds to those complementary sequences, and DNA strands. Can be attached to various devices as a label (Donepudi, 2017a). These properties are being investigated for ways to self-assemble molecules into nanoscale units. For example, DNA sequences that attach only to specific crystal planes of compound semiconductors have been created, providing the basis for self-organization. Having the correct complementary sequence at the other end of a DNA molecule allows you to create specific faces of small semiconductor building blocks that attach or repel each other. For example, thiol groups at the ends of molecules attach them to the surface of gold, while carboxyl groups can be used to attach them to the surface of silica. Directed assemblies are an increasingly important variation of self-organization, where in a quasi-equilibrium environment, parts move mechanically, electrically, or magnetically and are placed exactly where they are intended.

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