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Department of Electronics and Communication Engineering

THE INSTITUTION OF ELECTRONICS AND TELECOMMUNICATION ENGINEERS
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K.J.S.I.E.I.T.

MICROELECTRONICS TO NANOELECTRONICS

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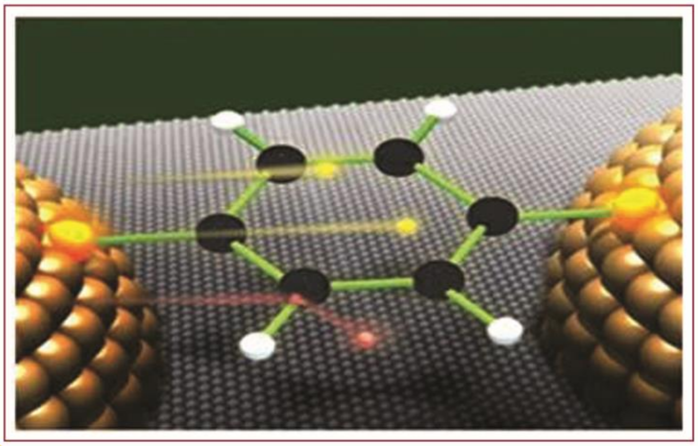

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Preface

Microelectronics relates to the study and manufacture (or microfabrication) of very small electronic designs and components. These devices are typically made from semiconductor materials. Many components of normal electronic design are available in a microelectronic equivalent. These include transistors, capacitors, inductors, resistors, diodes and insulators and conductors can all be found in microelectronic devices. Unique wiring techniques such as wire bonding are also often used in microelectronics because of the unusually small size of the components, leads and pads. This technique requires specialized equipment and is expensive.

Nanoelectronics refer to the use of nanotechnology in electronic components. The term covers a diverse set of devices and materials, with the common characteristic that they are so small that inter-atomic interactions and quantum mechanical properties need to be studied extensively. Some of these candidates include: hybrid molecular/semiconductor electronics, one-dimensional nano tubes/nano wires (e.g. Silicon nano wires or Carbon nano tubes) or advanced molecular electronics. Recent silicon CMOS technology generations, such as the 22 nanometer node, are already within this regime.

VLSI Design

S.Praveen – II Year

Very-large-scale integration (VLSI) is the process of creating an **integrated circuit** (IC) by combining thousands of **transistors** into a single chip. VLSI began in the 1970s when complex **semiconductor** and **communication** technologies were being developed. The **microprocessor** is a VLSI device.

An **electronic circuit** might consist of a **CPU, ROM, RAM** and other **glue logic**. VLSI lets IC designers add all of these into one chip. The electronics industry has achieved a phenomenal growth over the last few decades, mainly due to the rapid advances in large scale integration technologies and system design applications. With the advent of very large scale integration (VLSI) designs, the number of applications of integrated circuits (ICs) in high-performance computing, controls, telecommunications, image and video processing, and consumer electronics has been rising at a very fast pace. The current cutting-edge technologies such as high resolution and low bit-rate video and cellular communications provide the end-users a marvelous amount of applications, processing power and portability. This trend is expected to grow rapidly, with very important implications on VLSI design and systems design.

Integrated Circuit

Integrated Circuit is the circuit in which all the Passive and Active components are fabricated onto a single chip. Initially the Integrated Chip could accommodate only a few components. As the days passed, the devices became more complex and required more number of circuits which made the devices look bulky. Instead of accommodating more circuits in the system, an **Integration technology** was developed to increase the number of components that are to be placed on a single chip. This Technology not only helped to reduce the size of the devices but also improved their speed. Depending upon the number of components (Transistors) to be integrated, they were categorized as SSI, MSI, LSI, VLSI, ULSI & GSI.

Small Scale Integration (SSI):

In this Technology, 1-100 Transistors were fabricated on a single chip.

Eg: Gates , Flipflops.

Medium Scale Integration (MSI):

Using this Technology, 100-1000 number of Transistors could be integrated on a single chip.

Eg: 4 bit Microprocessors.

Large Scale Integration

In this Technology, 1000-10000 Transistors could be integrated on a single chip. eg 8 bit Microprocessors, RAM, ROM

Very Large Scale Integration(VLSI):

In this Technology, 10000-1 Million Transistors could be accommodated.

Eg: 16-32 bit Microprocessors.

Ultra Large Scale Integration (ULSI):

In this Technology, 1 Million-10 Million Transistors could be accommodated.

Eg: Special Purpose Registers.

Giant Scale Integration (GSI):

In this Technology more than 10 Million Transistors could be accommodated.

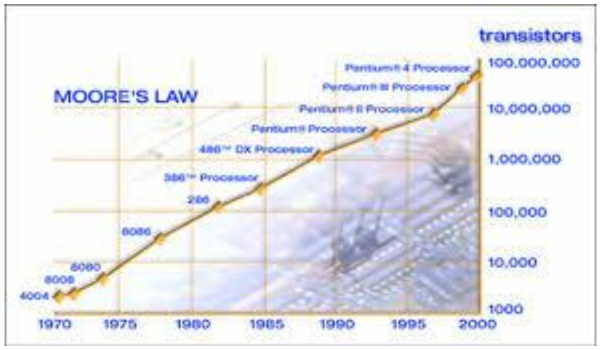
Eg: Embedded Systems.

VLSI and its Uses:

10000-1 Million Transistors can be fabricated on a single chip. In olden days during the vacuum tube era, the size of Electronic Devices were huge, required more power, dissipated more amount of heat and were not so reliable. So there was certainly a need to reduce the size of these devices and their heat dissipation. After the invention of SSD's, the size and the heat produced by devices was undoubtedly reduced drastically, but as the days passed the requirement of additional features in Electronic Devices increased which again made the devices look bulky and complex. This gave birth to the invention of technology which can fabricate more number of components onto a single chip. As the need of additional features in Electronic Devices arised, the growth of VLSI Technology has improved.

Moore'sLaw:

In 1965, Gordon Moore, an industry pioneer predicted that the number of Transistors on a chip doubles every 18 to 24 months. He also predicted that Semiconductor Technology will double its effectiveness every 18 months and many other factors grow exponentially.

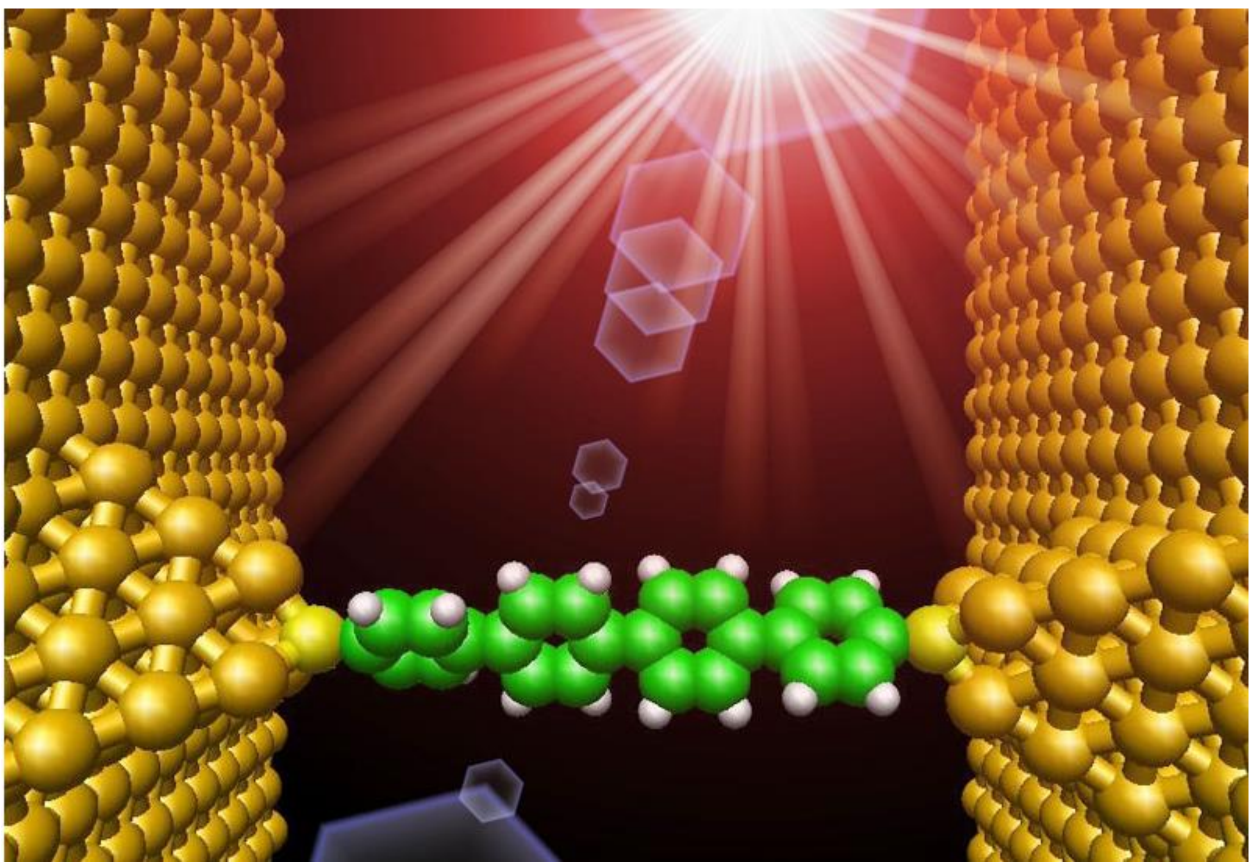


Ultra –Large -Scale Integration (ULSI) Technology and Nano electronic Devices:

The advances in ultra –large –scale -integration (ULSI) technology based on aggressive scaling of CMOS devices provide enormous opportunities for high- performance communication, and computing systems. However, new device structures and designs are essential, as the scaling of devices is approaching its limit. the recent advances in nanotechnology for the growth and fabrication of nanometer -scale structures provide opportunities for novel electronic and photonic devices.

Moletronics- Technology after ULSI

Moletronics is also called as **molecular electronics**. From the name itself, it is clear that moletronics is the combination of molecules and electronics. Molecule is the smallest particle of element or compound and they are made up of **atoms**. Moletronics is a new technology which uses molecules to perform the functions of electronic components such as **diodes**, **transistors**, **logic gates** etc. The molecular building blocks can be used for the fabrication of passive components such as resistors and active components such as transistors. It is a branch of electronics which uses single molecules or collection of single molecules to perform the same function performed by the current active or passive electronic components. Moletronics technology is based on organic compounds which possess electronic properties. Thus moletronics replaces the bulk electronics.



Conventional electronics components are made from bulk electronic materials which is expensive. By using the **moletronics** technology, a single molecule is enough to make a stable structure which reduces the size of conventional bulky electronic components. Moletronics access the structural and electronic properties of silicon atom or molecule. The existing inorganic electronic material may not be capable of producing next generation electronic components with small size, high speed, high efficiency etc. So by using the organic compounds for making electronic components have so many advantages such as size, power, manufacturing cost, efficiency, etc. Moletronics use organic molecules instead of silicon which helps to reduce the size, and produce high speed processors and memory components.

The number of components integrated on single chip for different integration techniques are given below:-

Integration Technology	No: of Components
Small Scale Integration(SSI)	1-2
Medium Scale Integration(MSI)	12
Large Scale Integration(LSI)	30-300
Very Large Scale Integration(VLSI)	300-10000
Ultra Large Scale Integration(ULSI)	>10000

History- Moletronics

In 1940, Robert Muliken and Albert Szent-Gyorgy proposed the concept of charge transfer theory using molecules. In 1974 Mark Ratner and Avi Aviram illustrated a theoretical molecular rectifier in their paper. In 1988 Avi Aviram described about a single molecule **field effect transistor**. In the same year Forrest Carter proposed further concept about single molecule logic gate. C. Joachim and J.K Gimzewsky studied and experimented the conductance of single molecule in IBM. In 1990 Mark Reed and coworker add few hundred molecules. In 2000 Shirakawa,Heeger and MacDiarmid won the nobel prize in physics for the development of highly conductive poly acetelene.

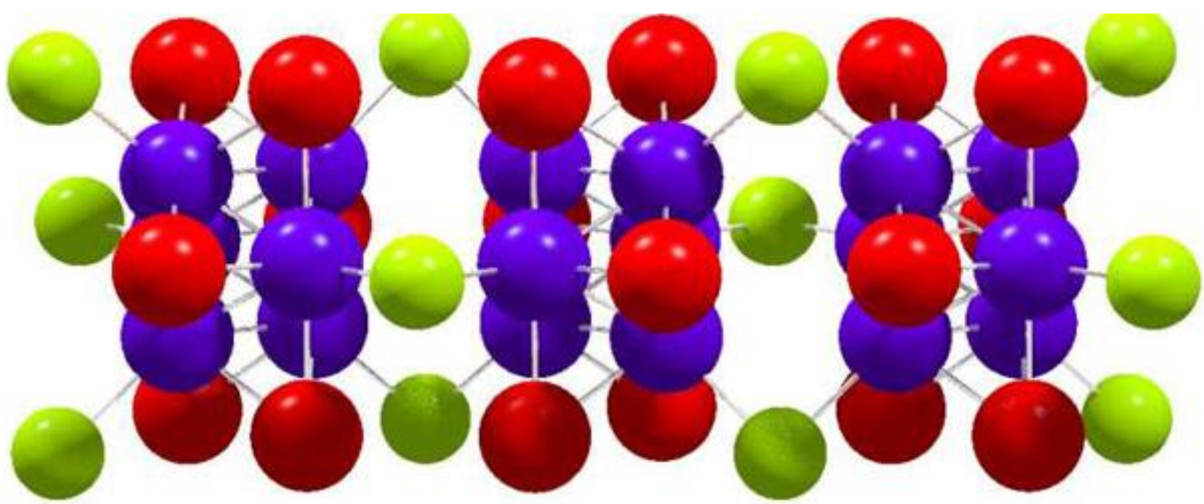
The moletronics technology is based on molecules because of the following reasons:-

- Molecules are small.
- Electrons are confined in molecules.
- Molecules are flexible.
- Molecules are identical.

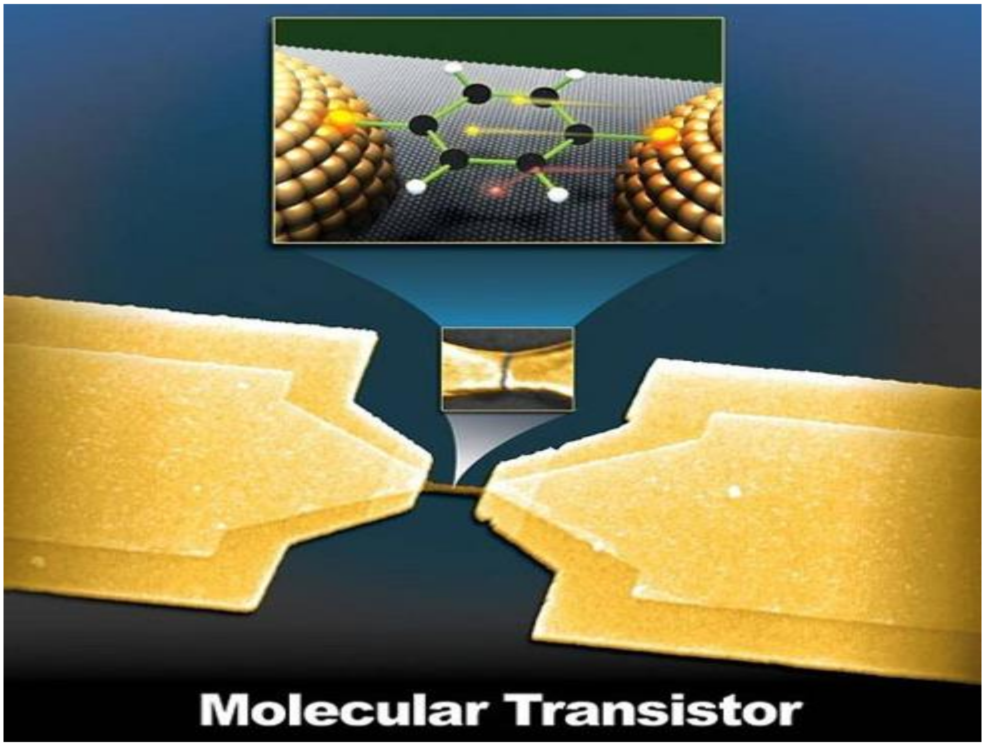
- Molecules can self assemble.

The molecular wire, molecular Diode, molecular transistors are some of the moletronics devices. The molecular devices will replace the conventional semiconductor devices in the future.

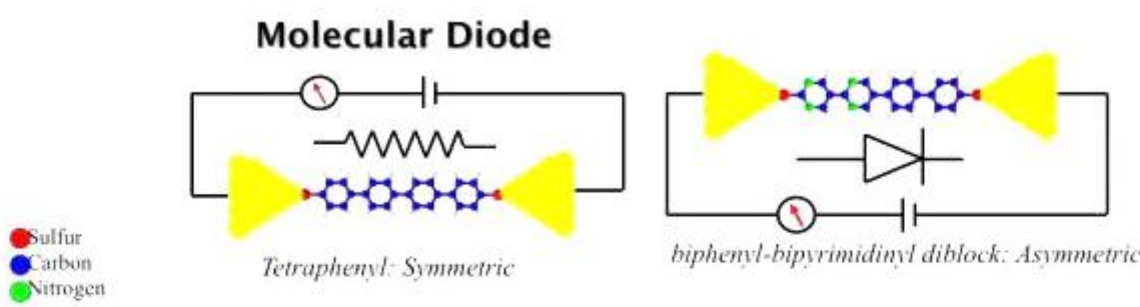
Molecular Wire:- The main purpose of molecular wire is to connect the different parts of molecular electrical circuit. Still the research is going on to produce the molecular wires. The main problem is the difficulty to interconnect the molecular wires with the electrodes.



Molecular Transistors:- Transistors is used to amplify or switch the signals. It is entirely different from the conventional bulk electronics. Molecular transistors are binary. That is either ON or OFF. In conventional transistors, the gate controls the conduction of charge carriers between source and drain. But in molecular transistors the gate controls the single electron to ON or OFF by modifying the energy of molecular orbitals. The size of single molecule is very small .So charging of single electron is sufficient to turn ON or OFF the transistor. The figure below shows the molecular transistor made from a single molecule. The benzene molecule attached with gold contact performs same as silicon transistor. Silicon transistors replaces the vaccum tubes. In future molecular transistor replaces the silicon transistor.



Molecular diodes :- The molecules have electronic donor and electronic acceptor. Electronic donor at one end and electronic acceptor at another end causes the flow of current through molecules.



Advantages of Moletronics

- Size- molecules are in the nanometer range (1-100nm). Moletronics is the only solution to extend Moore’s law beyond the limitations of conventional silicon integrated circuits.

- Power- Current transistors cannot be stacked into three dimensions due to the melting of silicon which decreases the efficiency. By using the moletronics, transistors can be stacked which increases efficiency of the transistors.
- Manufacturing cost- Majority of the moletronics designs using single spin coating or molecular self assembly of organic compounds.
- Low temperature manufacturing- The organic compounds do not need high temperature to assemble. The room temperature is enough for assembling. So it is possible to use a cheap plastic substrate instead of using expensive silicon substrates.
- Stereo Chemistry- Many molecules exist in the form of geometric structures or isomers which exhibits unique electronic properties.
- Synthetic Flexibility- This provides molecules with desired properties such as physical, chemical, optical etc.
- Can integrate large circuits by using moletronics.
- Molecular switch can perform computational functions.

Disadvantages of Moletronics

- Moletronics is integrated along with silicon substrate.
- It is difficult to determine the resistance of single molecule in terms of theoretical and experimental.
- It is difficult to perform direct characterization due to imaging of single molecule is impossible in several experimental devices.
- Moletronics is difficult to interconnect between two components at molecular level.
- Measuring of single molecule is difficult.
- It is difficult to connect a moletronic device into conventional bulk electronic components.
- Some single molecules are measured at absolute zero temperature which is very energy consuming.
- Fabrication must be controlled with specified tolerance.
- Experimental verification is difficult. It is very difficult to find the error because they are integrated at small scale. So it is hard to find the error from the devices.

Applications of Moletronics

- Wide range of applications in the field of physics, chemistry,electronics, medical equipment etc.
- Moletronics uses few molecules to perform the function of switches, logic devices etc in future computational devices.
- Transistors Processors, with speed in terahertz range , highly efficient will be produced in future. The speed of conventional computers depends upon the time taken by an electron to travel between devices. Moletronics based computational devices will replaces the silicon based integrated circuits.
- The transmittance time could be reduced by the use of molecular scale electronic interconnects.
- Moletronics devices such as molecular wires, molecular diodes, molecular transistors, molecular motors, logic devices.
- Sensors**,** Displays etc

SUPERLIGHT AND ACTIVE MATERIALS

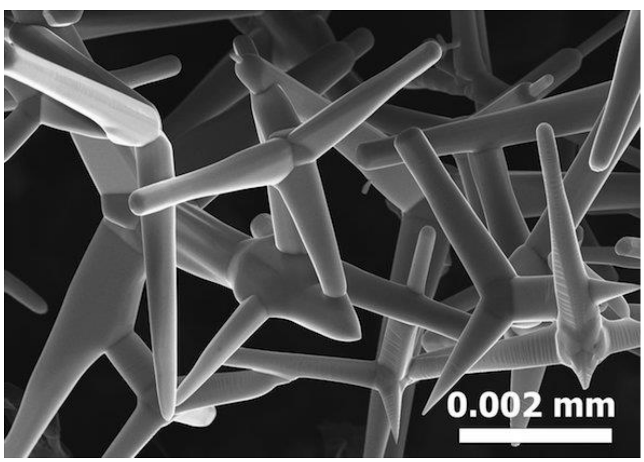
Sowmiya.V.S – III Year

Next-generation materials include super-light materials and active materials that react to changes in their environment and ultimately smart materials that explain how they are doing. Functional materials follow by borrowing ideas from biology to improve performance and add new behaviours. Self-assembling materials are about making large-scale products that are more precise, enabling better properties (strength, tear resistance, conductivity, etc.).

Superomniphobic materials: Inspired by water bugs that float on liquid surfaces, these materials repel both oily and watery fluids.

Auxetic materials: When stretched, auxetic materials become thicker perpendicular to the applied force. This occurs due to their hinge-like structures, which flex when stretched. Auxetics may be useful in applications such as body armor, packing material, knee and elbow pads, robust shock absorbing material, and sponge mops.

Aerogel: A synthetic porous ultra-light material derived from a gel, in which the liquid component of the gel has been replaced with a gas. The result is a solid with extremely low density and thermal conductivity which feels like polystyrene (styrofoam) to the touch. Potential applications include improved thermal insulation, chemical absorber for cleaning up spills, electrochemical super capacitors and shock absorption.



Aerographite, the lightest material in the world

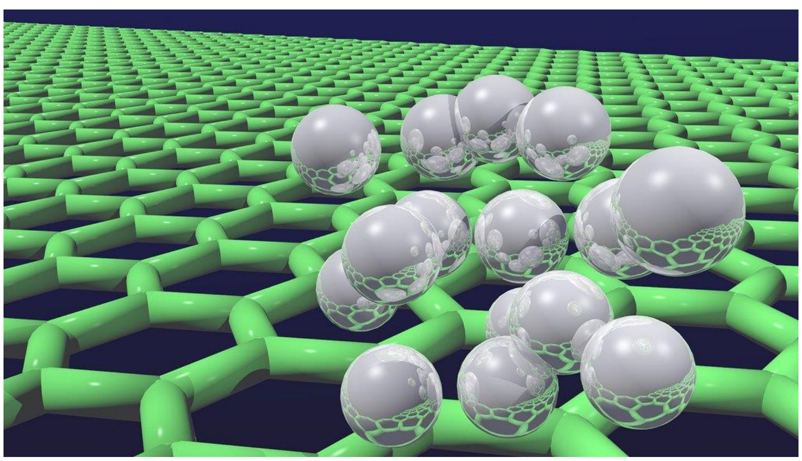
Thermo-bimetals: Thermally activated bimetals would allow for panes of glass capable of becoming shades when exposed to the sun, self-regulating energy consumption throughout the day.

Smart materials: Designed materials that have one or more properties that can be significantly changed in a controlled fashion by external stimuli, such as stress, temperature, moisture, pH, electric or magnetic fields.

Biomaterials: Derived either from nature or synthesized in the laboratory, biomaterials can be used to enhance or replace natural functions in the body. Already used to a small degree, future biomaterials have the potential of improving drug delivery (by permitting extended drug release) or to improve grafting in transplants.

Meta-materials: Materials with a precise shape, geometry and arrangement which can affect light and sound in unconventional manners. Potential applications are diverse, including remote aerospace applications, infrastructure monitoring, smart solar power management, and public safety, improving ultrasonic sensors, and even shielding structures from earthquakes.

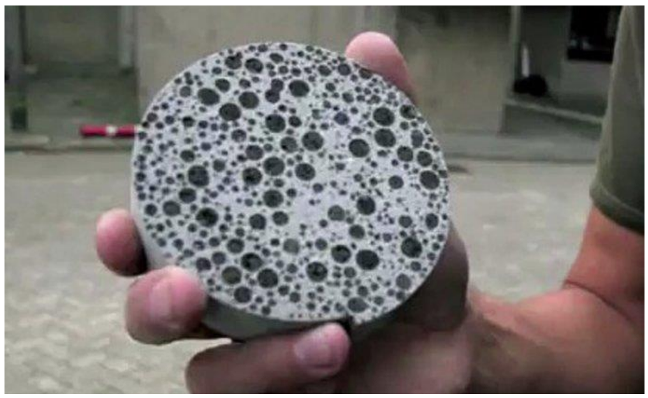
Graphene: A substance composed of pure carbon with atoms arranged in a regular hexagonal pattern similar to graphite, but in a one-atom thick sheet. With a 1-square-meter sheet weighing only 0.77 mg, the material is incredibly light yet strong. Potential applications are incredibly diverse, and include: Components with higher strength to weight ratios, lower cost solar cells, lower cost display screens in mobile devices, storing hydrogen for fuel cell powered cars, medical sensors, faster charging batteries, ultra capacitors, chemical sensors and many others.



Graphene

Nanoelectricmechanical systems (NEMS): Devices integrating electrical and mechanical functionality on the nanoscale. NEMS typically integrate transistor-like nanoelectronics with mechanical actuators, pumps, or motors, and may thereby form physical, biological, and chemical sensors.

Self-healing materials: A class of smart materials that have the structurally incorporated ability to repair damage caused by mechanical usage over time. The inspiration comes from biological systems, which have the ability to heal after being wounded. A material (polymers, ceramics, etc.) that can intrinsically correct damage caused by normal usage could lower production costs of a number of different industrial processes through longer part lifetime, reduction of inefficiency over time caused by degradation, as well as prevent costs incurred by material failure.



Self Healing concrete

Controlled self-assembly: Machines that manipulate individual atoms with organism-like self-replicating abilities. These bottom-up, atomically precise 3D printers would be able to carefully create sequences of DNA, RNA or protein.

Large-scale self-assembling materials: A process in which a disordered system of pre-existing components forms an organized structure or pattern as a consequence of specific, local interactions among the components themselves, without external direction. Such materials could potentially heal themselves and grow/contract on cue.