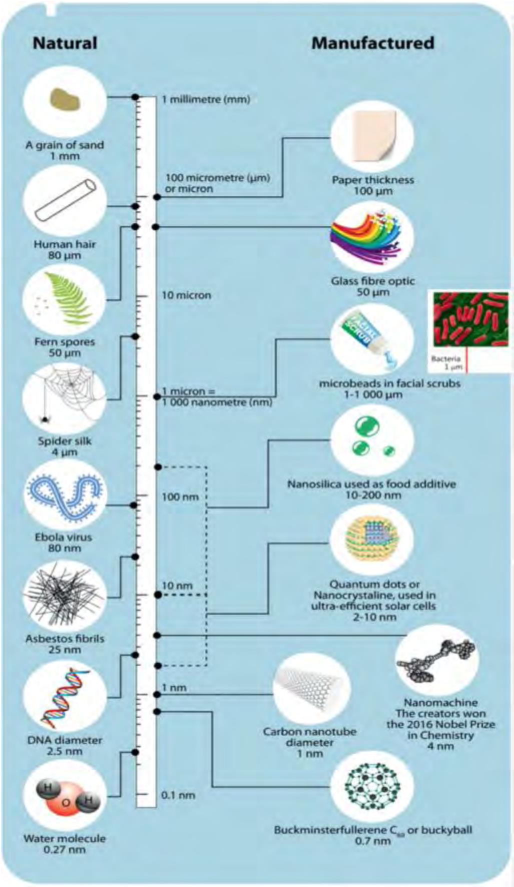
1. Overview

1.1 History

1959 Richard P. Feynman Nobel prize in Physics → World smallest movie

1.2 Definition

Nano = 10^{-9} Most bacteria = 10^{-6}; Water molecule = 0.3nm



Nano materials = where sizes of the individual building blocks <100nm in at least 1 dimension

0D: quantum dots, fullerene
1D: Nanofiber, Nanotubes, nanowires
2D: 2D material family (graphene, clay…), nano thin film
3D: nanostructured assembly(nano aerogel…), nanocrystalline, composites

Figure 1 – dimensions

Other nanomaterials:

Enamel = HA crystals are nanomaterial

1.3 Nanomaterials vs Nanotechnology

Nanotechnology = creation of functional materials, devices & systems through control of matter on the n scale & exploitation of novel phenomena and properties at nm scale.

Includes:

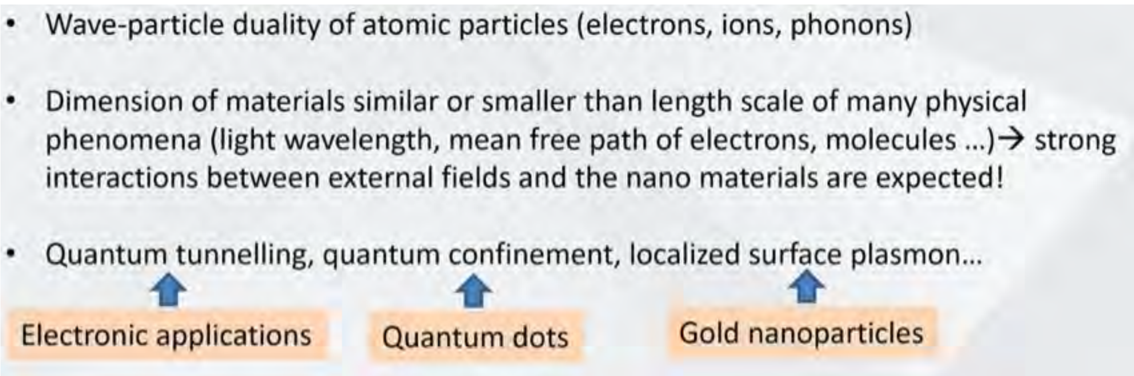
- Manufacturing technology of nanomaterials
- Technologies of nanomaterials applied to various fields (including but not limited to high-tech fields)
- Any device that is built in a nanoscope for operation of atoms and molecules
- The understanding of new laws of the material
- Transfer and energy transfer within the nanoscope

BUT NOT THE FOCUS OF MODULE

2. Importance of Nanosize

Mp decreases
Gold nanoparticles can show red colour @ nano
Electric tunnelling properties

2.1 Size dependent properties

1) Conventional case – gravitational force dominates. @ nanoscale electromagnetic forces dominate ∵ mass is negligible, so g is negligible. EM = function of Q and d
2) Classical mechanics model = newton law. @ nanoscale, quantum mechanics is used to describe motions & E
    a. 

    b. Wave-particle, quantum tunnelling, confinement, plasmon

3) Very large/interface to V ratios
    a. Nano → low unit V & weight
    b. High surface/volume ratio
    c. Surface area increases
4) Random molecular movement becomes significant ∵ nanomaterial has low weight = easier to move & @ nanoscale, atom at surface has weak bond to the whole material = makes random molecular movement more significant

2.2 Examples

2.2.a Surfaces

Large surface area:

1) High surface energy

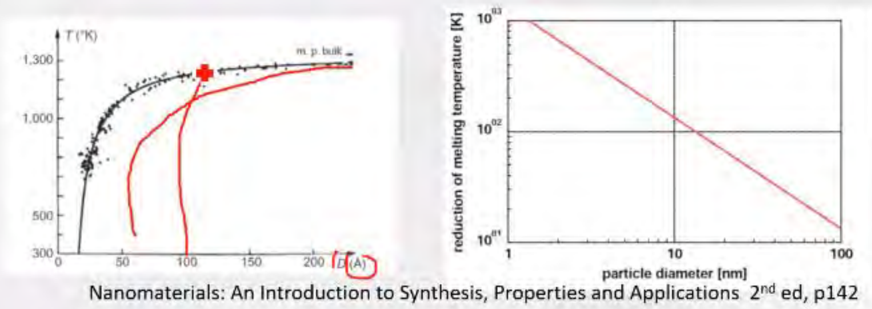
$$u_{surface} = \gamma A$$

(γ is the specific surface energy, A is the surface area of one particles)

a. Melting point depression

@ nanoscale, SA is a lot so must be considered:

$$G = U - TS + u_{surface}$$



Nanomaterials: An Introduction to Synthesis, Properties and Applications 2nd ed, p142

Melting point vs particle size of silver(left) and aluminum(right)

- T_m of Bulk gold :1064 °C, 2 nm, 327 °C
- T_m of bulk silver:962 °C, ~3 nm, ~400 °C

b. Aggregation of nano particles

→ reduce total surface → low system free E

- To prevent aggregation →

2.2.b Interfaces

More interfaces → stronger materials

Interface = the point/layer where 2 system matters meet.
E.g. Grain boundaries

- Comparison of mechanical strength of nanocrystalline & micrometre Cu sheets + why
  - GB strengthen ∵
- We know the crystalline size of nanocrystalline Cu samples through XRD

2.2.c Diffusion scaling Law

→ rapid homogenisation

Diffusion length = much faster
Conc. Gradient –

Gas senor – related to diffusion so quicker diffusion, faster it reacts/senses

Read nanomaterials intro to s

How are the electrodes &

Efficient & abundant absorption
Fast chemical reactions

3. Preparation of nanomaterials

3.1 Top-down strategy for fabrication of nano materials

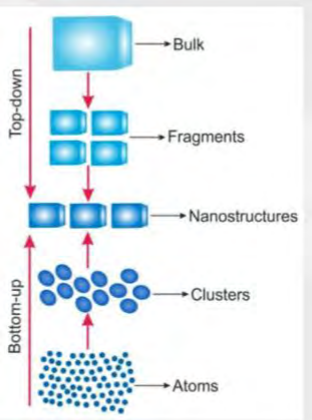


Figure 2 - top-down vs bottom↑

Top-down: start with bulk, then use different methods to break in fragments. = size shrinking. Most small structures are mass produced by this method (most electronic devices made by this)

Bottom↑: assembly from atom/molecules to final products

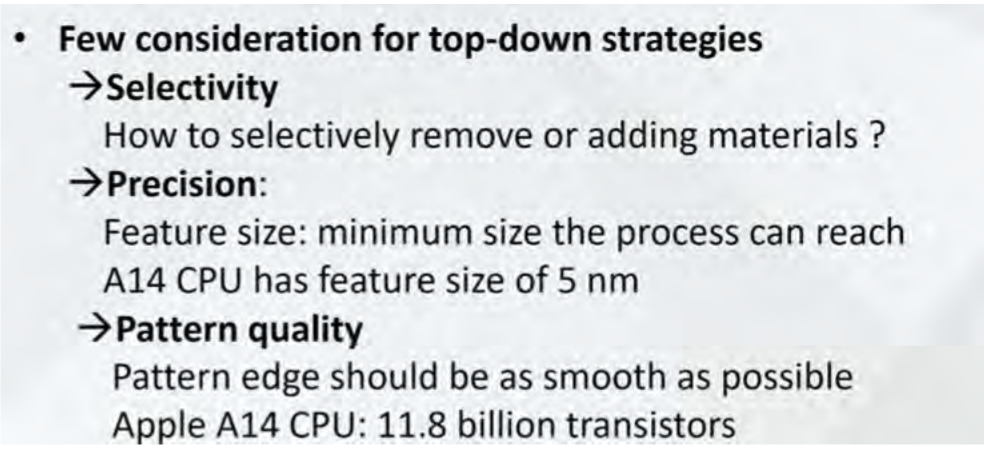


Figure 3 - considerations for top-down strategies

3.1.a Methods for top-down strategy

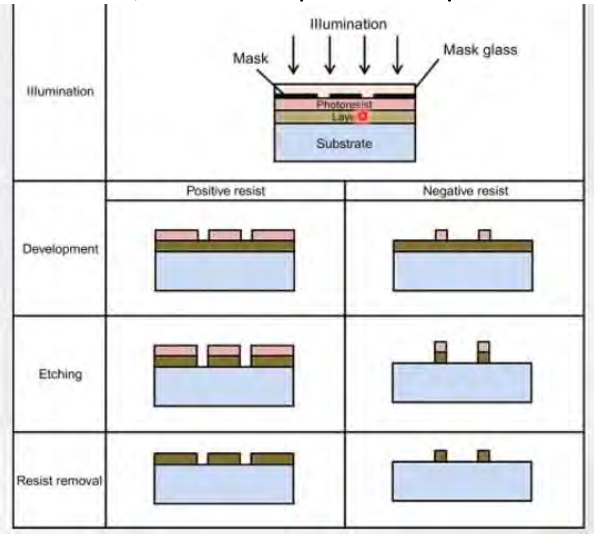
3.1.ai *Photolithography*

2 important components

Photo resist = light sensitive polymers

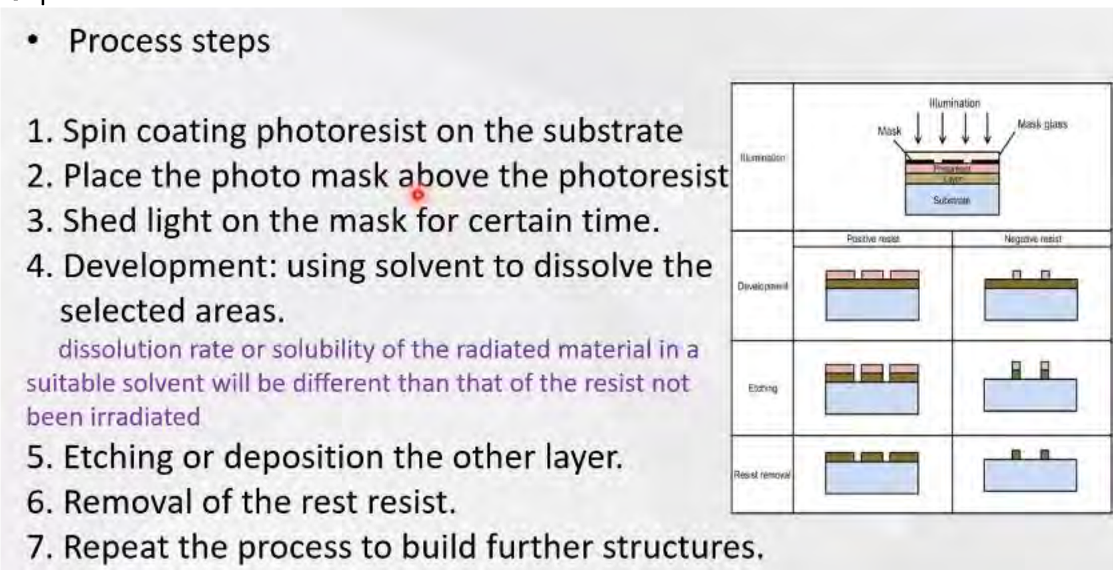
2 types: 1) +ve resist = photo induced scission of polyer chain
1) -ve resist = photo induced cross-linking of polymer chains

Photo mask = quartz/glass substate w/chrome mask (reflects light) anf tranpsraencies (allows light to be shed through)
In a whole, it selectively allow the photo resist underneath to be shed by light



1) Apply a photoresist, then a mask
2) Shed uv light through mask. Light will be reflected back via mask. Gaps will allow through

+ve resist – development – pt silicon wafer in a particular solvent. Photoresist is less stable? Will dissolve → pattern



-ve light induce cross link = more stable – parts that are not crosslinked will be removed in certain solvents. Apply ion/plasma or ething to remove

Case study