Syllabus-Module II: New Vistas in Chemistry (6 hrs)

Module II: New Vistas in Chemistry (6 hrs)

Nanochemistry: Introduction – classification of nanomaterials (0D, 1D, 2D) – size dependence of material properties (optical, electrical and catalytic) - surface to volume ratio and its significance - application of nanomaterials in electronics, optics, catalysis and medicine (detailed discussion not expected).

Green Chemistry: Definition and need of green chemistry - principles (detailed discussion **not expected) - atom economy - green solvents - green synthesis of Ibuprofen.**

References

1. M. A. Shah, Tokeer Ahmad, *Principles of Nanoscience and Nanotechnology*, *Narosa* Publishing House, New Delhi, 2010.

2. T. Pradeep, *A Textbook of Nanoscience and Nanotechnology, McGrawhill*, *New Delhi*, 2012.

3. V. K. Ahluwaliya, *Green Chemistry*, *Narosa Publishing House*, *New Delhi*, *2011*.

The Green Chemistry – Introduction

Hypothetical Reaction

$$A + B \longrightarrow C$$

Imagine

No by-products
No waste
At ambient temperature
No need of separation

Chemistry is not straight forward as people are !
We have less than perfect chemical reactions !

Chemistry has less than perfect chemical reactions

Chemistry : Has impurities to remove, solvents to purified, hazardous materials to manage, hazardous reaction conditions to control, energy transfer to optimise, competing reactions to avoid, by-products to separate, and recover and etc.

$A + B \longrightarrow C$ is not so Simple

Green Chemistry- Definition

Green chemistry is defined as "The invention, design and application of chemical products and processes to reduce or to eliminate the use and generation of hazardouz substances"

It involve tools and principles used to make chemical reactions more efficient, safer, cleaner and produce less waste.

It assists us in thinking about and designing synthetic routes and processes that are more similar to the hypothetical reaction $A + B \longrightarrow C$ without any by-products, with out any waste, operates at ambient temperature and no need of separation etc.

Green chemistry is a philosophy of chemical research and engineering that encourages the design of products and processes that minimize the use and generation of hazardous substances.

Green chemistry - Focus

Green chemistry focuses on using less toxic reactants by adopting micro-scale methods to achieve the goal of eliminating toxic emissions altogether by systematic phase-out of low efficiency processes replaced by better alternatives.

Green chemistry - Objective

The Objective of Green Chemistry is the design of most efficient chemical reactions which leads to have lowest environmental impact and synthesis of environmentally benign materials.

The Green Chemistry – The history

The interest in Green Chemistry was **first started in USA** when the **pollution prevention act was passed in 1990**. When all the previous acts dealt with the aftermath of pollutions and the cleaning aspects, this act first dealt with the prevention of pollution.

Pollution Prevention Act 1990

- Pollution Prevention can be accomplished by several approaches:
  - Inventory controls.
  - Process controls.
  - In-process recycling.
  - Housekeeping changes.
  - Green Chemistry.

History of Green Chemistry

Then the **Environmental Protection Agency (EPA)** got involved in the **activities of Green Chemistry**. This led to the invention of new technologies and processes to avoid the formation and or use of hazardous substances.

Reactions were encouraged to be conducted in solid state or in green solvents of natural origin (water).

Nobel Prize in 2005 was for Green Chemistry [Yves Chauvin (France), Robert Grubbs (USA) and Richard Schrock (USA)] for the development of metathesis (energetically favoured and less hazardous method in organic synthesis)

History of Green Chemistry

Three key developments in green chemistry (identified by Ryoji Noyori in 2005)

Ryōji Noyori - Japanese Chemist- Nobel Prize Winner in Chemistry-2001- Study of chirally catalyzed hydrogenations and Oxidations

The term Green Chemistry was coined by Paul Anastas in 1991. Paul Anastas, Director, Center for Green Chemistry and Green Engineering, Department of Chemistry, Yale University, USA

The term *green chemistry* was coined by Paul Anastas in 1991.

Green chemistry and Environmental Chemistry

Environmental Chemistry is the chemistry of the natural environment and pollutant chemicals in nature and their chemical phenomena in the environment.

Green chemistry seeks to reduce and prevent pollution at its source.

Therefore both are different.

Need of Green Chemistry

Developments in chemistry led to great improvement in the quality of life but they also led to environmental pollutions

1. Societal Image of Chemistry has changed from a **Central Science** to a **Terminator Science**

   Chemistry was once viewed as a field of innovation yielding medical developments and modern conveniences. **But now chemistry is viewed by the society as the science the mostly pollutes the planet-**

2. Pollution due to pesticides - DDT, highly water soluble carbofuran, endosulphan etc. with very high decomposition temperature – accumulates in the animal tissues.
3. Pollution due to CFC – Used as solvents, refrigerants, and propellants for aerosols – Highly unreactive and therefore they remain in the atmosphere for long time – In UV light, they react with O_3 causing O_3 holes.

4. Pollution due to acid rain – Due to oxides of N_2 and S
5. Pollution due to global warming- Due to the release of CO_2, CH_4, NO, CFC to the atmosphere.

6. Pollution due to disasters

(a). Bhopal gas tragedy: Release of MIC-death of over 25000 people – serious injuries to over 200000 people

(b). Vietnam War – Agent Orange herbicide spray by US military to destroy forest cover - But the herbicide was contaminated by Dioxine (most dangerous carcinogenic)

(c). Europe-Thalidomide- Used by pregnant women to reduce the effects of nausea and vomiting – children were affected with acute birth defects

(d). Love Canal disaster – Chemical dumping

(e). Photochemical Smogs (London & Los Angeles smog)

Love Canal disaster – Chemical dumping

Love Canal in Niagara Falls, NY a chemical and plastics company had used an old canal bed as a chemical dump from 1930s to 1950s. The land was then used for a new school and housing track. The chemicals leaked through a clay cap that sealed the dump. It was contaminated with at least 82 chemicals (benzene, chlorinated hydrocarbons, dioxin). Health effects of the people living there included: high birth defect incidence and siezure-inducing nervous disease among the children.

Cuyahoga River – Cleveland, Ohio

There were many things being dumped in the river such as: gasoline, oil, paint, and metals. The river was called "a rainbow of many different colors". Fires erupted on the river several times before June 22, 1969, when a river fire captured national attention when Time Magazine reported it. (Time Magazine, August 1969)

7. Pollution due to Diseases

Minamata in Japan (from eating fish contaminated with methyl mercury chloride)
Itai Itai (Cd poisoning)
Methaemoglobinaemia (high concentration of nitrate ion in leafy vegetables due to the excessive use of nitrogen fertilisers-nitrate is reduced to nitrite in body-which oxidised Fe in Haemoglobin to Methaemoglobin which lacks oxygen carrying capacity-Lack of Haemoglobin caused the birth of blue babies and even neonatal deaths)

In all these contexts of environmental pollution and related diseases, Green Chemistry plays an important role to keep the environment clean (by preventing the pollution (formation of hazardous by products) using appropriate methods, conditions and starting materials), to address environmental issues in an economically profitable view and taking these to even school class rooms and laboratory.

12 + 12 principles of green chemistry

Paul Anastas and John C. Warner developed 12 principles of green chemistry to cover the

<u>Main concepts or goals of Green Chemistry</u>

1. The design of processes to maximize the amount of raw material that ends up in the product.
2. The use of safe, environment-benign substances, including solvents, whenever possible.
3. The design of energy efficient processes, the best form of waste disposal: not to create it in the first place

12 principles of Green Chemistry

1. It is better to prevent waste than to treat or clean up waste after it is formed.
2. Synthetic methods should be designed to maximise the incorporation of all materials used in the process in to the final product.
3. Wherever practicable, synthetic methodologies should be designed to use and generate substances that possess little or no toxicity to human health and the environment.
4. Chemical products should be designed to preserve efficacy of function while reducing toxicity.
5. The use of auxiliary substances (e.g. solvents, separation agents, etc.) should be made unnecessary wherever possible and innocuous when used.

12 principles of Green Chemistry

6. Energy requirements should be recognized for their environmental and economic impacts and should be minimized. Synthetic methods should be conducted at ambient temperature and pressure.
7. A raw material or feedstock should be renewable rather than depleting wherever technically and economically practicable.
8. Reduce derivatives –Unnecessary derivatization (blocking group, protection / deprotection, temporary modification) should be avoided whenever possible.
9. Catalytic reagents (as selective as possible) are superior to stoichiometric reagents.

12 principles of Green Chemistry

10. Chemical products should be designed so that at the end of their function they do not persist in the environment and break down into harmless degradation products.
11. Analytical methodologies need to be further developed to allow for real-time, in-process monitoring and control prior to the formation of hazardous substances. The monitoring of chemical processes, side reactions and dangerous by-products must be done.
12. Substances and the form of a substance used in a chemical process should be chosen to minimize potential for chemical accidents, including releases, explosions, and fires.

Twelve Principles of Green Chemistry

1. Prevention
2. Atom Economy
3. Less Hazardous Chemical Syntheses
4. Designing Safer Chemicals
5. Safer Solvents and Auxiliaries
6. Design for Energy Efficiency
7. Use of Renewable Feedstocks
8. Reduce Derivatives
9. Catalysis
10. Design for Degradation
11. Real-time Analysis for Pollution Prevention
12. Inherently Safer Chemistry for Accident Prevention

12 More Principles of Green Chemistry

1. Identify and quantify by-products
2. Report conversions, selectivities and productivities
3. Establish full mass balance for a process
4. Measure catalyst and solvent losses in aqueous effluent
5. Investigate basic thermochemistry
6. Anticipate heat and mass transfer limitations
7. Consult a chemical or process engineer
8. Consider the effect of the overall process on the choice of chemistry
9. Help develop and apply sustainability measures
10. Quantify and minimise the use of utilities
11. Recognize where safety and waste minimisation are incompatible.
12. Monitor, report and minimise laboratory waste emitted.

12 principles of Green Chemistry Explained

1. ***It is better to prevent waste than to treat or clean up waste after it is formed.***

   Explanation: Here the concept is 'prevention is better than cure'. One a waste is formed, it remains unreacted, then actually the starting materials are wasted and we have also spent for that wasted material. If that waste is not cleaned, it will create environmental pollution. How ever, the cleaning up of the waste after its formation is expensive than eve the cost of the starting materials.

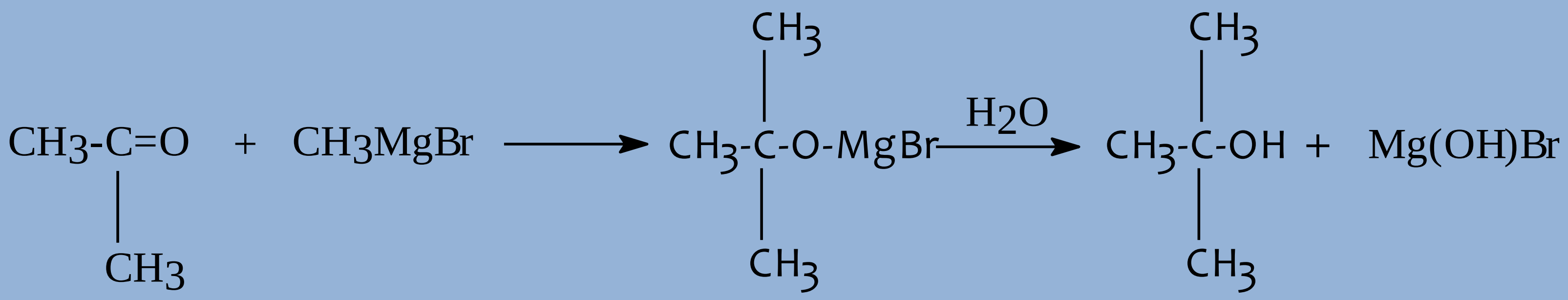
   Suggestion: Carry out reactions and titrations at a lower concentrations (say 0.01 N) than the current 0.1 N so that waste formation can be reduced (Perform microscale experiments?). But the indicator used should be able to show colour change at the correct end point.

2. Synthetic methods should be designed to maximize the incorporation of all materials used in the process into the final product.

Explanation: When one mole of the reactant starting material is converted fully to one mole of product, the yield is 100 %.

% Yield = [(Actual yield to the product) / Theoretical yield] 100

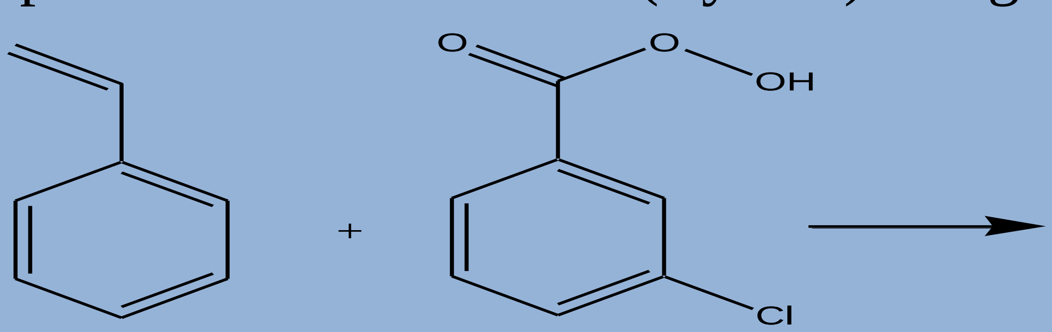
A particular reaction may give 100 % yield, but it may involve a significant amount of by-products generation. The above equation ignores the formation of by-products which is actually a waste. Therefore, even though the reaction gives 100 % yield, the synthesis cannot be considered as a Green Synthesis. **For example see below;**



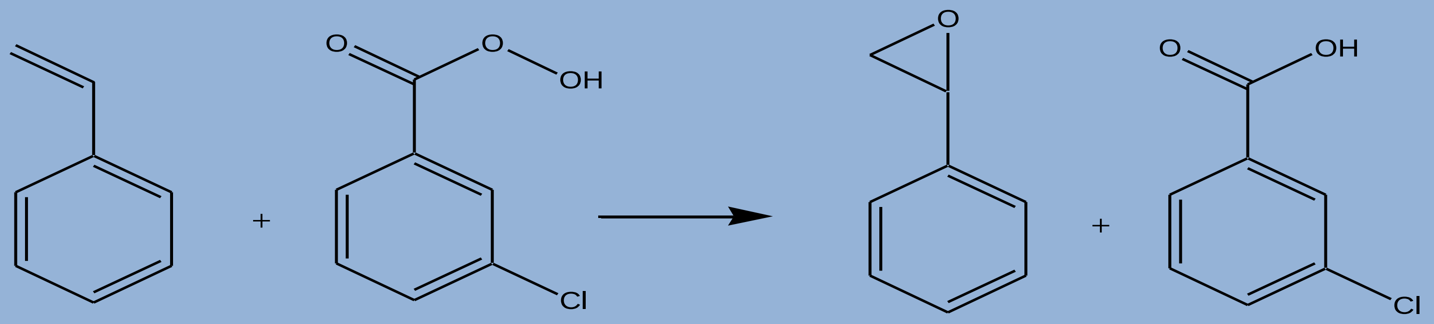
Acetone Methyl Mg Bromide
1 mole, 58 g

tert-Butyl alcohol 1 mole, 121.2 g
1 mole, 74 g BYPRODUCT-WASTE

Epoxidation of an alkene (styrene) using a peroxyacid (100 % yield)



How many biproducts? How much waste? Is it env friendly waste? Energy requirement? Need purification steps? Solvents? Catalysts?



Assume 100% yield.

100% of the desired epoxide product is recovered.

100% formation of the co-product: m-chlorobenzoic acid.

A.E. of this reaction is 23%. 77% of the products are waste.

Therefore, even though the reaction gives 100 % yield, the synthesis cannot be considered as a Green Synthesis.

Second Principle works on the basis of a number of concepts

A. Concept of Atom Economy

In a true Green Synthesis, all the atoms in the starting material must be incorporated in to the final product so that byproducts should not be formed as waste. This is called **Atom Economy** in a Green Synthesis (Concept by Barry Trost, Stanford University).

According to Berry Trost,

Percentage Atom Utilization = [(Mol. Wt. of desired Product)/(Mol. Wt. of formed product + Mol. Wt. of Waste Product)] 100

Percentage Atom Economy = [FW of atom utilised/FW of all the reactants used in its reaction]100

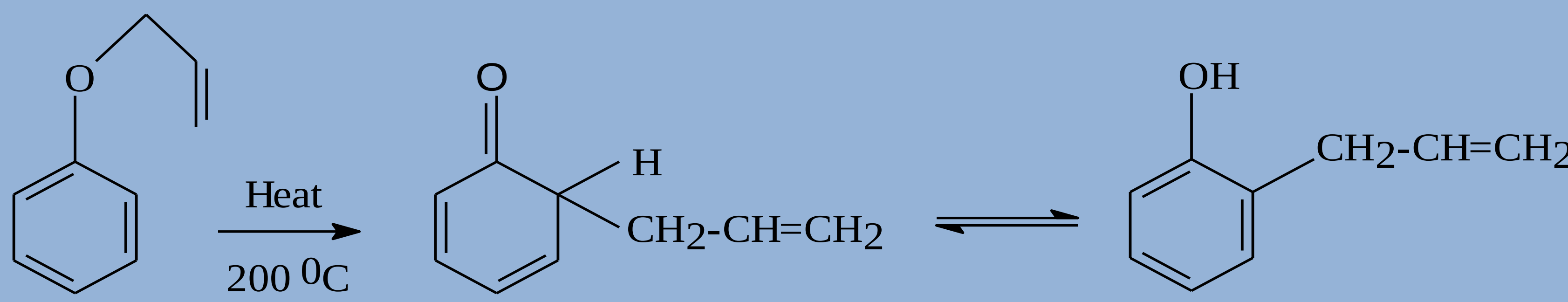
(In order to find, if a particular reaction is green, the concept of atom economy was developed by Berry Trost of Stanford University).

Atom Economy and various organic Syntheses

1. Atom Economy and Rearrangement Reactions

   A rearrangement reaction involves only a re-organisation of atoms, therefore all the reactant atoms are incorporated in to the final product. Therefore it has 100 % atom economy.

   Example: Claisen Rearrangement – Heating of Allyl phenyl ether at 200 ^{0}C gives o-allyl phenol.



Allyl phenyl ether

o-Allyl Phenol

Percentage Atom Economy = [FW of atom utilised/FW of all the reactants used in its reaction]100 = [134.173/134.173] 100 = 100 %

Atom Economy and various organic Syntheses

2. Atom Economy and Addition Reactions [most preferred]

An addition reaction involves the addition of groups to a molecule across a double or triple bond.

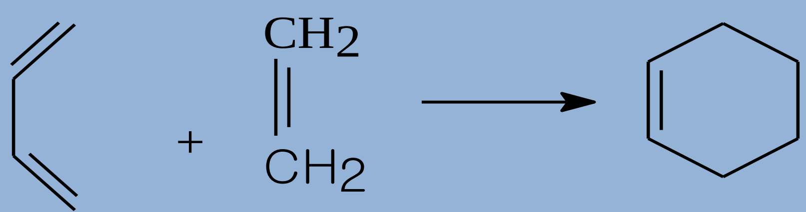
As the atoms or groups of atoms are added only, addition reactions also has 100 % atom economy.

Example: Catalytic Hydrogenation

$$CH_3\text{-}CH{=}CH_2 + H_2 \xrightarrow{Ni} CH_3\text{-}CH_2\text{-}CH_3$$

Propene Propane

Percentage Atom Economy = [FW of atom utilised/FW of all the reactants used in its reaction]100 = [44/44] 100 = 100 %



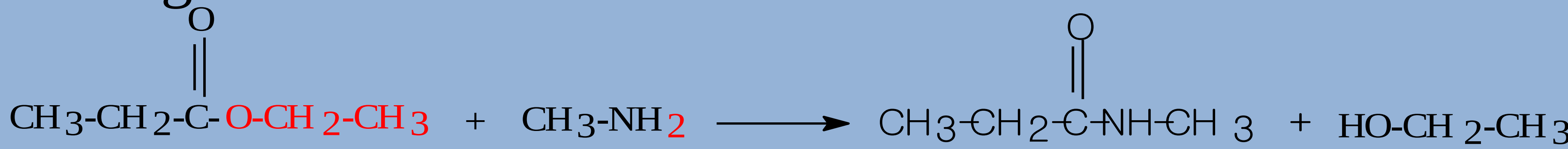
Butadiene Ethene Cyclohexen

Percentage Atom Economy = [FW of atom utilised/FW of all the reactants used in its reaction]100 = [82/82] 100 = 100 %

Atom Economy and various organic Syntheses

3. Atom Economy and Substitution Reactions

A substitution reaction involves the replacement of one atom or a group of atoms by another atom or group of atoms. As the atom which is replaced is not used in the final product, substitution reactions are less atom economical than rearrangement or addition reactions.



Ethyl propionate | Methyl amine | N-methyl propamide (Product) | Ethyl alcohol

LHS – black- Utilised in the product, Red –unused(C_2H_5O + H)

Reagent Formula = $C_5H_{10}O_2 + CNH_5 = C_6H_{15}O_2N$

Reagent FW = (12X6) + (1X15) + (16X2) + (14X1) = 133

Utilised Formula = $C_3H_5O + CH_4N = C_4H_9NO$

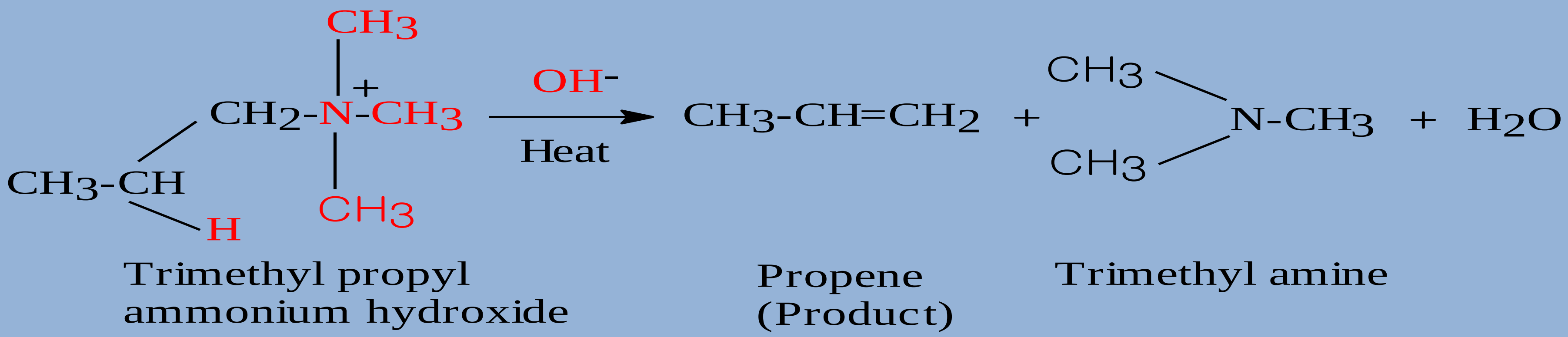
Utilised FW = (12X4) + (1X9) + (14X1) + (16X1) = 87

Atom Economy = [87/133]100 = 65 %

Atom Economy and various organic Syntheses

4. Atom Economy and Elimination Reactions

In an elimination reaction, two atoms of a group of atoms are lost from the reactant and this results in a π bond. As the two atoms eliminated are not incorporated in the final product, elimination reactions will have low atom economy.



LHS – black- Utilised in the product, Red –unused($C_3H_{11}NO$)

Reagent Formula = $C_6H_{16}N$ + OH = $C_6H_{17}NO$

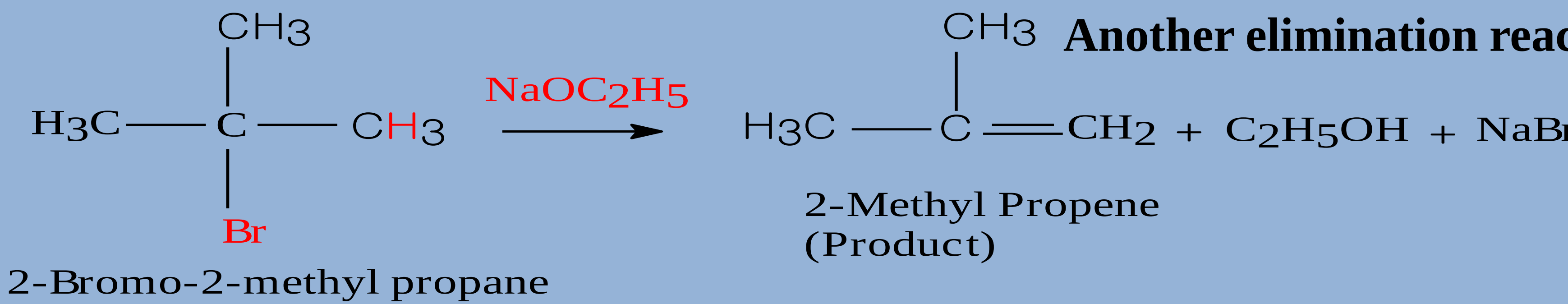
Reagent FW = (12X6) + (1X17) + (14X1) + (16X1) = 119

Utilised Formula = C_3H_6

Utilised FW = (12X3) + (1X6) = 42

Atom Economy = [42/119]100 = 35 %

Another elimination reaction



LHS – black- Utilised in the product, Red –unused($C_3H_{11}NO$)

Reagent Formula = $C_4H_9Br + C_2H_5NaO = C_6H_{14}NaOBr$

Reagent FW = (12X6) + (1X14) + (23X1) + (16X1) + (80X1) = 205

Utilised Formula = C_4H_8, Utilised FW = (12X4) + (1X8) = 56

Atom Economy = [56/205]100 = 27 %

Thus a Green Synthesis should

(1). be atom economic

(2). result in a nontoxic product which is easily extractable and purifiable without the consumption of large amount of materials,

3. consume less energy

4. Show selectivity(chemoselectivity, regioselectivity, enantioselctivity and diastereoselectivity)

Atom Economy– Other Examples

Ethylene to ethylene oxide via chlorohydrin [chlorohydrion route]

$$CH_2{=}CH_2 + Cl_2 + H_2O \longrightarrow Cl\text{-}CH_2\text{-}CH_2\text{-}OH + HCl$$

$$Cl\text{-}CH_2\text{-}CH_2\text{-}OH + Ca(OH)_2 \longrightarrow \overset{O}{CH_2 — CH_2} + CaCl_2 + H_2O$$

$$CH_2{=}CH_2 + Cl_2 + Ca(OH)_2 \longrightarrow \overset{O}{CH_2 — CH_2} + CaCl_2 + H_2O$$

Atom Economy = 0.25

[Home work: Calculate AE and F factor]

5. The use of auxiliary substances (e.g. solvents, separation agents, etc.) should be made unnecessary wherever possible and innocuous when used.

Auxiliary substances are used in the processing and many other stages in the manufacture but their harmful effects may be unknown. Many solvents and CFC's used as auxiliary substances are **carcinogenic and toxic to human beings, animals and environment**.

Pfizer's results: Solvent Replacement Guide

1. 50% reduction in chlorinated solvent use across the whole of their research division (more than 1600 lab based synthetic organic chemists, and four scale-up facilities) during 2004-2006.
2. Reduction in the use of an undesirable ether by 97% over the same two year period
3. Heptane used over hexane (more toxic) and pentane (much more flammable)

Preferred	Useable	Undesirable
Water	Cyclohexane	Pentane
Acetone	Heptane	Hexane(s)
Ethanol	Toluene	Di-isopropyl ether
2-Propanol	Methylcyclohexane	Diethyl ether
1-Propanol	Methyl t-butyl ether	Dichloromethane
Ethyl acetate	Isooctane	Dichloroethane
Isopropyl acetate	Acetonitrile	Chloroform
Methanol	2-MethylTHF	Dimethyl formamide
Methyl ethyl ketone	Tetrahydrofuran	N-Methylpyrrolidinone
1-Butanol	Xylenes	Pyridine
t-Butanol	Dimethyl sulfoxide	Dimethyl acetate
	Acetic acid	Dioxane
	Ethylene glycol	Dimethoxyethane
		Benzene
		Carbon tetrachloride

Red Solvent	Flash point (° C)	Reason
Pentane	-49	Very low flash point, good alternative available.
Hexane(s)	-23	More toxic than the alternative heptane, classified as a HAP in the US.
Di-isopropyl ether	-12	Very powerful peroxide former, good alternative ethers available.
Diethyl ether	-40	Very low flash point, good alternative ethers available.
Dichloromethane	n/a	High volume use, regulated by EU solvent directive, classified as HAP in US.
Dichloroethane	15	Carcinogen, classified as a HAP in the US.
Chloroform	n/a	Carcinogen, classified as a HAP in the US.
Dimethyl formamide	57	Toxicity, strongly regulated by EU Solvent Directive, classified as HAP in the US.
N-Methylpyrrolidinone	86	Toxicity, strongly regulated by EU Solvent Directive.
Pyridine	20	Carcinogenic/mutagenic/reprotoxic (CMR) category 3 carcinogen, toxicity, very low threshold limit value (TLV) for worker exposures.
Dimethyl acetate	70	Toxicity, strongly regulated by EU Solvent Directive.
Dioxane	12	CMR category 3 carcinogen, classified as HAP in US.
Dimethoxyethane	0	CMR category 2 carcinogen, toxicity.
Benzene	-11	Avoid use: CMR category 1 carcinogen, toxic to humans and environment, very low TLV (0.5 ppm), strongly regulated in EU and the US (HAP).
Carbon tetrachloride	n/a	Avoid use: CMR category 3 carcinogen, toxic, ozone depletor, banned under the Montreal protocol, not available for large-scale use, strongly regulated in the EU and the US (HAP).

Undesirable Solvent	**Alternative**
Pentane	Heptane
Hexane(s)	Heptane
Di-isopropyl ether or diethyl ether	2-MeTHF or *tert*-butyl methyl ether
Dioxane or dimethoxyethane	2-MeTHF or *tert*-butyl methyl ether
Chloroform, dichloroethane or carbon tetrachloride	Dichloromethane
Dimethyl formamide, dimethyl acetamide or N-methylpyrrolidinone	Acetonitrile
Pyridine	Et_3N (if pyridine is used as a base)
Dichloromethane (extractions)	EtOAc, MTBE, toluene, 2-MeTHF
Dichloromethane (chromatography)	EtOAc/heptane
Benzene	Toluene

Environmental Issues of organic solvents

1. Photochemical Ozone Creation Potential (POCP)

   The highly volatile organic solvents (VOC) can produce photochemical ozone by reacting with nitrogen oxides. This can lead to smog formation.

2. A number of organic solvents ($CHCl_3$, CH_3Cl, CH_2Cl_2, 1,1,1-trichloethane) have global warming potentials while others such as CCl_4 and1,1,1-trichloethane are ozone layer depleters.

3. Most of these solvents have low LD-50 or LC-50 values (lethal dose or lethal concentration).

4. Organic solvents have total life cycle impacts on environment.

   Total environmental footprint of solvent use = manufacturing impacts + solvent use impacts + solvent disposal impacts.

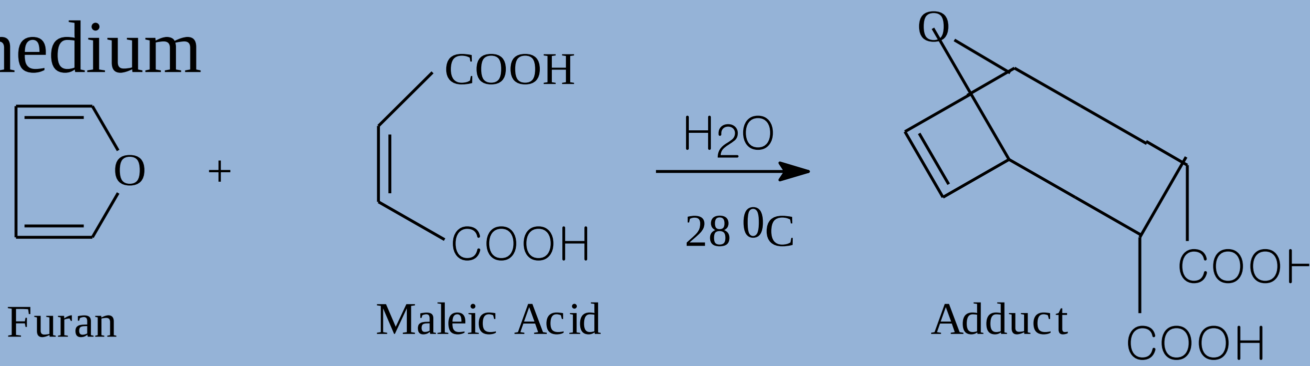
5. Health and safety issues of solvents (carcinogenic nature, hexane flash point is -22 ^{0}C).

It is better to use **green solvents** such as water and super critical CO_2, ionic liquids and the reactions can be carried out in the solid state with out any solvent.

A. Use of water as a Green Solvent

Use of Water as a solvent is economic and helps the easy separation of products from by-products.

Eg., Diels-Alder reaction of furan with Maleic acid in water medium



Other Examples of reactions in aqueous medium

Pericyclic reactions, Michael addition, Wittig reaction, Benzoin condensation etc.

[Home Work: Collect details of the above reactions in aqueous medium]

Use of supercritical water (SCW) as a Green Solvent

Water near its critical point (374 ^{0}C, 218 atm) has properties different from normal water. Supercritical water has much lower dielectric constant and very few hydrogen bonds and lower persistence of hydrogen bonds. Also, SCW has ionic product or dissociation constant that is three times higher than that of normal water. The high concentration of H^+ and OH^- due to this behaviour, increases its application in acid/base catalysed reactions. Therefore, organic solvents and gases have high solubility in SCW. Reactions carried out in SCW medium are

1. Conversion of glucose to pyruvaldehyde, dihydroxy acetone, fructose etc.
2. Oxidation of phenol to water and CO_2.

B. Supercritical CO_2 as Green Solvent

At 1 atm. pressure and room temperature (28 ^{0}C), CO_2 is a gas. It freezes at – 70 ^{0}C to a solid which sublimes and thus cools without wetting and is therefore called **dry ice.** Dry ice when placed in a sealed tube sublimes and thus builds up pressure. On increasing the pressure, it becomes a liquid. In the phase diagram of CO_2, there is a triple point (-56 ^{0}C and 5.1 atm.) at which it exists simultaneously as a solid, liquid and gas. At another point (31 ^{0}C and 73 atm.), it exists as a **supercritical fluid**. The specialty of the supercritical state is that its **viscosity is similar to that of a gas and density is similar to that of a liquid.** Therefore, this supercritical CO_2 can be used as a solvent to conduct many reactions

Chemical Synthesis Using Liquid or Supercritical Carbon Dioxide.

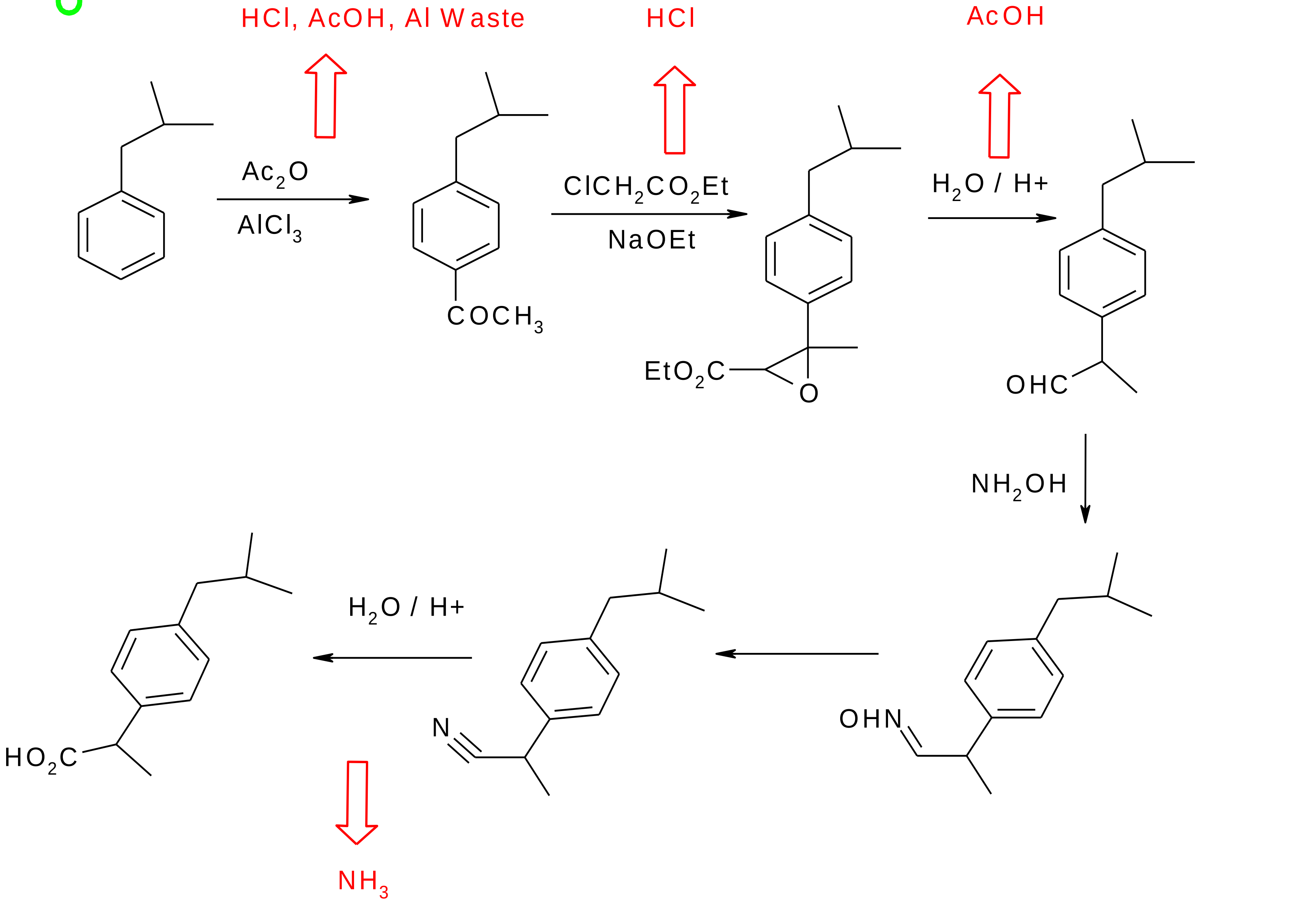
- Liquid or SC-CO_2 as an alternative "green" solvent
  - non-toxic, non-flammable, inexpensive, environmentally benign;
- Basic Physical Properties:
  - solvating power similar to hexane and CCl_4;
  - Miscibility with gases such as H_2 and O_2;
  - Can evaporate as gas on lowering to atmospheric pressure, therefore facilitates purification. Useful for extraction (decaffeinated coffee).

Drying of milk powder – Freeze drying]

7. A raw material or feedstock should be renewable rather than depleting wherever technically and economically practicable.

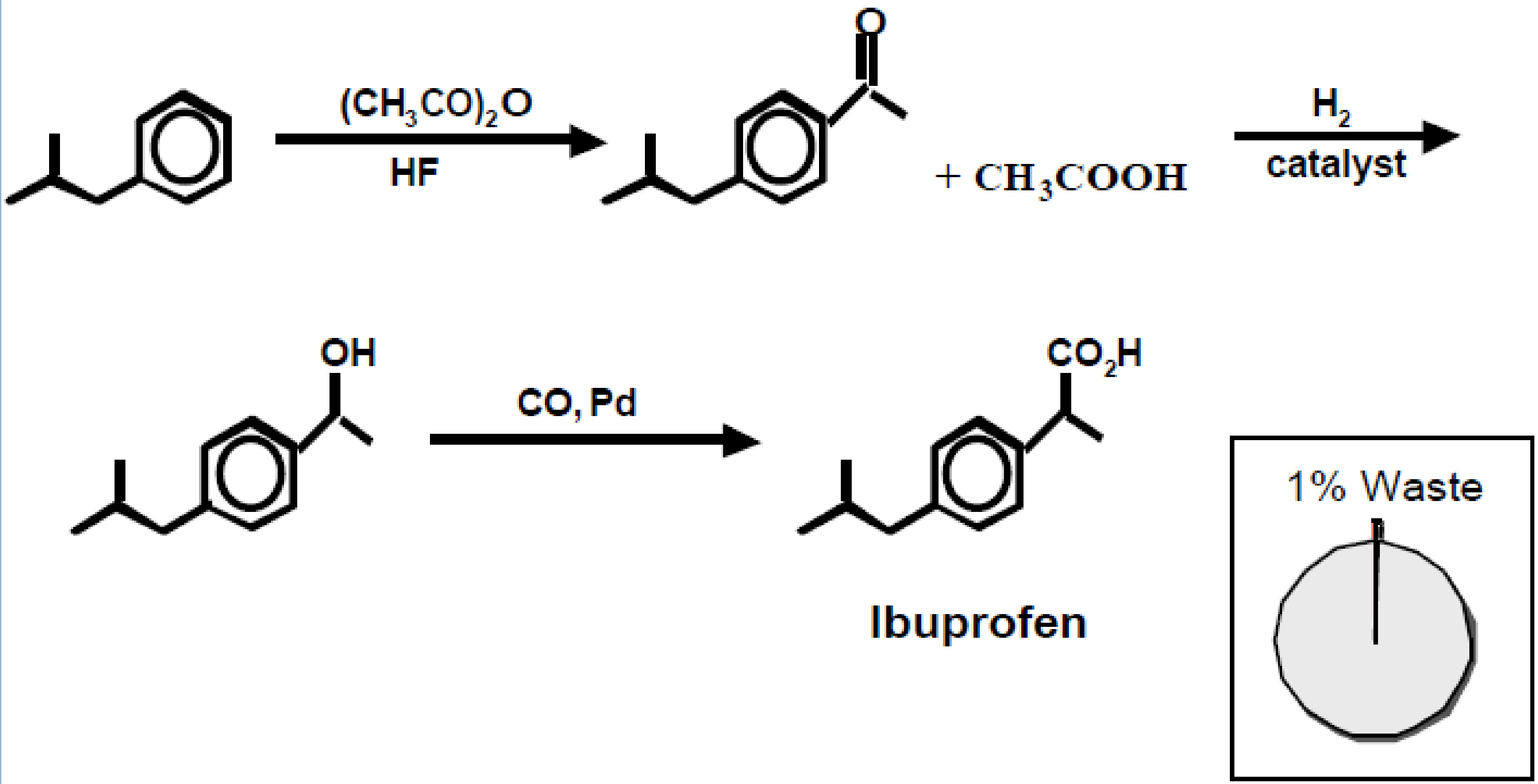
Petrochemicals can be obtained from renewable and non-renewable resources. But as the non-renewable resources such as coal and petroleum oil are limited and get finished with the use, **they are not regarded as sustainable in environmental aspects.** Also the formation of petroleum oil takes millions of years. Green chemistry always suggests the realisation of work using fuels from **renewable resources such as Jathropa, bio-ethanol by fermentation, solar energy, CO_2,CH_4 (available excess)** etc. But there are concerns about these biological and renewable feed stocks also. These are the possibilities of crop failure, time consumption and need of land for maintaining a constant supply.

Classic Route to Ibuprofen



Green Synthesis - Ibuprofen

Green Chemistry Alternative Synthesis of Ibuprofen



Microwave Organic Synthesis

Not only thermal energy, but also photoenergy (microwave) (new), sono (ultrasound) energy (new), electrochemical energy (old) and enzymatic energy (old) for chemical reactions.

Sonication of the matter also creates thermal energy

An ultrasonic transductor made of Quartz produces ultrasonic waves by the principle of **piezoelectric effect**. The application of equal and opposite electric charges to the opposite faces of a quartz crystal produces contractions and expansions of the crystal. When the charges are reversed rapidly, the resulting vibration produces ultrasonic waves. When these ultrasonic waves passes through a liquid medium, its molecules also oscillate and this creates the formation and collapse of small bubbles and this creates very high temperature and pressure (even up to 5000 ^{0}C and 1000 bar). The formation of such a high temperature and pressure initiates chemical reactions.

Limitations of Green Chemistry

1. A particular pollutant may be of high toxicity, unknown toxicity, chronic toxicity or carcinogenicity which are unknown characteristics of the pollutant. The fixing of the upper limit of various chemical pollutants in to various segments of the environment is very difficult and hence the fixing of their tolerance level (level of pollution that every living organism can tolerate) is also very difficult.
2. Green chemistry is thought to be as an innovative way of thinking but on the other hand, some chemists think that green chemistry is no more than a public relations label. In fact, a lot of chemists use the term "green chemistry" independently from the green chemistry paradigm, as proposed by Anastas and Warner. For example, if a titration can be conducted at 0.001 N concentration rather than the usual 0.1 N, it involves Green Chemistry as it reduces the use of chemicals. Thus there is an uncertainty of the scientific status of green chemistry.

Nano – Greek Word for Dwarf (means one billionth)

A strand of Human hair is 75000 nm across

10 hydrogen atoms side by side = 1 nm

Why do we need nanotechnology ? Nanotech bubble

A. Security and Service

1. Superior light weight smart materials (Performance to weight ratio must be high)
   Steel Shield for soldiers replaced with Kevlar fibers which now being replaced with nanomaterials which can give better protection and monitor the health condition of soldiers. (multiservices).
2. Advanced computing (quantum computing)
3. Increased situational awareness (chemical sensors)
4. Powerful Munitions (nanosized metals are more chemically reactive due to smaller size and high surface area).
5. Robotic services in daily life, bank services, Warfield (like C-3PO robot in starwars)

B. Healthcare

1. **Better diagnostics (lab on a chip , quick neonatal gene mapping, new contrast agents that float through blood)**
2. **Novel drugs - Nanoshells 100 nm dia float through body and attach only to cancer cells which when excited with a laser can cause heat to destroy the cell- Biocompatible joint replacements and artery stents which are life long lasting**

C. Resource

1. **Energy – Save energy by better and efficient conversion of electrical energy to light energy by quantum dots (nanocrystals of 5 nm across) – 2025 will be nanotech energy year**
2. **Water – Efficient water purification techniques (sea water desalination) help third world countries to get better drinking water.**

Future Expectations using Nanotechnology

1. Flexible cellphone with very long battery life, (quick charge-slow discharge-capacitors) range everywhere.
2. GPS which is smaller and accurate
3. Faster and smaller computers
4. Great memory in small space
5. Quick and accurate DNA fingerprinting

Fabrication in Nanoscale can be done by 2 appraoches

1. **A top–down approach – Cutting down of a big object to small object – Less time consuming**
   E.g., Microprocessor manufacturing
2. **A bottom–up approach – Self assembly process – More time consuming - E.g., Nanotube construction method**

History of Nanoscience – Three Pioneers

1. **Richard Feynman – The vision of Nanoscience (Richard Feynman - Nobel Prize 1965 – Quantum) electrodynamics]**

Lecture given by Physicist Richard Feynman at an American Physical Society Meeting at Caltech on December 29,1959:
There is Plenty of Room at the Bottom
2. Gerd Binning and Heinrich Rohrer (IBM Zurich Research lab) – created SEM.
3. Robert F Curl Jr, Harold W Kroto and Richard E

Nanotechnology turns fifty

The predictions of Feynman, to a large extent, have been realised today

December 29,1959 to December 29, 2009

On December 29, 2009, we celebrated the golden jubilee of Nanotechnology. It was on this day, fifty years ago Professor Richard P. Feynman (Nobel Laureate, 1965) delivered the celebrated talk, 'There's plenty of room at the bottom,' which predicted the era of nanotechnology — the technology of nanometre scale objects.

He proposed a new kind of technology by assembling things atom by atom, in today's terms, 'molecular nanotechnology'. The terminology, nanotechnology itself came into being in 1974, due to Professor Norio Taniguchi.

Feynman talked about writing the entire Encyclopaedia Britannica on the tip of a needle; he envisioned that one day the entire information of the world could be contained in an envelope!

He forecasted that little motors could move within blood vessels and do surgeries, as if the surgeon has gone. No talk was talked about so extensively as this one in the history of science, except probably the 'Candle light lectures' of Faraday.

The predictions of Feynman, to a large extent, have been realised today. Since 1991, we arrange atoms one at a time to create well-defined structures. Feynman said, "The principles of physics, as far as I can see, do not speak against the possibility of manoeuvring things atom by atom." A new methodology to see and place atoms called scanning tunnelling microscopy came in 1981 and numerous modifications of this tool revolutionized all branches of science.

THE POWER: *Nanotechnology implies the power to manipulate matter at the atomic level.* – PHOTO: V. SREENIVASA MURTHY

It is possible to direct tiny diagnostic and therapeutic objects into the body and even into specific cells. Although such 'surgeons' do not travel through the blood vessels as of now, diagnostic and therapeutic agents do. Single elements of electronic storage are now in nanoscale so that entire libraries can be written in hand-held devices. Molecules have been shown to store information.

The evolution

It is now possible to see the evolution in size, shape and properties of pieces of matter, atom by atom – as the object is made. As a result, we can probe questions such as the electrical conductivity of a single DNA strand or strength of single chemical bonds.

When one looks at matter closely, new phenomena are discovered. For example, one can make gold emitting light in all colours — from blue to red! New phenomena have made natural sciences most exciting.

Global nanotechnology research budget is substantial.

In the U.S. alone, the projected budget for FY 2010 is $1.6 billion. A sum of $10.1 billion was spent in this area in the U.S. during 2001-2009. Indian efforts have been small, the government started a Nano Mission two years ago with an investment of Rs.1,000 crores in five years.

Nanotechnology is expected to produce goods and services worth $2.6 trillion in the year 2014 globally. A total of about 400,000 research papers and 100,000 patents have already come out in the area. Annual research publications are nearly 59,000 in 2009. It grew five fold in 2000-2009.

Another peak?

What would nano do to the world? Will it be another peak in the unending chain of scientific excitements? Nanotechnology implies the power to manipulate matter at the atomic level. It is the power of the creator, as all are constructed with atoms.

Once this capability is comprehended fully, nothing that matter can deliver is impossible. Naturally, promises are plenty. It may appear like science fiction when topics such as single cell therapy are proposed. It is possible to repair the molecular machinery of life and thereby control, prevent and extend biological functions.

Materials can be made super tough, super light, etc; after all carbon is the toughest and still quite light. It may one day be possible to harvest all the energy needed for the planet from the sun and if more is needed, there is the reaction between hydrogen and oxygen forming water. The world may be clean and green again. Well, nanotechnology does give hopes.

Thinking of such possibilities, this is what is going on in nature. All the carbohydrate which plants cook in their leaves, to keep us going, is made atom by atom, from carbon dioxide and water, using sunlight.

In the way we convert that food to energy and then to work, very little wastage occurs. If biological machinery were to be as inefficient as our motors, the food we produce cannot even sustain one-tenth of the population. Thus, biology is nanotechnology in perfection.

Similarly best chemistry is nanotechnology. It converts atoms to molecules in a clean and green manner, chemists say with high atom efficiency. All physics is ultimately that is done at the atomic level. This convergence of disciplines at the nanometre level is probably one of the biggest benefits of nanotechnology.

T. PRADEEP
IIT Madras

Size Dependence of Properties or Unique properties due to Nanosize

As the physical properties are strongly dependent on the size of the particles of the substance, nanosystems display unusual physical and chemical properties.
Normally, in macroscience, composition must be changed to change the properties . But in nanoscience, properties can be changed by just varying the particles sizes to nano dimensions (without varying the Composition). The main reason for the change in properties is the considerable increase in surface area to volume ratio when a material dimension changes from macro or micro to nanodimensions. Owing to very high surface area to volume ratio , nanomaterials have better catalytic efficiency, high electrical conductivity, increased magnetic coercivity and super paramagnetism, spectral shift of optical region, high hardness and toughness (for metals and alloys) and

Very high surface area to volume ratio makes nanomaterials obey quantum physics than Newtoniam physics.

According to Newton or classical physics, a body can pass a potential barrier only if it has enough energy to jump over the barrier. If the material has less energy than to jump, the probability of finding the particle on the other side of the barrier is null.

But in quantum world, the probability of such a particles to be found on the other side of the barrier is not null if the energy potential is comparable to the wavelength of the particle.

This is because

(i). quantum mechanics predicts all phenomena in terms of probabilities

(ii). Nanomaterials are close to atoms or molecules in size, quantum mechanical laws are more applicable to them than classical mechanical laws.

Another reason is the presence of confined electrons in Nanomaterials

In nanomaterials, electrons are confined in a small space than in the space of the bulk material. This is quantum confinement. Electromagnetic waves can interact with these confined electrons of the nanomaterials making their optical properties unique.

Nanogold Samples are not golder. Their colour varies with the size of nanoparticles (Surface Palsmon Resonance)

Bulk (eg. Gold)	Nano (eg. Gold)
1. Lustrous–Shiny surface when polished.	1. Vary in appearance depending on size & shape of cluster.
2. Malleable–Can be hammered, bent or Rolled at any desired shape.	2. Are never gold in colour!.
3. Ductile–Can be drawn out into wires	3. Are found in a range of colours.
4. Yellow colour when in a mass	4. Are very good catalysts.
5. Heat & electricity conductor	5. Are not —metals but are semiconductors.
6. High densities	6. Melts at relatively low temperature (~940° C).
7. High melting point (1080°C)	7. Size & Shape of the nanoparticles determines the color. For example; Gold particles in glass: 25 nm — Red reflected 50 nm — Green reflected (Unexpected visible properties & they are small enough to scatter visible light rather than absorb)
8. Tough with high tensile strength	
9. Inert-unaffected by air and most reagents	

Distinction between molecules, nano-particles and bulk materials

1. **Reduced Melting Point** -- Nanomaterials may have a significantly lower melting point or phase transition temperature and appreciably reduced lattice constants (spacing between atoms is reduced), due to a huge fraction of surface atoms in the total amount of atoms.
2. **Ultra Hard** -- Mechanical properties of nanomaterials may reach the theoretical strength, which are one or two orders of magnitude higher than that of single crystals in the bulk form. The enhancement in mechanical strength is simply due to the reduced probability of defects.
3. **Optical properties** of nanomaterials can be significantly different from bulk crystals.
    - Semiconductor Blue Shift in adsorption and emission due to an increased band gap.
    - Metallic Nanoparticles colour changes in spectra due to surface plasmons resonances

4. **Magnetic properties** of nanostructured materials are distinctly different from that of bulk materials. Ferromagnetism disappears and transfers to superparamagnetism in the nanometer scale due to the huge surface energy.
5. **Electrical conductivity** decreases with a reduced dimension due to increased surface scattering.

Classification of Nanomaterials-
Classification I – Based on Origin

1. Natural nanomaterials

Nanomaterials which are belonging to resource of nature are defined as natural nanomaterials. Eg: Virus, protein molecules, antibody, mineral clays, natural liquid colloids (milk and blood, fog (aerosol type), gelatine (gel type), mineralised natural materials, such as shells, corals and bones, Insect wings and opals, Spider silk, Lotus leaf and similar (Nasturtium,). Gecko feet, volcanic ash, ocean spray,

2. Artificial nanomaterial

Artificial nanoparticles are those which are prepared deliberately through a well-defined mechanical and fabrication process.

Examples : Carbon nanotubes, semiconductor nanoparticles like quantum dots

Classification II

Nanomaterials can be organized into four types based on structural configuration.

- **Carbon Based Materials**
- **Metal Based Materials**
- **Dendrimers**
- **Composites**

1. Carbon Based Materials

These nanomaterials are composed mostly of carbon, commonly taking the form of a hollow spheres, ellipsoids, or tubes.

Spherical and ellipsoidal carbon nanomaterials are fullerenes, Cylindrical carbon nanomaterials are nanotubes.

Many potential applications

- **Improved films and coatings,**
- **Stronger and lighter materials**
- **Applications in electronics**

2. Metal Based Materials

Include quantum dots, nanogold, nanosilver and metal oxides (titanium dioxide). (A quantum dot is a closely packed semiconductor crystal comprised of hundreds or thousands of atoms, and whose size is on the order of a few nanometers to a few hundred nanometers. Changing the size of quantum dots changes their optical properties

3. Dendrimers

These are nanosized polymers built from branched units. The surface of a dendrimer has numerous chain ends, which can be tailored to perform specific chemical functions (useful for catalysis)

As three-dimensional dendrimers contain interior cavities they are useful for drug delivery.

4. Composites

Composites combine nanoparticles with other nanoparticles or with larger, bulk-type materials. Nanosized clays, are being added to products ranging from auto parts to packaging materials, to enhance mechanical, thermal, barrier, and flame-

Classification III– Based on Dimension

Zero dimensional, one dimensional, two dimensional and three dimensional nano materials.

1. Zero dimensional(0-D):These nanomaterials have Nano-dimensions in all the three directions. Metallic nanoparticles including gold and silver nanoparticles and semiconductor such as quantam dots are the perfect example of this kind of nanoparticles. Most of these nanoparticles are spherical in size and the diameter of these particles will be in the1-50 nm range. Cubes and polygons shapes are also found for this kind of nanomaterials.

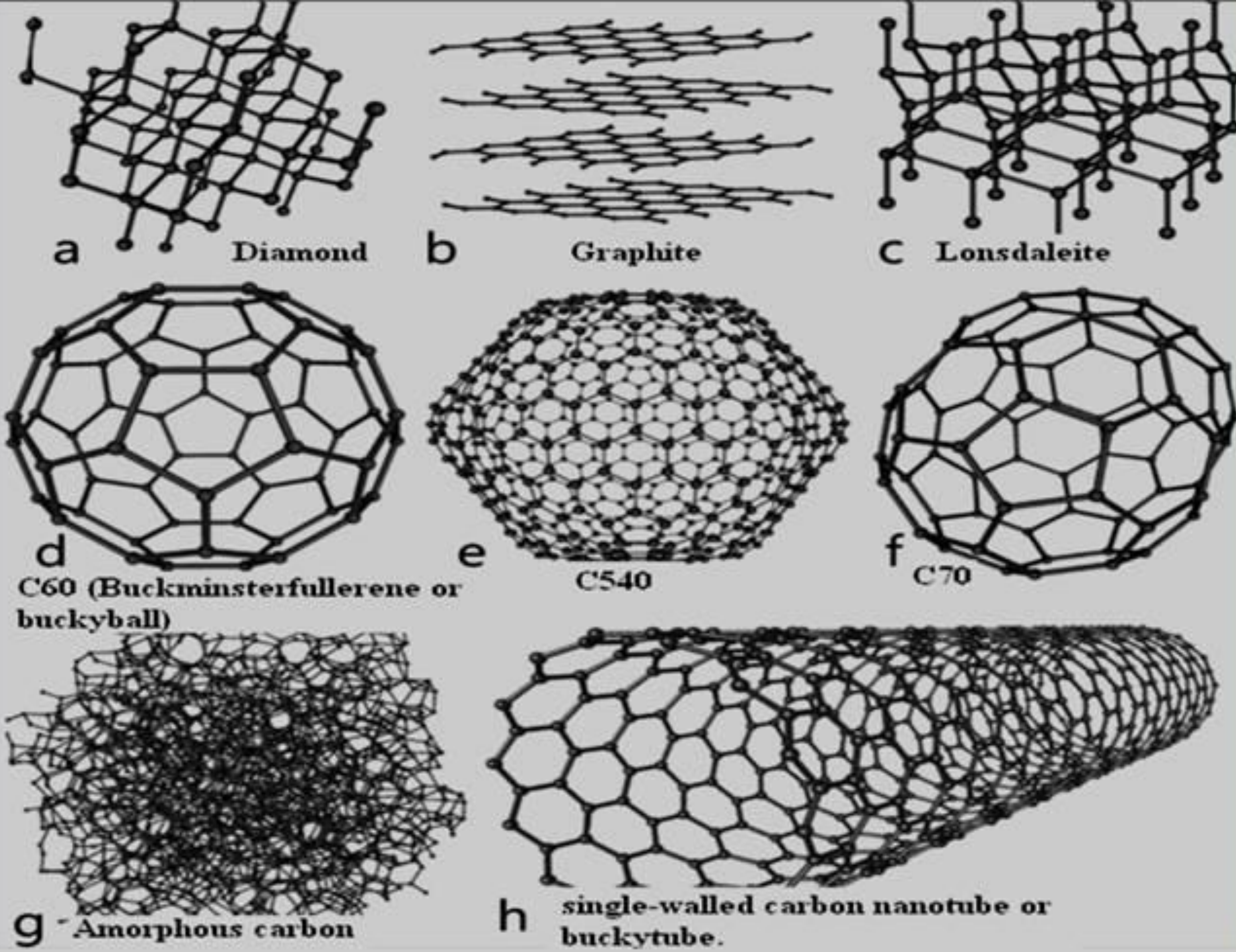
2. One dimensional(1-D):In these nanostructures, one dimension of the nanostructure will be outside the nanometer range. These include nanowires, nanorods, and nanotubes. These materials are long (several micrometer in length), but with diameter of only a few nanometer. Nanowire and nanotubes of metals, oxides and other materials are few

3. Two dimensional(2-D)
In this type of nanomaterials, two dimensions are outside the nanometer range.
These include different kind of Nano films such as coatings and thin-film-multilayers, nano sheets or nano-walls.
The area of the nano films can be large (several square micrometer), but the thickness is always in nano scale range

4. Three Dimensional(3-D)
All dimensions of these are outside the nano meter range.
These include bulk materials composed of the individual blocks which are in the nanometer scale (1-100 nm)

Synthesis of nanostructures can be done by 2 appraoches

1. **A top–down approach – Cutting down of a big object to small object – Less time consuming E.g., Microprocessor manufacturing**
2. **A bottom–up approach – Self assembly process – More time consuming - E.g**


a Diamond
b Graphite
c Lonsdaleite
d C60 (Buckminsterfullerene or buckyball)
e C540
f C70
g Amorphous carbon
h single-walled carbon nanotube or buckytube.

Leaf with nanofibers containing pesticide

Certain leafy vegetables must be protected from insects. But the simple spraying of the pesticide may cause environmental pollution and other problems. Simple technique is coating the leave with nanofibers containing the pesticide. After its use, the nanofibers can be easily removed and the leaves can be cut for

ചെമ്പുകമ്പിയെ ബാറ്ററിയാക്കാം: വിപ്ലവനേട്ടവുമായി മലയാളി

Malayala Manorama – 7 June, 2014

• ഒരേ സമയം ചാലകമായും വൈദ്യുതോർജ സംഭരണ മാധ്യമമായും മാറുന്ന ചെമ്പുകമ്പിയുടെ പുതിയ മാതൃക വികസിപ്പിച്ചു

ഒർലാൻഡോ (യുഎസ്) • വൈദ്യുതി കടത്തിവിടുന്ന ചെമ്പുകമ്പികളിൽ വൈദ്യുതോർജം സംഭരിക്കാൻകൂടി കഴിയുമെന്നു മലയാളി ശാസ്ത്രജ്ഞന്റെ ഗവേഷണഫലം. ഒരേസമയം ചാലകമാകാനും ബാറ്ററിയായി മാറാനും കഴിയുന്ന വൈദ്യുതകമ്പി വികസിപ്പിച്ചത് യുഎസിലെ സെൻട്രൽ ഫ്ലോറിഡ സർവകലാശാലയിൽ പ്രഫസറായ കോട്ടയം കാഞ്ഞിരപ്പാറ സ്വദേശി ജയൻ തോമസും ഗവേഷണ വിദ്യാർഥിയായ സെനാൻ യുവും ചേർന്ന്. ഇവരുടെ പഠനം രാജ്യാന്തര ശാസ്ത്ര ജേണലായ നേച്ചർ പ്രസിദ്ധീകരിച്ചു. മറ്റൊരു ജേണലായ അഡ്വാൻസ്ഡ് മെറ്റീരിയൽസും ഈ ഗവേഷണങ്ങൾക്ക് അംഗീകാരം നൽകിക്കഴിഞ്ഞു.

ബഹിരാകാശ ഗവേഷണം മുതൽ വാഹനനിർമാണം വരെയുള്ള മേഖലകളിൽ വിപ്ലവം സൃഷ്ടിക്കാൻ ഈ പുതിയ മാതൃകയ്ക്കു കഴിയുമെന്നാണു പ്രതീക്ഷ. വൈദ്യുതോപകരണങ്ങളിലെ ബാറ്ററികൾക്കു പകരക്കാരായി അവയ്ക്കുള്ളിലെ വയറുകൾ തന്നെ മാറുന്ന അവസ്ഥയാവും സൃഷ്ടിക്കപ്പെടുക. ഇത്തരം ചാലകങ്ങളുടെ നാരുകൾ ഉപയോഗിച്ചു നെയ്യുന്ന വസ്ത്രങ്ങളെ സഞ്ചരിക്കുന്ന ബാറ്ററികളാക്കി മാറ്റാം. വസ്ത്രത്തിൽനിന്നു മൊബൈൽ ഫോൺ ചാർജ് ചെയ്യാൻ കഴിയുന്ന തരത്തിലേക്ക് ഈ ഗവേഷണഫലത്തെ ഉപയോഗിക്കാനാണു ടെക്സ്റ്റൈൽ ഇലക്ട്രോണിക്സ് മേഖലയിലുള്ളവരുടെ ശ്രമം.

ജയൻ തോമസ്

ചെമ്പുകമ്പിയും നാനോവയറുകൾ രൂപപ്പെടുത്തുന്ന സൂപ്പർ കപ്പാസിറ്റർ കവചവും ചേർന്ന ഘടനയാണു ജയനും യുവും വികസിപ്പിച്ച വൈദ്യുത ചാലകത്തിനുള്ളത്. ചാലകമായി പ്രവർത്തിക്കുന്ന ചെമ്പുകമ്പിയുടെ ഉപരിതലത്തിൽ ലംബമായി ബ്രഷ് രൂപത്തിലുള്ള നാനോ വയറുകൾ വളർത്തിയെടുക്കുകയാണ് ആദ്യം ചെയ്തത്. സാധാരണ ചെമ്പുകമ്പിയെ അപേക്ഷിച്ചു നൂറുമടങ്ങു പ്രതലവിസ്തൃതിയുള്ള ഈ ബ്രഷുകൾക്കു വൈദ്യുതോർജം ശേഖരിക്കാൻ കഴിയും. ഇത്തരത്തിലുള്ള രണ്ടു നാനോ വയർ ബ്രഷുകളുടെ പാളികളാണു ജയൻ വികസിപ്പിച്ച ചെമ്പുകമ്പിക്കുള്ളത്. ഈ ഇരട്ട നാനോ വയർ ബ്രഷുകൾ സൂപ്പർ കപ്പാസിറ്ററിന്റെ രണ്ട് ഇലക്ട്രോഡുകൾ പോലെ പ്രവർത്തിക്കുമെന്നു ശാസ്ത്രജ്ഞർ പറയുന്നു. ഇത്തരം ചാലകങ്ങൾക്ക് കുറഞ്ഞ വോൾട്ടേജിലുള്ള നേർധാരാ വൈദ്യുതിയെ (ഡിസി) കടത്തിവിടാനും സംഭരിക്കാനും കഴിയും. പാരമ്പര്യേതര ഊർജസ്രോതസ്സുകളിൽ നിന്നുള്ള വൈദ്യുതി ഉപയോഗിച്ചുള്ള ഉപകരണങ്ങളിലാവും ഇത്തരം ബാറ്ററി - വൈദ്യുതക്കമ്പികളുടെ ഉപയോഗം ആദ്യം സാധ്യമാവുക.

ചെമ്പുകമ്പിയുടെ മാതൃക

സെൻട്രൽ ഫ്ലോറിഡ സർവകലാശാലയിലെ കോളജ് ഓഫ് ഓപ്റ്റിക്സ് ആൻഡ് ഫോട്ടോണിക്സിൽ നാനോ സയൻസ് ടെക്നോളജി സെന്ററിലാണു പ്രഫ. ജയന്റെ ഗവേഷണം. കാഞ്ഞിരപ്പാറ പൂവത്തുമ്മണ്ണിൽ പി.സി. തോമസിന്റെയും കുഞ്ഞമ്മയുടെയും മകനാണ്. ഭാര്യ ഡോ. ലിന്റ തോമസ് ഈസ്റ്റേൺ ഫ്ലോറിഡ സ്റ്റേറ്റ് കോളജിൽ പ്രഫസറാണ്. മെറിൻ, ജൂഡിൻ, ജോയ്സ് എന്നിവരാണു മക്കൾ.

Nano-Bricks – A coating film that can preserve food stuff for long

Eco-friendly film that combines

- Particles of **montmorillonite clay**
- A soil ingredient used to make bricks
- A variety of polymer materials.

It provides a barrier to oxygen and thus prevent food spoilage

Application of the new coating to soda bottles

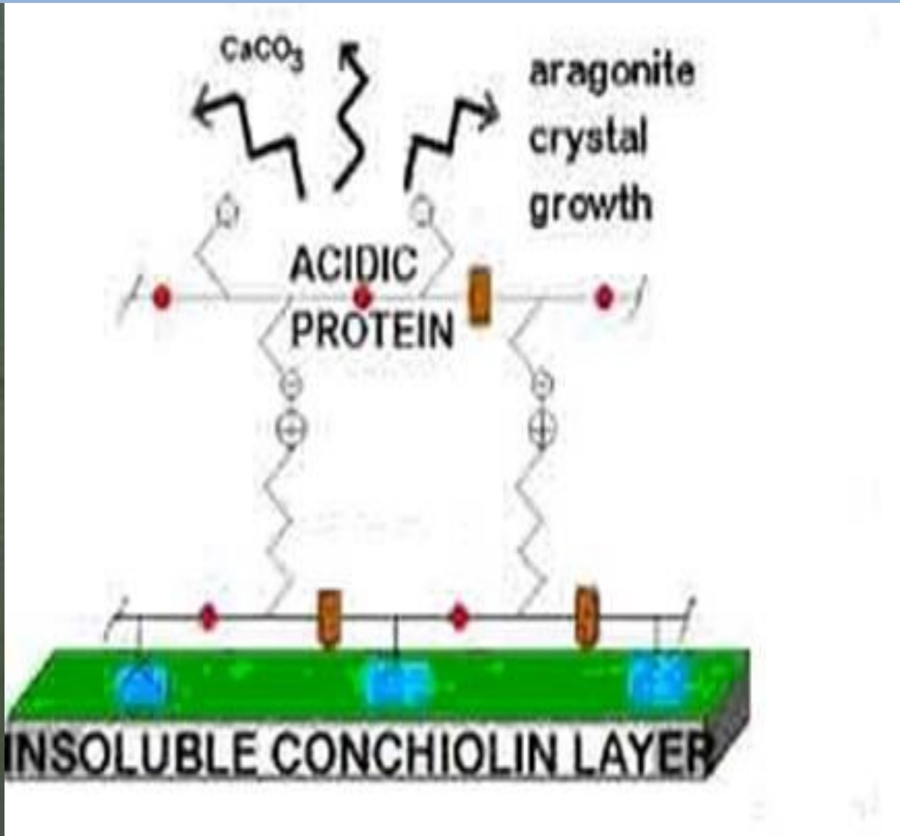
keep their fizz for long (months)

keep it fresh for long and increase shelf life

Word ‘Nano ‘means a billionth ($1X10^{-9}$)

The word appears to be new but actually nanostructures existed on earth much before the existence of Life. For example;

Abalone, a Mollusc with strong shells containing nanobricks



Nano**lithography** (from Greek -Means Stone Writing, *lithos*=stone, *graphein*=to write) -It is the art and process of producing a picture, writing, on a flat, specially prepared stone (or metals like Al, Zn), with some greasy or oily substance, and of taking ink impressions from this as in ordinary **printing-Like Making a rubber stamp**

Lithography on limestone

Ancient Lithography - Invented in 1796 by Bavarian author Alois Senefilder as a cheap method of publishing theatrical works. It used an image drawn (etched) into a coating of wax or an oily substance applied to a plate of lithographic stone. This is used as the medium to transfer ink to a blank paper sheet to produce a printed image.

In modern lithography, the image is made of a polymer coating applied to a flexible flat aluminum plate.

The flat surface of the plate is roughened slightly, etched and divided into

- hydrophilic regions that accept a film of water (remains wet), and thereby repel the greasy ink.
- hydrophobic regions that repel water and accept ink because the surface tensionis greater on the greasy image area, which remains dry.

The positive part of an image is a water-repelling (ink attracting) ("hydrophobic") substance, while the negative image is water-retaining ("hydrophilic").

Lithograph MAP

***City of Words*, lithograph**

Thus when the plate is introduced to a compatible printing ink and water mixture, the ink will adhere to the positive image and the water will clean the negative image.

Thus Lithography works because of the mutual repulsion of oil and water. The image can be printed directly from the plate (the orientation of the image is reversed), or it can transfer the image onto a flexible sheet (rubber) for printing and publication.

Thus with a flat print plate, many print runs can be made.

Photolithography

Photolithography generally uses a pre-fabricated photomask or reticle as a master from which the final pattern is derived.

Photolithography is usually applied to semiconductor manufacturing of microchips for fabricating Microelectromechanical (MEMS) systems.

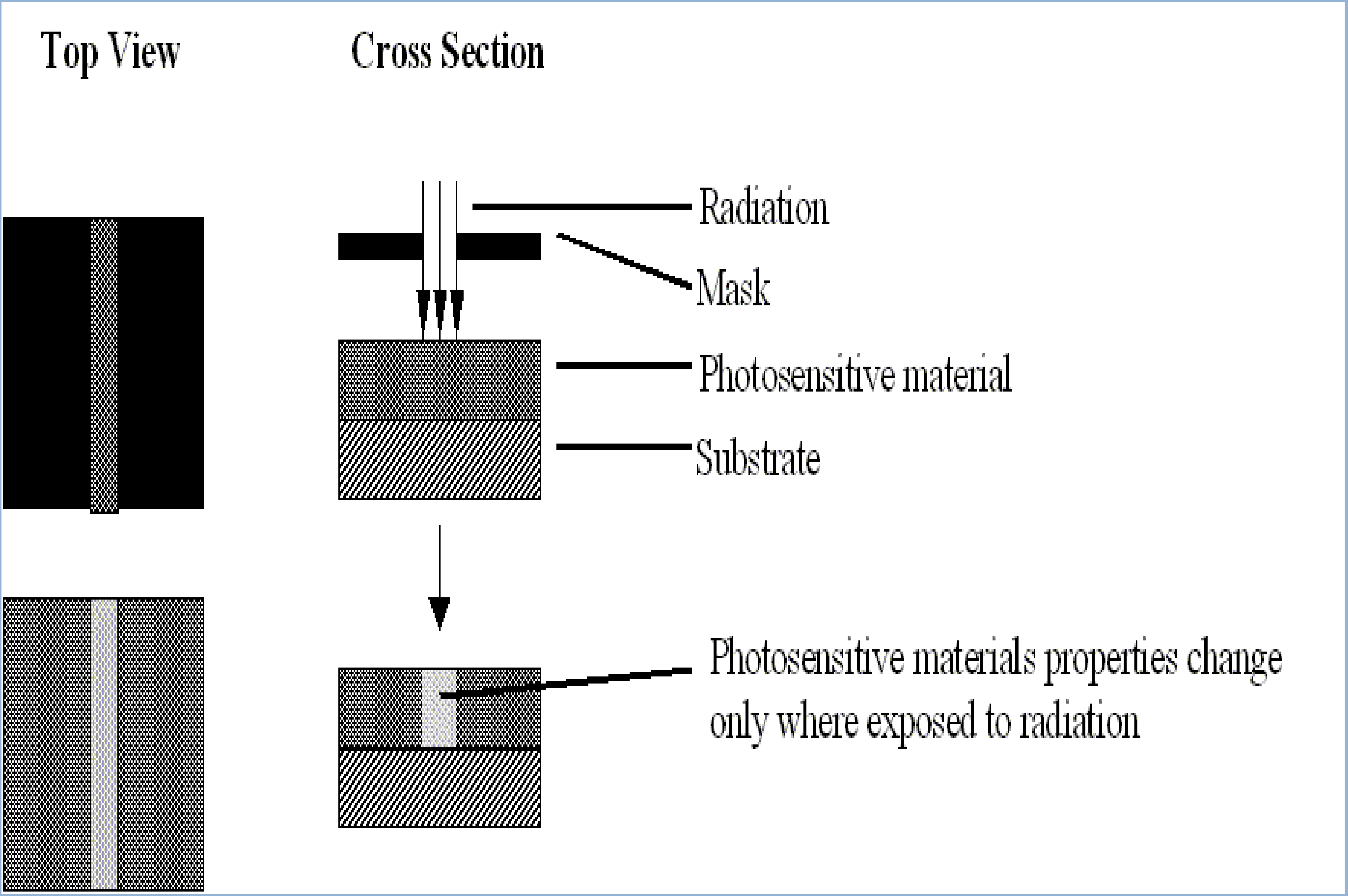
Both microlithography and nanolithography can be applied in Photolithography.

Microlithography and nanolithography

Microlithography and nanolithographyrefer specifically to lithographic patterning methods capable of structuring material on a fine scale
(features smaller than 10 micrometers - microlithographic)
(features smaller than 100 nanometers – nanolithographic).

Nanolithography is the branch of nanotechnology concerned with the study and application of fabricating nanometer-scale structures (includes patterns with at least one lateral dimension between the size of an individual atom and approximately 100 nm).
It is used during the fabrication of leading-edge semiconductor IC or nanoelectromechanical systems (NEMS).

Pattern Transfer in Photolithography



Transfer of a pattern to a photosensitive material

Lithography in the NEMS context is typically the transfer of a pattern to a photosensitive material by selective exposure to a radiation source such as light.

A photosensitive material is a material that experiences a change in its physical properties when exposed to a radiation source.

When a photosensitive material is exposed to radiation (e.g. by masking some of the radiation) the pattern of the radiation on the material is transferred to the material exposed, as the properties of the exposed and unexposed regions differs.

In lithography for micromachining, the photosensitive material used is typically a photoresist (also called resist, other photosensitive polymers are also used).
When resist is exposed to a radiation source of a specific a wavelength, the chemical resistance of the resist to developer solution changes.
If the resist is placed in a developer solution after selective exposure to a light source, it will etch away one of the two regions (exposed or unexposed).
If the exposed material is etched away by the developer and the unexposed region is resilient, the material is considered to be a **positive resist**
If the exposed material is resilient to the developer and the unexposed region is etched away, it is considered to be a **negative resist**

Nanotechnology For Aerospace

- Nanostructured materials: nanoparticles, powders, nanotubes, nanofibers,, rods, wires, etc.
- High Strength Composites (PMCs, CMCs, MMCs…)
- Multifunctional materials, self-healing materials
- Sensors (physical, chemical, bio)
- Nanoelectromechanical systems (NEMS)
- Batteries, fuel cells, power systems
- Thermal barrier and wear-resistant coatings
- Avionics, satellite, communication and radar technologies
- System Integration (nano-micro-macro)

Nanoparticles in Translational Research

Research Publications scientific journals

Various consumer products containing nanomaterials

ശരീരത്തിനുള്ളിൽ ഓടിക്കാവുന്ന വണ്ടർ കാർ!

28-1-2020

ടീച്ചിങ് നോട്സ്

■ സി.രവീന്ദ്രനാഥ്
വിദ്യാഭ്യാസ മന്ത്രി

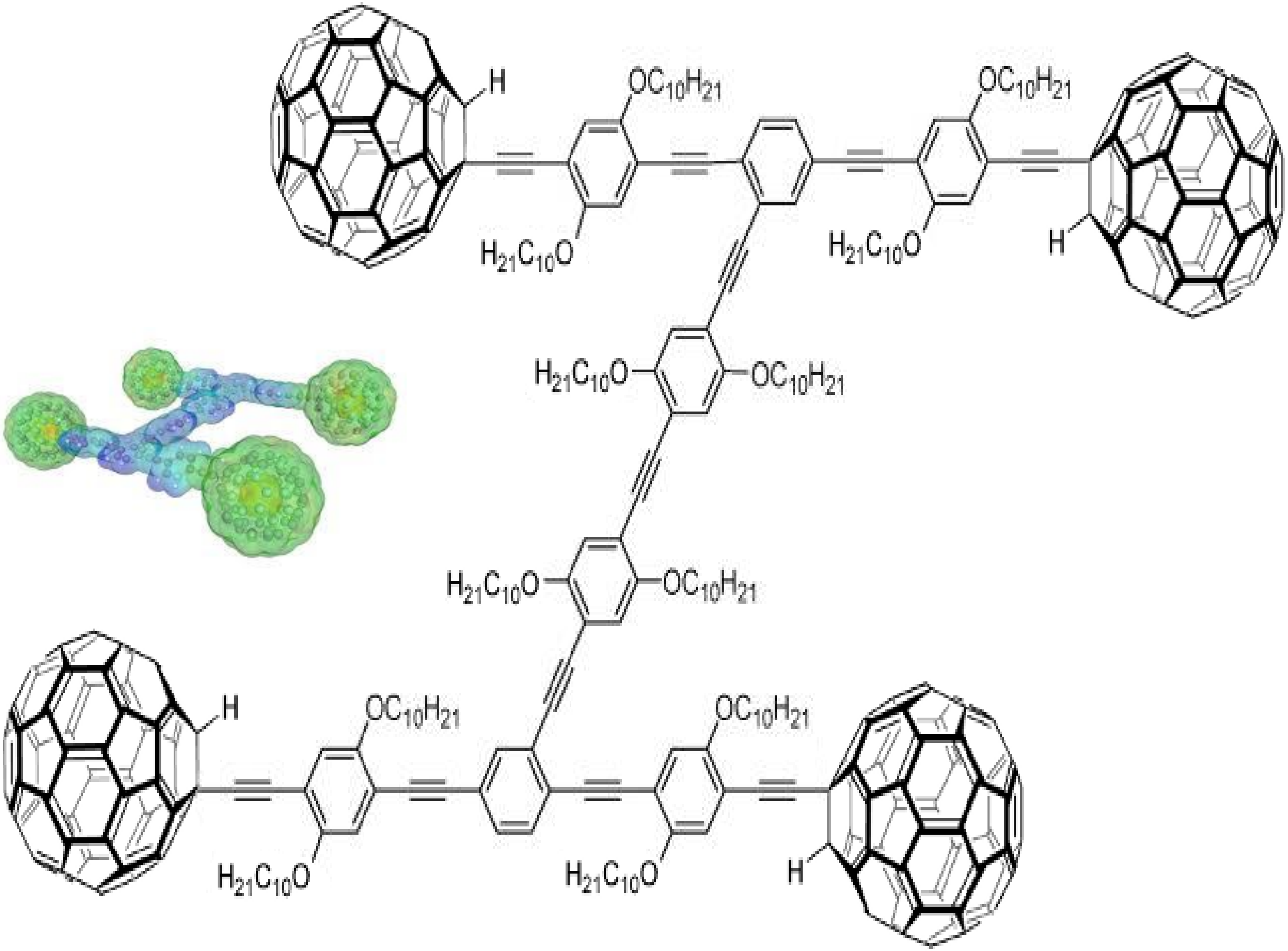
ശാസ്ത്രസാങ്കേതികവിദ്യ വളരെ വേഗം കുതിക്കുകയാണ്. അദ്ഭുതപ്പെടുത്തുന്ന നേട്ടങ്ങളാണ് സമൂഹം കണ്ടുകൊണ്ടിരിക്കുന്നത്. ഊർജ പ്രതിസന്ധി മുന്നിൽ കാണുന്ന സമയത്ത് ലിഥിയം അയോൺ എന്ന ആശയം വികസിപ്പിച്ചെടുത്തുകൊണ്ട് ശാസ്ത്രലോകം നമ്മെ വിസ്മയിപ്പിച്ചിരിക്കുന്നു. ഈ കണ്ടുപിടിത്തത്തിനാണല്ലോ ഈ വർഷത്തെ നൊബേൽ സമ്മാനം.

തലമുടിനാരിന്റെ ആയിരത്തിലൊന്ന് മാത്രം വലുപ്പമുള്ള ഒരു കാർ നിർമിച്ചതിനാണ് കഴിഞ്ഞ വർഷം നൊബേൽ സമ്മാനം നൽകിയത്. കാറിന്റെ പേര് 'മോളിക്യുലാർ വെഹിക്കിൾ'. ഈ കാറിന്റെ നാലു ടയറുകൾ ഉണ്ടാക്കിയിട്ടുള്ളത് തന്മാത്രകൾകൊണ്ടാണ്. ആവശ്യമുള്ള സമയത്തു ജെസിബി പോലെയും ടിപ്പർ പോലെയും പ്രവർത്തിക്കുന്ന ഈ കാർ ശരീരത്തിനകത്തു കൂടി ഓടി അദ്ഭുതങ്ങൾ സൃഷ്ടിക്കും. ആരോഗ്യരംഗത്തു വിപ്ലവവും. സെല്ലുകളെ ചുരണ്ടിയെടുക്കാവുന്ന ഈ ഉപകരണം ചികിത്സാലോകത്തിലെ സൂക്ഷ്മതയുടെ പര്യായമായി മാറുവാൻ പോകുന്നു.

പരിസ്ഥിതിയെ നശിപ്പിക്കുന്ന രാസവസ്തുക്കൾ ഉൽപാദിപ്പിക്കുന്ന രാസപ്രക്രിയകൾ രസതന്ത്രത്തിൽ ഉണ്ട്. ആറ്റമോ അയോണോ ഒരു തന്മാത്രയിലെത്തുമ്പോൾ മറ്റൊരെണ്ണം പുറത്തേക്കു ബഹിർഗമിക്കുന്ന രാസപ്രക്രിയകൾ ഉണ്ട്. അന്തരീക്ഷ, ജലമലിനീകരണങ്ങൾക്ക് ഒരു പരിധിവരെ ഉത്തരവാദികളാണിവ. 'ഹരിതരസതന്ത്രം' വന്നുകഴിഞ്ഞു. അന്തരീക്ഷത്തിലേക്കു മാലിന്യം എത്തിക്കാത്ത രാസപ്രക്രിയ കണ്ടെത്തിക്കഴിഞ്ഞു. നിർമിതബുദ്ധി (ആർട്ടിഫിഷ്യൽ ഇന്റലിജൻസ്) അദ്ഭുത കണ്ടുപിടിത്തങ്ങളെയൊക്കെ മറ്റൊരു ചക്രവാളത്തിൽ എത്തിക്കുന്നു. മനുഷ്യനെ വേറൊരു തലത്തിലേക്കെത്തിക്കുന്ന റോബോട്ടിക്സും നാനോ ടെക്നോളജിയും കുതിപ്പിന്റെ രംഗത്താണ്.

മോളിക്യുലാർ വെഹിക്കിൾ

വളർച്ചയുടെ ഈ അനന്തസാധ്യതകളിലേക്കാണു കുട്ടികളെ വളർത്തേണ്ടത്. അക്കാദമിക് തലത്തിൽ ഈയൊരു ലക്ഷ്യമാണ് ഉണ്ടാകേണ്ടത്. പ്രാഥമിക വിദ്യാഭ്യാസം മുതൽതന്നെ ഓരോ കുട്ടിയുടെയും വൈജ്ഞാനിക മണ്ഡലത്തെ വികസിപ്പിക്കുവാൻ ബോധപൂർവം ശ്രമിക്കണം. അക്കാദമിക് മാസ്റ്റർ പ്ലാനുകൾ ഈ ലക്ഷ്യത്തിൽ കേന്ദ്രീകരിക്കുന്നവയായിരിക്കണം.


H
$OC_{10}H_{21}$
$OC_{10}H_{21}$
$H_{21}C_{10}O$
$H_{21}C_{10}O$
H
$H_{21}C_{10}O$
$OC_{10}H_{21}$
$H_{21}C_{10}O$
$OC_{10}H_{21}$
H
$OC_{10}H_{21}$
$OC_{10}H_{21}$
$H_{21}C_{10}O$
$H_{21}C_{10}O$
H

Quantum Dots

Cancer cell detection 'dots' developed from coal

Costs one-twentieth of imported CQDs

Binoy K. Sai[illegible], se[illegible]d f[illegible]m right, in the lab with coal and carbon quantum dots (inset). • SPECIAL ARRANGEMENT

CQD, 10 NM

RAHUL KA[illegible]
GUWAHATI

A team of scientists in Assam has developed a chemical process that turns 'dirty' coal into a biomedical 'dot' to help detect cancer cells.

The team, led by Binoy Kumar Saikia and Tonkeswar Das, has applied for a patent for their chemical method of producing carbon quantum dots (CQDs) from cheap, abundant, low-quality and high-sulphur coals.

CQDs are carbon-based nanomaterials whose size is less than 10 nm, or nanometre.

"Carbon-based nanomaterials are used as diagnostic tools for bio-imaging, especially in detecting cancer cells, for chemical sensing and in opto-electronics. A few chemical companies in the U.S. and Japan have been manufacturing CQDs. What we have done is develop fluorescent carbon nanomaterials at one-twentieth the cost of imported CQDs," Mr. Saikia told *The Hindu* on Wednesday.

He is a scientist in the Polymer Petroleum and Coal Chemistry Group of the Council of Scientific & Industrial Research-North East Institute of Science and Technology (CSIR-NEIST) in eastern Assam's Jorhat, about 300 km from Guwahati.

The CQDs that the CSIR-NEIST team developed emit a bluish colour with "high-stability, good-conductivity, low-toxicity, environmental friendliness, and good optical properties". The finer details have been published in their study published in the *Journal of Photochemistry and Photobiology*.

"Our source material is abundant, low-quality Indian coal not directly suitable for thermal electricity production. Even if the selling price is twice our cost of production of ₹50 per ml, it will be much cheaper than the imported CQDs with market price of up to ₹2,000 per ml," he said.

Scientists said CQDs are futuristic materials whose demand in India has been increasing leading to a considerable volume of import. The CSIR-NEIST technology can produce approximately 1 litre of CQDs per day at a low cost to become an import substitute.

Other advantages of the process are the use of environment-friendly reagents and less water than methods elsewhere.

പഞ്ചസാരത്തരികളും കൊണ്ട് ഉറുമ്പുകൾ യാത്ര ചെയ്യുന്നതു കണ്ടിട്ടുണ്ടാവും. പക്ഷേ, ഉറുമ്പി നോളം ചെറിയ ഒരു 'യന്ത്രം' അതു ചെയ്യുന്ന കാര്യം ആലോചിച്ചുനോക്കൂ. വളരെവളരെ ചെറിയ ഒരു എൻജിൻ! പഞ്ചസാരത്തരിയോളം ചെറുതായ ഒരെണ്ണം! ബുൾഡോസറെപ്പോലെ അതു പഞ്ചസാരത്തിരിയെ തള്ളിനീക്കുകയാണ്! എന്തതിശയം, അല്ലേ? പക്ഷേ, ഇതു സാധ്യമാണോ? ഇത്രയും ചെറിയ യന്ത്രങ്ങൾ നിർമിക്കാൻ? അസാധ്യമായി ഒന്നുമില്ല എന്നല്ലേ? ശാസ്ത്രജ്ഞർ അങ്ങനെയുള്ളവയെയും നിർമിച്ചിരിക്കുന്നു.

നമ്മുടെ രക്തക്കുഴലുകൾക്കുള്ളിൽക്കൂടിപോലും കടന്നുപോവാൻ കഴിയുന്ന കുഞ്ഞുമെഷീനുകൾ. 'നാനോ ടെക്നോളജി' എന്ന പുതിയ സങ്കേതമാണ് അവരെ ഇതിനു സഹായിച്ചത്. ഔഷധങ്ങളെ ശരീരത്തിന്റെ വിവിധ ഭാഗങ്ങളിലെത്തിക്കാനും ഹൃദയത്തിലെ തടസ്സങ്ങൾ നീക്കാനുമൊക്കെ ഈ 'നാനോയന്ത്ര'ങ്ങളെ ഉപയോഗിക്കാനാവും. ഇങ്ങനെ എന്തൊക്കെ വാഗ്ദാനങ്ങളാണ് നാനോ ടെക്നോളജിക്കു നൽകാനാവുക? അതറിയാൻ 'ദ് ഡയമണ്ട് ഏജ്' (The Diamond Age) എന്ന പുസ്തകം വായിച്ചാൽ മതി.

നീൽ സ്റ്റെഫൻസൺ (Neal Stephenson) എന്ന ശാസ്ത്രകഥാകാരനാണ് ഭാവനയിലൂടെ ഇതു വർണിച്ചത്. 1995ലാണ് ഈ പുസ്തകം പുറത്തിറങ്ങിയത്. നാനോ ടെക്നോളജിയുടെ സാധ്യതകൾ ഭാവനാപരമായി വിശകലനം ചെയ്യുന്ന മറ്റു പുസ്തകങ്ങൾ ഇതാ:

നെക്രോവില്ലെ (Necroville) 1994 - Ian McDonld
ബ്ലഡ് മ്യൂസിക (Blood Music) 1985 - Greg Bear
ഫെയറി ലാൻഡ് (Fairy Land) 1995 - Paul J.McAuley

'Nanoceramic' material for safer, cheaper nuclear reactors

WASHINGTON: Scientists, including one of Indian origin, have created a nanoceramic material, which may be used in next-generation nuclear reactors that will operate at higher temperatures and radiation fields, producing energy more efficiently and economically.

Tougher under radiation

The material can not only withstand the harsh effects of radiation, but also becomes tougher under radiation, researchers said.

Traditionally, water has been used as the primary coolant in reactors, absorbing the heat released from fission reactions.

Though water poses fewer risks of corrosion damage to materials, there are also limits to the temperatures up to which water-cooled reactors can operate — and in advanced reactors, increasing their temperature is the best way to increase energy production.

New coolants, such as liquid metals like sodium and lead, are effective at much higher temperatures, but also are much more corrosive to the materials from which a nuclear reactor is made. "There is a preferred use of metallic materials for structural components, but many of these materials cannot withstand high-temperature corrosion in advanced reactors," said Kumar Sridharan, professor at the University of Wisconsin-Madison in the U.S.

The research was published in the journal *Scientific Reports*. — PTI

> Traditionally, water is used as the primary coolant, absorbing the heat released from fission reactions

ഗ്ലാസിനെ സ്മാർട്ടാക്കാൻ നാനോ കണങ്ങൾ

ദേശാഭിമാനി
23 June, 2016

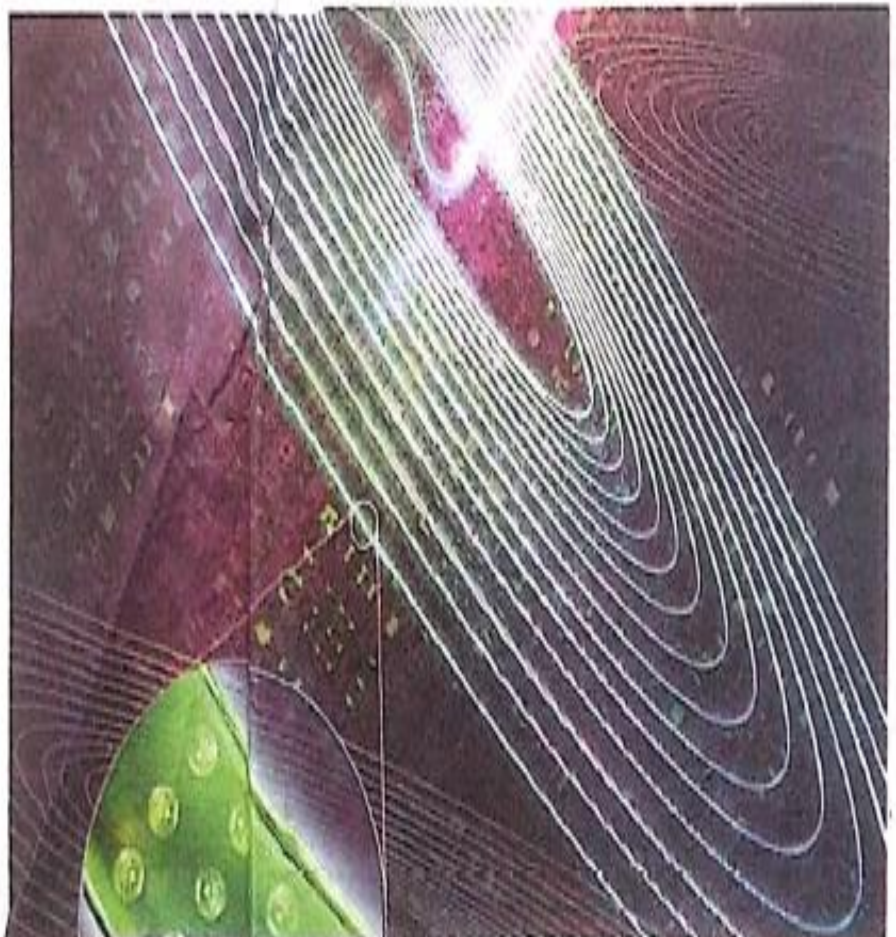
പ്രകാശം അടിസ്ഥാനമാക്കിയുള്ള സാങ്കേതികവിദ്യകൾക്കായി അന്വേഷണങ്ങൾ ഏറെ ഊർജിതമായ കാലഘട്ടമാണിത്. അടുത്ത കാലത്ത് ഏറെ ശ്രദ്ധനേടിയ ഒപ്ടിക്കൽ കംപ്യൂട്ടിങ്, ലൈ-ഫൈ എന്നിവക്കുശേഷം ഇതാ ഗ്ലാസിനെ സ്മാർട്ടാക്കാനുള്ള ഗവേഷണം.

● സംഗീത ചേനംപുല്ലി

നിങ്ങളുടെ ജനാലച്ചില്ല് വേണ്ടസമയത്ത് ഒരു ടിവി സ്ക്രീനായും കംപ്യൂട്ടർ സ്ക്രീനായുമൊക്കെ മാറുന്നത് സങ്കൽപ്പിച്ചുനോക്കൂ. അത്തരം ജനാലകൾ ഏറെ ദൂരത്തല്ലെന്നാണ് അഡിലെയ്ഡ് സർവകലാശാലയിൽനിന്നുള്ള പുതിയ വാർത്ത.

പ്രകാശം അടിസ്ഥാനമാക്കിയുള്ള സാങ്കേതികവിദ്യകൾക്കായി അന്വേഷണങ്ങൾ ഏറെ ഊർജിതമായ കാലഘട്ടത്തിലൂടെയാണ് നാം ഇപ്പോൾ കടന്നുപോകുന്നത്. വിവരകൈമാറ്റം, കംപ്യൂട്ടിങ്, സെൻസറുകൾ തുടങ്ങിയ മേഖലകളിലെല്ലാം പ്രകാശ സാങ്കേതികവിദ്യകൾ ഉപയോഗിച്ച് മെച്ചപ്പെടുത്താൻ വ്യാപകമായ ഗവേഷണം നടക്കുന്നുണ്ട്. ഒപ്ടിക്കൽ കംപ്യൂട്ടിങ്, ലൈ-ഫൈ തുടങ്ങിയവ അടുത്തകാലത്ത് വ്യാപകശ്രദ്ധ നേടുകയുണ്ടായി. ഉയർന്ന കാര്യക്ഷമത, കുറഞ്ഞ ഊർജോപയോഗം, കൈമാറുന്ന വിവരങ്ങളുടെ സുരക്ഷ, കുറഞ്ഞ ചെലവ് തുടങ്ങിയ ഒട്ടേറെ ഗുണങ്ങളുണ്ട് പ്രകാശാധിഷ്ഠിത സാങ്കേതികവിദ്യക്ക്. സുതാര്യത, എളുപ്പത്തിൽ നാരുരൂപത്തിലേക്ക് മാറ്റാനുള്ള കഴിവ്, നിഷ്ക്രിയ സ്വഭാവം ഇവയൊക്കെ ഗ്ലാസിനെ വിവര പ്രസാരണരംഗത്ത് പ്രിയങ്കരമാക്കുന്നുണ്ട്. ഈ മേഖലയിൽ പുതിയൊരു നേട്ടം കൈവരിച്ചിരിക്കുകയാണ് അഡിലെയ്ഡ് സർവകലാശാലയിൽനിന്നുള്ള ഗവേഷകസംഘം.

പ്രകാശം ആഗിരണംചെയ്ത് മറ്റൊരു രൂപത്തിൽ പുറത്തുവിടുന്ന നാനോകണങ്ങളെ ഗ്ലാസിൽ ഉൾക്കൊള്ളിക്കാനുള്ള പുതിയ വിദ്യയാണ് അഡിലെയ്ഡ് ഗവേഷകസംഘം വികസിപ്പിച്ചത്. നാനോകണങ്ങളും ചില്ലുപാളികളും വേറെവേറെ നിർമിച്ചശേഷം ഉയർന്ന താപനിലയിൽ സംയോജിപ്പിക്കുന്ന ഈ രീതി ഡയറക്ട് ഡോപ്പിങ് എന്നറിയപ്പെടുന്നു. ഗ്ലാസിന്റെ നിർമാണഘട്ടത്തിൽതന്നെ നാനോകണങ്ങൾ കൂടി ഉൾപ്പെടുത്തുന്നതാണ് നിലവിലുള്ള രീതി. പക്ഷേ ഗ്ലാസിന്റെ സുതാര്യത നഷ്ടപ്പെടാനും, ചിലയിടങ്ങളിൽ മാത്രം കണങ്ങൾ കേന്ദ്രീകരിക്കപ്പെടാനും ഈ രീതി കാരണമാകും. ഈ പരിമിതികളെ മറികടക്കാൻ ഡയറക്ട് ഡോപ്പിങ് രീതിക്ക് കഴിയുമെന്നാണ് ഗവേഷകർ അവകാശപ്പെടുന്നത്. ഇതുവഴി സുതാര്യമായതും, അതേസമയം പ്രകാശത്തോട് പ്രതികരിക്കുന്നതുമായ ഗ്ലാസ് നിർമിക്കാനാവും.



ആന്തരാവയവങ്ങളുടെ ചിത്രങ്ങൾ എടുക്കാനും, ത്രീഡിഡിസ്പ്ലേകളിലും, അണുപ്രസരണം തിരിച്ചറിയാനുള്ള ന്യൂക്ലിയർ സെൻസറുകളായും ജൈവകണങ്ങളെ തിരിച്ചറിയാൻ ബയോ സെൻസറുകളായുമൊക്കെ നാനോകണങ്ങൾ നിറഞ്ഞ ഗ്ലാസ് ഉപയോഗിക്കാം. മസ്തിഷ്കത്തിലെ സവിശേഷ ന്യൂറോണുകളെ തിരിച്ചറിഞ്ഞ് ശസ്ത്രക്രിയകൾ നടത്താൻ ഇത്തരം ഗ്ലാസ് കൊണ്ടുണ്ടാക്കിയ ഉപകരണങ്ങൾ ഉപയോഗിക്കാമെന്ന് ഗവേഷക സംഘം അഭിപ്രായപ്പെടുന്നു. ലേസർ ഉപയോഗിച്ചുള്ള നിലവിലെ രീതിയെക്കാൾ ഏറെ സുരക്ഷിതമാകും ഇത്.

പ്രകാശത്തോട് പ്രതികരിക്കുന്നവ മാത്രമല്ല, കാന്തിക സ്വഭാവം ഉള്ളതും, ഇലക്ട്രോണിക് ഉപകരണങ്ങളിൽ ഉപയോഗിക്കാവുന്നതും ഒക്കെയായി പലതരം നാനോകണികകൾ ഇത്തരത്തിൽ ഗ്ലാസുമായി സംയോജിപ്പിക്കാൻ സാധിക്കുമെന്ന് കരുതുന്നു. ഇവയടങ്ങിയ ഗ്ലാസിനെ എളുപ്പത്തിൽ നാരുരൂപത്തിലേക്ക് ([illegible]) 'മാറ്റാൻകഴിയും' എന്നതും ഇതിന്റെ പ്രയോഗസാധ്യത കൂട്ടുന്നു.

അവലംബം - https://www.adelaide.edu.au/news/news85362.html

നാനോ ടെക്നോളജിയിലൂടെ പദ്മ പുരസ്കാരനിറവിൽ ഡോ. പ്രദീപ്

27-1-2020 M;

ചെന്നൈ ▸ ശാസ്ത്രം ഏറ്റവും സാധാരണക്കാരന്റെ ജീവിതത്തിലും മാറ്റങ്ങൾ കൊണ്ടുവരുമെന്നു വിശ്വസിക്കുന്ന ഡോ. ടി. പ്രദീപിന് പദ്മശ്രീ പുരസ്കാരം നേടിക്കൊടുത്തത് നാനോ ടെക്നോളജിയിലെ മികവാണ്. നാനോ ടെക്നോളജി ഉപയോഗിച്ച് ജലം ശുദ്ധീകരിക്കാനുള്ള മാർഗം കണ്ടെത്തിയത് അദ്ദേഹത്തിന്റെ നേതൃത്വത്തിലുള്ള സംഘമാണ്. ലിറ്ററിന് അഞ്ചു പൈസ നിരക്കിൽ വെള്ളം ശുദ്ധീകരിക്കാനുള്ള സംവിധാനമായിരുന്നു ഒരുക്കിയത്. ലോകത്തിൽ ആദ്യമായിട്ടായിരുന്നു ഇത്തരം ഒരു സംരംഭം.

ഡോ. ടി. പ്രദീപ്

'അമൃത്' എന്ന പേരിലാണ് വെള്ളം ശുദ്ധീകരിക്കാൻ കഴിയുന്ന ഉപകരണത്തിന് രൂപംനൽകിയത്. ഈ ഉപകരണം എല്ലാ സംസ്ഥാനങ്ങളിലും ഉപയോഗിക്കാൻ കേന്ദ്ര ശുചിത്വ, കുടിവെള്ള മന്ത്രാലയം അനുമതി നൽകിയതിനെത്തുടർന്ന് ഇപ്പോൾ 60 ലക്ഷത്തിലേറെപ്പേർ ഇതുപയോഗിക്കുന്നുണ്ട്. സാധാരണക്കാരുടെ ജീവിതം ശാസ്ത്രം എങ്ങനെ മെച്ചപ്പെടുത്തുമെന്ന് ഡോ. പ്രദീപിന്റെ നേതൃത്വത്തിൽ തെളിയിക്കുകയായിരുന്നു.

പദ്മശ്രീ നേട്ടത്തിലൂടെ മദ്രാസ് ഐ.ഐ.ടി.ക്കും അഭിമാനമായിരിക്കുകയാണ് ഈ മലയാളി. ഐ.ഐ.ടി.യിലെ രസതന്ത്ര വിഭാഗത്തിലെ അധ്യാപകനാണ് ഡോ. പ്രദീപ്. നാനോ ടെക്നോളജി വിശദീകരിച്ച് മലയാളത്തിലും ഇംഗ്ലീഷിലും പുസ്തകങ്ങൾ രചിച്ചിട്ടുണ്ട്.

മലപ്പുറം എടപ്പാൾ സ്വദേശിയായ പ്രദീപ് കാലിക്കറ്റ് സർവകലാശാലയിൽനിന്നാണ് ബിരുദവും ബിരുദാനന്തരബിരുദവും നേടിയത്. പിന്നീട് യു.എസിൽ ഉപരിപഠനം നടത്തി.

കൊടുങ്ങല്ലൂർകാരൻ പുളിക്കൽ വീട്ടിൽ അജയൻ ഇന്നു ലോകത്തെ നാനോഗവേഷകരിൽ ഏറ്റവും മുൻപൻ. നഗ്നനേത്രങ്ങൾക്ക് ഒരിക്കലും കാണാൻകഴിയാത്ത കുഞ്ഞൻകണങ്ങളെക്കൊണ്ട് ലോകത്തെ മാറ്റിമറിക്കുന്ന അദ്ഭുതപ്രവർത്തകൻ. മൂന്നോ നാലോ ആറ്റങ്ങളുടെ മാത്രം വലുപ്പമുള്ള നാനോകണങ്ങളും നാനോട്യൂബുകളുമാണ് അജയന്റെയും കൂട്ടരുടെയും ആയുധം.

കുഞ്ഞൻ കണങ്ങളുടെ വലിയ തമ്പുരാൻ

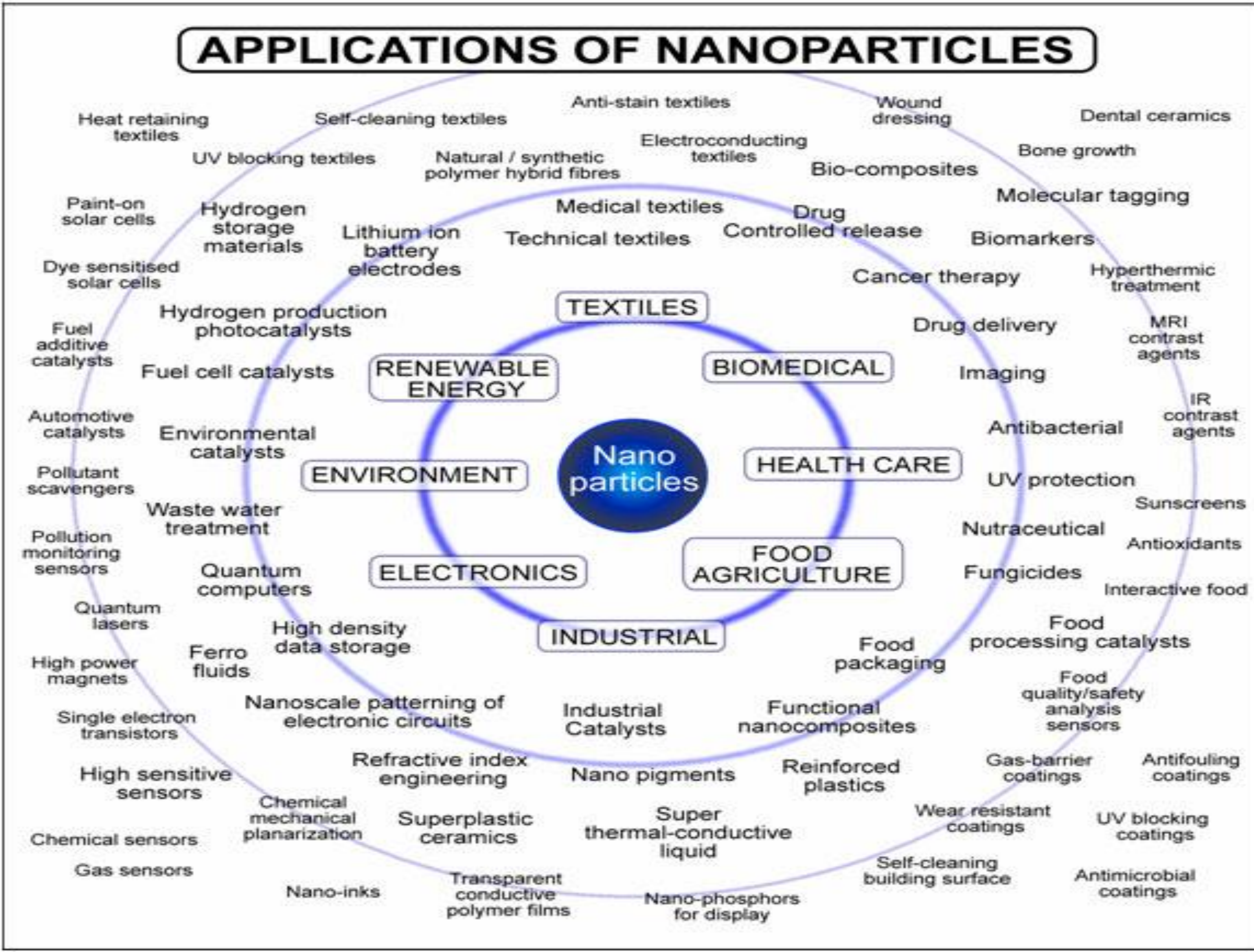
ഡോ. അനിൽകുമാർ വടവാതൂർ

Possible Harms from Nanomaterials-Disadvantages

1. SWNT can cause lesions (any abnormality in the tissue of an organism)in the lungs of rats (Fatality– 15%)
2. Owing to small size, they may interact with living cells in unexpected ways. C60 can disrupt the membranes of fish brain cells. In human beings, 20 parts per billion concentration of lab grown C60 very dilute) killed 50 % of hepatic and skin cells).

   Owing to the above reasons, Action Group on Erosion, technology and Concentration (ETC group) protects against nanomaterials.

   International Council on Nanotechnology (ICON) encourage collaboration among scientists to study and reduce the toxic effects of nanotechnology


APPLICATIONS OF NANOPARTICLES
Nano particles
TEXTILES
BIOMEDICAL
HEALTH CARE
FOOD AGRICULTURE
INDUSTRIAL
ELECTRONICS
ENVIRONMENT
RENEWABLE ENERGY
Heat retaining textiles
Self-cleaning textiles
Anti-stain textiles
Wound dressing
Dental ceramics
UV blocking textiles
Natural / synthetic polymer hybrid fibres
Electroconducting textiles
Bone growth
Bio-composites
Molecular tagging
Medical textiles
Technical textiles
Drug Controlled release
Biomarkers
Cancer therapy
Hyperthermic treatment
Drug delivery
MRI contrast agents
Imaging
IR contrast agents
Antibacterial
UV protection
Sunscreens
Nutraceutical
Antioxidants
Fungicides
Interactive food
Food processing catalysts
Food packaging
Food quality/safety analysis sensors
Functional nanocomposites
Industrial Catalysts
Gas-barrier coatings
Antifouling coatings
Reinforced plastics
Nano pigments
Wear resistant coatings
UV blocking coatings
Super thermal-conductive liquid
Self-cleaning building surface
Antimicrobial coatings
Nano-phosphors for display
Transparent conductive polymer films
Nano-inks
Superplastic ceramics
Refractive index engineering
Chemical mechanical planarization
Gas sensors
Chemical sensors
High sensitive sensors
Nanoscale patterning of electronic circuits
Single electron transistors
High power magnets
Ferro fluids
High density data storage
Quantum lasers
Quantum computers
Pollution monitoring sensors
Waste water treatment
Pollutant scavengers
Environmental catalysts
Automotive catalysts
Fuel cell catalysts
Fuel additive catalysts
Hydrogen production photocatalysts
Dye sensitised solar cells
Lithium ion battery electrodes
Hydrogen storage materials
Paint-on solar cells

1. Application of Nanomaterials in Electronics and Optics

Traditional light bulbs - A metal filament is used to generate light when electricity is run through the filament. Using metal generates a great deal of heat and therefore lowers efficiency.

Applied NanoWorks, Inc. (A New York based company)developed a consumer product that utilizes LED technology to generate light. LEDs, use only about 10% of the energy that a typical incandescenet or fluorescenet bulb uses.

White LEDs consist of semi-conducting organic layers (polyfluorenes , vinyl carbazoles) that are only about 100 nanometers in distance from each other and are placed between two electrodes, which create an anode and cathod. **When voltage is applied to the system, light is generated when electricity passes through the two organic layers. This is called electroluminescence These semiconductor properties of the organic layers allow for the minimal amount of energy necessary to generate light.**

Capacitors and Ultracapacitors

Miniaturisation Strategy in Science

A capacitor is a device that is made of a pair of electrodes separated by an insulator that each stores an opposite charge. A capacitor stores a charge when it is removed from the circuit that it is connected to; the charge is released when it is replaced back into the circuit. <u>Capacitors have an advantage over batteries in that they release their charge much more quickly than a battery.</u>

Traditional or foil capacitors are composed of ***thin metal conducting plates separated by an electrical insulator, which are then stacked or rolled and placed in a casing.*** *The problem with a traditional capacitor such as this is that they* ***limit how small an engineer can design a computer****.*

Nanotechnology and Ultracapacitors

Ultracapacitor-Capacitor that contains nanocomponents.

Ultracapacitors - Advantages

1. High density interior
2. Compact size (the decrease in size makes it increasingly possible to develop much smaller circuits and computers)
3. Reliability
4. High capacitance.
5. Ultracapacitors also have the capability to supplement batteries in hybrid vehicles by providing a large amount of energy during peak acceleration and allowing the battery to supply energy over longer periods of time, such as during a constant driving speed. This could decrease the size and weight of the large batteries needed in hybrid vehicles as well as take additional stress off the battery.

Possible materials for Ultracapacitors: Porous carbon aerogel and CNT. Porous carbon aerogel large interior surface area and can have its properties altered by changing the pore diameter and distribution along with adding nanosized alkali metals to alter its conductivity.

Electronic and Information Techonology Applications

Nanotechnology in computers provides the need for faster running computer processes at cooler temperatures than traditional, transistor-based computer components. In traditional computing, transistors have used silicon components as an affordable and easily manufactured method to provide smaller and faster computers and electronic gadgets, such as netbooks, smart phones and personal assistant devices. Such powerful gadgets at so small a size produce too much heat, however, reducing the effectiveness, performance and longevity of the silicon components. Nanotechnology in computing solves the heat dilemma by providing improved processor power at cooler temperatures and lighter weights.

Next-Generation Computer Chips: The microelectronics industry has been emphasising miniaturisation, whereby the circuits, such as transistors, resistors, and capacitors, are reduced in size. Nanoscale transistors that are faster, more powerful, and increasingly energy-efficient; soon your computer's entire memory may be stored on a single tiny chip.

Phosphors for High-Definition TV: The resolution of a television, or a monitor, depends greatly on the size of the pixel. These pixels are essentially made of materials called "phosphors," which glow when struck by a stream of electrons inside the cathode ray tube (CRT). The resolution improves with a reduction in the size of the pixel, or the phosphors.

Low-Cost Flat-Panel Displays: Flat-panel displays represent a huge market in the laptop (portable) computers industry. However, Japan is leading this market, primarily because of its research and development efforts on the materials for such displays.

Other computing and electronic products include Flash memory chips for iPod nanos; ultraresponsive hearing aids; antimicrobial/antibacterial coatings on mouse/keyboard/cell phone casings; conductive inks for printed electronics for RFID/smart cards/smart packaging; more life-like video games; and flexible displays for e-book readers.

2. Applications of Nanotech in Sensors

Environment related issues

Elimination of Pollutants: Nanocrystalline materials possess extremely large grain boundaries relative to their grain size. Hence, nanomaterials are very active in terms of their of chemical, physical, and mechanical properties. Due to their enhanced chemical activity, nanomaterials can be used as catalysts to react with such noxious and toxic gases as carbon monoxide and nitrogen oxide in automobile catalytic converters and power generation equipment to prevent environmental pollution arising from burning gasoline and coal.

Automobiles

Automobiles with Greater Fuel Efficiency: Currently, automobile engines waste considerable amounts of gasoline, thereby contributing to environmental pollution by not completely combusting the fuel. A conventional spark plug is not designed to burn the gasoline completely and efficiently. This problem is compounded by defective, or worn-out, spark plug electrodes.

Sensors

High-Sensitivity Sensors: Sensors employ their sensitivity to the changes in various parameters they are designed to measure. The measured parameters include electrical resistivity, chemical activity, magnetic permeability, thermal conductivity, and capacitance.

3. Applications of Nanotechnology in Catalysis

Catalysis

The extremely small size of the nanomaterials maximizes the surface area exposed to the reactants, allowing more reactions to occur. The application ranges from fuel cell to catalytic converters (nano-Pt), photocatalytic devices (e.g., nano-TiO_2) and for the production of chemicals (e.g., nano-ZrO_2 in CO hydrogenation in isobutene synthesis).

Catalytic Converters (colloquially, "cat" or "catcon)

Device used to reduce the toxicity of exhaust emissions from Internal Combustion Engines

Devised by Eugene Houdry

(French mechanical engineer & expert in catalytic oil refining)

Palladium (Pd) - Palladium is used as an Oxidation catalyst

Rhodium (Rh) - - Reduction catalyst

Cerium (Ce) - Iron (Fe) , Manganese (Mn), Nickel (Ni)

21 ലക്ഷം കാറിൽ കൃത്രിമം കാട്ടി: ഫോക്സ്‌വാഗൻ

29/9/2015
D

ബെർലിൻ > മലിനീകരണത്തോത് കുറച്ചുകാട്ടാൻ സോഫ്റ്റ്‌വെയർ ഘടിപ്പിച്ച് കൃത്രിമം കാട്ടിയത് 21 ലക്ഷം കാറിലാണെന്ന് ഫോക്സ്‌വാഗൻ. പടിഞ്ഞാറൻ യൂറോപ്പിൽ വിറ്റഴിച്ച ഇയു 5 എൻജിൻ വിഭാഗത്തിൽപ്പെട്ട കാറുകളെയാണ് ഏറെയും പ്രശ്നം ബാധിച്ചത്. 14.2 ലക്ഷം കാറാണ് ഇവിടെയുള്ളത്. ജർമനിയിൽ 5,77,000 എണ്ണത്തിലും അമേരിക്കയിൽ 13,000 എണ്ണത്തിലും കൃത്രിമം നടന്നു. എ1, എ3, എ4, എ5, എ6, ടിടി, ക്യു3, ക്യു5 എന്നീ മോഡലുകളിലും പ്രശ്നങ്ങളുള്ളതായി ജർമൻ കമ്പനി അധികൃതർ വാർത്താ ഏജൻസിയോട് പറഞ്ഞു.

യുഎസ് എൻവിയോൺമെന്റൽ പ്രൊട്ടക്‌ഷൻ ഏജൻസി നടത്തിയ പരിശോധനയിലാണ് തട്ടിപ്പ് കണ്ടെത്തിയത്. ഇതിനിടെ വെള്ളിയാഴ്ച കമ്പനി ചീഫ് എക്സിക്യൂട്ടീവിനെ മാറ്റിയിരുന്നു. മുതിർന്ന ആർ ആൻഡ് ഡി വിഭാഗം ഉദ്യോഗസ്ഥരെ തിങ്കളാഴ്ച സസ്പെൻഡ് ചെയ്തതായി സ്ഥിരീകരിക്കാത്ത റിപ്പോർട്ടുണ്ട്. തട്ടിപ്പ് പുറത്തായതിനെത്തുടർന്ന് കമ്പനിയുടെ ഓഹരിവില മൂന്നിലൊന്നായി ഇടിഞ്ഞിരുന്നു. ഏകദേശം 1800 കോടി ഡോളർ അമേരിക്ക പിഴ ഈടാക്കാൻ ഇടയുണ്ട്.

4. Nanofiltractions
Nanofiber nonwoven fabric

4. Applications of Nanotech in Biomedical Applications

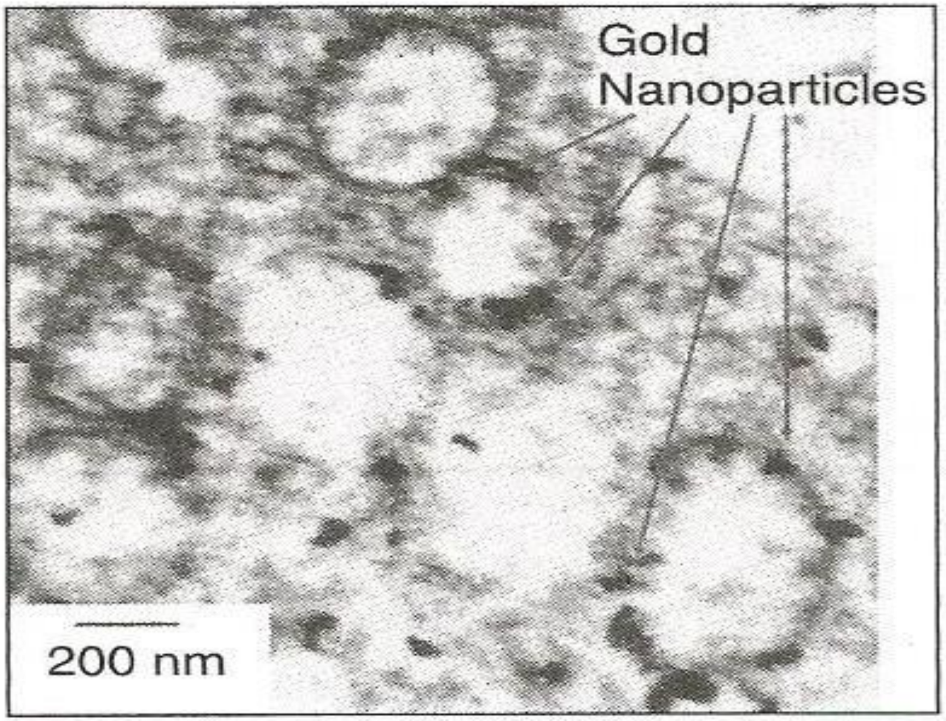
Medicine

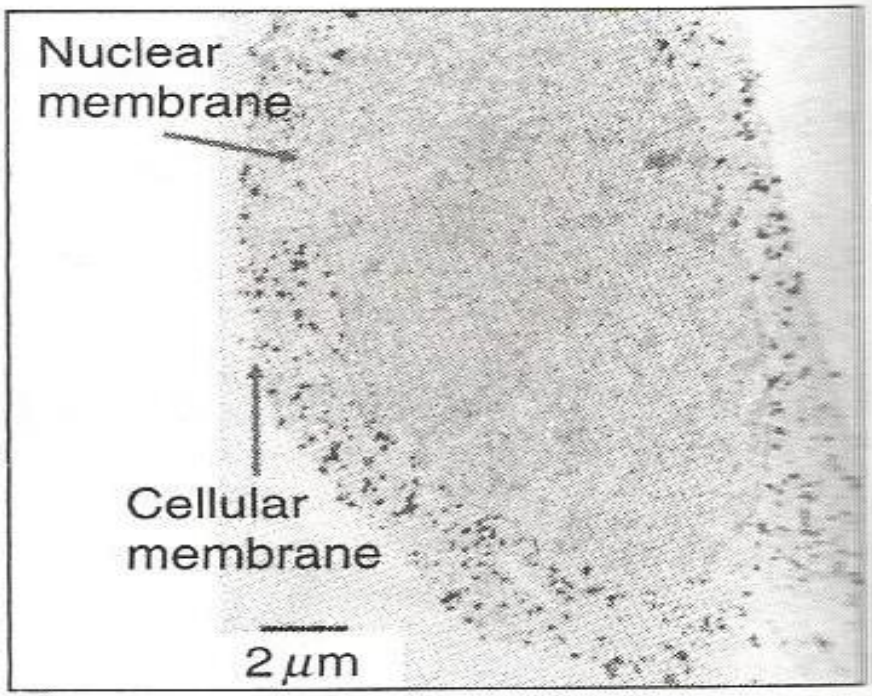
Nanotechnology has been a boon in medical field by delivering drugs to specific cells using nanoparticles

- ✓ One application of nanotechnology in medicine currently being developed involves employing nanoparticles to deliver drugs, heat, light or other substances to specific types of cells (such as cancer cells). Particles are engineered so that they are attracted to diseased cells, which allow direct treatment of those cells. This technique reduces damage to healthy cells in the body and allows for earlier detection of disease.
- ✓ *In Therapy Techniques*

  Researchers have developed "nanosponges" that absorb toxins and remove them from the bloodstream. The nanosponges are polymer nanoparticles coated with a red blood cell membrane. The red blood cell membrane allows the nanosponges to travel freely in the bloodstream and attract the toxins.
- ✓ Researchers have demonstrated a way to use nanoparticles for early diagnosis of infectious disease.
- ✓ Nanotechnology can also help to reproduce or to repair damaged tissue. "Tissue engineering" might replace today's conventional treatments like organ transplants or artificial implants. For example, bones can be regrown on carbon nanotube scaffolds.

The early detection of cancers and tumours before any symptoms is possible by this method . In cancer therapy, early detection can lead to more successful treatment. Intra and extracellular synthesis of metal nanoparticles using fungi, bacteria and viruses is possible by the reduction of metal (Gold) ions added to the cells. The cellular response towards the reduction of chloroaurate ions is different for normal cells (Left) and malignant cell (Right) . (Quantum dots also are used in diagnosis)





Drug Delivery : Nasal route of drug delivery (delivery of small peptides) is more effective because of better transport properties and lower enzymatic activity. Nanoparticle – drug system can easily cross the nasal epithelia. PEG or chitosan covered nanopartciles can circulate in the blood stream and the associated protein (drug, i.e., tetanus toxoid protein, will be delivered at the appropriate location in the body. In such cases, the absorption of the drug also was higher.

Also, Pilocar, the ,medicine for Glucoma (eye pressure) can be slowly released in to the eye as per the need (using nanodrug delivery) Similarly, nanopartcile –drug system [(polyalkylcyanoacrylate nanoparticles or chitosan nanoparticles-cyclosporine A can enter the well-organised corneal epithelium and show ocular retension and therefore slow delivery of the drug.

MEDICAL application

Drug and gene delivery, artificial blood vessels, artificial organs, and medical facemasks. For example, carbon fiber hollow nano tubes, smaller than blood cells, have potential to carry drugs in to blood cells

Comparison of red blood cell with nanofibers

Nanofibers and webs are capable of delivering medicines directly to internal tissues.

Researchers have spun a fiber from a compound naturally present in blood. This nanofiber can be used as varieties of medical applications such as bandages or sutures that ultimately dissolve in to body. This nano fiber minimizes infection rate, blood lose and is also absorbed by the body.

Thank you