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An Overview of Nanotechnology and its Energy Applications

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***Abstract*—The world's hunger for energy is rapidly increasing while we at the same time face critical environmental issues as well as dwindling resources. To manage this situation we need to produce, transport, store and consume energy in new and more efficient ways. Nanotechnology promises to be the tool we need. This paper is an outcome of literature survey in this field and thus the importance of nanotechnology and its energy applications is highlighted.**

***Keywords*—carbon nanotube, quantum dot, nanoparticle.**

I. INTRODUCTION

Nanotechnology is the creation of useful/functional materials, devices and systems (of any useful size) through control/manipulation of matter on the 1-100 nanometer length scale and exploitation of novel phenomena and properties which arise because of the nanometer length scale:

Nanometer One billionth (10-9) of a meter
Hydrogen atom 0.04 nm
Proteins ~ 1-20 nm
Feature size of computer chips 14nm (in 2014)
Diameter of human hair ~ 10 µm

A.Properties of nano materials

- Quantum size effects (atomic level of matter) result in unique mechanical, electronic, photonic, and magnetic properties of nanoscale materials.
- Chemical reactivity of nanoscale materials greatly different from more macroscopic form, e.g. gold.
- Vastly increased surface area per unit mass, e.g., upwards of 1000 m2 per gram.
- New chemical formation, e.g., fullerenes, nanotubes of carbon, titanium oxide, zinc oxide, other layered compounds.

II. NANOFABRICATION

A. Fabrication approaches.

Nanofabrication is the process of designing and creating devices on the nanoscale. Creating devices smaller than 100 nanometers helps for the development of new ways to capture, store, and transfer energy.

Thus nanofabrication involves three main approaches they are:

1. Top-down nanofabrication.
2. Bottom-up nanofabrication.
3. Hybrid nanofabrication.

1. The top-down nanofabrication makes nanostructures by repeated use of steps that put down films and take parts of them away. It involves four steps as show below:

- Lithography-It is the step which arranges (orchestrates) all the others. It controls where materials stay and where they are "sculpted" (etched) away.
- Addition/depositing/growing.
- Subtraction /modification.
- Etching.

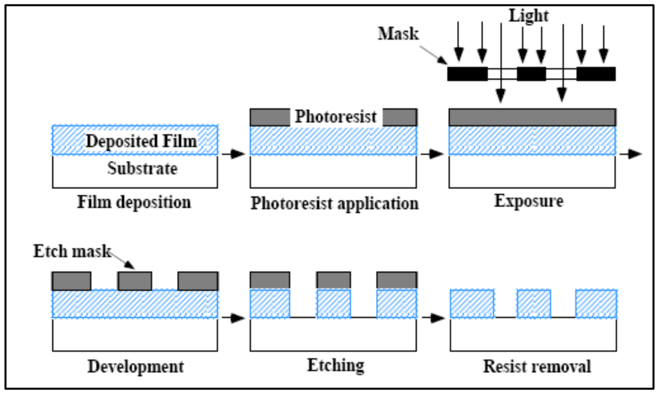

Fig.1. Top-down Approach

2. Bottom-up nanofabrication builds up nano-structures from atoms, molecules, particles or some combination of these. E.g.: putting building blocks together. It involves two steps:

- Building block
- Self-assembly (based on inherent patterning).

3. Hybrid nanofabrication is combination of both top-down and bottom-up approaches.

B. How to direct Nanofabrication

- Sometimes no direction is needed i.e. no patterns for positioning are required (e.g. nanoparticles in solution).
- Sometimes direction is required i.e. sometimes patterns for positioning are necessary (e.g. transistors on a substrate).
- No external pattern control in case of hybrid nanofabrication.

C. When pattern controlled fabrication is required it can utilize following:

- External patterning or externally imposed pattern approach which is generally called lithography is used for placing, growing or modifying materials into patterns on a substrate or else to remove materials from a substrate.
- Inherent pattern or Inherent patterning means to use size, shape, specific chemical bonding or all of these to establish a pattern in the nanofabrication.

D.CNT (Carbon Nano tubes)

- Carbon nanotubes (CNTs, also called Bucky tubes in earlier days) are elongated cylindrical fullerenes with diameters of nanometers and lengths of microns even millimetres.
- Graphene is the name given to a flat monolayer of sp2-bonded carbon atoms tightly packed into a two-dimensional (2D) honeycomb lattice, and is a basic building block for graphitic materials.
- Graphene can be wrapped up into 0-D fullerenes, rolled into 1-D nanotube or stacked into 3-D graphite.

Properties of CNT:

- High tensile strength.
- High electrical and thermal conductivities.
- High ductility.
- High thermal and chemical stability.

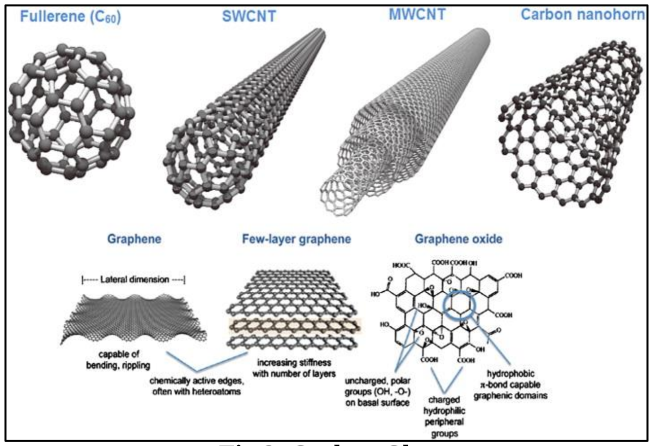

Fig.2. Carbon Clusters

III. ENERGY APPLICATIONS OF NANOTECHNOLOGY

- Power Generation Application (Energy harvesting micro devices using carbon nanotube film (CNF).
- Power Transmission Applications (ACCR, QW's, Nano-Particles, Nanosensors).
- Energy Usage Applications (Lighting (Nano crystals), NanoAir.

A.Energy harvesting micro devices using carbon nanotubes film (CNF).

Thermal and solar energies are attractive due to their cleanness and unlimited availability. Two related energy harvesting technologies are thermoelectric generators (TEG) and solar cells. However, only narrow spectral range (400 nm-1000 nm) from the sunlight can be efficiently utilized by the conventional silicon PN junction solar cells. The major drawback of a TEG is that a temperature gradient has to be maintained for electricity generation, suggesting extra power consumption. Few technologies are available for harvesting both types of energies on the same chip. Recently, it has been found that carbon nanotube film (CNF) generates fluctuating currents as far as it is exposed to a light and thermal radiation source, thus causing the repeated bending of a CNF-based cantilever .It also has been found that CNF has huge absorption of light and thermal radiation, thus the local temperature adjacent to the CNF can be raised efficiently. These interesting characteristics have been utilized to harvest both light and thermal energies with a single macro energy device: a CNF-lead zirconate titanate (PZT) based macro scale cantilever (20 mm long, 8 mm wide, 330 μm thick) .However, since its large internal resistance (~80 MΩ) due to the large thickness of PZT layer and thus most of the power is consumed by the device itself, the output power is very low even though the output voltage can be up to 10 V. To address this issue, the internal resistance has to be reduced significantly. Herein, a micro machined carbon nanotube film-based energy device is reported for the first time [8].

B. Power Transmission Applications.

B.1 ACCR

Nanotechnology may help improve the efficiency of electricity transmission and distribution wires. Conventional aluminium conductor steel reinforced (ACSR) wire is the standard overhead conductor against which alternatives were compared .Recently developed nano material-based metal-matrix overhead conductor known as the aluminium conductor composite reinforced (ACCR) wire, which is designed to resist heat sag and provide more than twice the transmission capacity of conventional conductors of similar size. This ACCR wire is currently in use, or has been selected for use, by six major utilities across the country. "Aluminium has been a key ingredient in bare overhead conductors for decades. The difference is that ACCR wire is based on the use of aluminium processed in new ways to create high-performance and reliable overhead conductors that retain strength at high temperatures and are not adversely affected by environmental conditions." The constituent materials are chemically inert with respect to each other and can withstand extreme temperatures without chemical reactions or any appreciable loss in strength. The material used in the core of the cable replaces the steel used in conventional cables.

B.2 *QW (Quantum Wires)*

The use of armchair CNTs, a special kind of single-walled CNT that exhibits extremely high electrical conductivity (more than 10 times greater than copper). Also possessing flexibility, elasticity, and tremendous tensile strength, CNTs have the potential, when woven into wires and cables, to provide electricity transmission lines with substantially improved performance over current power lines. Replacing current wires with nanoscale transmission wires, called quantum wires (QWs) or armchair QWs, could revolutionize the electrical grid. The electrical conductivity of QW is higher than that of copper at one-sixth the weight, and QW is twice as strong as steel. A grid made up of such transmission wires would have no line losses or resistance, because the electrons would be forced lengthwise through the tube and could not escape out at other angles. Grid properties would be resistant to temperature changes and would have minimal or no sag. (Reduced sag would allow towers to be placed farther apart, reducing footprint and attendant construction and maintenance impacts.) QW, if spun into noncorrosive polypropylene-like rope, could conceivably be buried "forever" with no fear of corrosion and "no need for shielding of any kind". Such a grid could have a million times greater capacity than what exists today (assuming the 1-centimeter-diameter aluminium cable carrying about 1,000 to 2,000 amps); even if the capacity were increased by only 0.1%, the amount of enhanced capacity would still be impressive.

B.3 *Nanosensors*

Nano electronics have the potential to revolutionize sensors and power-control devices. Nanotechnology-enabled sensors would be self-calibrating and self-diagnosing. They could place trouble calls to technicians whenever problems were predicted or encountered. Such sensors could also allow for the remote monitoring of infrastructure on a real-time basis. Miniature sensors deployed throughout an entire transmission network could provide access to data and information previously unavailable. The real-time energized status of distribution feeders would speed outage restoration, and phase balancing and line loss would be easier to manage.

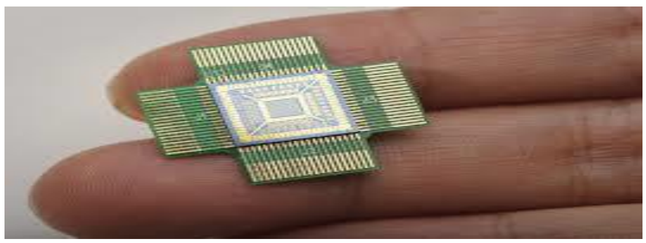

Fig.3. Silicon based sensing chip with 64 Nanosensors.

helping to improve the overall operation of the distribution feeder network. Nanosensors, or sensors made of nanomaterials, can be extremely sensitive, selective, and responsive. As such, they could be smaller and cheaper, and consume less power than conventional sensors. Sensors and controls that are small in size; work safely in the presence of electromagnetic fields, high temperatures, and high pressures. Also they be used to identify approaching vehicles or equipment that may otherwise lead to third-party damage; or, if the pipeline is damaged, provide an immediate indication (e.g., alarm or other notification) so that any potentialenvironmental damage may be mitigated quickly.

B.4 Nanoparticles

Fluids containing nanomaterials could provide more efficient coolants in transformers, possibly reducing the footprints, or even the number, of transformers. Nanoparticles increase heat transfer, and solid nanoparticles conduct heat better than liquid. Nanoparticles stay suspended in liquids longer than larger particles, and they have a much greater surface area, where heat transfer takes place. Using nanoparticles in the development of HTS transformers could result in compact units with no flammable liquids, which could help increase siting flexibility.

C. Energy usage applications

C.1 Lighting

Electricity is consumed in providing incandescent electrical efficiency, light-emitting diodes (LEDs) now rival incandescent light sources in many parts of the visible spectrum and are being used in displays, automobile lights, and traffic lights. Semiconductors used in the preparation of LEDs for lighting are increasingly being built at nanoscale dimensions, and projections indicate that nanotechnology-based lighting advances have the potential to reduce worldwide consumption of energy by more than 10% (NNI 2000). Nano crystals, also known as quantum dots, are known primarily for their ability to produce distinct colours of light as the size of the individual crystals is varied.

C.2 Air conditioning

The current buzz word in the air conditioning world is "NanoAir." This revolutionary air treatment method uses nanotechnology to eliminate the need for using common refrigerants like CFC/HCFC that are commonly used by HVAC – heating, ventilating, air conditioning, and refrigeration –industries. Since NanoAir is based on harnessing energy using nanoparticles, it doesn't need cooling/agents like fluorocarbon, thereby cutting down on carbon footprint by more than 50%. Moreover, toxic CO2emissions are reduced as much as 57%. Once this technology becomes a standard, there'll only be a huge upside to its use. Consumers will be able to save more, get more comfort, breathe in fresher, cleaner air inside and outside, and generally, enjoy a better quality of life.

Nano Air's mechanism is based on having separate controls for moisture (humidity) and temperature. This 'separation' mechanism is the value proposition of the NanoAir system and studies have determined SEER or Seasonal Energy Efficiency Ratings of higher than 30, and EER or Energy Efficiency Ratings of around 25 as a result of this method. NanoAir Requirements NanoAir spells simplicity, whether it's the parts, the system, the operation or the design. So much so that the air conditioning unit will be installed at almost the same or lower cost than the current systems. With Dias nanomaterial (Dias is the company working on this project) for internal components, the system will also use regular HVAC parts and a supply of drinkable water. The NanoAir system will contribute heavily to repair the damage caused to the environment as well as increase efficiency.

- The biggest sources of the depletion of ozone layer are fluorocarbons like CFC and HCFCs. While reducing the use of these gases has been a challenge, successful use and implementation of NanoAir can reduce these harmful emissions to ZERO!

IV.ADVANTAGES AND DISADVANTAGES

A. Advantages

- A reduction of energy consumption can be reached by better insulation systems, by the use of more efficient lighting or combustion systems, and by use of lighter and stronger materials in the transportation sector.
- Currently used light bulbs only convert approximately 5% of the electrical energy into light. Nano technological approaches like or quantum caged atoms (QCAs) could lead to a strong reduction of energy consumption for illumination.
- Commercially available solar cells have much lower efficiencies (15-20%) i.e. they utilize only (400-1000nm)spectral range of sunlight with CNF enabled micro-devices other part of spectral range can be utilized.
- Hot nuclear compounds such as corium or melting fuel rods may be contained in "bubbles" made from nanomaterial that are designed to isolate the harmful effects of nuclear activity occurring inside of them from the outside environment where organisms inhabit.

B. Limitations

- Diamonds have lost its value because it is now produced massively with the help of nanotechnology. People and manufacturer can now produce bulk of the products at molecular scale and decomposition is done to create new components as a result there is fall of certain markets like diamond and oil.
- Another big threat, which is born with the advent of nanotechnology, is the easy accessibility of atomic weapons. Nanotechnology has made these weapons more powerful and more destructive unauthorized, criminal bodies can reach nuclear weapons easily, and its formulation could be stolen.
- At present nanotechnology is on the most expensive technologies and its cost is increasing day by day. The main reason for very high cost is the molecular structure and processing of the product. It quite difficult of the manufacturers to randomly produce dynamic products with the nanotechnology. Huge pricing of nanotech machines make it unaffordable for the common people.
- Some ethical issues which include the poisoning of mass material which has been processed at nano scale, this may leave negative impacts on the health and industry. Mass poisoning could happen only if the coatings on the products that nanotechnology has to produce include poisonous micro particles that can penetrate into the brain.

VI.CONCLUSION

Thus Nanotechnology provides the potential to enhance energy efficiency across all branches of industry and to economically leverage renewable energy production through new technological solutions and optimized production technologies. In the long run, essential contributions to sustainable energy supply and the global climate protection policy will be achieved. On overcoming limitations of nanotechnology in energy sector, the energy applications can be fulfilled as per design.

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