

# Nanoscience: A historical perspective

R. Díez Muiño and P. M. Echenique

*Lecture Notes*  
*Fall 2007*



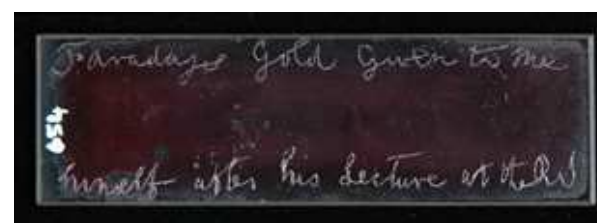
**key points**

## Faraday and size-dependent properties (1858)

Faraday was famous for his captivating lectures featuring superbly choreographed demonstrations, and would have used a projecting microscope to show the slide.

The preparations of gold 'sols' (colloids) that Faraday studied were ruby-red in colour. He discovered that he could turn the preparation blue by adding certain salts.

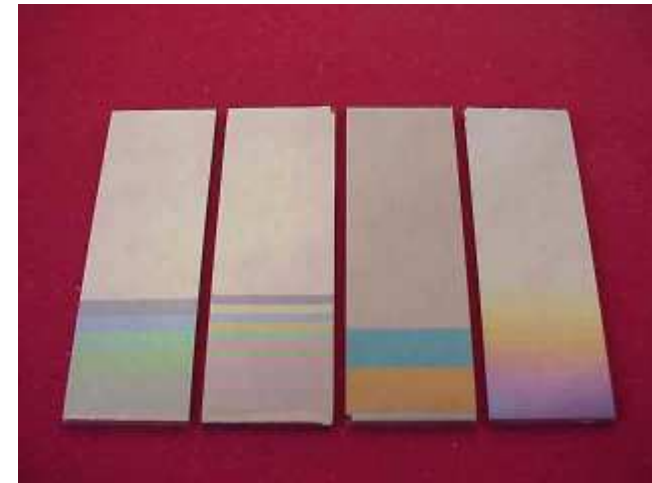
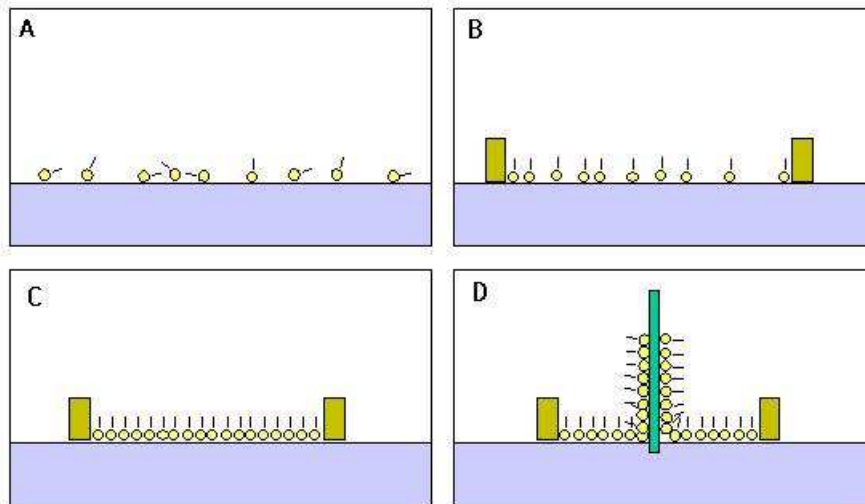
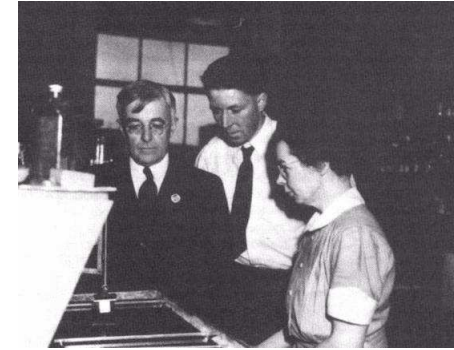
Faraday made some attempt to explain what was causing the vivid colouration in his gold mixtures, saying that *"known phenomena seemed to indicate that a mere variation in the size of [gold] particles gave rise to a variety of resultant colours."*



*Slide that Faraday used in his lecture on gold sols, in 1858.*

## Langmuir-Blodgett layers (1930's)

Langmuir and Blodgett studied thin films and surface absorption. They introduced the concept of a **monolayer** (a layer of material one molecule thick) and the **two-dimensional physics** which describe such a surface.



A Langmuir-Blodgett film contains one or more monolayers of an organic material, deposited from the surface of a liquid onto a solid by immersing (or emerging) the solid substrate into (or from) the liquid. A monolayer is added with each immersion or emersion step, thus films with very accurate thickness can be formed. Traditional compounds used to prepare these films are **amphiphilic** materials that possess a hydrophilic headgroup and a hydrophobic tail.

***Plenty of Room at the Bottom, Richard P. Feynman (1959)***

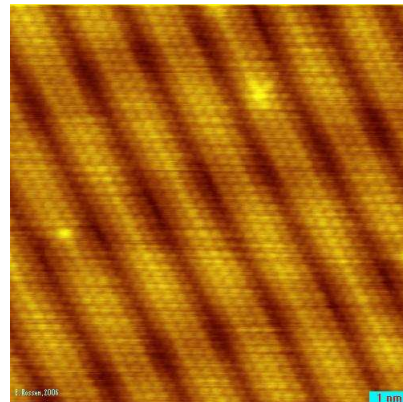
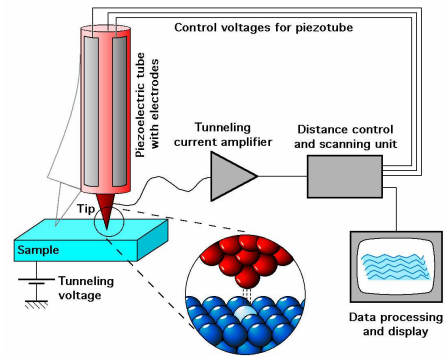
What I want to talk about is the problem of manipulating and controlling things on a small scale.

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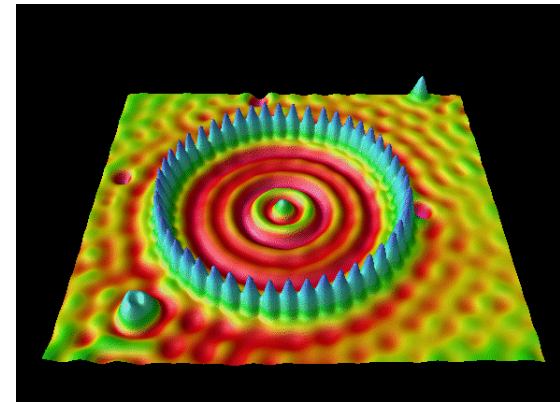
In the year 2000, when they look back at this age, they will wonder why it was not until the year 1960 that anybody began seriously to move in this direction.



## Scanning tunneling microscope STM, Binnig and Rohrer (1981)

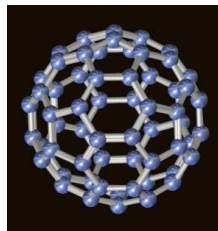
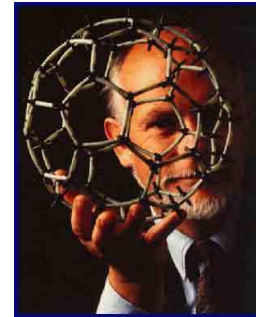


as a characterization tool

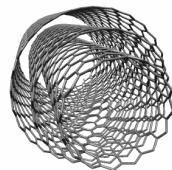


as a manipulation tool

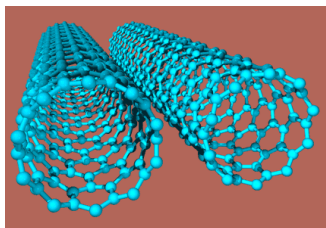
## Carbon Fullerenes and Nanotubes (1985-1993)



Kroto, Heath, O'Brien, Curl, and Smalley,  
'C<sub>60</sub>: Buckminsterfullerene', Nature **318**, 162 (1985).



*Helical microtubules of graphite carbon*  
Nature **354**, 56 (1991).



S. Iijima and T. Ichihashi, Nature **363**, 603 (1993)  
D. S. Bethune *et al.*, Nature **363**, 605 (1993)

# The Scale of Things – Nanometers and More

## Things Natural

Dust mite  
200  $\mu\text{m}$

Human hair  
~60-120  $\mu\text{m}$  wide

Fly ash  
~10-20  $\mu\text{m}$

Red blood cells  
(~7-8  $\mu\text{m}$ )

Ant  
~5 mm

DNA  
~2-1/2 nm diameter

ATP synthase  
~10 nm diameter

Atoms of silicon  
spacing 0.078 nm

## Things Manmade

1 cm  
10 mm

1,000,000 nanometers =  
1 millimeter (mm)

Microwave

0.1 mm  
100  $\mu\text{m}$

0.01 mm  
10  $\mu\text{m}$

Infrared

1,000 nanometers =  
1 micrometer ( $\mu\text{m}$ )

Visible

0.1  $\mu\text{m}$   
100 nm

Ultraviolet

0.01  $\mu\text{m}$   
10 nm

Soft x-ray

1 nanometer (nm)

10<sup>-10</sup> m

10<sup>-9</sup> m

10<sup>-8</sup> m

10<sup>-7</sup> m

10<sup>-6</sup> m

10<sup>-5</sup> m

10<sup>-4</sup> m

10<sup>-3</sup> m

10<sup>-2</sup> m

Microworld

Nanoworld

Head of a pin  
1-2 nm

MicroElectroMechanical (MEMS) devices  
10 -100  $\mu\text{m}$  wide

Pollen grain  
Red blood cells

Zone plate x-ray "lens"  
Outer ring spacing ~35 nm

Self-assembled, Nature-inspired structure  
Many 10s of nm

Nanotube electrode

Carbon nanotube  
~1.3 nm diameter

Carbon buckyball  
~1 nm diameter

Quantum corral of 48 iron atoms on copper surface  
positioned one at a time with an STM tip  
Corral diameter 14 nm

The Challenge

Fabricate and combine nanoscale building blocks to make useful devices, e.g., a photosynthetic reaction center with integral semiconductor storage.

Office of Basic Energy Sciences  
Department of Energy  
November 23, 2004, 4:42



*In the words of Don Eigler:*

**Nanoscience has been around for at least 100 years, and probably a lot longer. Much of chemistry could be defined as nanoscience for example. Nanotechnology on the other hand should incorporate a manufacturing process with a clear market application.**

- There is a strong awareness that 'small is different'**
- We have the means to design and manipulate small things**

<http://dipc.ehu.es/ricardo/master/nanohistory.htm>

