DEPARTMENT OF PHYSICS AND NANOTECHNOLOGY
SRM INSTITUTE OF SCIENCE AND TECHNOLOGY

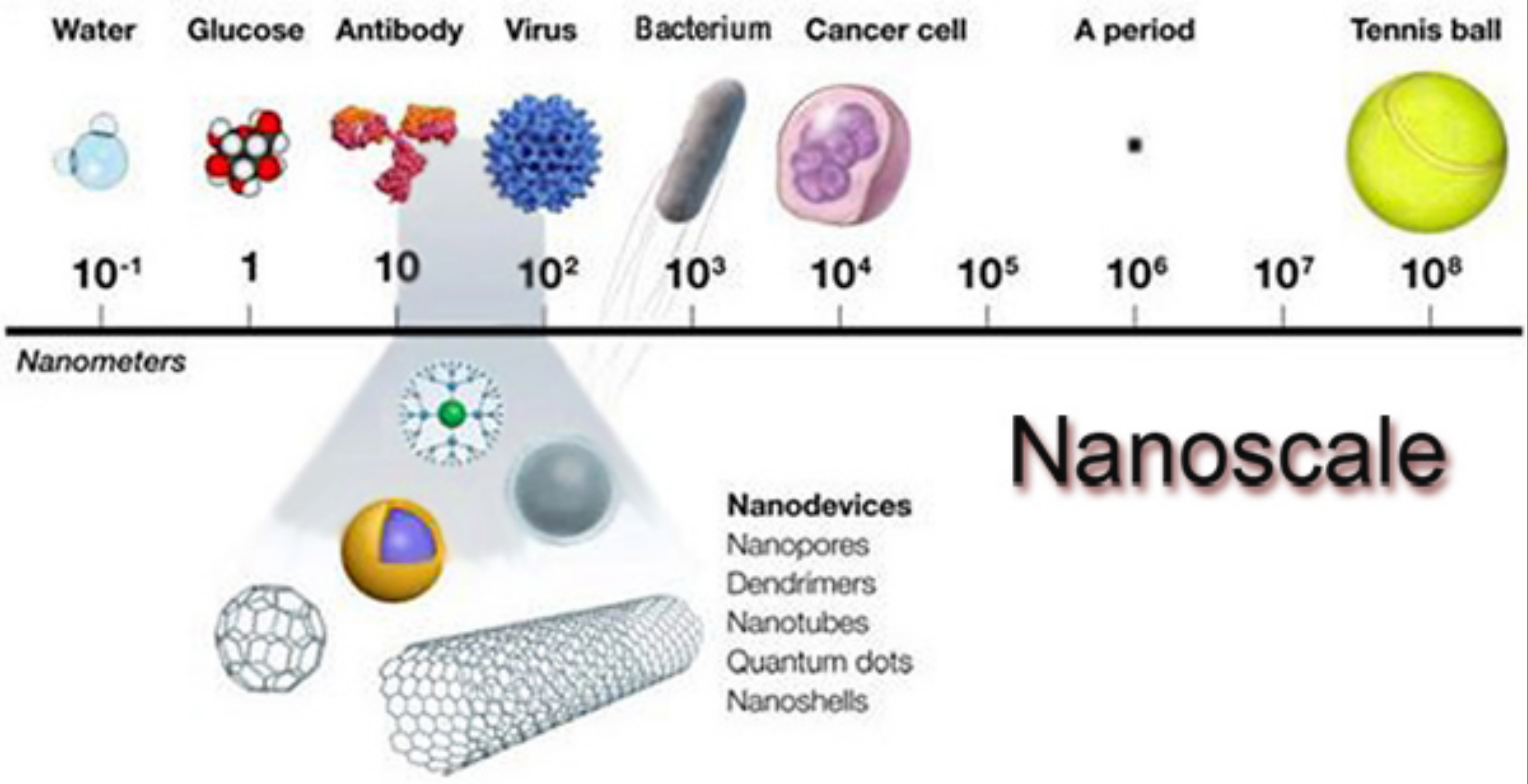
18NTO301T - APPLICATIONS OF NANOTECHNOLOGY

Module-III

Nanotechnology in Electronics Devices

Nanotechnology

- Scale
- Definition
- Quantum Mechanics
- Approaches to fabricate



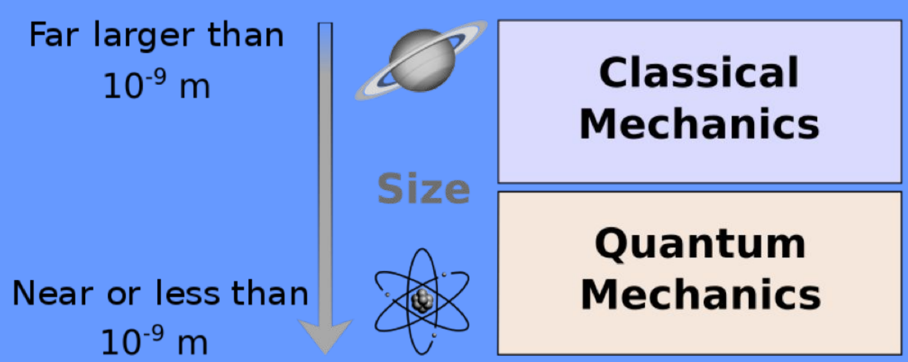
Principles of Quantum Mechanics

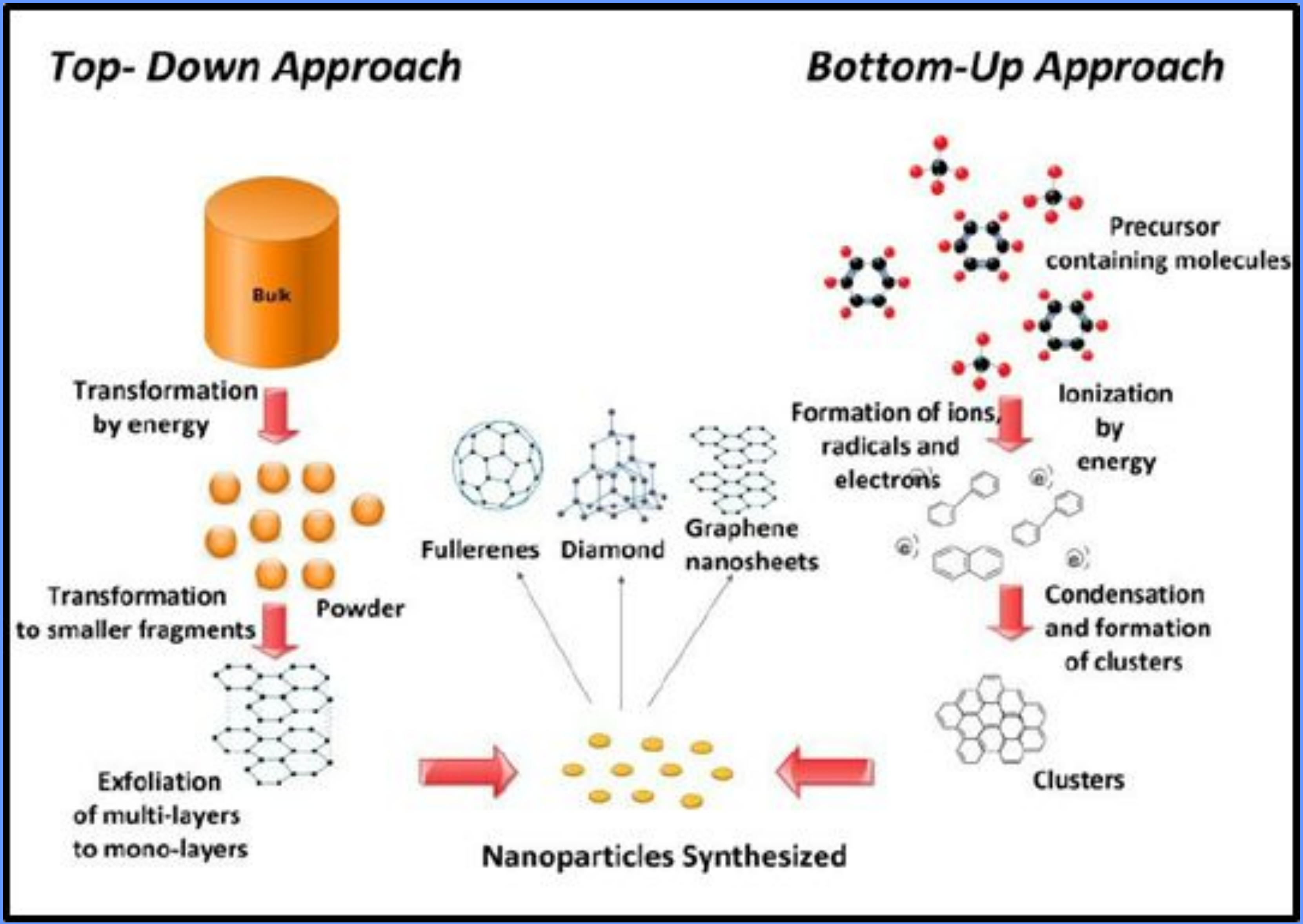
What is Quantum Mechanics?

QM is the theory of the behavior of very small objects (e.g. molecules, atoms, nuclei, elementary particles, quantum fields, etc.)

Why ***Quantum*** Mechanics?

One of the essential differences between classical and quantum mechanics is that physical variables that can take on continuous values in classical mechanics (e.g. energy, angular momentum) can only take on discrete (or quantized) values in quantum mechanics (e.g. the energy levels of electrons in atoms, or the spins of elementary particles, etc).




Top- Down Approach
Bottom-Up Approach
Bulk
Transformation by energy
Powder
Transformation to smaller fragments
Exfoliation of multi-layers to mono-layers
Fullerenes
Diamond
Graphene nanosheets
Nanoparticles Synthesized
Precursor containing molecules
Formation of ions, radicals and electrons
Ionization by energy
Condensation and formation of clusters
Clusters

Semiconductor Nanowires

Researchers are trying and creating wires which possess on carbon nanotubes and it is expected that these wires could lower resistance, which will reduce the transmission power loss.

The semiconductor nanowires (NWs) nowadays presented a unique significance and are assumed to be representing critical role in future electronics.

Research in the area of semiconductor NWs over the past periods, has aided to redesign crystal atomic - scale assemblies and expose novel physical understanding at the nanometer scale.

In the next generation of photonic and electronic devices, compound semiconductor nanowires have been recognized as dominant components. This is particularly beneficial for efficient collection of photo generated carriers when core and shell segments are engineered to be thinner than minority carrier diffusion lengths.

Nanowires (NWs) are more conductive to heterogeneous mixed solutions, owing to the nature of the NW geometry to accommodate heteroepitaxially - induced strain by relaxation along the NW free surface. This advantage successfully raises the critical width of lattice – mismatched NW crystals in comparison to epi- layers having a purely planar geometry.

Consequently, NW array based constructions are effective for multi - junction PVs, insofar as high - efficiency devices trusting on the monolithic integration of III-V materials with Si technology have been envisioned. Nowadays, Semiconductor NWs are considered as one of the most influential platforms available in nanoscience.

Nano Fluids - Based Dielectric Fluid Transformer

The transformer is considered one of the key components of the electricity network which distributed and transmitted electricity. The fault in any part of this component can leads to interruption of power system

The dielectric fluids present in transformer is also the main element. It performs two functions, insulating and cooling. These fluids acts like as blood in human body.

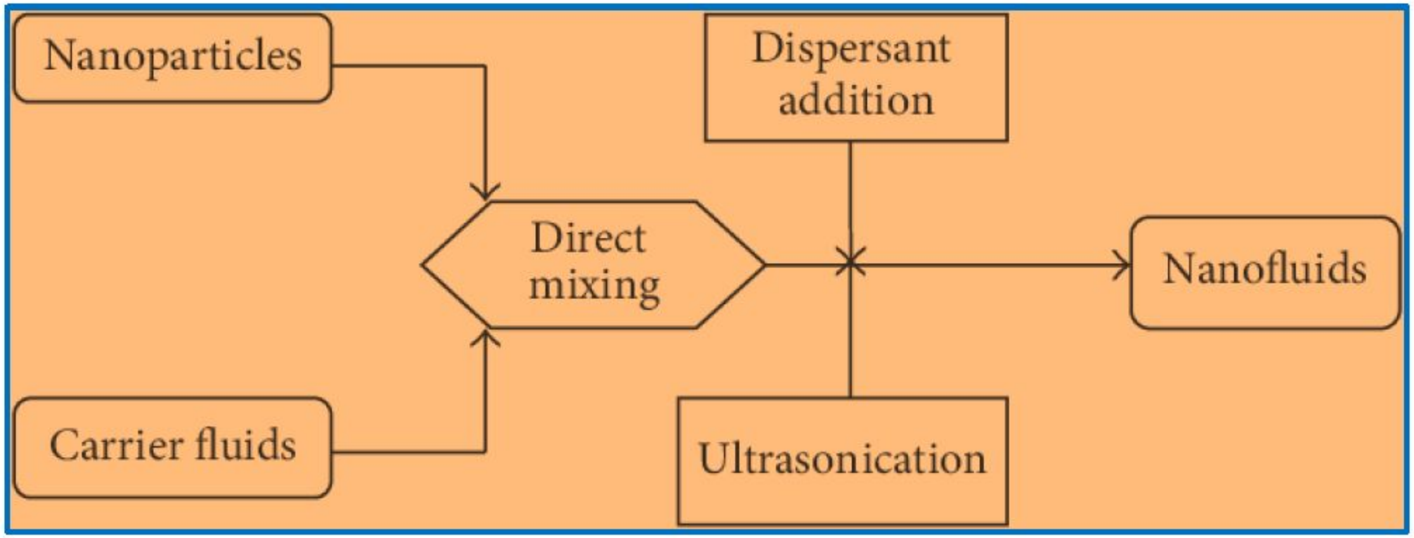


Figure 2. Preparation method of nano-fluids

Nanotechnology in High Voltage Insulators

One of the greatest important developments in the history of ceramics was the creation of a vitrified, translucent porcelain body. Porcelain has been extensively used in decorative ware, sanitary ware, medicine and dentistry, dinnerware and electrical insulators. The cheap and easy availability of raw materials and the simplicity for processing a body have made porcelain manufacturing or pottery - making a principal business since the prehistoric times.

Definition of Porcelain is the traditional ceramics which are made from raw materials possess on clay, followed by heating. This type of Porcelain is extensively studied for application of advanced engineering. Still it is challenging to understand the relation of raw material and of its science.

Trixie Porcelain is one of the major popular materials. This is used historically for both high and low voltage insulators. Trixie has the same chemical composition as of porcelain which is designed by a combination of three materials. The three materials are feldspar, clay and alumina or silica. Distinct characteristics are given each raw material to porcelain.

Nowadays, nanotechnology innovations have enhancedthe property of porcelain insulators. These interesting and extraordinary investigations results carried out in various ceramics materials and porcelain system for traditional and dental applications

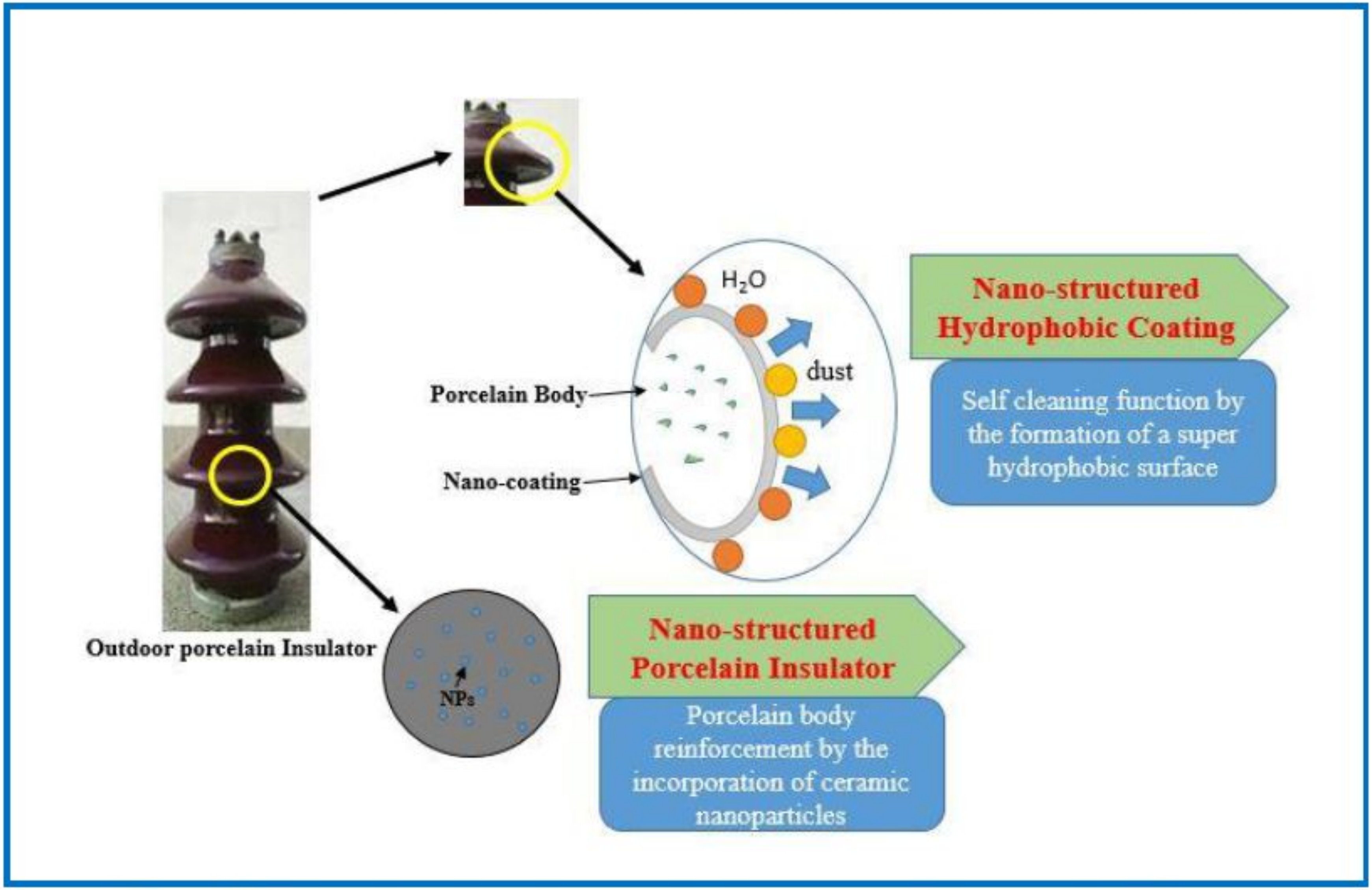


Figure 3. Schematic of the main nanotechnology concepts for outdoor insulators

Nano Applications in Electric Transformer

Electrical transformer carries variety of potential materials like aluminum and copper conductors for winding. It comprises silicon - steel and amorphous metal for magnetic cores, steel for inner tank and structures, external and internal coating for the tank etc, polymeric gaskets etc.

Aluminum and copper has been used from long time for winding conductor of electrical transformers. Current developments focused to create new material with high efficiency, high conductivity and better mechanical performance. Copper nanotube has been studied from long time as alternative to copper in electric machine.

It is used because of its excellent and unique properties. In the year of successfully developed a new Carbon nano-tube (CNT) based technology for wires and coils to replace copper wire conductor in a small electric transformer. Researchers stated that CNTs based metallic conductors could scale up the manufacturing capacity of electric transformers.

Recently electrical industries are focusing on nanostructured steel to make more potent materials using nanotechnology applications for transformer. These technologies specify to make steel for multipurpose properties.

Novel strategies are using to fabricate microstructure material at Nano - scale level. Recently, for the first time Tata steel with collaboration of Cambridge University developed a steel based new super bainite alloy. For the enhancement of magnetic presentation of transformer core, nanotechnology could play a vital role.

The tank of electric transformers is painted for the purpose to protect them from corrosion. Nanotechnology applications attained a great attention of researcher’s to protect the tank from corrosion and degradation. Nanoparticles coating on tank recently showed remarkable growth.

These application of nanoparticles coating exhibits attractive characteristics as compared to traditional products. From these all it is concluded that nanotechnology strategies could enhance the quality and performance of electric transformer Materials.

Nanoelectronics – Nanotechnology in Electronics

The term nanoelectronics refers to the use of nanotechnology in electronic components.

The tinier electronic components become, the harder they are to manufacture.

physical effects alter the materials‘ properties on a nanoscale – inter-atomic interactions and quantum mechanical properties play a significant role in the workings of these devices.

Quantum effects such as tunneling and atomistic disorder dominate the characteristics of these nanoscale devices

The first transistors built in 1947 were over 1 centimeter in size; the smallest working transistor today is 7 nanometers long – over 1.4 million times smaller.

The result of these efforts are billion-transistor processors where, once industry embraces 7nm manufacturing techniques, 20 billion transistor-based circuits are integrated into a single chip.

Nanoelectronic Devices

Graphene spintronics - from science to technology

When spin is manipulated with magnetic and electric fields, the result is a spin-polarised current that carries more information than is possible with charge alone.

Spin-transport electronics, or spintronics, is a subject of active investigation within Graphene Flagship.

spintronics – the study and exploitation in solid-state devices of electron spin and its associated magnetic moment, along with [illegible] ed technology.

spintronics is a maturing field of applied science and engineering, as well as fascinating pure science in its own right.

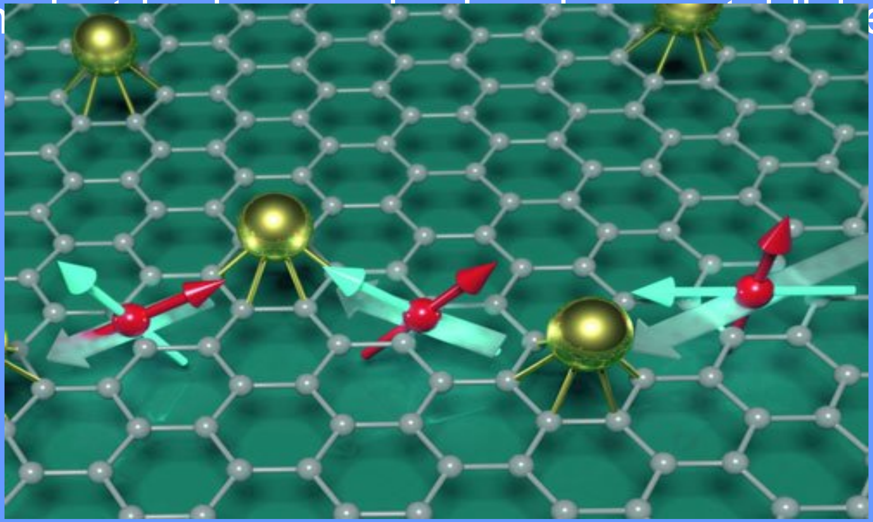


Illustration of electron spin in a graphene lattice

Electron spin and quantum logic

Spin can be thought of as the rotation of the electron around its own axis. It is a form of intrinsic angular momentum, and can be detected as a magnetic field with one of two orientations: up and down.

Combine these magnetic orientations with the on/off current states in binary logic, and we have a system of four states, with the two magnetic orientations forming a quantum bit, or qubit.

In computing technology terms, four states rather than two provides for higher data transfer speeds, increased processing power and memory density, and added storage capacity.

Optoelectronics

Highly energy-efficient (less heat generation and power consumption) optical communications are increasingly important because they have the potential to solve one of the biggest problems of our information age: energy consumption.

In the field of nanotechnology, materials like nanofibers and carbon nanotubes have been used and especially graphene has shown exciting potential for optoelectronics.

Nanotechnology in Displays

OLEDs and OLETs

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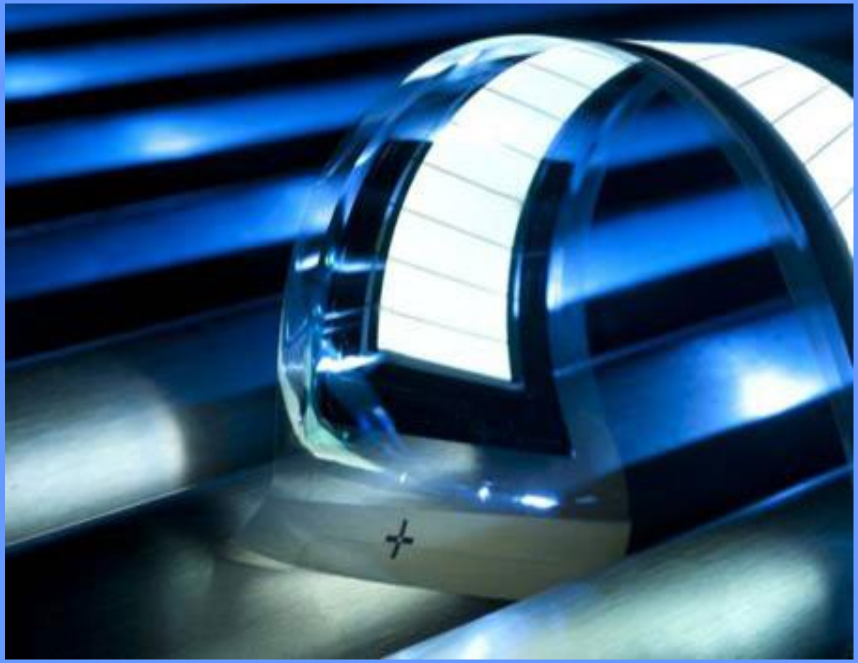
OLED technology is based on the phenomenon that certain organic materials emit light when fed by an electric current and it is already used in small electronic device displays.

With more efficient and cheaper OLED technologies it will possible to make ultra flat, very bright and power-saving OLED televisions, windows that could be used as light source at night, and large-scale organic solar cells.

In contrast to regular LEDs, the emissive electroluminescent layer of an OLED consists of a thin-film of organic compounds.

It require less power to operate; also, since they are thinner than comparable LEDs, they can be printed onto almost any substrate.



Transparent organic light-emitting diode on foil

Areas where nanomaterials and nanofabrication techniques are used in OLED manufacturing are transparent electrodes

nanoparticles-based coatings for packing the OLEDs to protect them from environmental damages (e.g. water).

Nanoparticle-based deposition methods that might also overcome OLED fabrication problems where issues such as material damage, yield, and thickness uniformity haven't been completely solved yet.

And recently, researchers have even developed brand new concept of OLEDs with a few nanometer of graphene as transparent conductor.

exciton quenching and photon loss processes still limit OLED efficiency and brightness

Organic light-emitting transistors (OLETs)

Organic light-emitting transistors (OLETs) are alternative, planar light sources combining, in the same architecture, the switching mechanism of a thin-film transistor and an electroluminescent device.

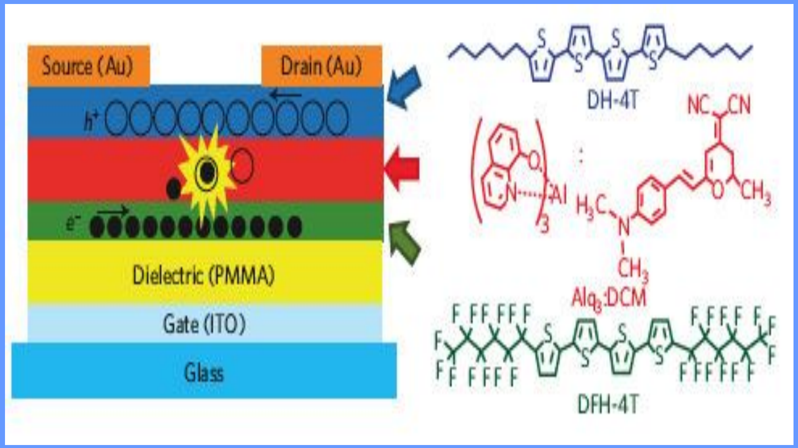
"OLET is a new light-emission concept, providing planar light sources that can be easily integrated in substrates of different nature – silicon, glass, plastic, paper, etc. – using standard microelectronic techniques

new display/light source technologies, and exploit a transport geometry to suppress the harmful photon losses and exciton quenching mechanisms inherent in the OLED architecture.“

using a p-channel/emitter/n-channel tri-layer semiconducting heterostructure in OLETs providing a novel approach to dramatically improve OLET performance.

The trilayer heterostructure OLETs used by the researchers were fabricated on glass/indium tin oxide/PMMA substrates.

The active region consists of the superposition of three organic layers.



The first, in contact with the PMMA dielectric, and the third layers are field-effect electron-transporting (n-type) and hole-transporting (p-type) semiconductors, respectively, whereas the middle layer is a light-emitting host guest matrix.

The new trilayer heterostructure field-effect concept unravels the full potential of the light-emitting field-effect technology and restricts the limitation of OLEDs to only materials-related issues.

"Improvements in the top-layer field-effect mobility at high current density coupled to the use of triplet emitters will enable OLETs with even higher brightness."

Quantum Dot LEDs

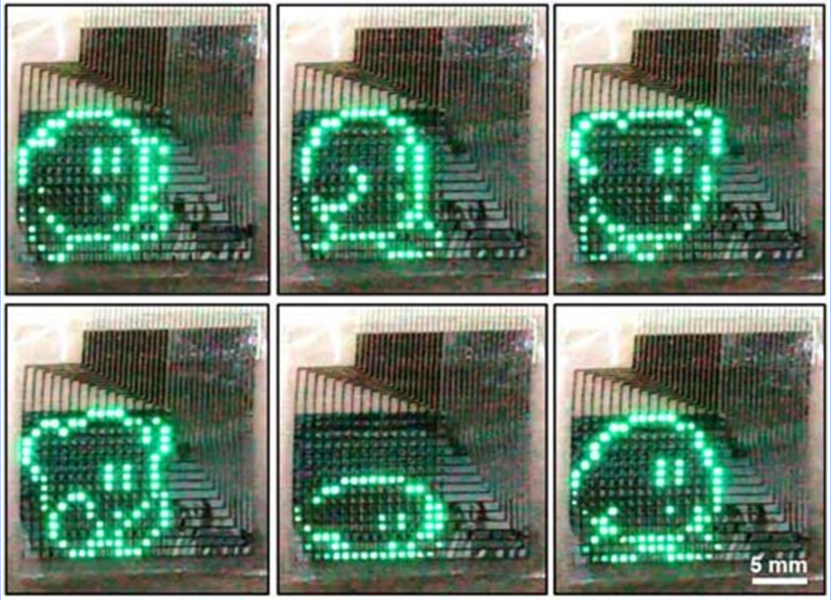
Quantum Dot LEDs (QLEDs)

Quantum dots (QDs), because they are both photo-active (photoluminescent) and electro-active (electroluminescent) and have unique physical properties, are one of the most promising optoelectronic materials

Compared to organic luminescent materials used in organic light emitting diodes (OLEDs), QD-based materials have purer colors, longer lifetime, lower manufacturing cost, and lower power consumption.

Because QDs can be deposited on virtually any substrate, you can expect printable and flexible – even rollable – displays of all sizes.

For instance, researchers have demonstrated a passive matrix quantum dot light-emitting diode (QLED) display fully integrated with flexible electronics.



Photographs of sequential frames

What Is QLED, And Why Does It Matter?

Quantum Dots offer a different way for screens to produce color instead of the usual inefficient and limited combination of white LEDs and color filters.

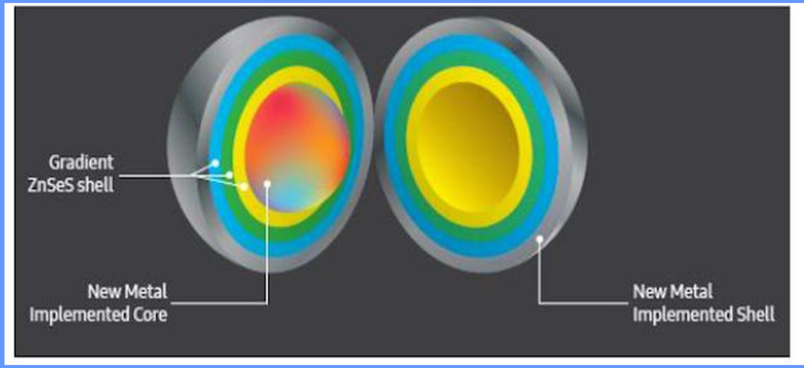
It produce different colors depending on their size. For instance, the smallest dots focus on blue, the larger ones focus on red.

produce more heavily saturated and precisely defined primary colors from blue LEDs than you can get from the relatively broad and thus imprecise light spectrum associated with white LEDs.

This ability to deliver less 'watered down' brightness and color intensity - 'go to' color solution for high quality high dynamic range LED/LCD TVs.

First, it makes the QDs much less susceptible to oxidation, meaning that their performance will erode much less rapidly over time than normal QDs.

Second, the QDs can be positioned differently in the TV's structure, enabling them to deliver their color and light more efficiently.



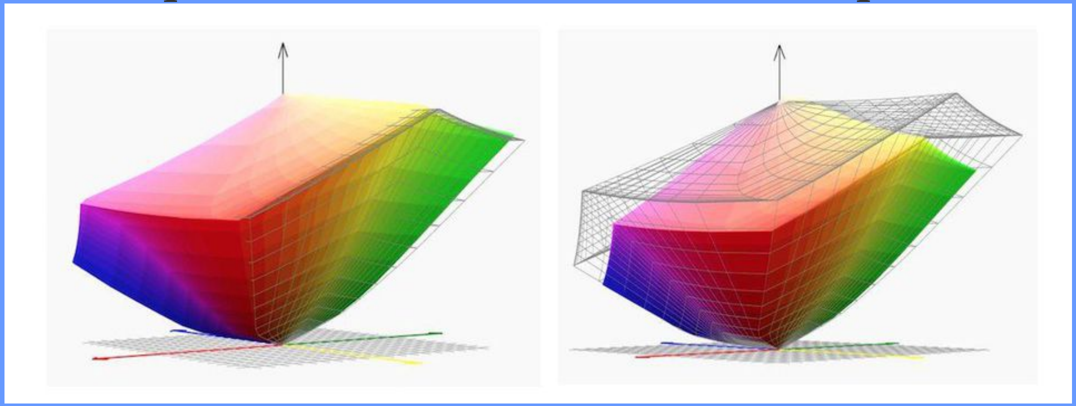
Samsung's metal-clad QDs deliver three main advantages to the viewing experience. First, they enable Samsung to push for extreme levels of brightness.

The flagship Q9F models can hit 2000 nits of peak brightness - an unprecedentedly high figure for a consumer TV.

The second big HDR-friendly benefit opened up by Samsung's QLED approach is color volume-how different amounts of light can impact the range of color tones a TV can achieve.

QLED's third key benefit as a TV technology is that despite its intense brightness and color saturations, it is immune to screen burn.

you can leave intense graphical elements such as channel logos and gaming 'HUD' readouts in the same place on the screen for extended periods of time



The key focus for QLED technology is expanding the color volume (a function of brightness

ZnO nanoparticles

Behind the QLED structure, the ZnO nanoparticles (ZnO NPs) have gained substantial interest in the research community as the charge transport layer (CTL).

In 2008, demonstrated all-solution-processed multilayer QLEDs by using ZnO NPs as ETLs and organic materials as HTLs.

The colloidal ZnO NPs were dispersed in isopropanol, and the deposition of the ZnO NPs on the top of the QD layers did not dissolve the underlying layers.

Since then, continuous efforts were made to improve the performance of QLED with solution-processed n-type oxides as CTLs.

ZnO NPs are widely used as CTLs in the state of the art of high-performance QLEDs.