



UPSC CSE 2025



# PRELIMS REVISION PROGRAMME

**SCIENCE AND TECHNOLOGY**

By Dr. Shivin Chaudhary

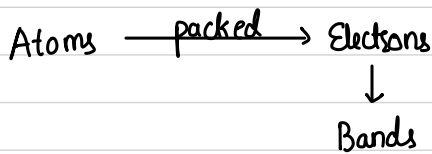
Nanotechnology

↳ comes from word → 'nanometers'  
( $10^{-9}$  m)

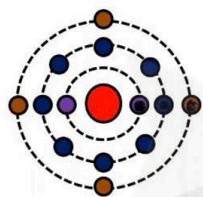
Special Effects :

- i) Electrical Conductivity
- ii) Color Effects
- iii) Chemical Reactivity
- iv) Melting point
- v) Wettability

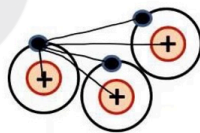
Concepts :



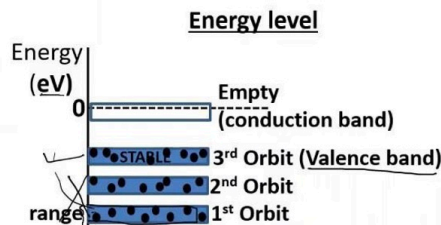
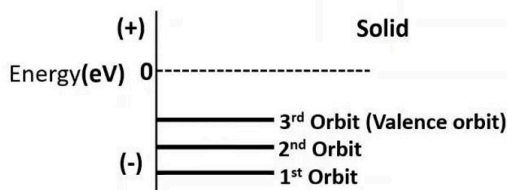
Band  
Theory  
of solids



Isolated Si atom  
Tetra valent atom



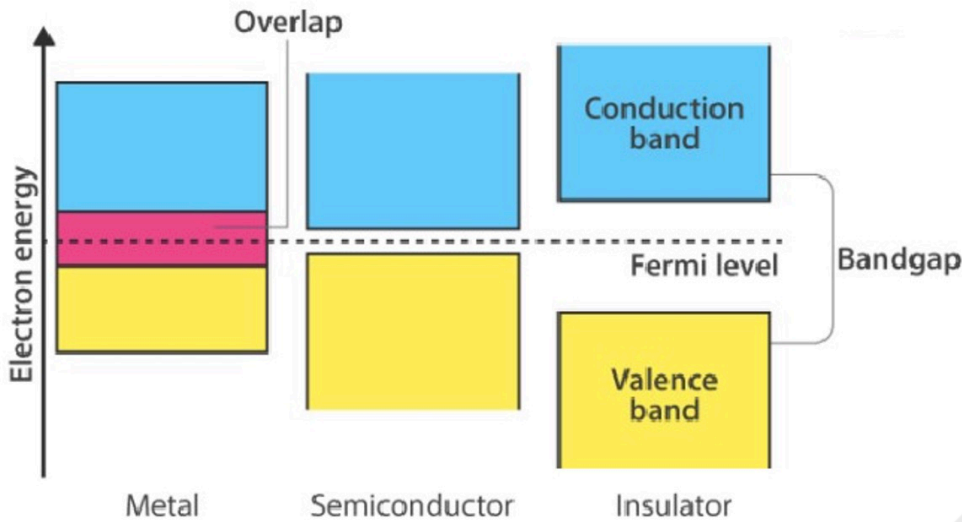
Solid



There is no electron in conduction band .so it will behave like an insulator

BAND THEORY OF SOLIDS





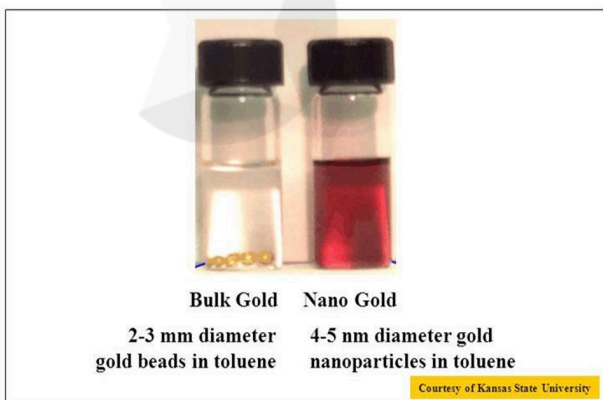
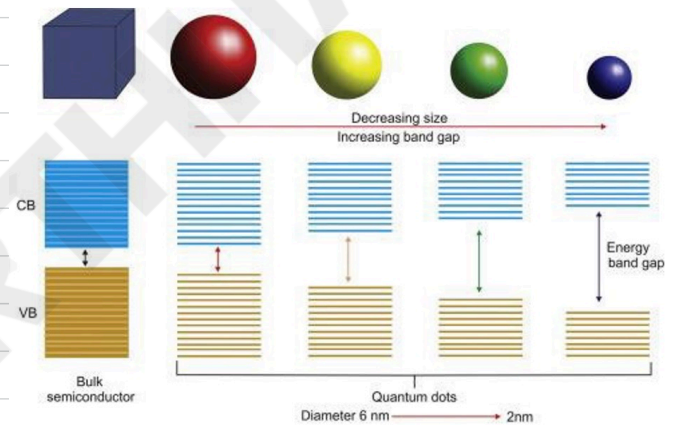
Band arrangement  $\longrightarrow$  changes at level of nanomaterials.

Bandgap  $\uparrow$   $\longrightarrow$  certain properties change.

Change in electrical conductivity

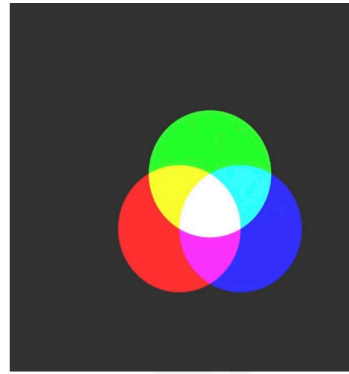
Change in color

Color size  $\longrightarrow$  dependent due to band gap alteration.



## Change in optical properties

- from Bands  $\longrightarrow$  energy states become discrete
- Wavelengths emitted are pure.



### QLED

- Stands for Quantum dot Light Emitting Diode
- Uses quantum dot technology to emit light. Add an additional layer in front of a LED light panel
- Delivers 100% colour volume with unmatched saturation levels
- Not as power efficient as LED

### LED

- Stands for Light Emitting Diode
- Uses LED to backlit the display
- Not as good as QLED in colour volume or picture quality
- Delivers optimal brightness level without consuming more power



## Chemical Reactivity

More Surface area  $\longrightarrow$  More reactivity

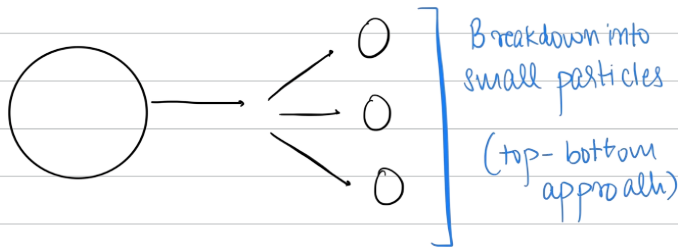
These changes in properties are known as Quantum effects

$\hookrightarrow$  Size-dependent

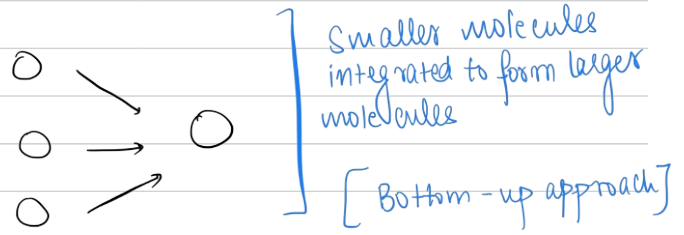
**Quantum confinement** is the phenomenon that occurs when the motion of a particle is restricted in one or more dimensions. This restriction causes the energy spectrum to become discrete, or quantized.



## Approaches to make nanomaterials

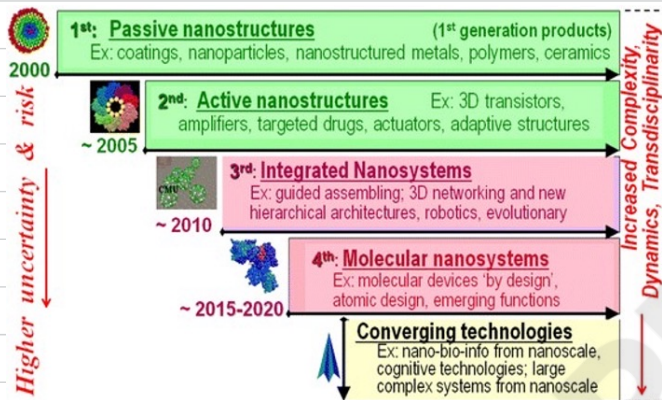


Eg, Nanocatalyst, Nano-Silicon based Solar Panels



Eg, Nanoelectronics & I.C.

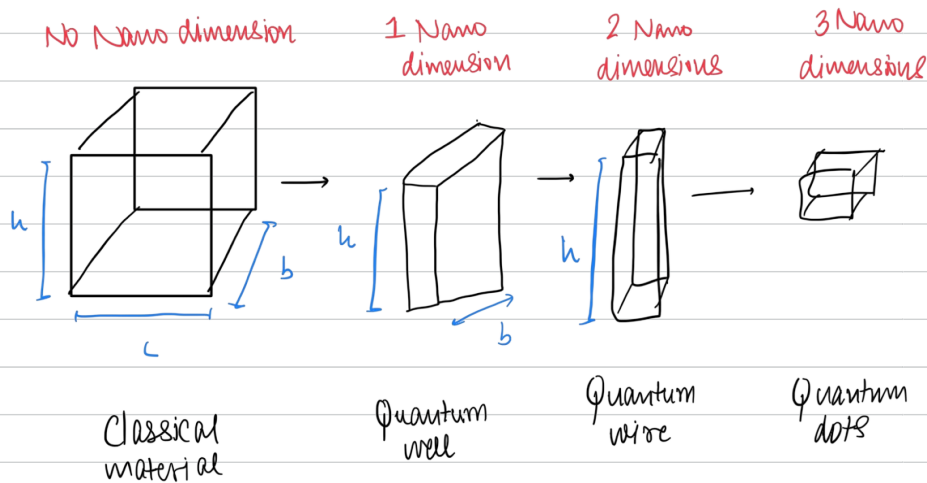
## Generations of nano materials



- Passive structures
- Active: interact with environment and drug delivery
- Nanosystems : Complete systems of nanomaterials (nobel prize of 2016)
- Molecular nanosystems : bottom up approach and concept of additive manufacturing (3d printer).



## Types of Nanomaterials



## Quantum Dots

↳ nano-meters size assembly of atoms  
↳ named → "quantum"

↳ electron have limited space to move → quantum mechanical effects

↳ "artificial atoms"

Scientist	Year	Contribution
Alexei Ekimov (Soviet Union)	Early 1980s	Discovered copper chloride nanocrystals in glass, proving size-dependent color changes, indicating quantum dots.
Louis Brus (U.S.)	1983	Successfully created quantum dots in a liquid instead of glass. Further developed their mathematical behavior.
Moungi Bawendi (MIT)	1993	Developed the hot-injection method, allowing precise control over quantum dot size, making them commercially viable.

Alexei I. Ekimov, Louis E. Brus, and Moungi G. Bawendi have been awarded the 2023 Nobel Prize for chemistry "for the discovery and synthesis of quantum dots".

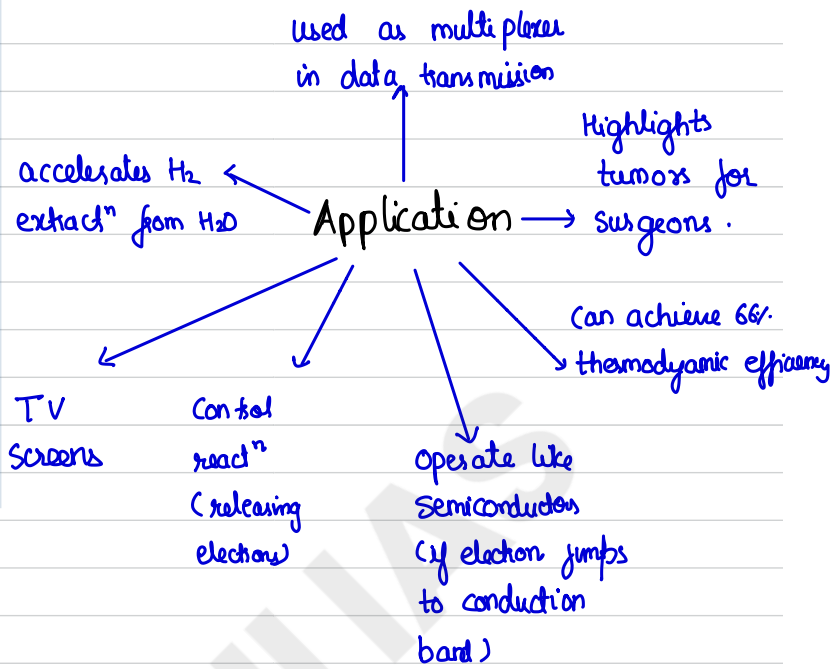
## Features

- ① Intermediate b/w atomic & bulk materials.
- ② Size -dependent property → changing their size alters properties like M.P/ Chemical reactivity
- ③ Light absorption & Emission → when illuminated → smaller dots emit blue light  
larger dots emit red light.



### How Are Quantum Dots Made? (Hot-Injection Method)

- A reagent is injected into a high-boiling-point solvent.
- The solution is heated until nanocrystals form.
- Larger crystals form if heated for longer.
- Smooth surfaces improve functionality.
- Allows precise control over quantum dot properties



### Applications of Nanotechnology.

- ① Nano-Fertilizers → nano-scale nitrogen particles which have more surface area & no. of particles

India → first country to start commercial production of NPL

- Signific<sup>n</sup> →
- ↓ requirement of conventional urea by 50% or more
  - Improves soil, Air & Water Quality
  - Cheaper than Conventional Urea.

## Nano-urea reduced grain yield: study

Research by Punjab Agricultural University scientists finds reduced protein content in the grain of the two crops; the plants were unable to use the urea sprayed, it finds; since its commercial release in 2022, the evidence for nano-urea as a reliable substitute of conventional variety has been thin

Key findings → Protein content ↓ by 35% in Paddy grain  
↓ by 24% in Wheat grain

- one spray of 80 ml nano urea can replace more than 32kg of Nitrogen.
- sprayed @ leaves, NOT roots at flowering stages

Issues → i) lack of evidence for yield gains.

- ii) Plants unable to absorb nano-urea efficiently in the field.
- iii) Root development Issues

Heavily subsidized  
₹ 3000 → ₹ 242



# IFFCO receives FCO approval for nano zinc liquid, nano copper liquid fertilisers

ANI 01 May, 2024 08:02 pm IST

Addresses nutrient deficiency → Zinc → enzyme functioning  
 ↳ Copper → enzymatic activities & chlorophyll  $fm^2$

Earlier → Nano-Urea liquid } also approved  
 nano-liquid DAP }

Nano-fertilizers

↳ 1-100 nm → controlled release, better absorption.

FCO → under Essential Commodities Act, 1955  
 ↳ regulates "product", distrib<sup>n</sup>, quality of fertilizers

Purpose of FCO → ensures quality & safety  
 ↳ regulates import, sale, price, labelling, packaging, storage.  
 ↳ Approves fertilizers for agriculture

Application

Foliar Spray – Quick uptake (Nano Urea - IFFCO)

Soil Application – Slow release (Nano Phosphorus)

Seed Treatment – Better germination (Nano Zinc)

Hydroponics/Drip – Precise supply (Nano Copper)

## Triboelectric Nano Generators

# IIT Indore develops e-shoes for live location tracking

Updated - August 07, 2024 at 07:18 PM. | New Delhi, August 7

The shoe harnesses energy from human motion to power electronic devices and with help of a satellite-based GPS module offers precise live location tracking

TENG → works on principle of creation of electrostatic charges.

App<sup>n</sup> → optoelectronic,  
 self-powered devices,  
 Biomedical applic<sup>n</sup>  
 Pacemakers

## Piezoelectric Polymers

**Bengaluru: Researchers develop piezoelectric polymer nanocomposite for energy harvesting**

Published - September 02, 2024 08:26 pm IST - Bengaluru  
 THE HINDU BUREAU

→ by Centre for Nano and Soft Matter Sciences (CeNS) + CSIR-National Chemical Laboratory.

→ aims to create a piezoelectric polymer nano-composite for pressure sensing & energy harvesting.

↳ Researchers synthesized 2 zirconia-based metal organic framework converted → Zirconia

Nanoparticles



## Piezoelectric Polymers

↳ converts mechanical energy → Electrical Energy.

Two ways

contact  
electrification /  
triboelectric  
effect

Piezo electric  
effect

Advantages:

- ① Flexible
- ② lightweight
- ③ Easy to process

Key Application:

- ① Sensors
- ② Wearables
- ③ Medical Implants
- ④ Consumer Electronics

Nanomicelles → can be used for Cancer treatment

Nanomicelles are globe-like structures with a hydrophilic outer shell and a hydrophobic interior. This dual property makes them a perfect carrier for delivering drug molecules.

Advantages → low toxicity

- ↳ Ability to minimize drug degradation
- ↳ permeate tissues easily for drug delivery
- ↳ lower adverse drug side effects.

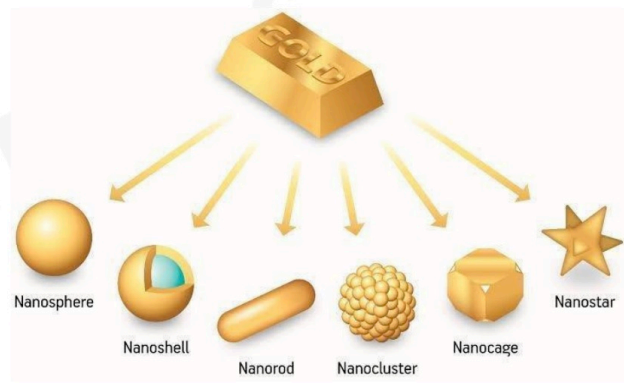
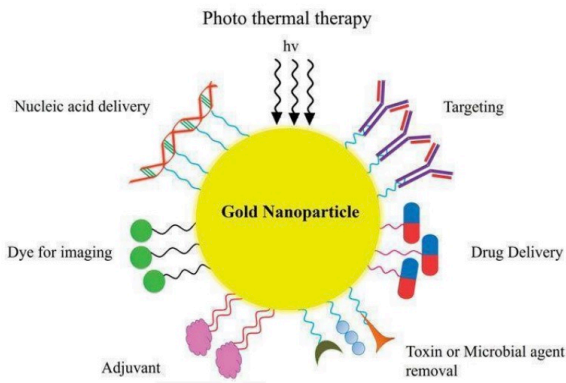
## Gold Nanoparticles

- ↳ developed by NCPOR + Goa University using Antarctic bacteria
- ↳ Bio compatible, stable, non-toxic
- ↳ Lower MP (300°C) v. Bulk Gold (1064°C)

Advantages:

- ① Better solar absorption → used in photovoltaic cells
- ② Unique Optical Properties → Therapeutic imaging.
- ③ Electronic use → NOMFET (mimics human synapse.)





## Goldene

# Why researchers have created Goldene, a sheet of gold that is only one atom thick

Creating 'goldene', as the one-atom thick material has been named, was not easy for the scientists behind the development, from Sweden's Linköping University. It is not that such 2D materials have not been created before.

What is Goldene?

- single-atom-thick sheet of gold
- 400 times thinner

Method: Gold  $\longrightarrow$  Silicon  $\longrightarrow$  Monolayer of gold (formed)  
 (replaces Si)  
 $\downarrow$   
 sandwiched  
 b/w  
 Titanium Carbide  
 layers

Potential application:

- ① Catalyst in electronics industry  $\longrightarrow$  Economically viable.
- ② CO<sub>2</sub> conversion for sustainability
- ③ H<sub>2</sub> generat<sup>n</sup> for clean energy, water purification.



## Fluorescent Nanodiamonds

# Scientists spin diamonds at a billion RPM to test the limits of physics

TH Premium

Fluorescent nanodiamonds may be smaller than small but they pack a punch big enough to reverberate across many industries

FNDs → composed of Carbon nanoparticles.

- ↳ emits low frequency light when exposed to high-frequency light
- ↳ produced under high temp, high pressure conditions
- ↳ stable under light & non-toxic to living organisms.

Applications →

- ↳ High resol<sup>n</sup> imaging
- ↳ Microscale temperature sensing.
- ↳ Correlative microscopy
- ↳ Cell tracking.

- irradiated with lasers → light of different colors in different directions.  
*'world's smallest disco party'*
- Sensitive to acceleration and electric fields → sensors in High value industries.  
Cyroscope.
- Related terms → Berry phase | Nitrogen vacancy (with Quantum computing)

## Hybrid Nanoparticles

- ↳ size < 8 nm
- ↳ formed by combined two different nanoparticles.

Significance:

- non-invasive, precise diagnosis
- minimal side effects
- Potential for routine cancer screening.

Mechanism of action:

Diagnosis

Treatment

Photoacoustic → light → Ultrasound  
properties  
↓  
Cancer  
detect<sup>n</sup>

• Photothermal effect → light → Heat → Destroys tumours  
• ROS generat<sup>n</sup> → Kills Cancer Cells  
• Light-triggered → Targeted Cancer Treatment.



## IIT - Madras : Water microplets & Nanoparticles formation.

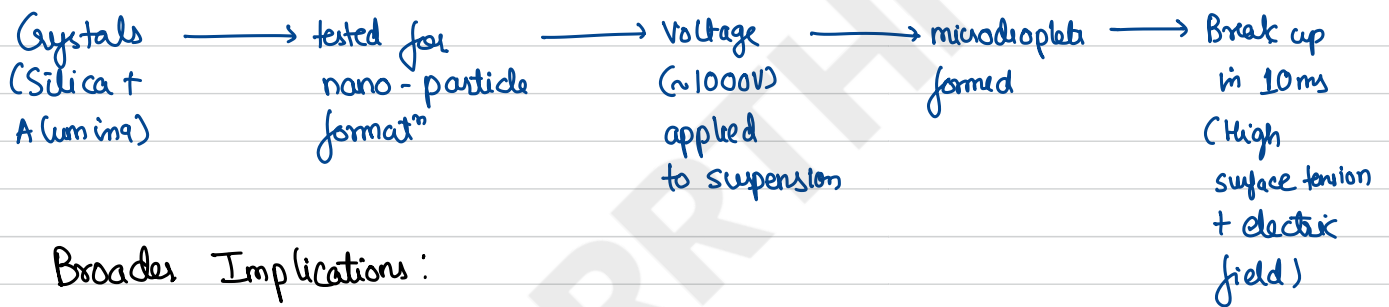
### Key findings:

- ① microplets enhance chemical reactions
  - ↳ good charge carriers
  - ↳ converts minerals into nanoparticles

### Mechanism of Action:

- More mobile protons → faster chemical react<sup>ns</sup>
- helps in peptide bond formation

### Experiment :



### Broader Implications :

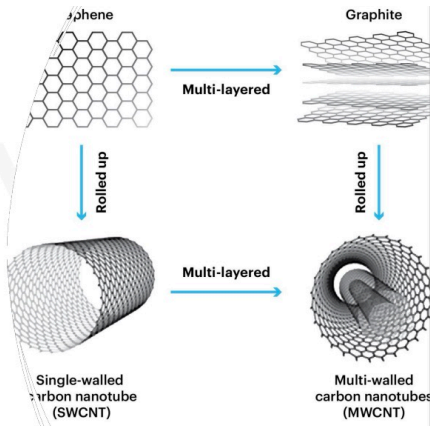
- Mimics proto-cells → insights into origins of life
- Useful in agriculture.



## Carbon Nanotubes

↳ C-60 Buckminsterfullerene

fullerene



### Features :

- ① Cylindrical Hollow figure with graphite sheets
- ② Light weight
- ③ Tensile strength
- ④ Electrical conductivity
- ⑤ Not Bio compatible

Appl<sup>n</sup> : Electronics,  
Automobiles  
Sports,  
Space,  
Aerospace industry

## India and Nanotechnology

- ① Nano Mission by CNR Rao in 2007  
↳ by DST

② ICONSAT

Objective → Basic Research Promotion  
Infrastructure Development  
Nano applic<sup>n</sup> & Tech Development  
HRD  
International Collaborat<sup>n</sup>

③ Center of Excellence in Nano Electronics

Sector	Application
Industrial Products	Sunscreens - Titanium dioxide & Zinc oxide (UV protection)
	Non-flammable furniture - Nano-coatings
	Fabrics & Body Armour - Lightweight, easy-clean textiles
	Films on glasses, computers, and camera displays
Environmental Remediation	Quantum dots - QLED TV (Electrical effects)
	Nanosensors - Neutralize pollutants
	Wastewater treatment using nanotechnology
Energy Sector	Nano membranes - Desalination
	Biofuel production - Nanobioengineering of enzymes
	Solar panels - TENG technology
	Hydrogen economy & storage systems
	Nanotube scrubbers & electrostatic precipitators
	Gold Nanoparticles (GNP) - Solar panels
	Carbon Nanotubes (CNT) - PV cells
Agriculture Sector	Graphene - Green hydrogen production
	Nanoherbicides & Nanopesticides - Targeted delivery
	Nanophosphorous fertilizer - Millet & Cluster beans
	Silver Nanoparticles - Protect against phytopathogens
	Carbon Nanoparticles - Enhance seed germination
	Nickel / Ferrite - Antifungal properties
	Zinc oxide / Chitosan - Viral disease control
	Precision farming - Nanosensors
	Antigen-Antibody tests - ELISA test
	Health Sector
Targeted drug delivery - Nanomicelles	
Nanosensors - HIV & Cancer detection	
Gold Nanoparticles (GNP) - Medical imaging	
Nanohydrogel-based eye drops	
Defence	Tank polymer & Camouflage
	Lightweight materials for defense
	Precision-guided missiles using nanotechnology
Electronics	Quantum dots - Advanced electronics
	Graphene - Flexible touch screens
	Optoelectronics - Improved performance
	Carbon Nanotubes (CNT) - Replacing silicon-based chips
	Additional nanotechnology application to balance entries



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