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UNIVERSITY OF BUCHAREST

NTNU
Norwegian University of Science and Technology

Nanotechnology - introduction

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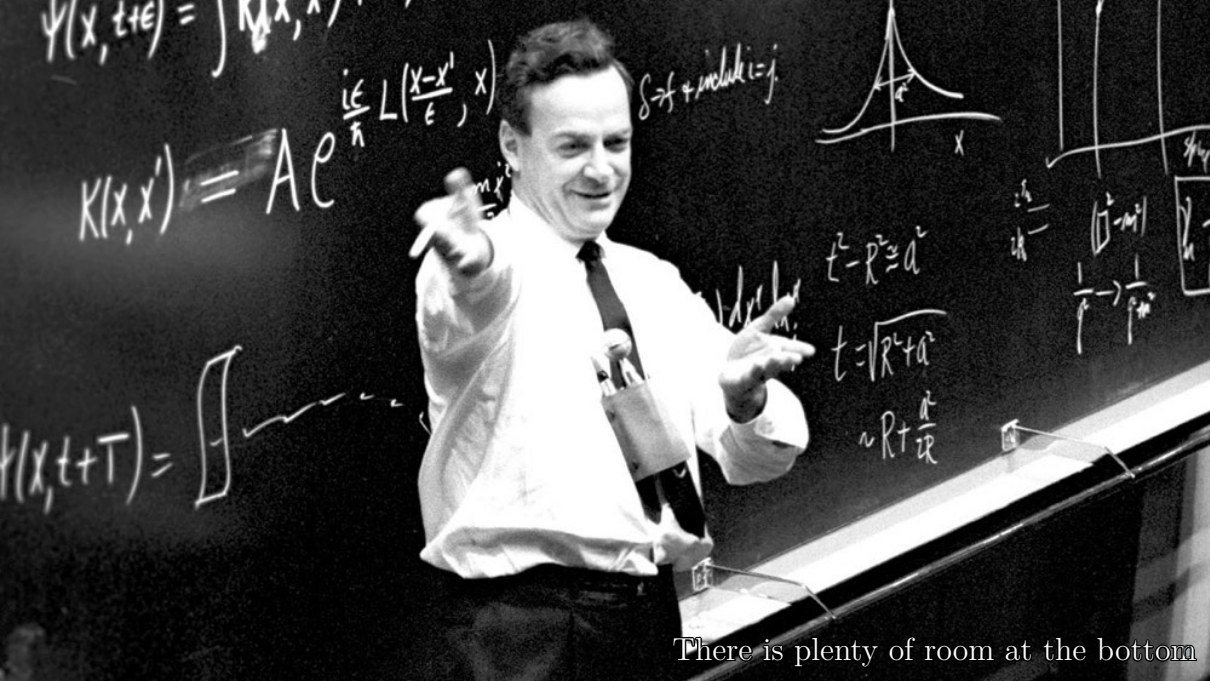
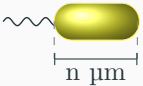
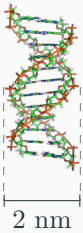
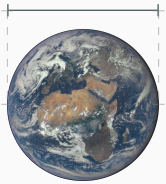
Welcome!

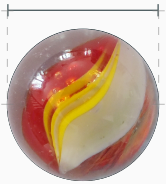
What is Nanotechnology?

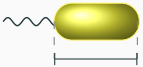

There is plenty of room at the bottom

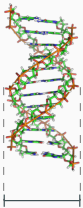

n µm


2 nm

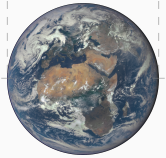




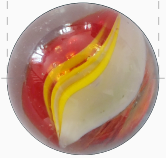


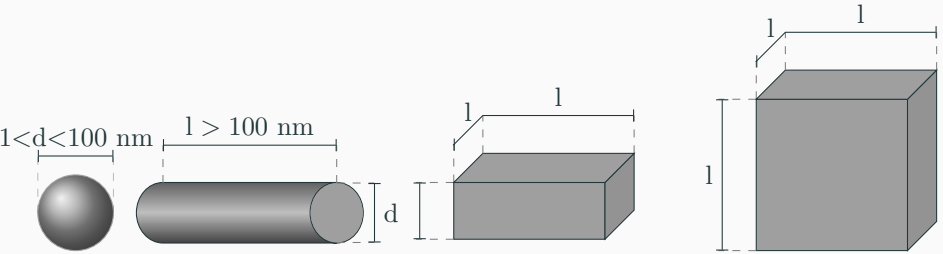


12.7 Mm



1.27 cm




1<d<100 nm
l > 100 nm
d
l
l
l
l
0 D
1 D
2D
3D

$$\mathrm{SSA} = \frac{\mathrm{A}}{\mathrm{V}\rho}$$

$$[\mathrm{SSA}] = \frac{\mathrm{m}^2}{\mathrm{g}}$$

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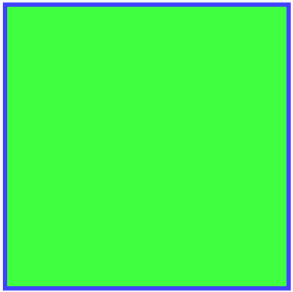
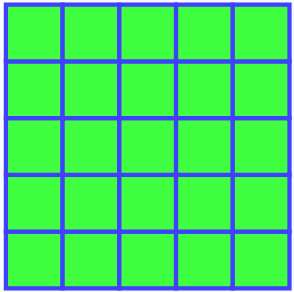


$$\mathrm{SSA} = \frac{\mathrm{A}}{\mathrm{V}\rho}$$

$$[\mathrm{SSA}] = \frac{\mathrm{m}^2}{\mathrm{g}}$$



Bandgap

$$E_{nano} = E_{g,bulk} + \frac{h^2\pi^2}{2mr^2_{nano}} \quad (1)$$

Bandgap

$$E_{nano} = E_{g,bulk} + \frac{h^2\pi^2}{2mr_{nano}^2} \tag{1}$$

Melting temperature

Bandgap

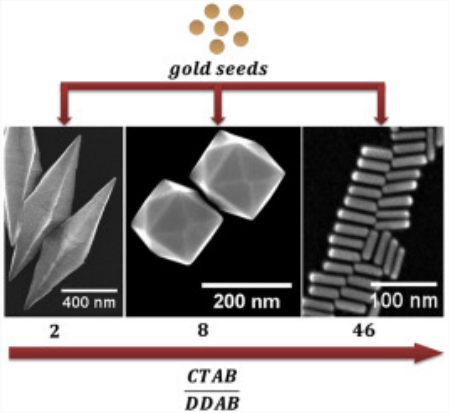
$$E_{nano} = E_{g,bulk} + \frac{h^2\pi^2}{2mr_{nano}^2} \tag{1}$$

Melting temperature

Interactions with environment

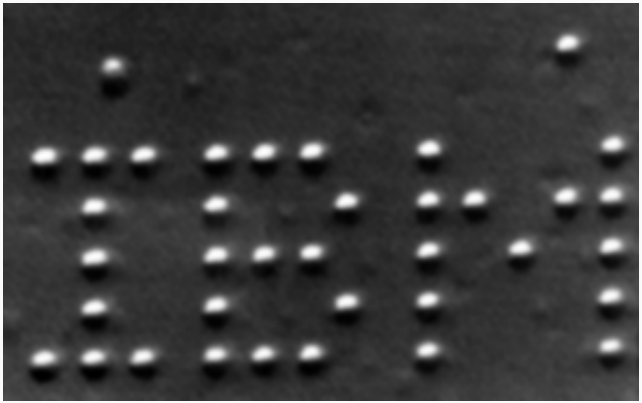
Top-Down
vs.
Bottom-Up

Nucleation and growth

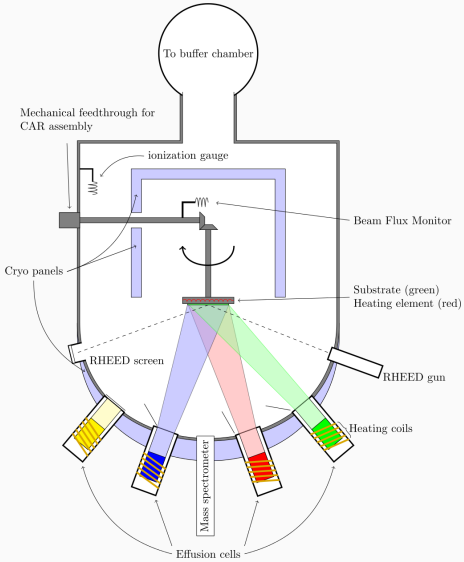


Sulalit Bandyopadhyay, Mat. Today, 2017

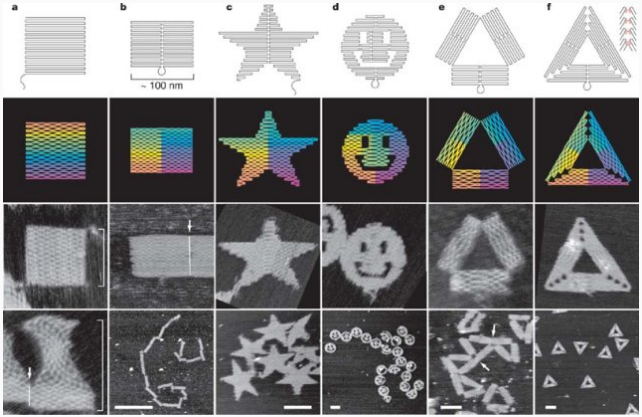
Nucleation and growth
Scanning Probe Microscopy (SPM)



Nucleation and growth
SPM
Molecular Beam Epitaxy (MBE)

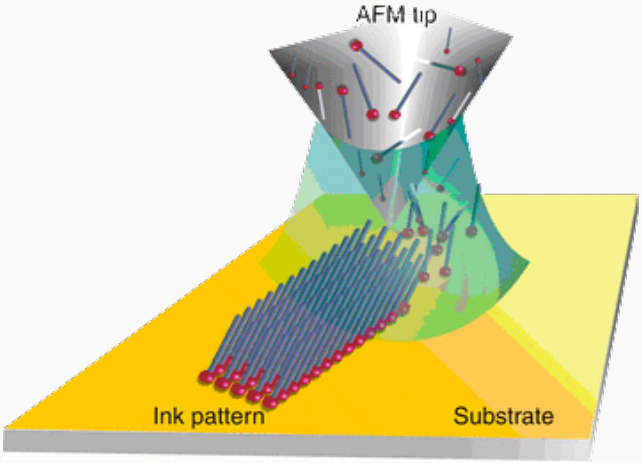


Nucleation and growth
SPM
MBE
Polymer origami



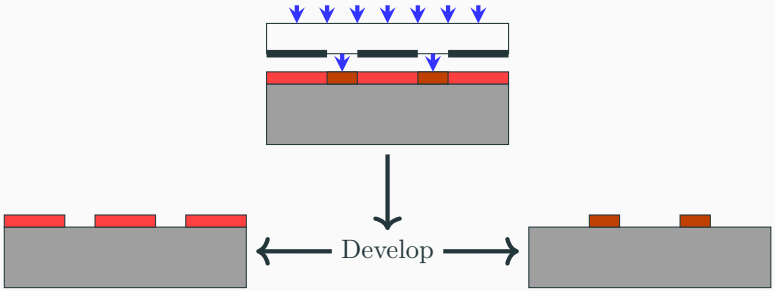
Rothemund, Nature, 2006

Nucleation and growth
SPM
MBE
Polymer origami Lithography
    Dip-pen, Soft lithography...



Smith et al, Nano Letters, 2003

Top-down
Lithograhpy
Photolithography, EBL,
SCIL, NIL...



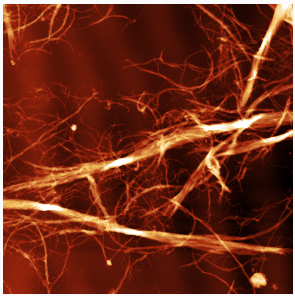
Top-down

Lithograhpy

- Photolithography, EBL,
- SCIL, NIL...

Forces

- Shear, impact



Top-down

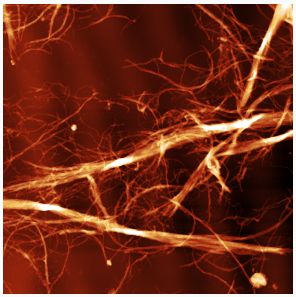
Lithograhpy

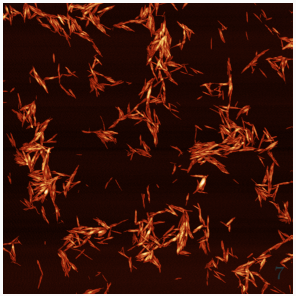
- Photolithography, EBL,
- SCIL, NIL...

Forces

- Shear, impact

Top-down
Lithograhpy
Photolithography, EBL,
SCIL, NIL...
Forces
Shear, impact
Partial dissolution
Acids, bases





Characterization

Statistical

- X-Ray Scattering (WAXS/SAXS)
- Neutron Scattering
- Nuclear Magnetic Resonance (NMR)

$$\mathrm{d} = \frac{\lambda}{2\mathrm{NA}}, \mathrm{d} > 0.25\mu\mathrm{m}$$

STED, PALM, STORM, SIM...

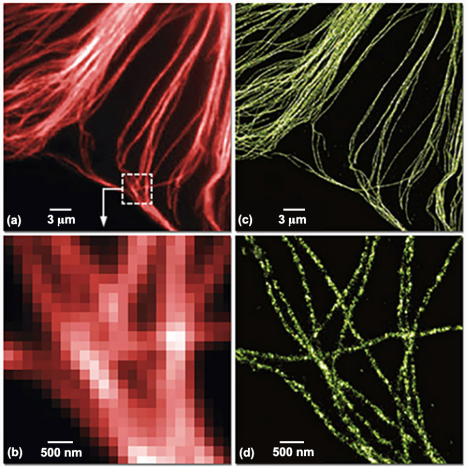
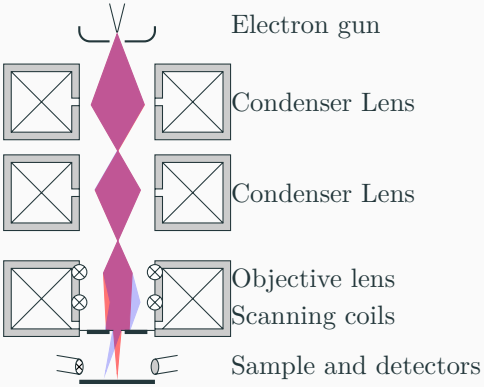
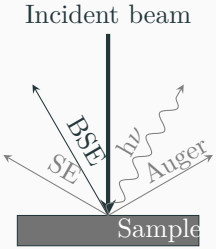
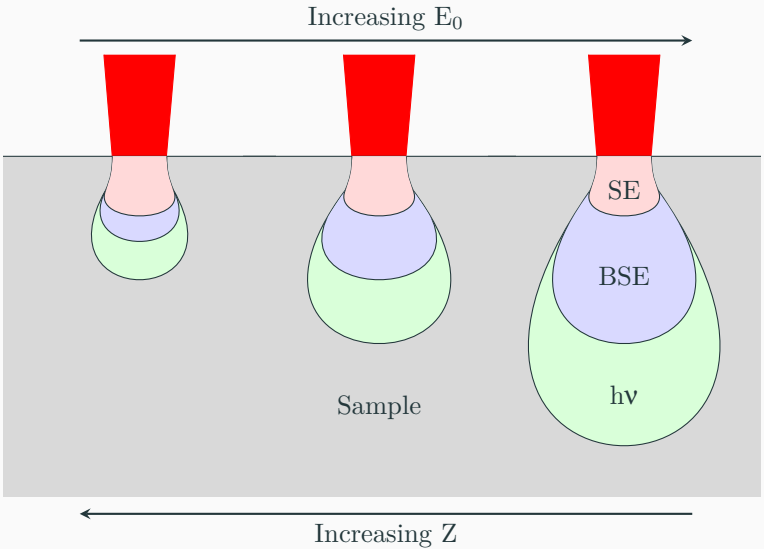
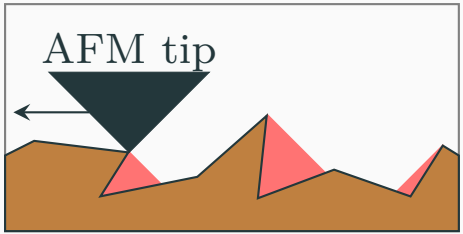


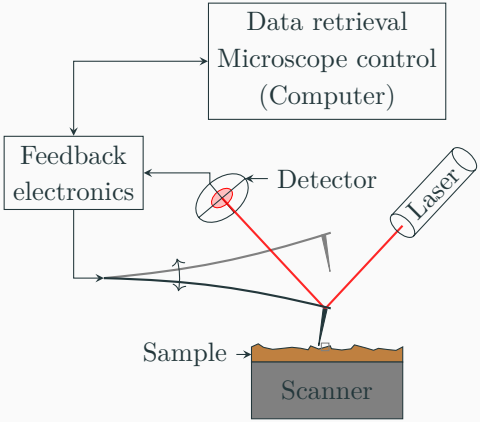
Image: Nikon

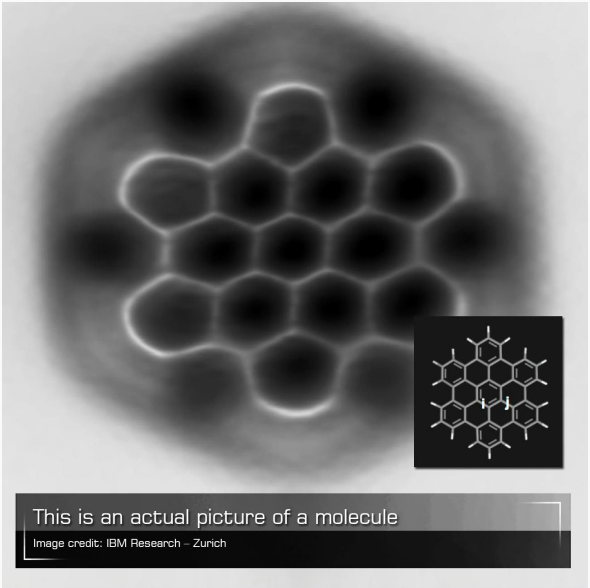

Electron gun
Condenser Lens
Condenser Lens
Objective lens
Scanning coils
Sample and detectors


Incident beam
BSE
SE
hν
Auger
Sample


Increasing E_0
SE
BSE
hν
Sample
Increasing Z


AFM tip


Data retrieval
Microscope control
(Computer)
Feedback
electronics
Detector
Laser
Sample
Scanner


This is an actual picture of a molecule
Image credit: IBM Research – Zurich

summary

1-3D $\in \{1, 100\}$ nm

summary

1-3D $\in \{1, 100\}$ nm
novel properties

summary

1-3D $\in \{1, 100\}$ nm
novel properties
Build from ground up
Produce from larger whole

summary

1-3D $\in \{1, 100\}$ nm
novel properties
Build from ground up
Produce from larger whole
Demanding characterization