Nanoparticle Technology

Lecture 01: Course Overview

Nanoparticle Technology

Nanotechnology in our daily life

Information Technology

- Smaller, faster, more energy efficient and powerful computing and other IT-based systems

Energy

- More efficient and cost effective technologies for energy production
  - Solar cells
  - Fuel cells
  - Batteries
  - Bio fuels

Medicine

- Cancer treatment
- Bone treatment
- Drug delivery
- Drug development
- Medical tools
- Diagnostic tests
- Imaging

Consumer Goods

Foods and beverages

- Advanced packaging materials, sensors, and lab-on-chips for food quality testing

- Appliances and textiles
  - Stain proof, water proof and wrinkle free textiles

Nanotechnology in our daily life: example 1

Sunscreen (or sunblock)

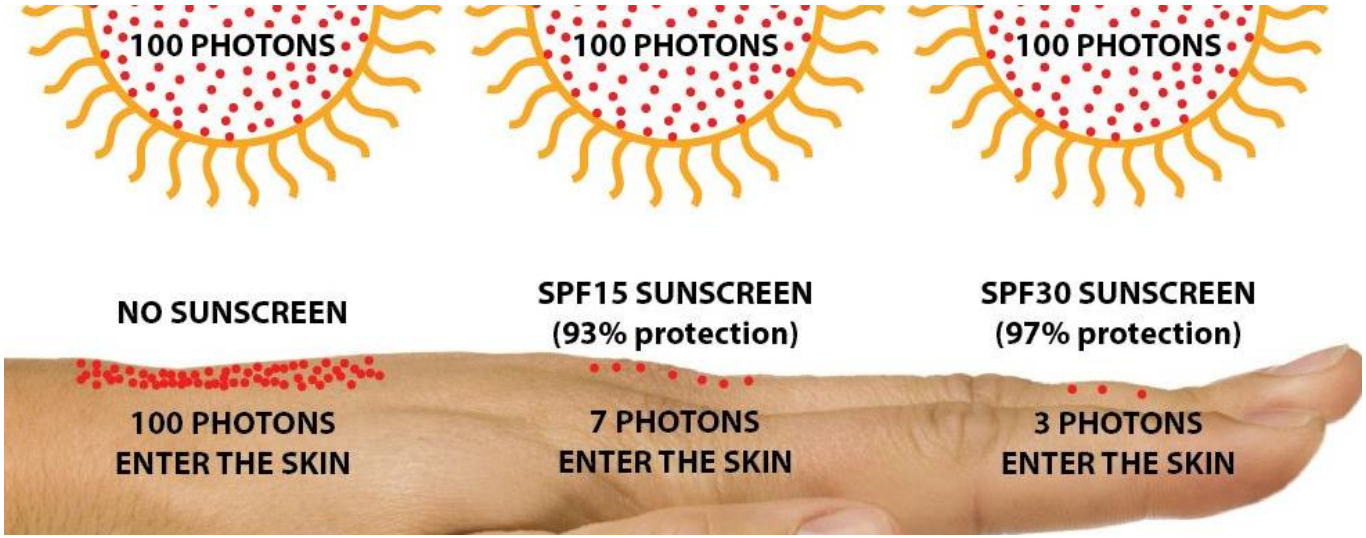
Everybody knows…

"Sunscreen is necessary for outdoor activity to protect our skin from UV-light."
"Increasing SPF number of sunscreen is more effective for protection from UV-light."

Nanotechnology in our daily life: example 1

What should we know?

The protection percentage from UV-light can be calculated by using SPF number.



SPF (sunscreen protection factor) 30 means…

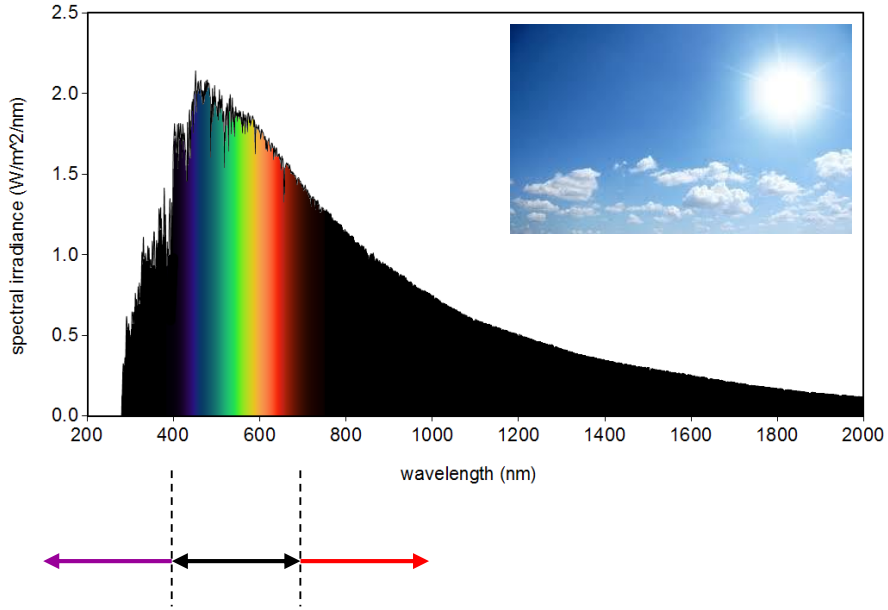
Protection percentage: $(1 - 1/30) \times 100 = 97\ \%$

Nanotechnology in our daily life: example 1

What should we know?

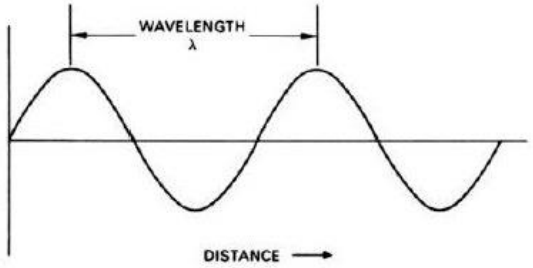
Sunlight energy is continuously changed by wavelength.

Sunlight spectrum as a function of wavelength



$$E\,(eV) = \frac{hc}{\lambda} = \frac{1239}{\lambda\,(nm)}$$

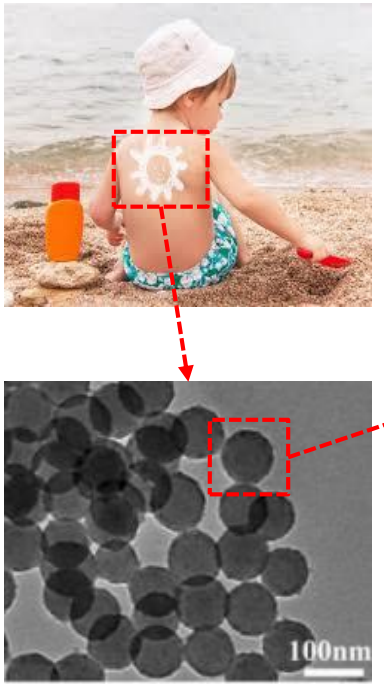
Planck constant: $h = 4.136 \times 10^{-15}$ eV·s
Light velocity: $c = 2.998 \times 10^{8}$ m/s
Wavelength: λ



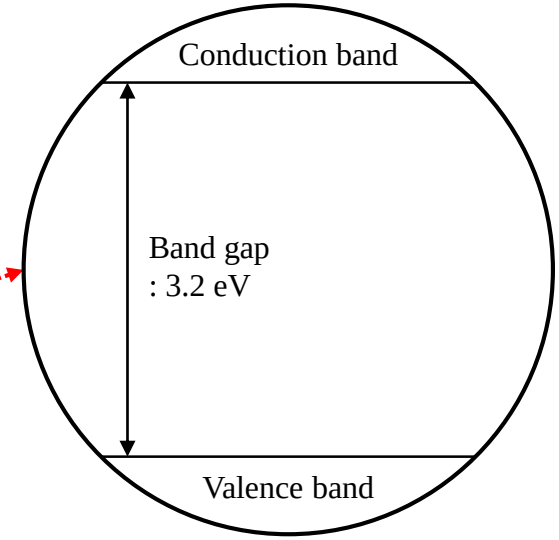
Nanotechnology in our daily life: example 1

What should we know?

TiO_2 nanoparticles which have band gap of 3.2 eV, are included in sunscreen as a main component.



TiO_2 nanoparticles

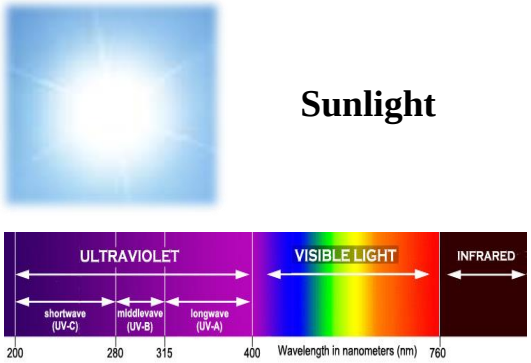


TiO_2 electron band structure (semiconductor)

Nanotechnology in our daily life: example 1

What should we know?

Ultraviolet can be absorbed by TiO_2 nanoparticles because the energy of ultraviolet is larger than bandgap of TiO_2 (3.2 eV).



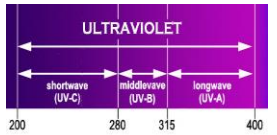
Sunlight

E (eV)

Ultraviolet: 3.10 ~ 12.39

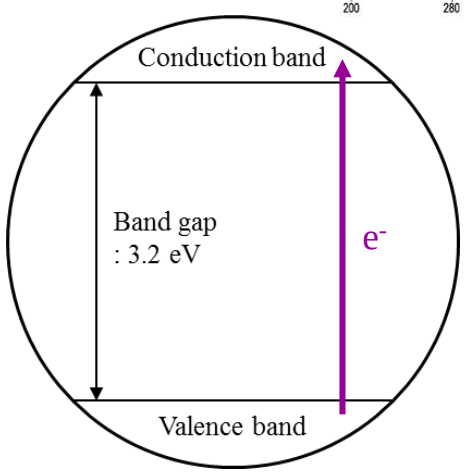
Visible: 1.59 ~ 3.26

Infrared: ~ 1.77

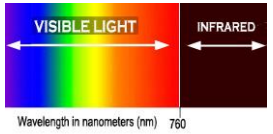


Absorption

$E > 3.2$ eV



TiO_2 electron band structure



Emission

$E < 3.2$ eV

Nanotechnology in our daily life: example 1

What should we know?

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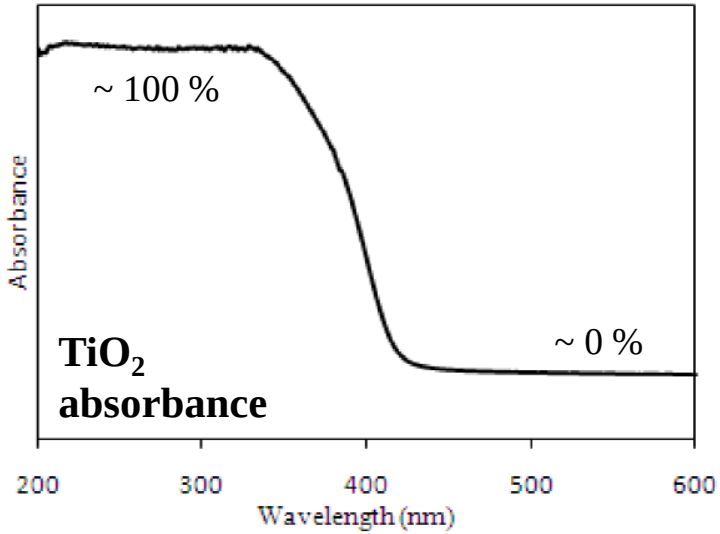
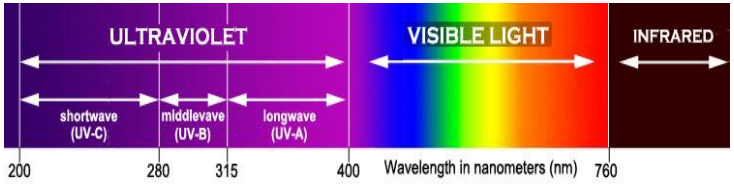
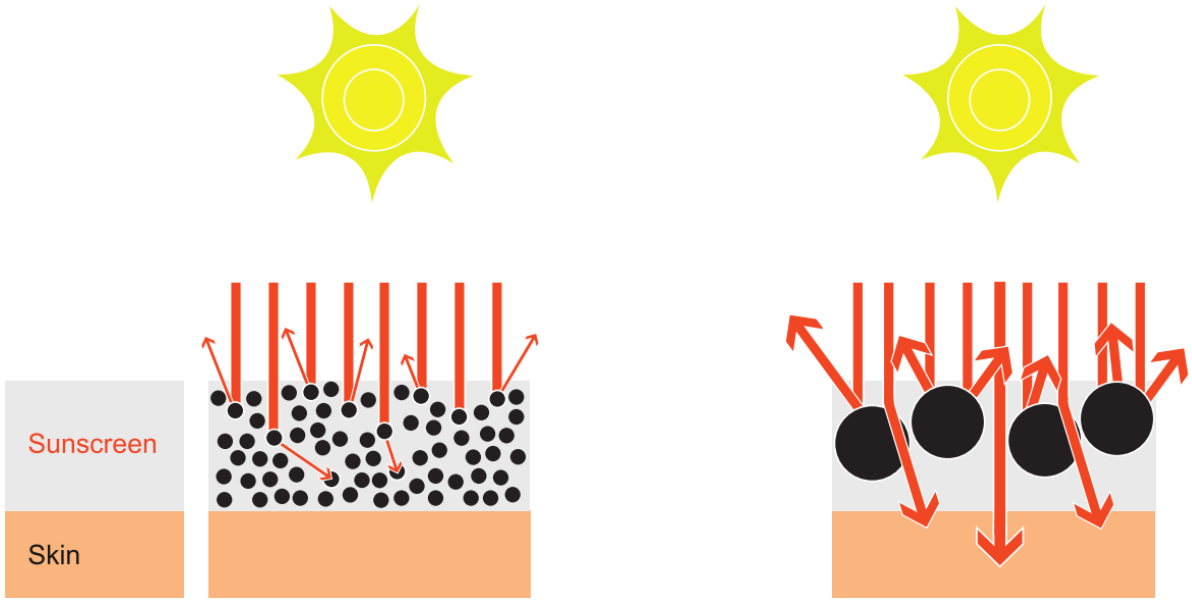




Nanotechnology in our daily life: example 1

What should we know?

Well-dispersed TiO_2 nanoparticles in sunscreen are more effective.



TiO_2 in nanoscale **TiO_2 in microscale**

Nanotechnology in our daily life: example 2

Vehicle

Fuel cell vehicle

~ 150,000 $

Gasoline vehicle

~ 30,000 $

Everybody knows…

“Although fuel cell vehicle is environmental-friendly, it is very expansive now.”
“So many engineer and researcher are trying to reduce the price for its commercialization.”

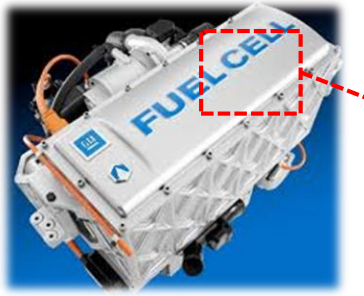
Nanotechnology in our daily life: example 2

What should we know?

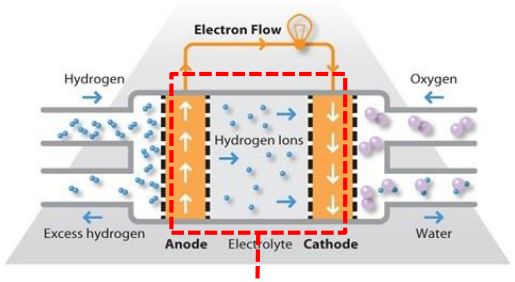
Fuel cell vehicle is expansive because a lot of Pt metal are used as catalysts.

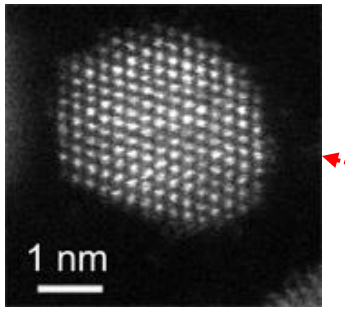
Fuel cell vehicle

Fuel cell engine (stack)

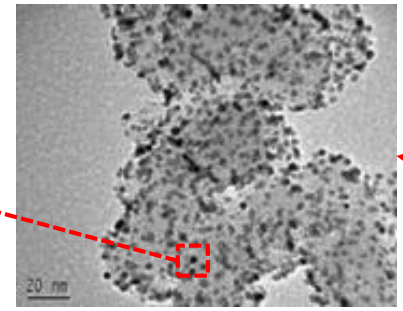


Single fuel cell

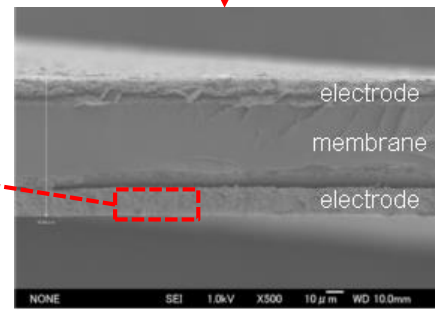




Single Pt nanoparticle



Pt/C catalysts



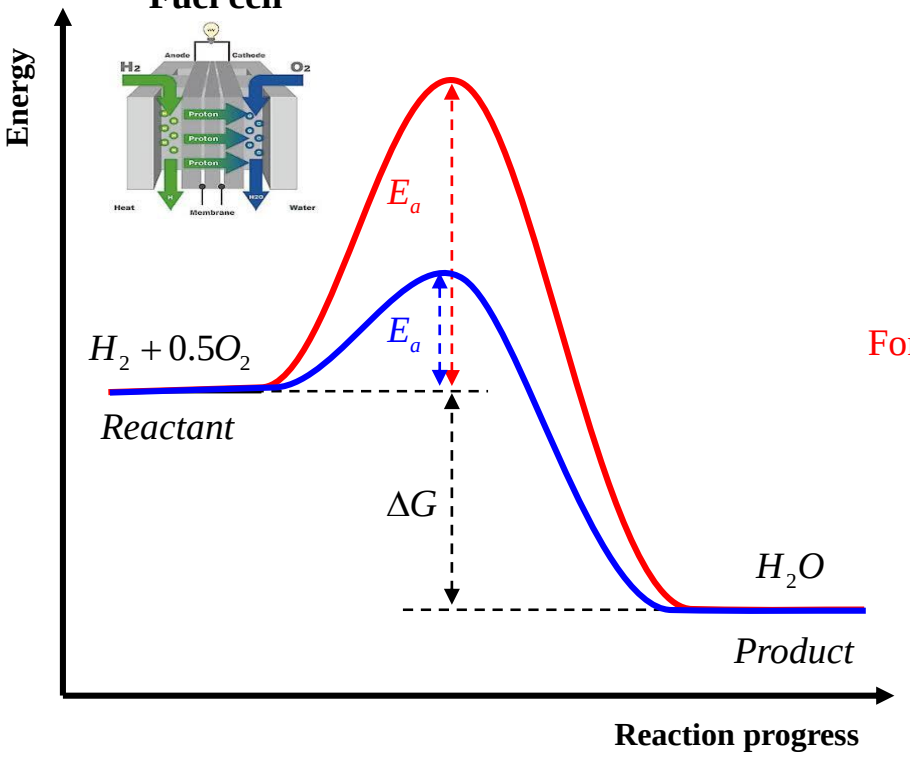
Membrane electrode assembly

Nanotechnology in our daily life: example 2

What should we know?

Pt catalysts should be used to decrease the activation energy for fuel cell reactions.

Fuel cell



Fuel cell reactions

$$H_2 + 0.5O_2 \xrightarrow{r} H_2O$$

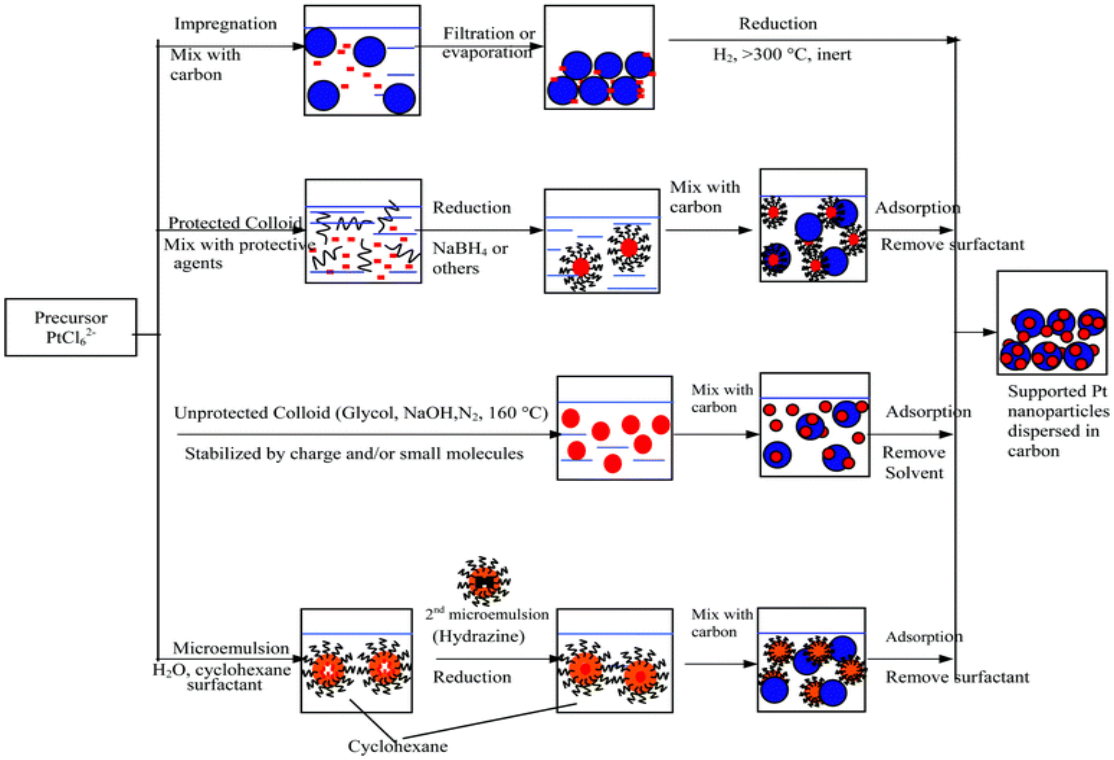
$$r = kC_{reatant}, \quad k = Ae^{-E_a/RT}$$

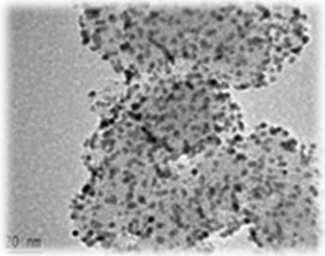
For non-catalyzed reaction: $k = Ae^{-Ea/RT}$ < For catalyzed reaction: $k = Ae^{-Ea/RT}$

Nanotechnology in our daily life: example 2

What should we know?

Pt nanoparticle catalysts can be fabricated from Pt solution by various methods.



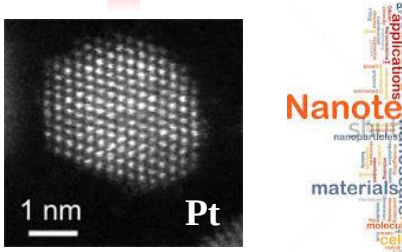


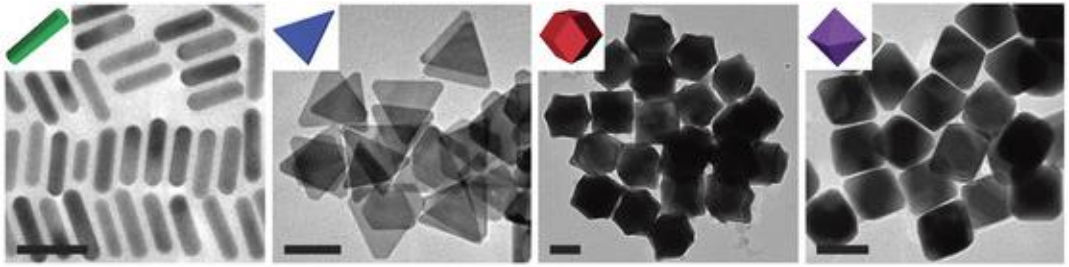
Nanotechnology in our daily life: example 2

What should we know?

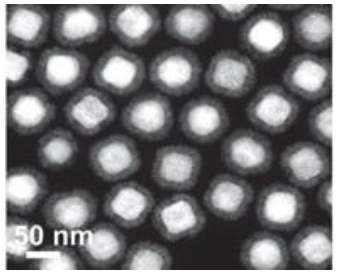
Nanotechnology can increase activity of Pt catalysts or decrease cost of Pt catalysts.

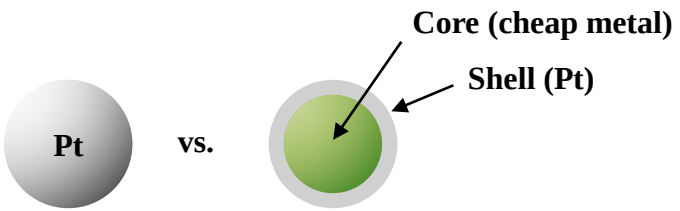
Shape control: increase activity





Core-shell structure: decrease cost





36.3 $/g **Lower price**

What is nanotechnology?

- In general, nanotechnology can be understood as a technology of design, fabrication and applications of nanostructures and nanomaterials.