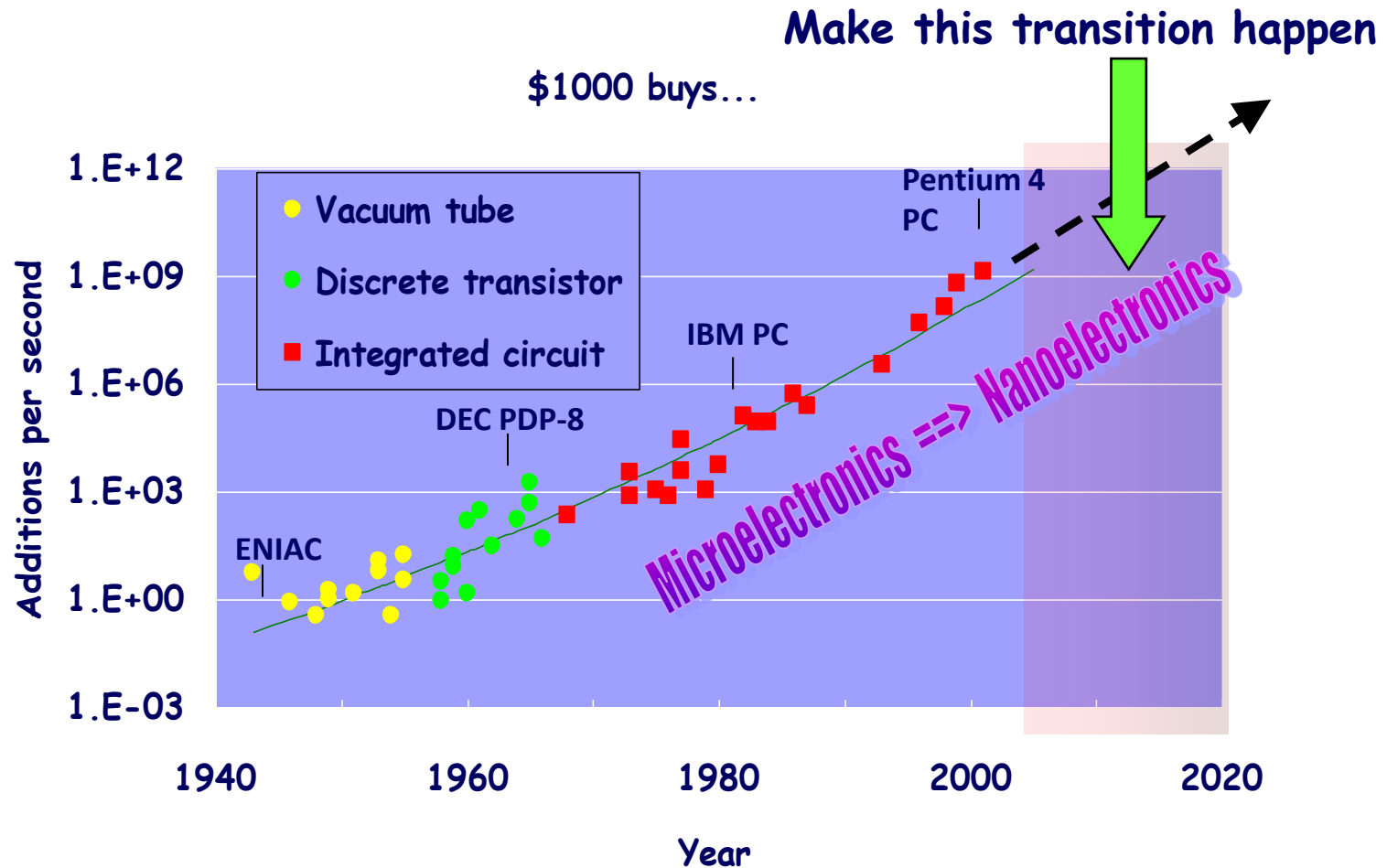


ESE 111 – Nanofabrication and Technology



... and the other applications that are enabled by nanoscale science and technology

Evolution of Electronics

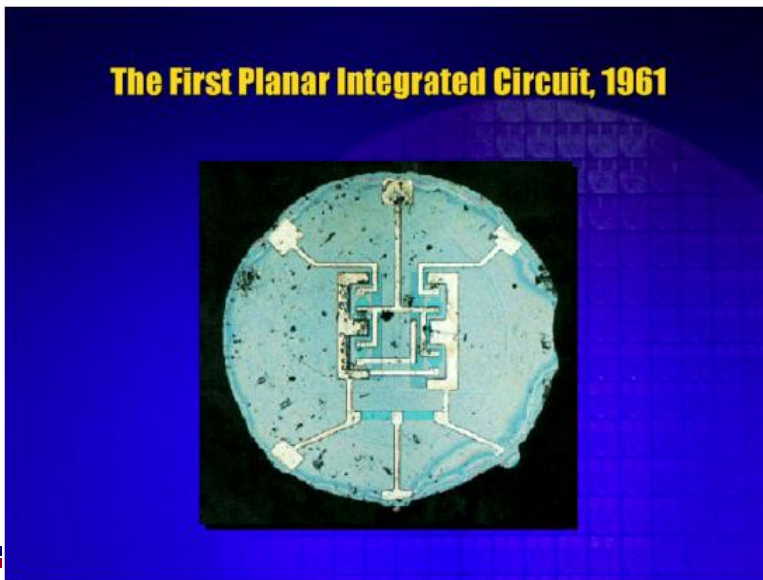


Vacuum tube

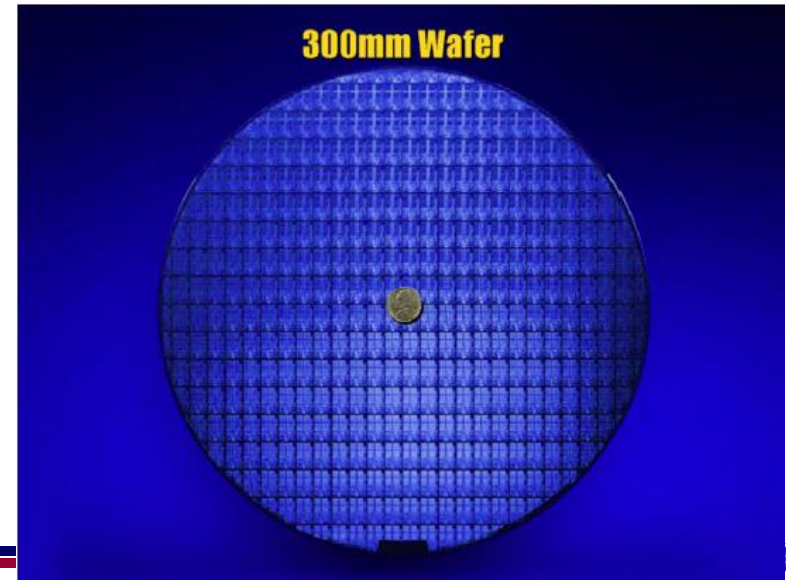
ENIAC = Electronic Numerical Integrator and Computer



First Transistor, 1947 Bell Labs
Discrete Transistor

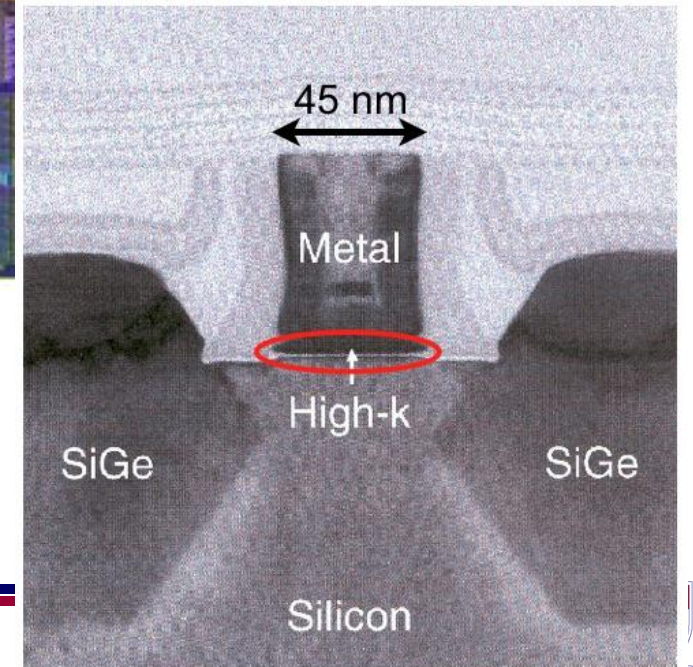
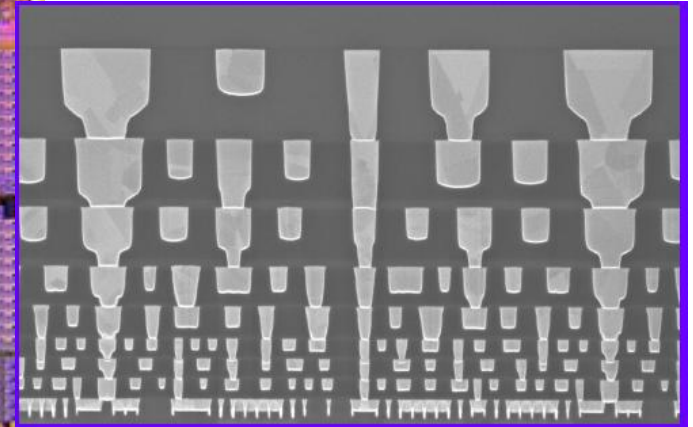
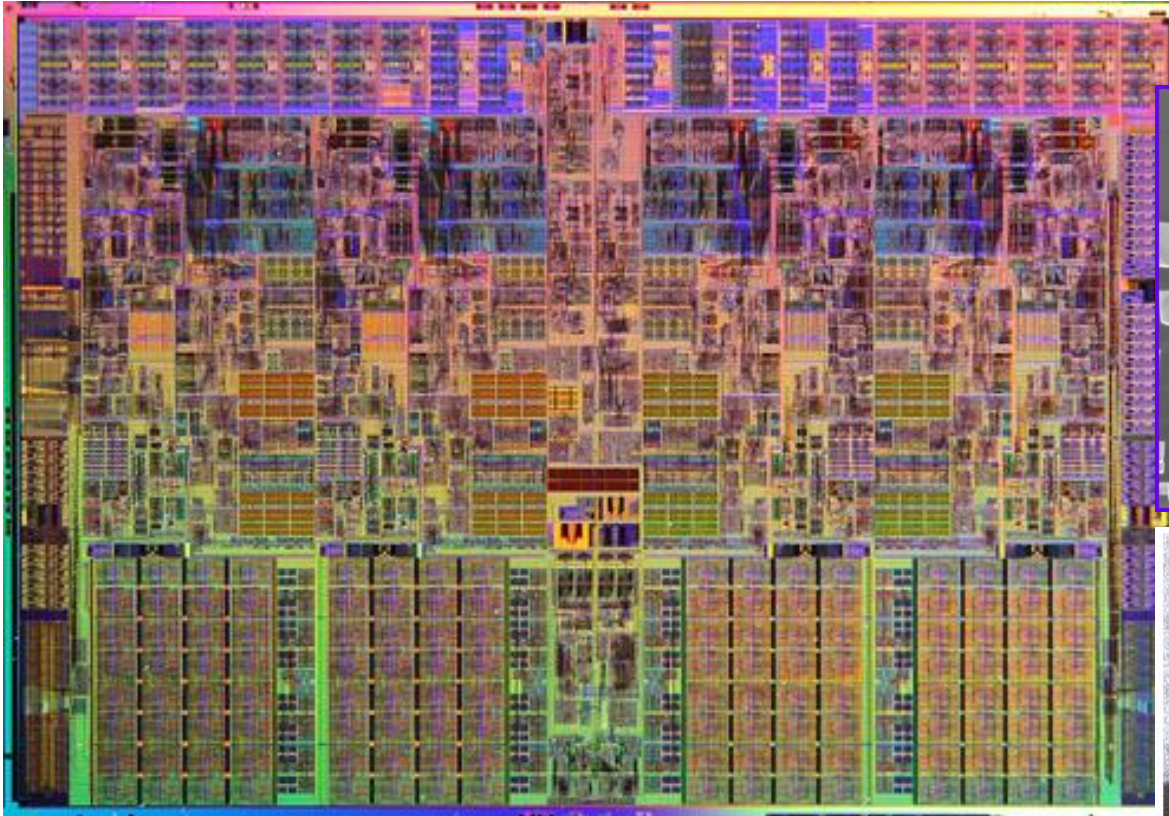


The First Planar Integrated Circuit, 1961



300mm Wafer

Intel Core i7 Processor with 45 nm Transistors



The Fabrication Facility of Today



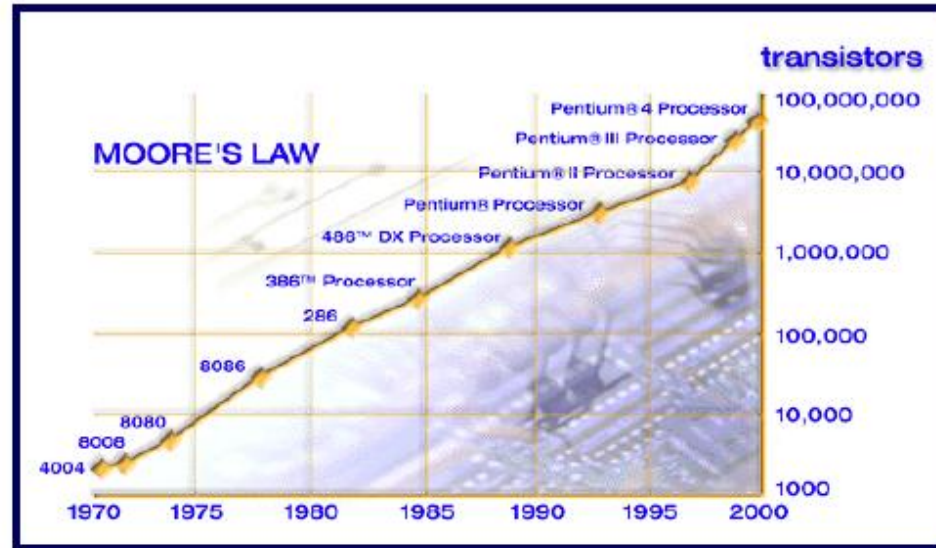
300 mm wafer Fabrication
<http://www.youtube.com/watch?v=inoOAOOMjHo>

Intel

Moore's Law



Intel Co-Founder
Gordon E. Moore



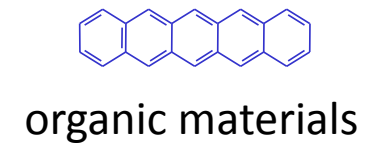
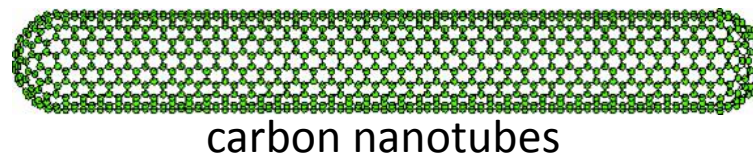
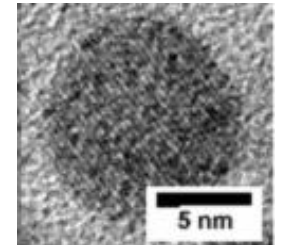
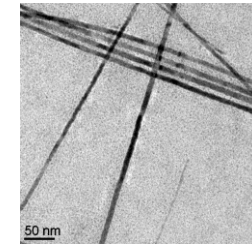
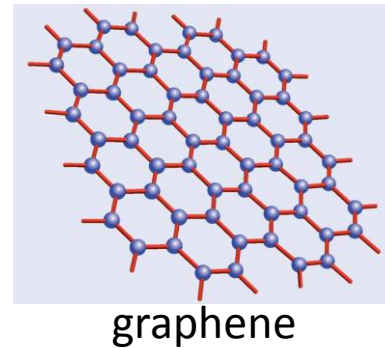
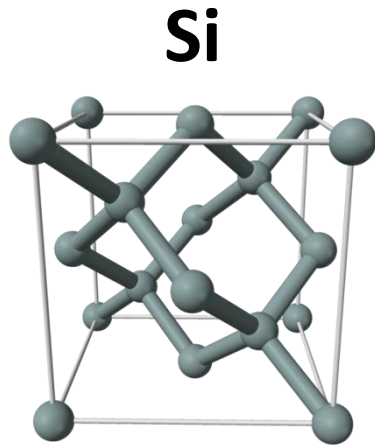
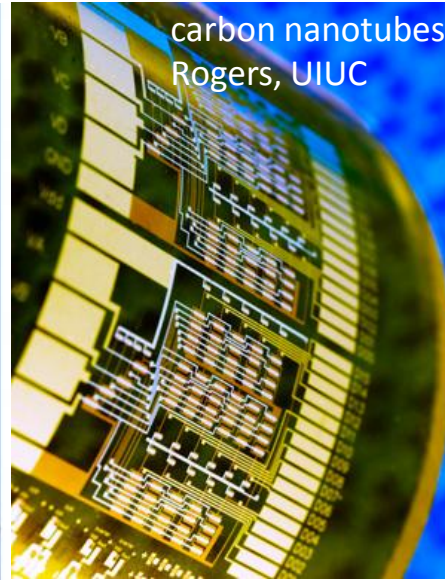
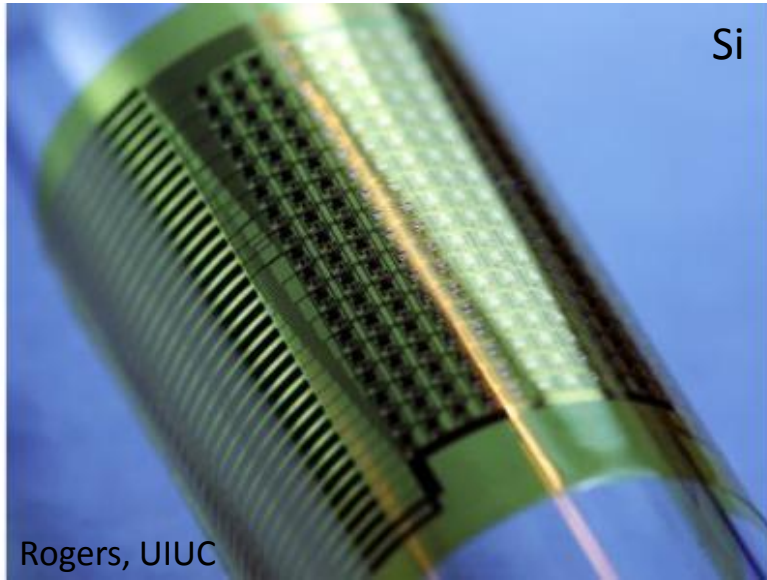
“Cramming More Components Onto Integrated Circuits”

Author: Gordon E. Moore

Publication: Electronics, April 19, 1965

Other Electronic Applications = "More than Moore"

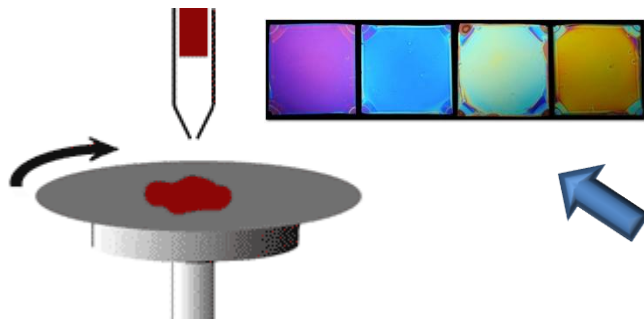
Silicon and New Materials



Alternative, Low-Cost Fabrication

Printable Electronics – Spin, Dip, Spray, Print, Imprint ... From Solution

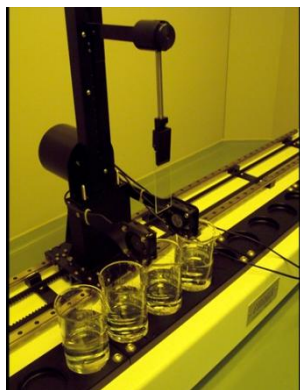
Spin-coating



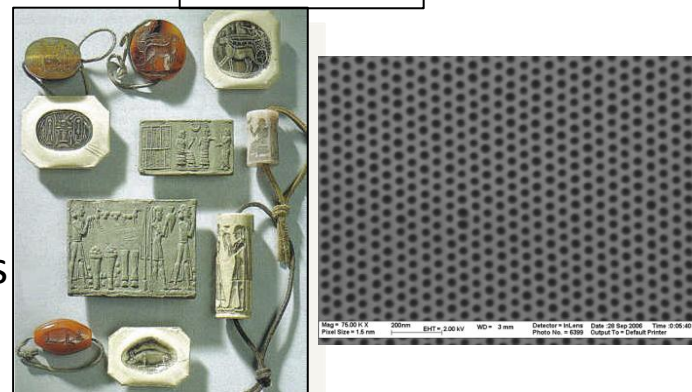
Printing



Dip-coating



Imprinting



Example: nanocrystals
In general for solutions

Mesopotamian Templates 25 nm holes
600 AD

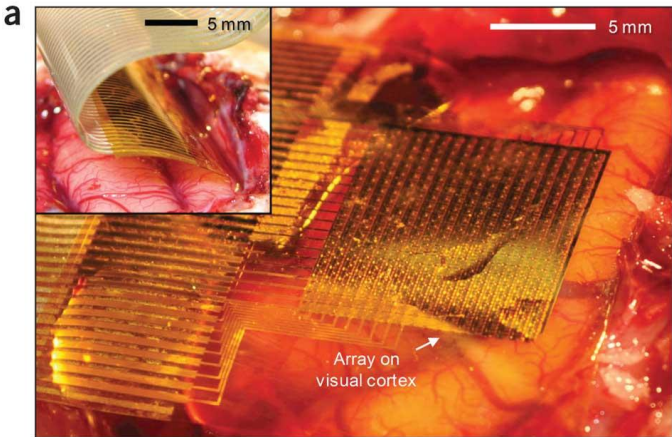
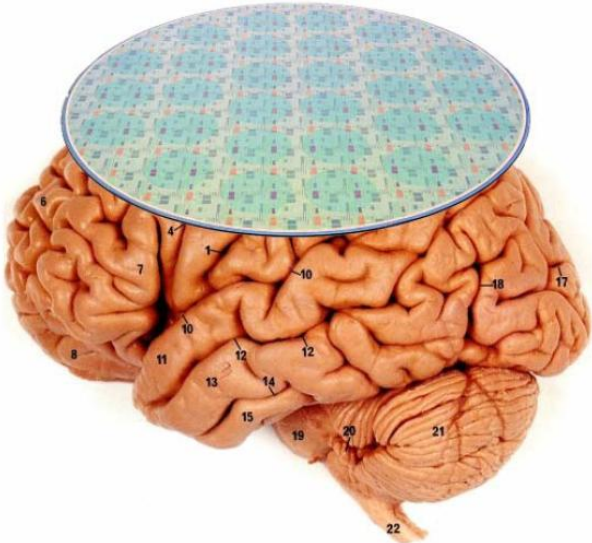
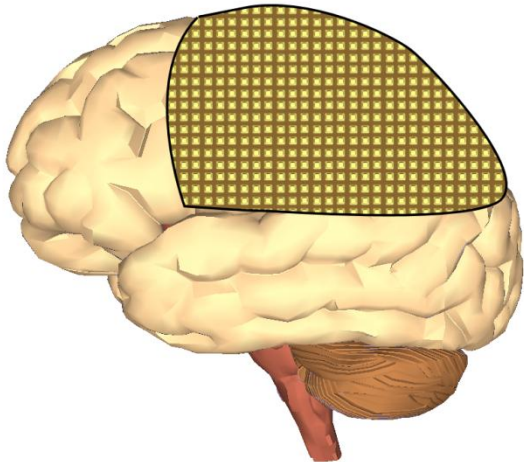
Examples of Some Electronic and Optoelectronic Applications



BioElectronics



Utah Electrode Array
10 x 10 array of electrodes
 $\frac{1}{4}$ " x $\frac{1}{4}$ " in size



Litt, Penn and Rogers, UIUC

Light at the Nanoscale



The First Nanotechnologists

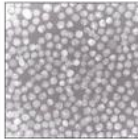
Ancient stained-glass makers knew that by putting varying, tiny amounts of gold and silver in the glass, they could produce the red and yellow found in stained-glass windows. Similarly, today's scientists and engineers have found that it takes only small amounts of a nanoparticle, precisely placed, to change a material's physical properties.

Gold particles in glass

Size*: 25 nm
Shape: sphere
Color reflected:

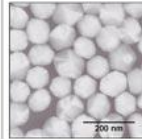


100 nanometers = 0.0001 millimeter



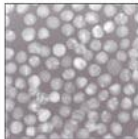
Silver particles in glass

Size*: 100 nm
Shape: sphere
Color reflected:

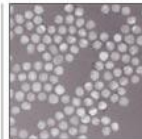


Had medieval artists been able to control the size and shape of the nanoparticles, they would have been able to use the two metals to produce other colors. Examples:

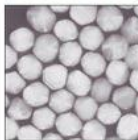
Size*: 50 nm
Shape: sphere
Color reflected:



Size*: 40 nm
Shape: sphere
Color reflected:



Size*: 100 nm
Shape: sphere
Color reflected:

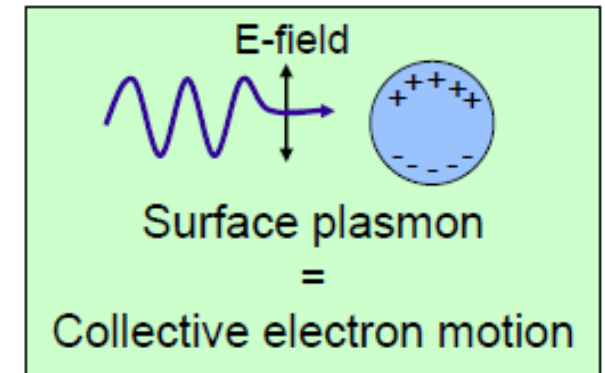
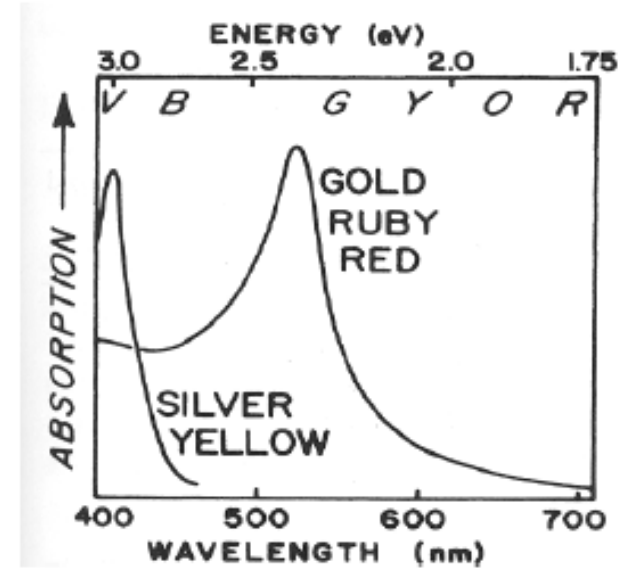


Size*: 100 nm
Shape: prism
Color reflected:



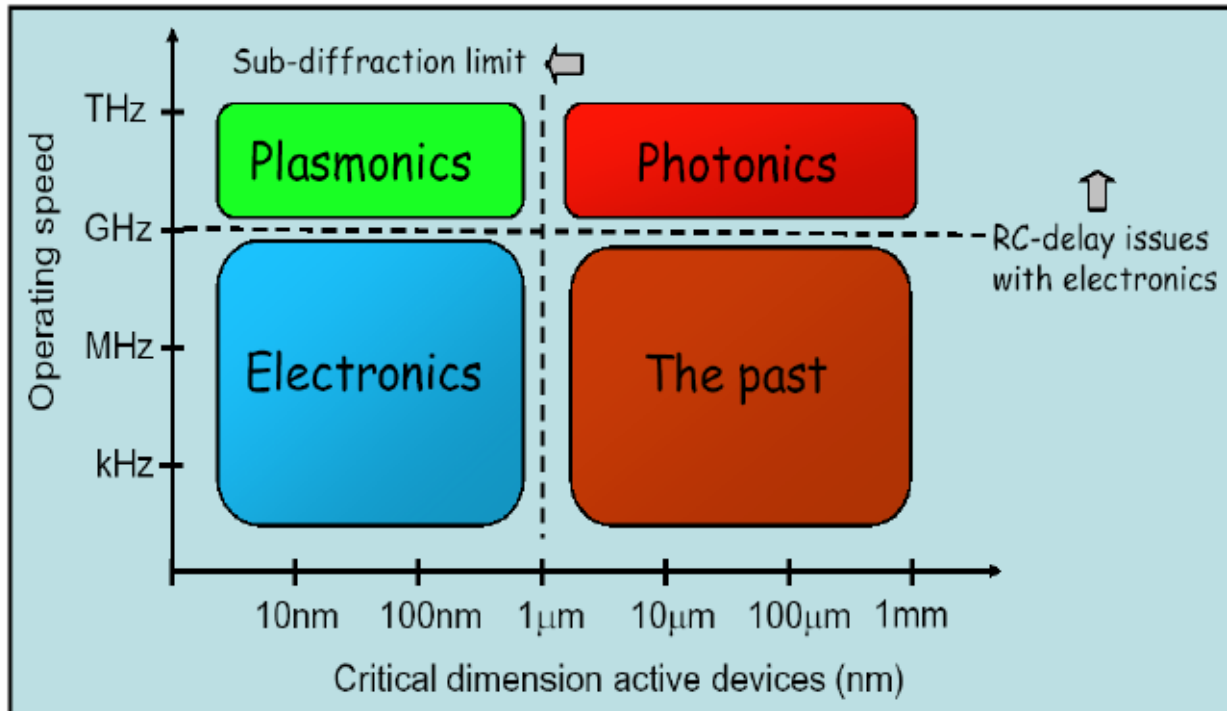
Source: Dr. Chad A. Mirkin, Institute of Nanotechnology, Northwestern University

*Approximate



Nanophotonics and Plasmonics

- Graph of the operating regimes of different technologies

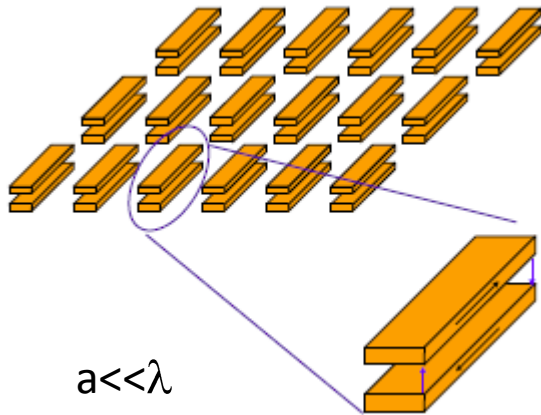


- Plasmonics will enable an improved synergy between electronic and photonic devices
 - ⇒ Plasmonics naturally interfaces with similar size electronic components
 - ⇒ Plasmonics naturally interfaces with similar operating speed photonic networks

Courtesy of M. Brongersma

Metal Nanoparticle Assemblies as Building Blocks for Optical Metamaterials

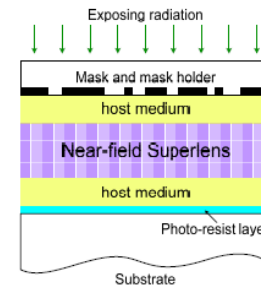
Designing composite materials with electromagnetic properties not found in nature and not observed in the constituent materials



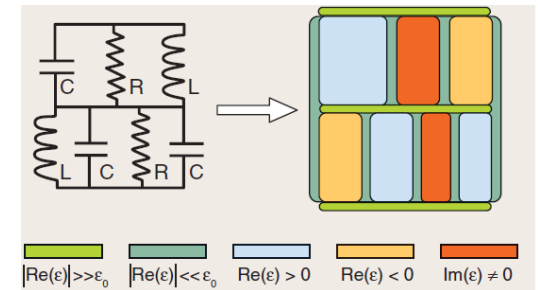
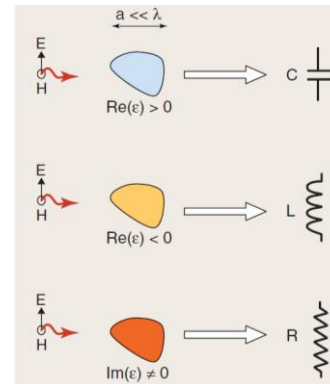
Effective medium
Description using
Maxwells equation



cloaking



superlenses
sensors
lithography



metatronics =
optical nanocircuits

Samsung Galaxy

