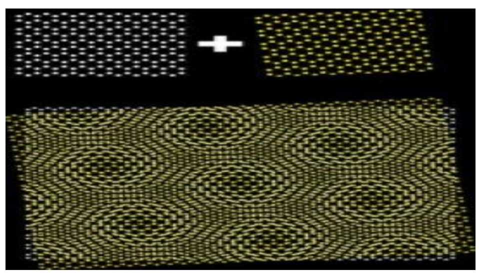
Nanotechnology with Computer Using Graphene

*Dr. Pooja Jain

Abstract

Nanotechnology is the study of extremely small structures, having size of 0.1 to 100 nm (1 nm is approximately 100,000 times smaller than the diameter of a human hair.). It is an interdisciplinary field having its application and development in various fields such as applied science, mechanical, electrical and many others. **Nanotechnology** has greatly contributed to major advances in computing and electronics, leading to faster, smaller, and more portable systems that can manage and store larger and larger amounts of I**nformation**. In this paper; we explore the development and advancement of nanotechnology which provides ample opportunity to develop a smaller, faster and reliable computer. This technology is termed as molecular technology or bottom-up technology. This bottom-up technology could be the answer for the computer industry. Such technology has wide ranging and includes: software engineering, networking, internet security, image processing, virtual reality, human machine interface, artificial intelligence, and intelligent systems.



Microprocessor from Graphene

The discovery of Graphene in 2004 began a flurry of studies to isolate other two-dimensional materials. **Graphene** was found to be a wonder material, possessing a set of unique and remarkable properties. One of these is its ability to conduct heat ten times better than copper, the most commonly used conductor in electronics.

Keywords: Nanotechnology, Applications, Graphene with Computer, Future of Nanotechnology.

Introduction

Nanotechnology is defined as the engineering of functional systems at the molecular scale. Nanotechnology refers to the manipulation of matter on an atomic and molecular scale.

The term nanotechnology is defined as "the design, characterization, production and application of structures, devices and systems by controlled manipulation of size and shape at the nanometre scale (atomic, molecular and macromolecular scale) that produces structures, devices and systems with at least one novel / superior characteristic or property".

Nanotechnology is a scientific field that uses system or component development techniques to build products on highly granular levels. Nanotechnology works through different approaches to build nano materials or products, including bottom-up, top-down and functional system development. In a bottom-up approach, a product is designed as it evolves from its tiniest form factor to larger product. In a top-down approach, a large product may be reverse engineered to develop products scaled according to nanometer. A functional approach deals with a complete system and may incorporate bottom-up and top-down approaches.

Nanotechnology is implemented in many different fields and applications, such as computing, biotechnology, electronics and chemical engineering.

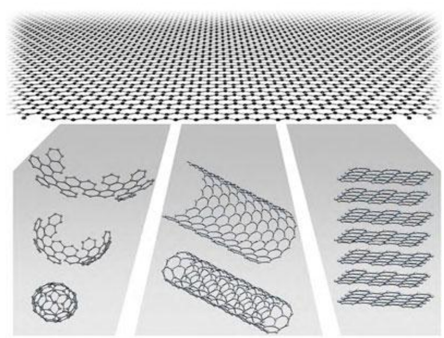
What is Graphene?

Graphene is a flat honeycomb lattice made of a single layer of carbon atoms, which are held together by a backbone of overlapping sp2 hybrids bonds. This nanocrystal is a basic building block for all other graphitic materials; it also represents a conceptually new class of materials that are only one atom thick, so-called two-dimensional (2D) materials (they are called *2D* because they extends in only two dimensions: length and width; as the material is only one atom thick, the third dimension, height, is considered to be zero).

The extraordinary characteristics of graphene originate from the 2p orbitals, which form the π state bands that delocalize over the sheet of carbons that constitute graphene.

Graphene has emerged as one of the most promising nanomaterials because of its unique combination of superb properties: it is not only one of the thinnest but also strongest materials; it conducts heat better than all other materials; it is a great conductor of electricity; it is optically transparent, yet so dense that it is impermeable to gases – not even helium, the smallest gas atom, can pass through it.

These amazing properties, and its multifunctionality, make graphene suitable for a wide spectrum of applications ranging from electronics to optics, sensors, and biodevices.



Mother of all graphitic forms. Graphene is a 2D building material for carbon materials of all other dimensionalities. It can be wrapped up into 0D buckyballs, rolled into 1D nanotubes or stacked into 3D graphite.

How Graphene is Made

The quality of graphene plays a crucial role as the presence of defects, impurities, grain boundaries, multiple domains, structural disorders, wrinkles in the graphene sheet can have an adverse effect on its electronic and optical properties.

In electronic applications, the major bottleneck is the requirement of large size samples, which is possible only in the case of CVD process, but it is difficult to produce high quality and single crystalline graphene thin films possessing very high electrical and thermal conductivities along with excellent optical transparency.

Another issue of concern in the synthesis of graphene by conventional methods involves the use of toxic chemicals and these methods usually result in the generation hazardous waste and poisonous gases. Therefore, there is a need to develop green methods to produce graphene by following environmentally friendly approaches.

The preparation methods for graphene should also allow for *in situ* fabrication and integration of graphene-based devices with complex architecture that would enable eliminating the multi-step and laborious fabrication methods at a lower production.

Graphene uses and IT applications

Energy storage and Solar Cells

Graphene-based nanomaterials have many promising applications in energy-related areas. Just some recent examples: Graphene improves both energy capacity and charge rate in rechargeable batteries; activated graphene makes superior supercapacitors for energy storage; graphene electrodes may lead to a promising approach for making solar cells that are inexpensive, lightweight and flexible; and multifunctional graphene mats are promising substrates for catalytic systems.

These examples highlight the four major energy-related areas where graphene will have an impact: solar cells, supercapacitors, graphene batteries, and catalysis for fuel cells.

An excellent review paper ("Chemical Approaches toward Graphene-Based Nanomaterials and their Applications in Energy-Related Areas") gives a brief overview of the recent research concerning chemical and thermal approaches toward the production of well-defined graphene-based nanomaterials and their applications in energy-related areas.

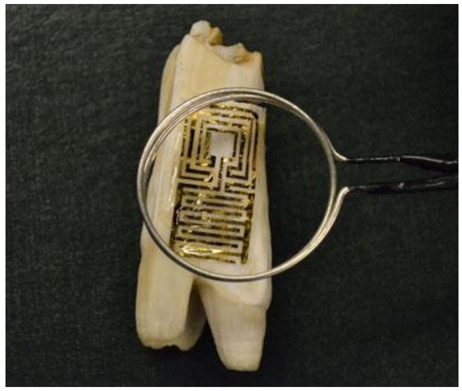
The authors note, however, that before graphene-based nanomaterials and devices find widespread commercial use, two important problems have to be solved: one is the preparation of graphene-based nanomaterials with well-defined structures, and the other is the controllable fabrication of these materials into functional devices.

Sensor Applications

Functionalized graphene holds exceptional promise for biological and chemical sensors. Already, researchers have shown that the distinctive 2D structure of graphene oxide (GO), combined with its superpermeability to water molecules, leads to sensing devices with an unprecedented speed ("Ultrafast graphene sensor monitors your breath while you speak").

Scientists have found that chemical vapors change the noise spectra of graphene transistors, allowing them to perform selective gas sensing for many vapors with a single device made of pristine graphene no functionalization of the graphene surface required ('Selective gas sensing with pristine graphene')

Quite a cool approach is to interface passive, wireless graphene nanosensors onto biomaterials via silk bioresorption as demonstrated by a graphene nanosensor tattoo on teeth monitors bacteria in your mouth.



Optical image of the graphene wireless sensor biotransferred onto the surface of a tooth. (Image: McAlpine Group, Princeton University)

Researchers also have begun to work with graphene foams – three-dimensional structures of interconnected graphene sheets with extremely high conductivity. These structures are very promising as gas sensors ("Graphene foam detects explosives, emissions better than today's gas sensors") and as biosensors to detect diseases (see for instance: "Nanotechnology biosensor to detect biomarkers for Parkinson's disease").

Electronics Applications

Graphene has a unique combination of properties that is ideal for next-generation electronics, including mechanical flexibility, high electrical conductivity, and chemical stability. Combine this with inkjet printing and you get an inexpensive and scalable path for exploiting these properties in real-world technologies ("Inkjet printing of graphene for flexible electronics").

Transistors and memory

Some of the most promising applications of graphene are in electronics (as transistors and interconnects), detectors (as sensor elements) and thermal management (as lateral heat spreaders). The first graphene field-effect transistors (FETs) – with both bottom and top gates – have already been demonstrated. At the same time, for any transistor to be useful for analog communication or digital applications, the level of the electronic low-frequency noise has to be decreased to an acceptable level ("Graphene transistors can work without much noise").

Transistors on the basis of graphene are considered to be potential successors for the some silicon components currently in use. Due to the fact that an electron can move faster through graphene than through silicon, the material shows potential to enable terahertz computing.

In the Ultimate Nanoscale Transistor – Dubbed a Ballistic Transistor

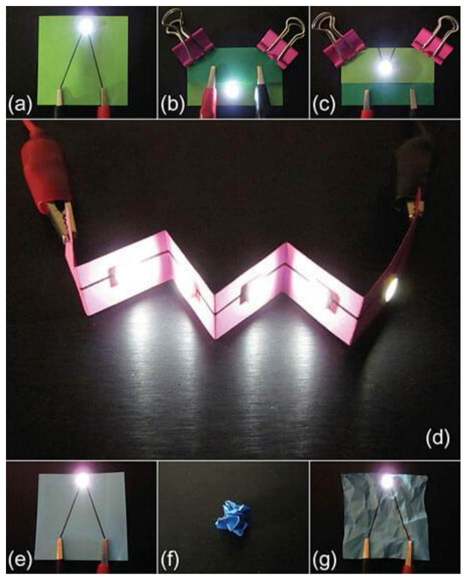
The electrons avoid collisions, i.e. there is a virtually unimpeded flow of current. Ballistic conduction would enable incredibly fast switching devices. Graphene has the potential to enable ballistic transistors at room temperature. While graphene has the potential to revolutionize electronics and replace the currently used silicon materials ("High-performance graphene transistor with high room-temperature mobility"), it does have an Achilles heel: pristine graphene is semi-metallic and lacks the necessary band gap to serve as a transistor. Therefore it is necessary to engineer band gaps in graphene.

Experiments have demonstrated the benefits of graphene as a platform for flash memory which show the potential to exceed the performance of current flash memory technology by utilizing the intrinsic properties of graphene.

Flexible, Stretchable and Foldable Electronics

Flexible electronics relies on bendable substrates and truly foldable electronics requires a foldable substrate with a very stable conductor that can withstand folding (i.e. an edge in the substrate at the point of the fold, which develops creases, and the deformation remains even after unfolding).

That means that, in addition to a foldable substrate like paper, the conductor that is deposited on this substrate also needs to be foldable. To that end, researchers have demonstrated a fabrication process for foldable graphene circuits based on paper substrates.



Photographs of applications. a,b,c) Operation of a LED chip with graphene circuits on a paper substrate under -180° folding and 180° folding. d) Array of LED chips on a three-dimensional circuit board including negative and positive angle folding. e,f,g) Operation of a LED chip on the paper-based circuit board before and after crumpling.

Graphene's remarkable conductivity, strength and elasticity has also made it a promising choice for stretchable electronics – a technology that aims to produce circuits on flexible plastic substrates for applications like bendable solar cells or robotic-like artificial skin.

Scientists have devised a chemical vapor deposition (CVD) method for turning graphene sheets into porous three-dimensional foams with extremely high conductivity. By permeating this foam with a siloxane-based polymer, the researchers have produced a composite that can be twisted, stretched and bent without harming its electrical or mechanical properties ("Graphene: Foaming for stretchable electronics").

Photodetectors

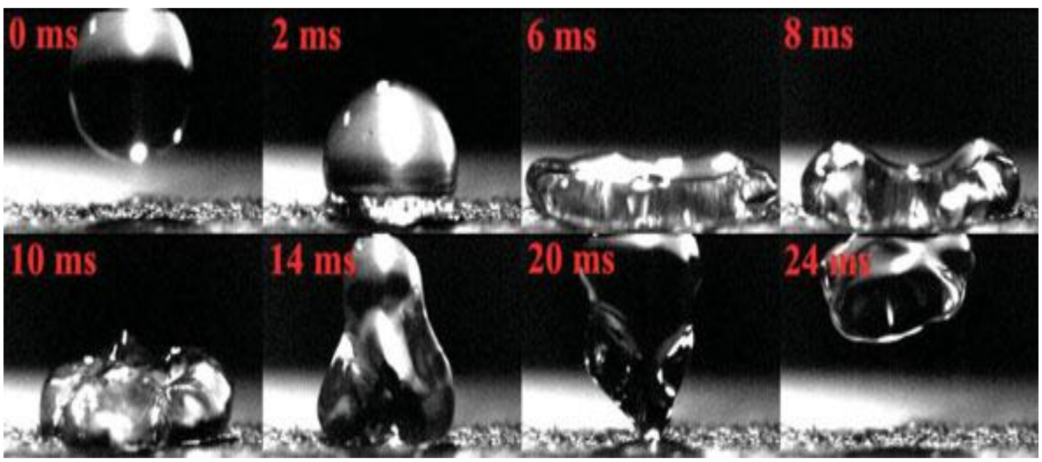
Researchers have demonstrated that graphene can be used for telecommunications applications and that its weak and universal optical response might be turned into advantages for ultrafast photonics applications. They also found that graphene could be potentially exploited as a saturable absorber with wide optical response ranging from ultra-violet, visible, infrared to terahertz ("The rise of graphene in ultra-fast photonics").

There is a very strong research interest in using graphene for applications in optoelectronics. Graphene-based photodetectors have been realized before and graphene's suitability for high bandwidth photodetection has been demonstrated in a 10 GBit/s optical data link ("Graphene photodetectors for high-speed optical communications").

One novel approach is based on the integration of graphene into an optical microcavity. The increased electric field amplitude inside the cavity causes more energy to be absorbed, leading to a significant increase of the photoresponse ("Microcavity vastly enhances photoresponse of graphene photodetectors").

Coatings

Coating objects with graphene can serve different purposed. For instance, researchers have now shown that it is possible to use graphene sheets to create a superhydrophobic coating material that shows stable superhydrophobicity under both static as well as dynamic (droplet impact) conditions, thereby forming extremely water repelling structures.



Snapshots of a water droplet impacting the surface of the Teflon coated graphene foam. The impact velocity just prior to the droplet striking the surface was ~76 cm/sec. The sequence of snapshots shows the deformation time history of the droplet upon impact. The droplet spreads, then retracts and successfully rebounds off the surface. The coefficient of restitution (i.e. ratio of droplet impacting velocity to ejecting velocity) is ~0.37 for the Teflon coated foam. (Reprinted with permission from Wiley-VCH Verlag)

Graphene also is the world's thinnest known coating for protecting metals against corrosion. It was found that graphene, whether made directly on copper or nickel or transferred onto another metal, provides protection against corrosion. Researchers demonstrated the use of graphene as a transparent conductive coating for photonic devices and show that its high transparency and low resistivity make this two-dimensional crystal ideally suitable for electrodes in liquid crystal devices (LCDs).

Another novel coating application useful for researchers is the the fabrication of polymeric AFM probes covered by monolayer graphene to improving AFM probe performance.

Other Uses

Loudspeakers - The extraordinary electrical and mechanical properties of graphene have been exploited to create a very efficient electrical/sound transducer. This experimental graphene loudspeaker, without any optimized acoustic design, is simple to make and already performs comparably to or better than similar sized commercial counterparts, and with much lower power consumption.

Biotechnology and Medicine - Recent research also points to an opportunity to replacing antibiotics with graphene-based photothermal agents to trap and kill bacteria.

In the decades-old quest to build artificial muscles, many materials have been investigated with regard to their suitability for actuator application (actuation is the ability of a material to reversibly change dimensions under the influence of various stimuli). Besides artificial muscles, potential applications include microelectromechanical systems (MEMS), biomimetic micro-and nanorobots, and micro fluidic devices. In experiments, scientists have shown that graphene nanoribbons can provide actuation.

Radiation Shielding - Graphene appears to be a most effective material for electromagnetic interference (EMI) shielding. Experiments suggests the feasibility of manufacturing an ultrathin, transparent, weightless, and flexible EMI shield by a single or a few atomic layers of graphene.

Thermal Management - Due to rapidly increasing power densities in electronics, managing the resulting heat has become one of the most critical issues in computer and semiconductor design. As a matter of fact, heat dissipation has become a fundamental problem of electronic transport at the nanoscale.

This Is Where Graphene comes in – it conducts heat better than any other known material ("'Cool' graphene might be ideal for thermal management in nanoelectronics"). Thermal interface materials (TIMs) are essential ingredients of thermal management and researchers have achieved a record enhancement of the thermal conductivity of TIMs by addition of an optimized mixture of graphene and multilayer graphene ("Graphene sets new record as the most efficient filler for thermal interface materials").

Cloakin -- The concept of *plasmonic cloaking* is based on the use of a thin metamaterial cover to suppress the scattering from a passive object. Research shows that even a single layer of atoms, with the exciting conductivity properties of graphene, may achieve this functionality in planar and cylindrical geometries. This makes a single layer of graphene the thinnest possible invisibility cloak.

Lubrication - Over the last decade, various solid lubricant materials, micro/nano patterns, and surface treatment processes have been developed for efficient operation and extended lifetime in MEMS/NEMS applications, and for various fabrication processes such as nanoimprint lithography and transfer printing. One of the important considerations in applying a solid lubricant at the micro- and nanoscale is the thickness of the lubricant and the compatibility of the lubricant deposition process with the target product. Graphene, with its atomically thin and strong structural with low surface energy, is a good candidate for these applications ("Graphene - the thinnest solid lubricant").

Water Purification - A relatively new method of purifying brackish water is *capacitive deionization*

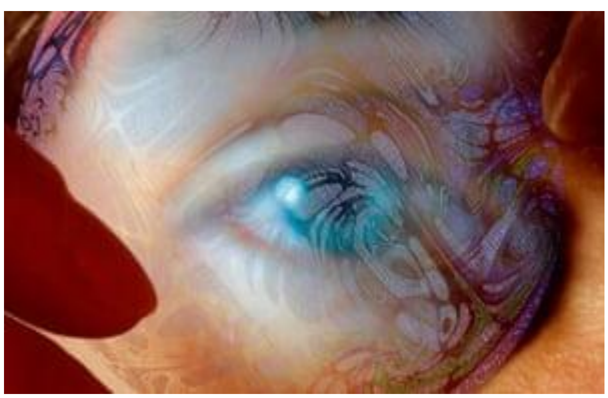
(CDI) technology. The advantages of CDI are that it has no secondary pollution, is cost-effective and energy efficient. Researchers have developed a CDI application that uses graphene-like nanoflakes as electrodes for capacitive deionization. They found that the graphene electrodes resulted in a better CDI performance than the conventionally used activated carbon materials ("Water desalination with graphene").

Future of Nanotechnology Using Graphene With Computer

"What distinguishes graphene from other next-generation memories, in particular phase-change materials, is its vastly higher on/off power ratio – the amount of current a circuit holds when it's on, as opposed to off," Tour explains to Nanowerk. "While the on/off ratios of phase-change materials are generally in the 10-100 region, with graphene it can be as high as a whopping million-to-one or even more – we have seen as high as 10 million-to-one."

The transistors currently used in computer chips have on/off ratios of 10,000 - 100,000, but they are three-terminal devices (in a three terminal device the electric current or voltage between two of the terminals is controlled by applying an electric current or voltage to the third terminal). Two-terminal memories based for instance on nanowires or carbon nanotubes are actively researched for future computer applications. Their structure makes three-dimensional memory practical as the materials can be stacked, multiplying a chip's capacity with every layer. The main challenges so far have been a requirement for large-scale fabrication and reliable and large on/off ratios. The recent research results coming out of Tour's lab show the possibility of building next-generation memory devices with vast amounts of memory using nanocables with a silicon dioxide core and a shell of stacked sheets of graphene (the team experimented with three different nanocable configurations: two layer graphite/silicon dioxide and three-layer graphite/silicon dioxide/silicon and graphite/silicon dioxide/ silicon carbide). Tour points out that graphene memory would increase the amount of storage in a two-dimensional array by a factor of five, as individual graphitic thin film sheets could be made as thin as 5-10 nanometers, compared to the 45-nanometer circuitry in today's flash memory chips.

Computer memory has increased rapidly over the past few decades but, as scientists struggle to reduce the size of conventional computer chips any further, these advances will sooner or later hit a wall. So can nanotechnology offer a way forward?



Future developments in nanotechnology are predicted to come from probing a scale one hundred times smaller than the cells in current silicon chips.

The advances have been so rapid that they will soon reach a wall. Pack the cells much closer together and electrical interference between them shoots up, affecting the device's performance. Again, nanotechnology ideas can come to the rescue – using graphene (a one-atom-thick sheet of carbon) in a layer between the silicon and the memory cells can keep electrical interference low, even past the 25 nanometre barrier.

As computer chips continue to get smaller and more powerful, so their prevalence in our everyday lives is set to increase. Kevin Ashton, a British technologist who created a system for tagging and tracking objects using radio frequencies, has predicted a future where everything is connected to the internet via tiny computer chips embedded within, or as he called it, an "internet of things". A fridge is already available with an on-board computer, allowing it to know its contents, order food when you run out and even suggest suitable recipes, before setting the oven to the right cooking temperature. It is also currently possible to control an entire room – the thermostat, light switch, TV, stereo etc – all from a tablet or smartphone using wirelessly connected chips in each of the controlled devices.

***Assistant Professor**
Department of Computer Science
S.S. Jain Subodh Girls College, Jaipur

References

1. https://www.ijsr.net/archive/v5i2/NOV161529.pdf
2. http://ijomfr.gdk.mx/web_documents/17-21_surbhi.pdf?i=1
3. https://globaljournals.org/GJRE_Volume12/6-Nanotechnology-and-Its-Impact-on-Modern-Computer.pdf
4. https://www.ripublication.com/irph/ijeee_spl/ijeeev7n3_03.pdf