An Introduction to NanoScience and NanoTechnology

ELEC 6271

An Overview

Introduction

Evolution of IC characteristics in order of magnitude from the time that the technology was introduced in 1960:

- In 1960 one transistor consisted of 10^{20} atoms
- In 2000 these reduced to 10^{7}
- In 2010 expected to decrease to few thousands
- Introducing Single Electron Transistors will reduce the size of the device to few atoms.
- Meanwhile the area of capacitors is reduced from 1 cm^2 to 0.01 $micron^2$ and reducing the voltage from 10V to 1V and below.

Golden Rule

- No matter what the size, make it smaller
- No matter what the speed, make it faster
- No matter what the function, make it larger
- No matter what the cost, make it cheaper
- No matter how little it heats up, make it cooler

Introduction

The following factors helped the Golden Rule:

1) Reducing the size of the device
2) Enlarging the chip area
3) Increasing functional integration

It is assumed that silicon technology has its limit for further miniaturization to approx 10 nm.

Therefore to overcome this restriction we need to increase functionality integration or alternatively approaching nanoelectronics which offers integration level 2 to 4 orders larger than 10 nm technology.

Emerging a new technology called Nanotechnology

Introduction

- The physical, mechanical, chemical, and in general most properties of the materials will change once the size of the structures reduces to nano scale.

- In electronics, no matter what form of electronic devices we have, we need to learn how to model and describe the electronic properties of the device.

- As the size of devices reduces, *elements of the Nanoelectronics*, structures become more complex. Due to the complexity of these structures and their different nature at very low scales, one need to investigate and reexamine the characteristics of these structures.
- Their properties sometimes are very different from their macro or micro counterparts.

- As a result, a new science called *nanoscience* is emerging.

What is Nanotechnology?

- Nanotechnology deals with fabrication and structures of objects with dimensions in order of nanometers.
- Nanotechnology is the research and technology development at the atomic, molecular or macromolecular levels, in the length scale of approximately 1 - 100 nanometer range.
- Nanoscale 10^{-9} meter

What is NanoScience?

- Nanoscience deals with sciences related to the systems structured by nanotechnology.
- Generally in the nanometer region, most physical, chemical, biological, mechanical, electrical etc. become size-dependent.
- For example, the color of a piece of gold remains golden until the piece it reduced to nanometer sizes. Similarly, the color of a piece of silicon wafer changes as its size reduces to nanometer.
- The same is true for their conductivity, melting points, crystalline structures or any other physical or chemical properties.

Nanotechnology

- Because properties at the nanoscale are size-dependent, nanoscale science and engineering offer an entirely new design motif for developing advanced materials and their applications.

- Nanotechnology deals with the creation of functional materials, devices and systems through control of matter on the nanometer length scale (1-100 nanometers), and ability to control them. Nanoscience deals with novel phenomena and properties (physical, chemical, biological, mechanical, electrical etc.) at that length scale.

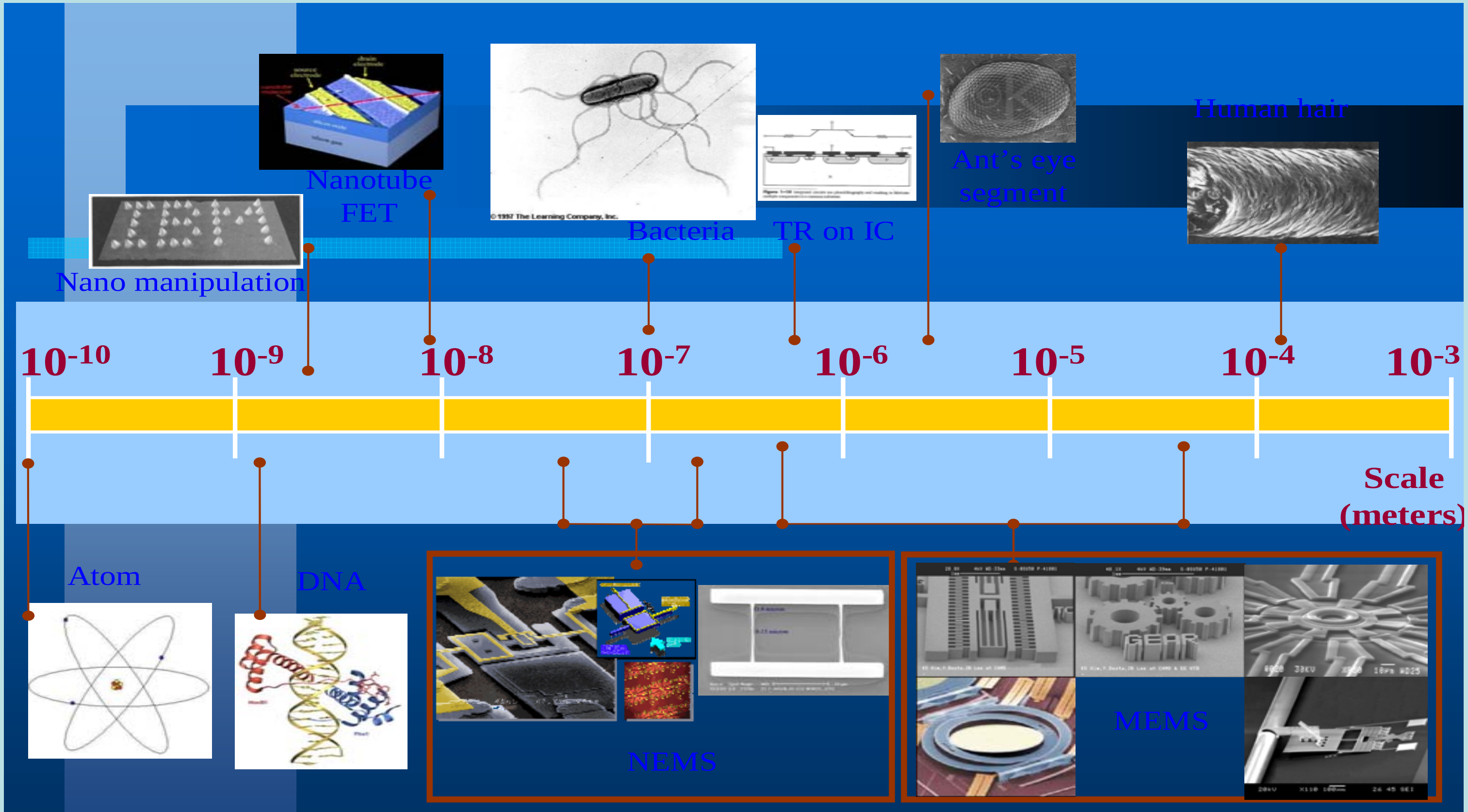
Nanotechnology

- Nano and quantum computing, nano-formed components and nano-based wiring have been some of the focus areas.
- Research has led to some important developments: demonstration of Coulomb blockade, quantum effect, single electron memory and logic gates that operate at room temperature; integration of scanning probe tips into sizable arrays for lithographic and mechanical information storage applications; and fabrication of photonic band-gap structures.
- In addition, biological computing is becoming a possibility.

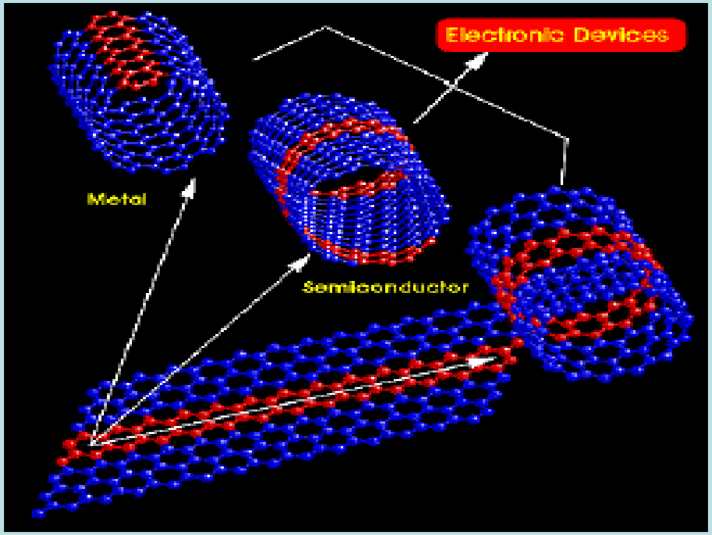
Nanotechnology

- Laws relating to physical, chemical, biological, electrical, magnetic and other properties at the nano-scale are different from those that apply to macro matters. It is the laws of *quantum mechanics* (and not classical mechanics) that apply at that scale.

Nanotechnology



Why nanotechnology?



- Size
- Weight
- Cost
- ...
- Most importantly is Sensitivity.

  It is the surface to volume ratio in any nanostructure which makes this technology very attractive for many applications.

Nanostructures

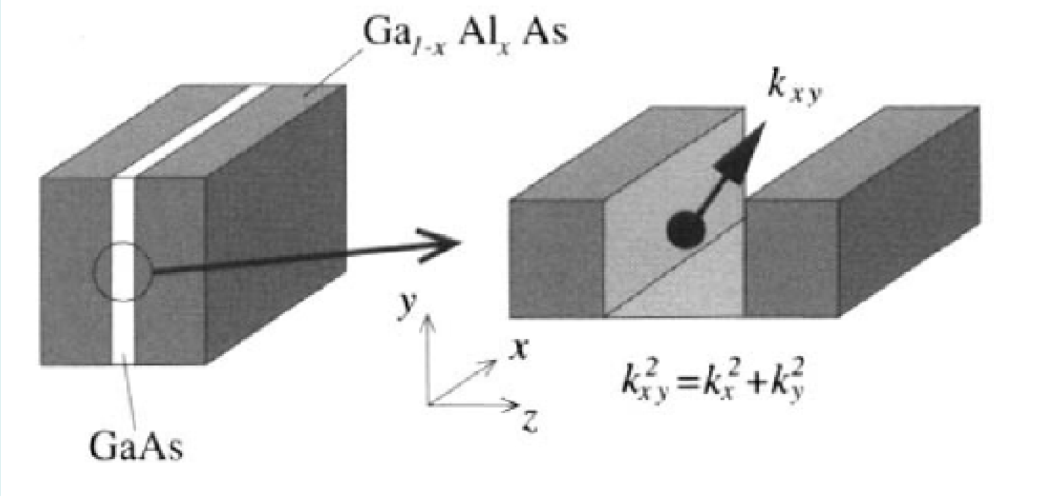
Elements of nanostructures:

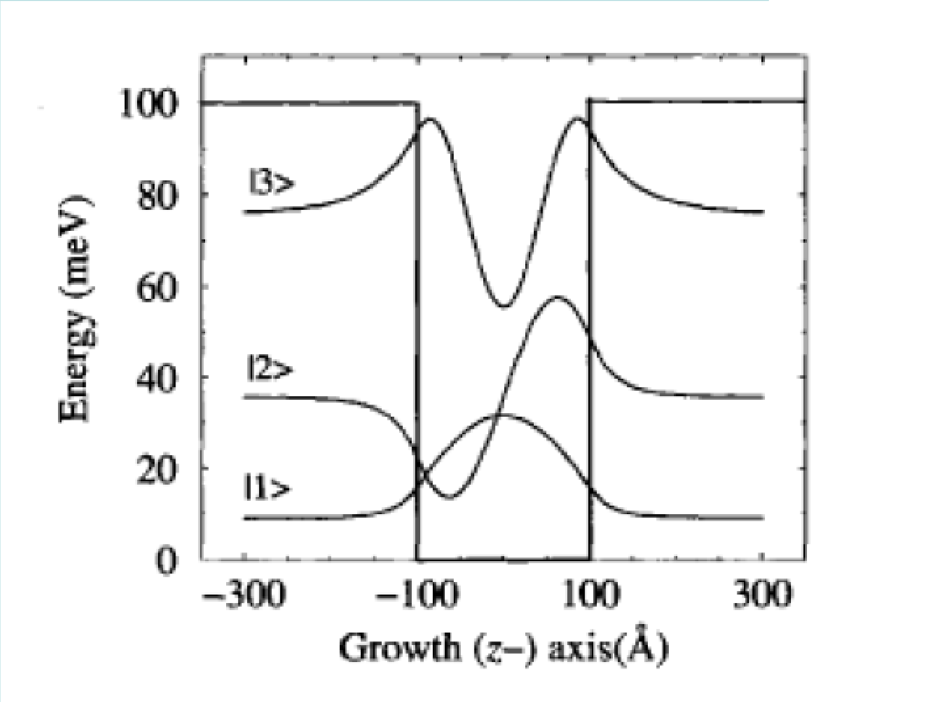
- Quantum Dots (0 D)
- Quantum Wires (1 D)
- Quantum Walls (2 D)
- Large particles (3 D)

Quantum Structures

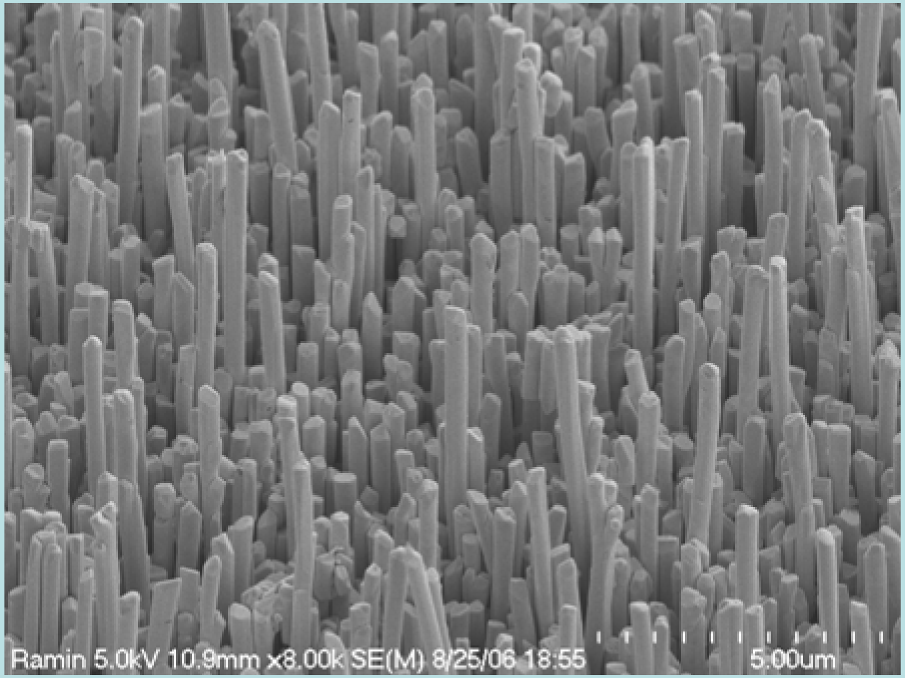
- When the size or dimension of a material is continuously reduced from a large or macroscopic size, such as a meter or a centimeter, to a very small size, the properties remain the same at first. Then small changes begin to occur, until finally when the size drops below l00nm, in this case dramatic changes in properties can occur.
- If one dimension is reduced to the nano-range while the other two dimensions remain large, then we obtain a structure known as an extremely thin films, usually called *quantum well*.
- If two dimensions are so reduced and one remains large, the resulting structure is referred to as a *quantum wire*.
- The extreme case of this process of size reduction in which all three dimensions reach the low nanometer range is called a *quantum dot*.
- The word quantum is associated with these three types of nanostructures because the changes in properties arise from the quantum-mechanical nature of physics in the domain of the ultra small scales.

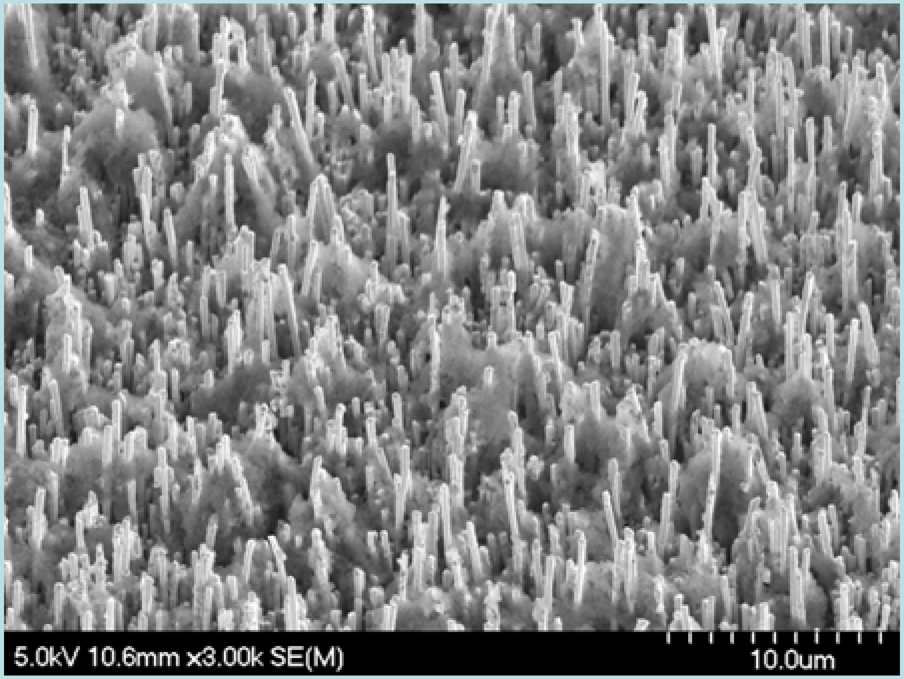
Quantum Well





Quantum Wires



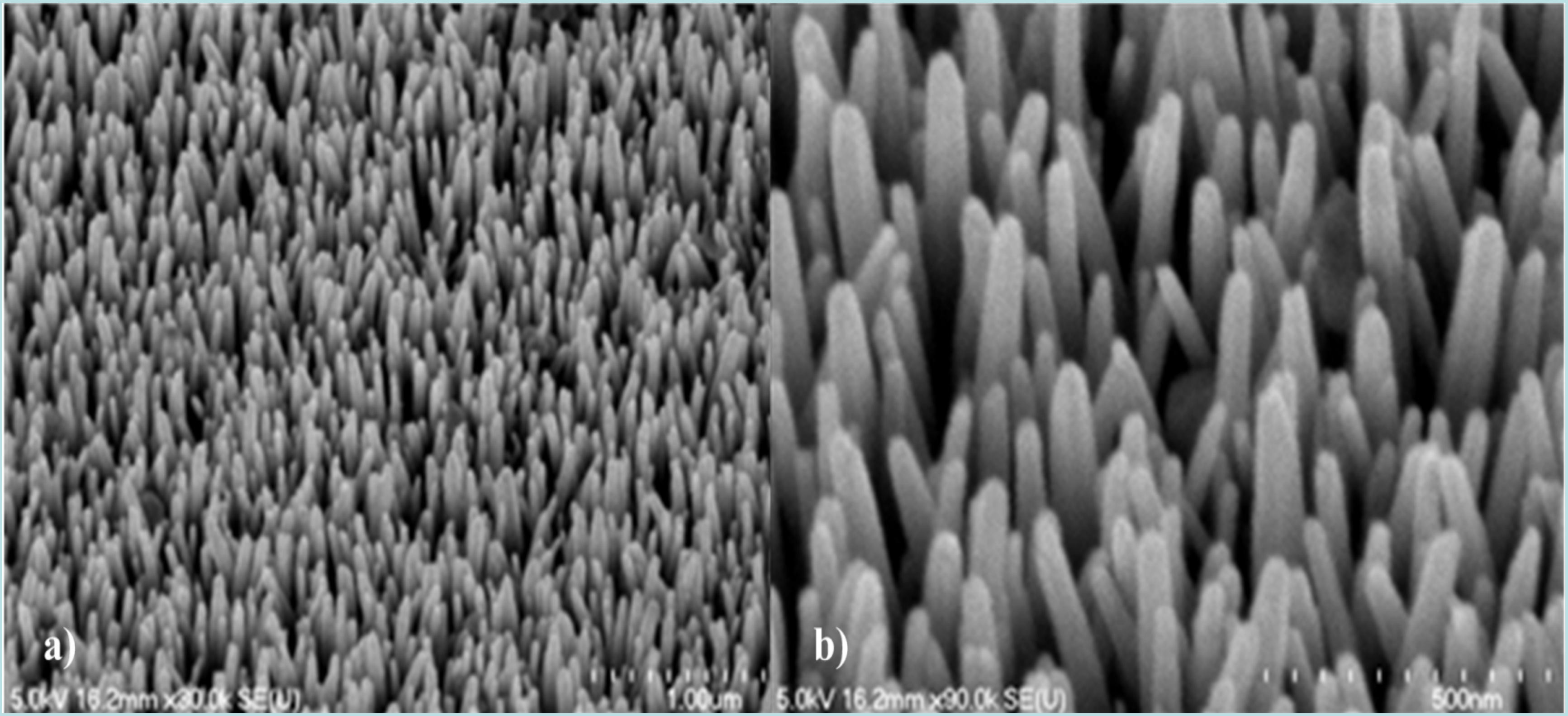


Self-Standing AuNWs

Quantum Wires

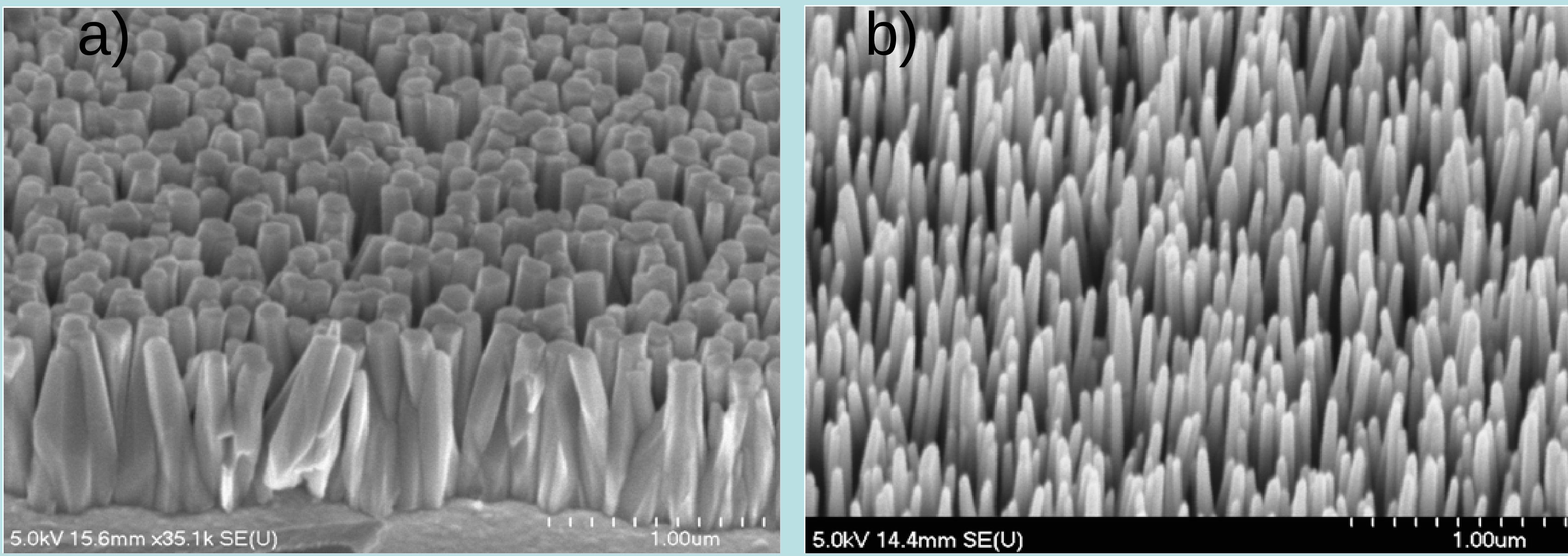
- Metal/Semiconductor Nanowires
- A variety of quasi 1-D nano sized materials, like carbon nanotubes, porous silicon, GaAs, Silicon, Germanium nanowires, metal nanowires have been synthesized.
- These materials show physical properties different from those of the bulk.
- Create opportunities for fundamental studies and for potential nano-device applications.
- One dimensional high speed field effect transistors and laser working at low-threshold current density and high gain were developed using GaAs and InAs nanowires.
- Nano-sized metal-semiconductor heterojunction using silicon nanowire connected with a carbon nanotube is fabricated.

Quantum Wires



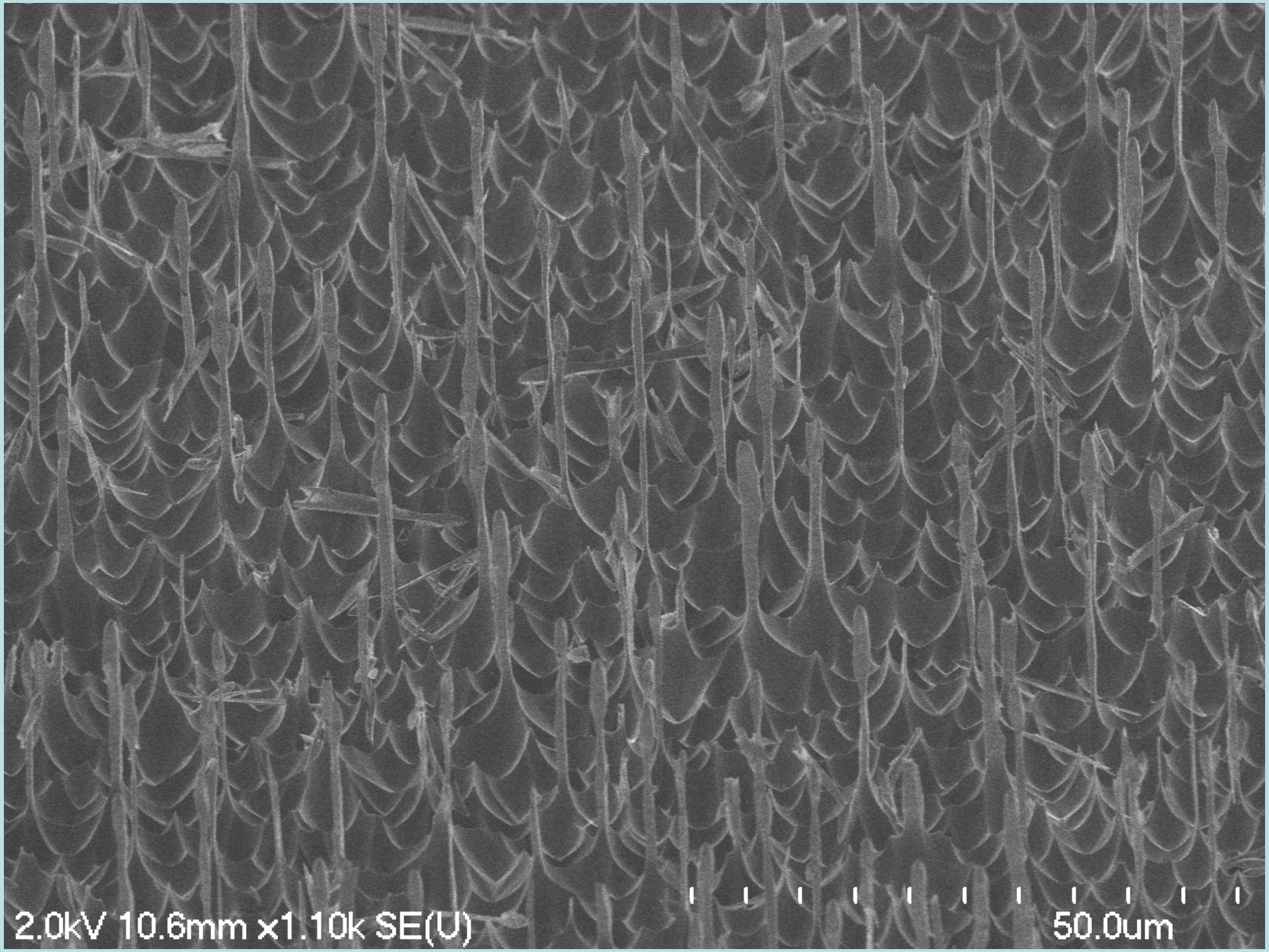
Self-Standing ZnO NWs

Quantum Wires



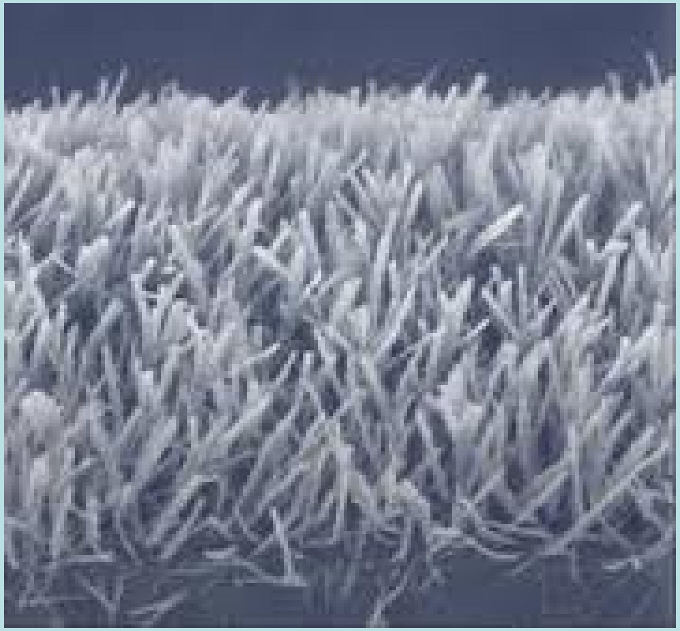
Self-Standing ZnO NWs

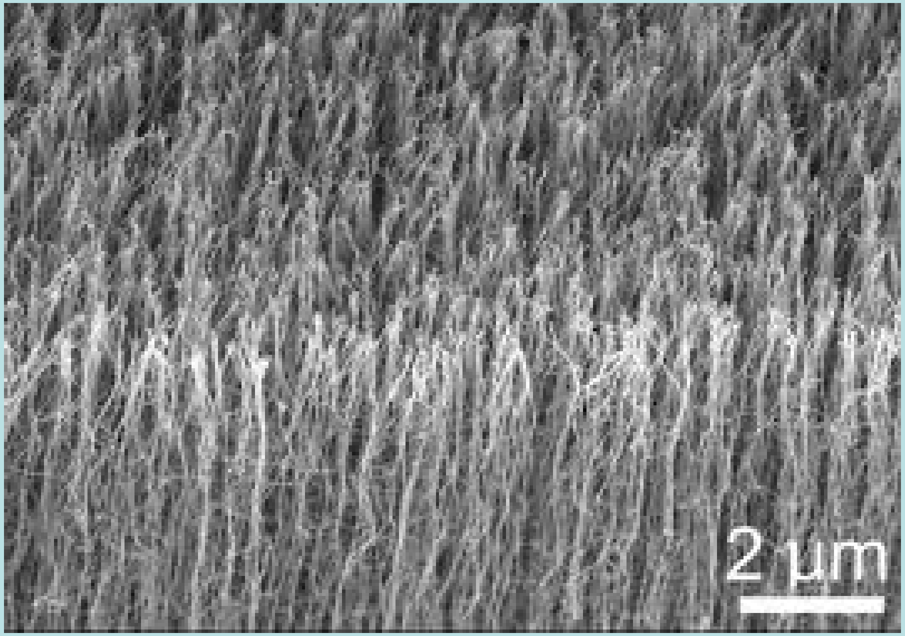
Quantum Wires



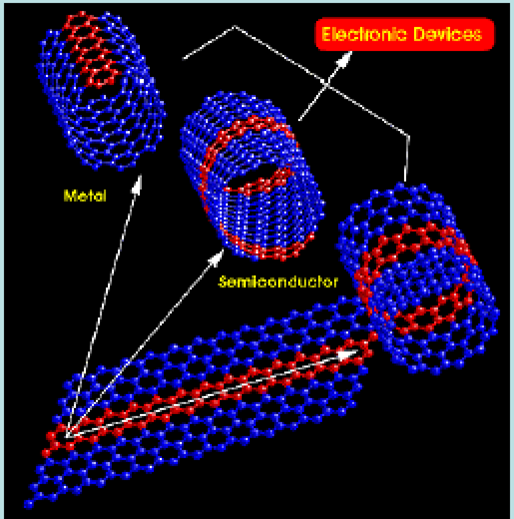
Self-Standing Si-NWs

Quantum Wires





Nanotubes

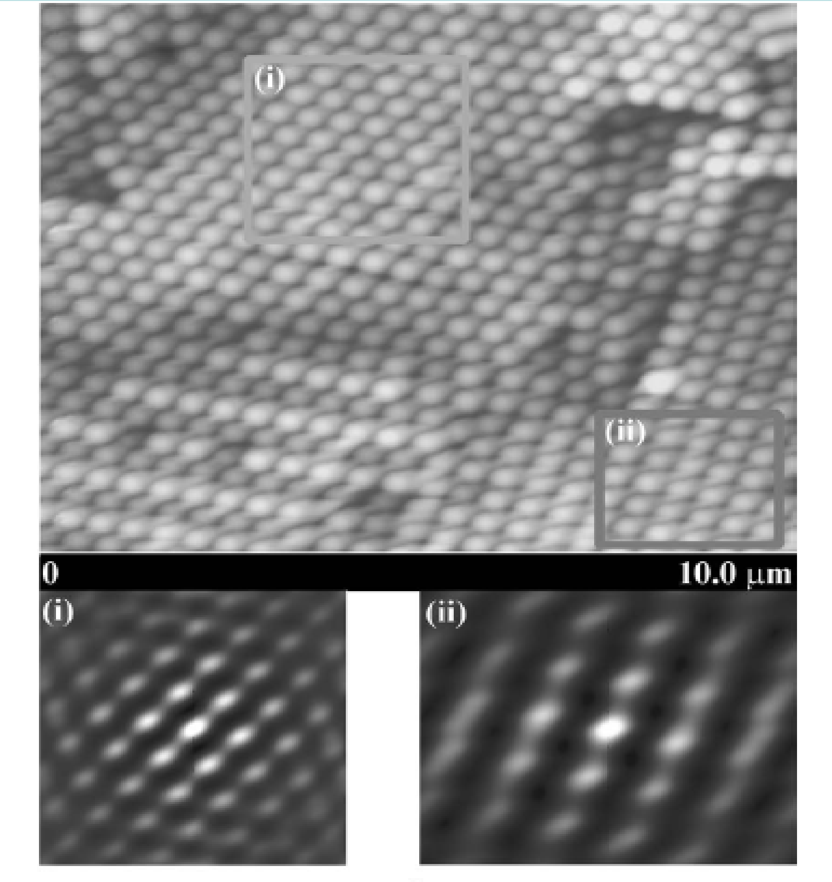


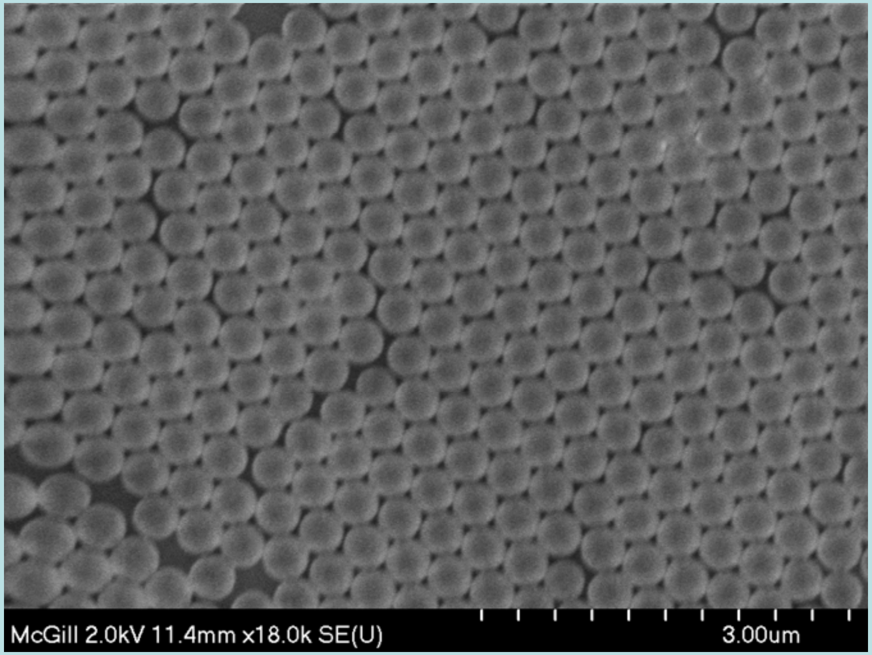
Nanostructures

- Quantum dots are small metal or semiconductor boxes that hold a well-defined number of electrons.
- The number of electrons may be adjusted.
- The problem of a particle moving in presence of external potentials is a standard-textbook example of quantum mechanics: For a fully three-dimensional confinement, the particle spectrum is known to break into a number of discrete eigenenergies. Atoms represent natural realization of such confined systems. Semiconductor quantum dots (or "artificial atoms", as they are sometimes called) are man-made realizations: Exploiting the most advanced tools of nano-fabrication or self-assembly, it has become possible to tailor dot-confinement potentials with a high degree of flexibility.

Nanoparticles

MULTILAYERS OF PS MICROSPHERES AND Au NANOPARTICLES (AFM IMAGE)





Poly Styrene microspheres: 510 nm; Au: 5 nm

Vertical deposition 55^{o}C, 3 days

Types of Nanostructures

- Physical
- Mechanical
- Electrical
- Optical
- Chemical
- Biological
- Medical
- Integration of the several structures

Materials & Methods of Synthesis

- Semiconductor nanostructures (nanoparticles, nanowires,…)
- Metallic nanostructures (nanoparticles, nanowires, thin films…)

Semiconductors Nanostructures

- Semiconductor nanostructures are unique for two very important reasons:
- As a semiconductor nanostructures become smaller the ratio of the number of surface atoms to those in the interior increases, i.e. in very small particles greater than a third of all atoms reside on the surface.
- There is a change in the electronic properties of the material, as the size of the nanostructures becomes smaller e.g. the band-gap becomes larger.

Semiconductors Nanostructures

- They are interesting because they have chemical and physical properties different from those of the bulk and isolated atoms and molecules with the same chemical composition.
- They provide opportunities to study the effect of spatial confinement and problems related to surfaces and interfaces.
- They can be fabricated in the form of Quantum Dots, Quantum Particles, nanowires or nanocrystals.
- They have unique electronics, magnetic and optical properties because of their small size and large surface-to-volume ratio.

Semiconductors Nanostructures

- They have potential applications in a number of areas:
- Electronics
- Healthcare and Life Science
- Information and Communication Technologies, in light emitting diodes, single electron devices, quantum computing, photo-catalysis, non-linear optics, photo-electrochemistry, imaging science and electro-optics.
- Energy applications, solar cells.
- Fine Chemicals.

Synthesis

- Main challenge: control the size, shape, and surface properties (particles with single size, well-defined shape and surface characteristics).
- II-VI semiconductor materials, such as CdS, CdSe, ZnS can be prepared using wet colloidal chemistry methods both in single sized and surface passivated forms.
- They can be prepared in solutions, glasses and polymers.
- e.g. CdS Nanoparticles can be prepared in a number of environments by controlled mixing of Cd2+ ions with S2- ions in the presence of various acidic or basic stabilizers.
- Likewise, CdSe, CdTe, ZnS, ZnxCd1-xS, Mn-doped ZnS can be made using suitable precursors in different solvents.
- Metal oxide nanoparticles such as TiO2, ZnO and SnO2 can be prepared by forced hydrolysis techniques.
- Although difficult but preparation of III-V semiconductor nanocrystals of GaAs and InP has been possible.

Synthesis

- Chemical Vapor Deposition (CVD)

  Nanowires of Si, Ge, GaAs, InP
- Laser Ablation

  Carbon nanotubes, silicon nanowires, silica nanowires
- Carbon Nanotube Confined Reaction

  A technique which uses carbon nanotubes to fabricate variety of carbide nano-rods , like SiC, TiC, Fe_3C.

  It is extended to synthesize nano-rods without carbon element, like GaN, Si_3N_4, …
- .

Synthesis

- Vapor Phase Evaporation

  Many metal nanowires were prepared by this technique, like nanowires of Ag, Al, Au, Cu, Fe, …

  Also some semiconductors nanowires like Si, Ge, ZnO, GeO2, GaSe, …

- Electrochemical Deposition

  Three step approach:

  --preparation of nanopores on polycarbonate membrane film using heavy ion beam bombardment of the film.

  --electrochemical deposition of the metallic nanowires into the nanopores template.

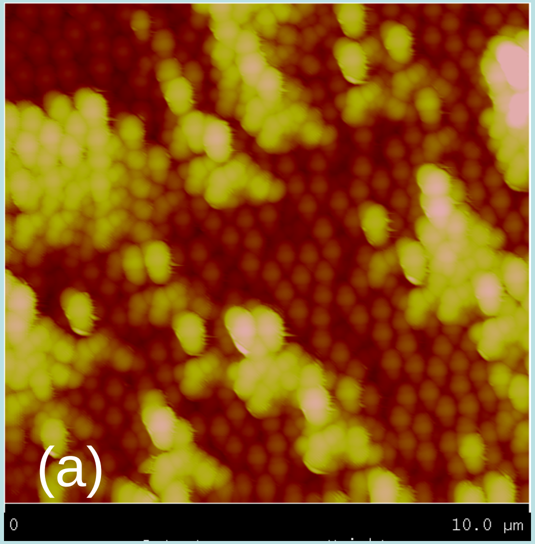
  --lift-off of the nanowires by dissolving the membrane

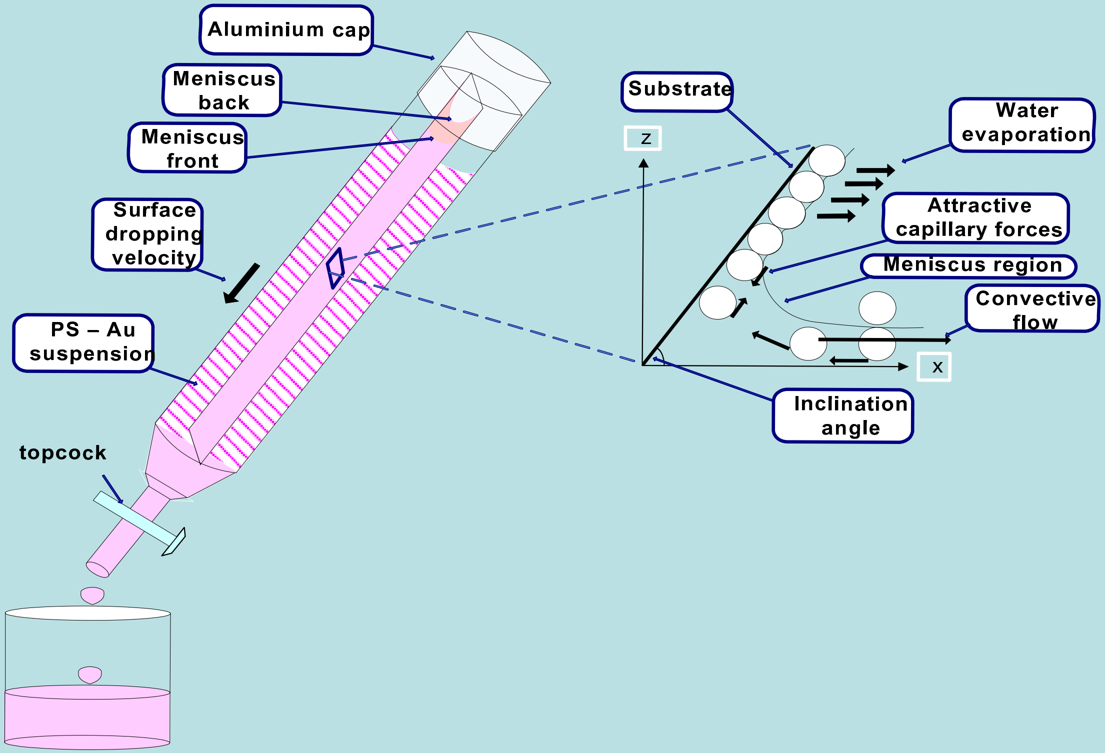
- Self-assembly techniques

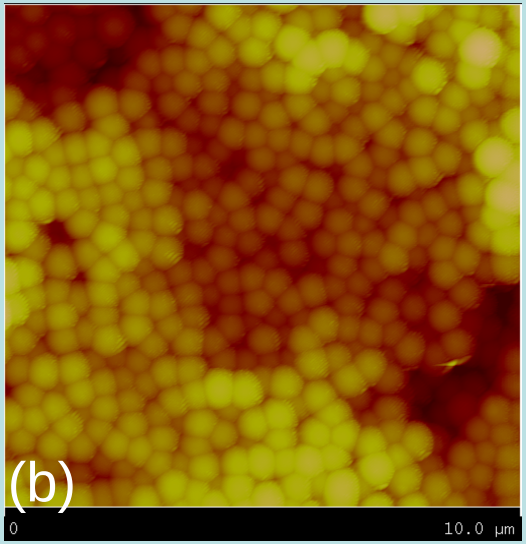
Self-Assembly Techniques

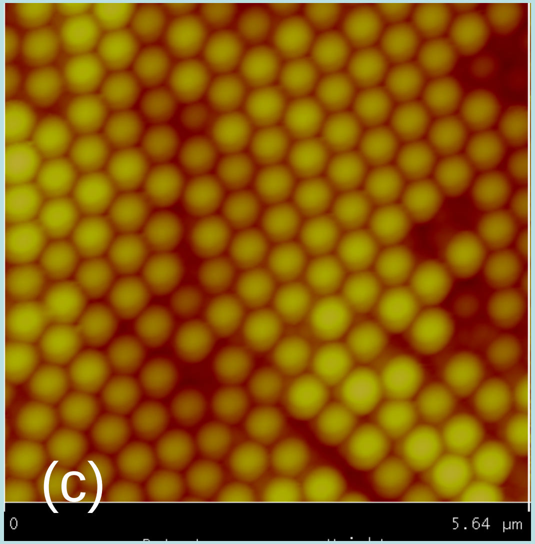
S. Badilescu, M. Kahrizi, Journal of Materials Science: Materials, 2007

nanospheres colloidal crystal





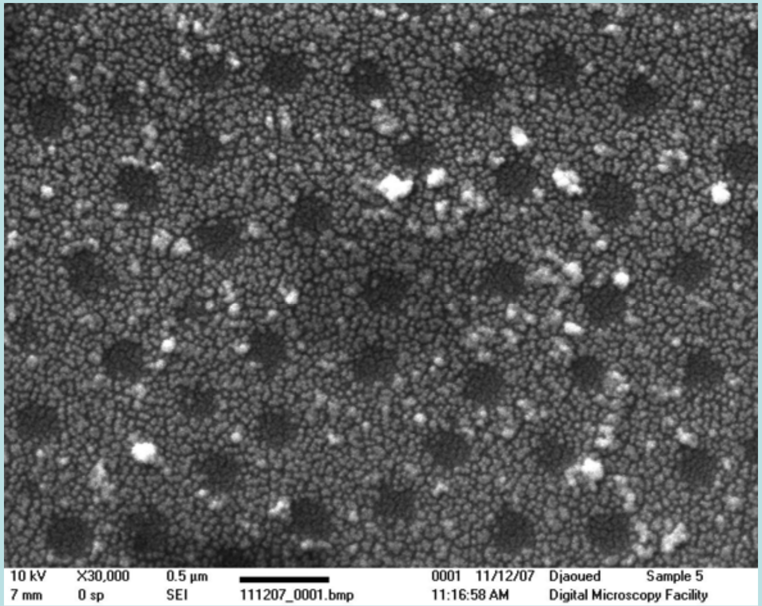


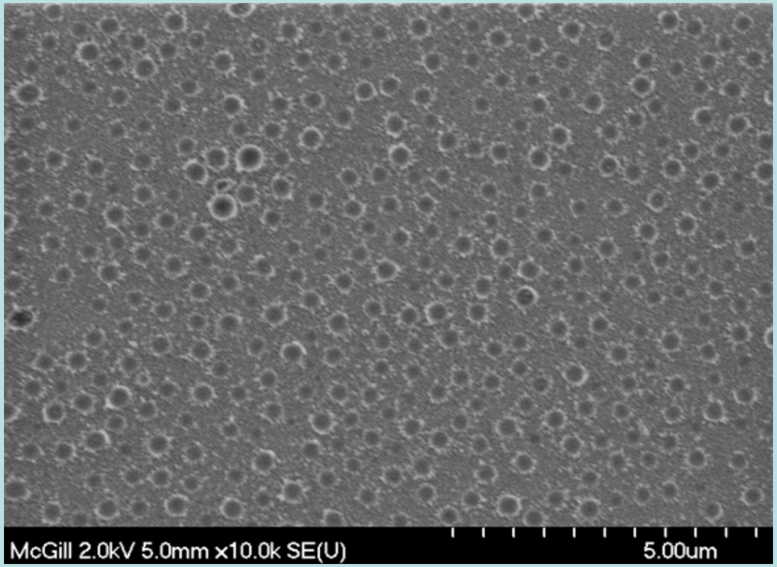


a) V_d = 100 µm/s

b) Vd = 40 µm/s

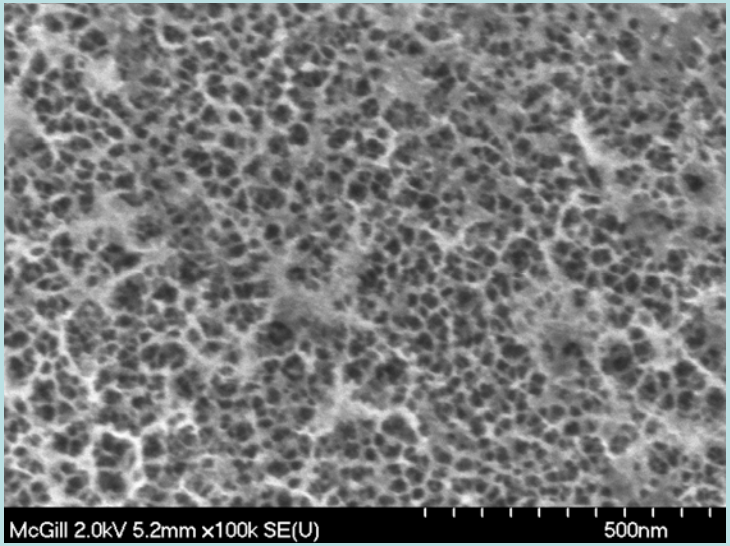
c) Vd = 15 µm/s

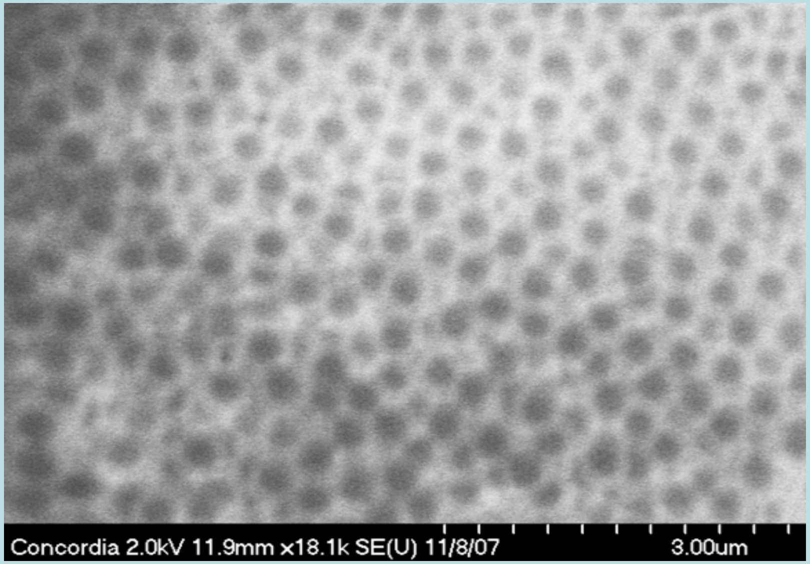




Nanocups

Nanorings





Nanoholes fabricated using Porous Silicon Method

Growth Mechanism of Nanowires

The following growth mechanism will be discussed in detail.

- --Vapor-Liquid-Solid (VLS) Growth
- --Solution-Liquid-Solid (SLS) Growth
- --Vapor Phase Epitaxy

Nanowire systems

- The following nanowire materials and the method of their synthesis will be discussed in detail
- --Si and Ge Nanowires
- --Semiconductor Compound Nanowires; GaAs, InAs, GaN,
- ZnSe, ZnS, CdS, GaSe
- --Metal Nanowires
- --Oxide Nanowires; Silicon Oxide, Germanium Oxide,
- Gallium Oxide
- --Silicon Carbide, Silicon Nitride

Summary: Methods of Synthesis

Nanoparticles

- Scanning probe instruments like Atomic Force Microscope (AFM)
- Lithography Techniques:
  - Dip-Pen Lithography
  - E-Beam Lithography
  - Ion-Beam Lithography
  - Soft Lithography (nano printing)
- Plasma arcing
- Laser Ablation
- Chemical Vapor Deposition
- Electro-deposition
- Sol gel synthesis
- Ball milling, and the use of natural nanoparticles
- Self Assembly techniques

Nanowires

- 1. Top-Down Approach
- **Thermal methods**
- **Chemical Methods**
- **Mechanical Methods**
- **Lithography Methods**

- 2. Bottom-Up Approach
  - Assemble from units
  - Compact powders
  - Solid-Solution precipitation
  - Deposition and Coatings
  - Electro-depositions

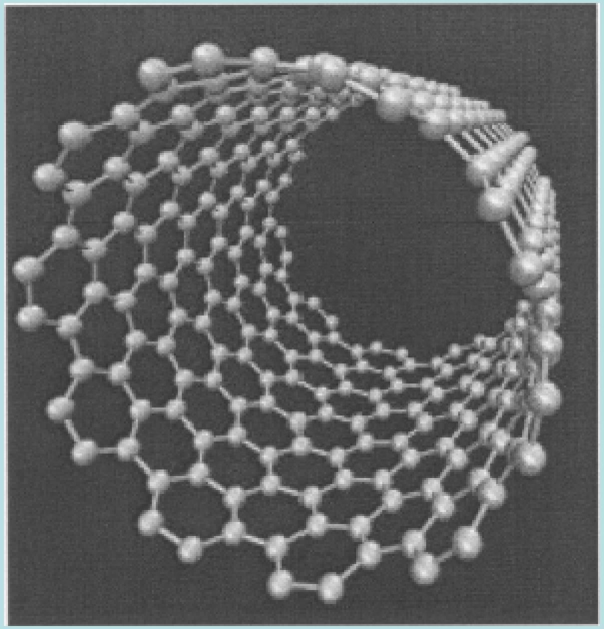
Characterization

- Spectroscopy, Microscopy and X-ray techniques are used to characterize the size, shape and surface properties of nanoparticles.
- UV – visible, and Raman Spectroscopy, Scanning Tunneling Microscopy, Atomic Force Microscopy are used to characterize semiconductor nanoparticles.
- UV-visible spectroscopy is useful for characterizing optical properties of nanoparticles and for determining particle size. e.g. the spectra of CdS nanoparticles show a clear blue shift in the absorption onset for smaller particles compared to that of bulk CdS. This is due to the increase in effective band-gap with decreasing particle size.
- Transmission Electron Microscope can provide direct spatial resolution on the order of 0.1 nm and can be used to characterize the shape and lattice structures of nanoparticles.
- Photoluminescence

Carbon Nano Tubes (CNT)

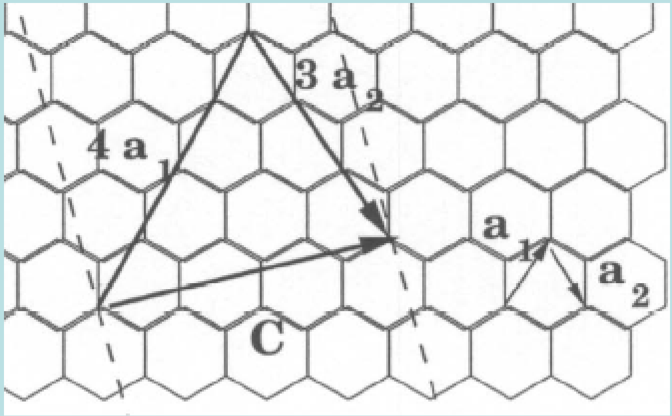
- Carbon nanotubes are long, thin cylinders of carbon. These are large macromolecules that are unique for their size, shape, and remarkable physical properties. An ideal nanotube can be thought of as a single layer of graphite atoms arranged in hexagonal pattern that has been rolled up to make a cylinder. The tubes are tough and when bent or squeezed, spring back to their original shape.

CNT



A single walled CNT

CNT



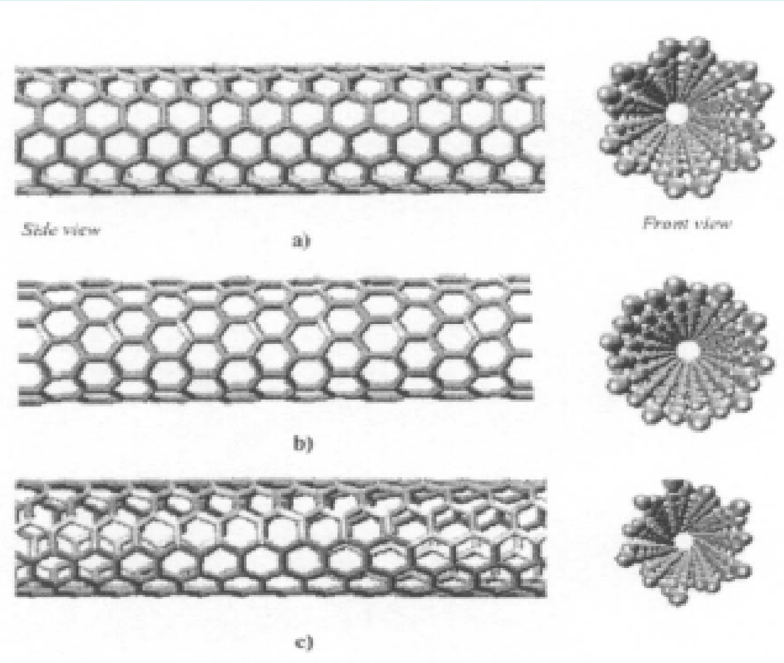
To understand nanotube we need to know few basic terms. Considering the unrolled nanotube in figure above, the two unit vector â1 and â2 are defined as shown in the figure. The chiral vector of the nanotube, *C*h, is defined as the vector normal to the circumference vector in the direction in which it is being

i**.e.** **Ch =** ***n*****â1 +** ***m*****â2**

CNT

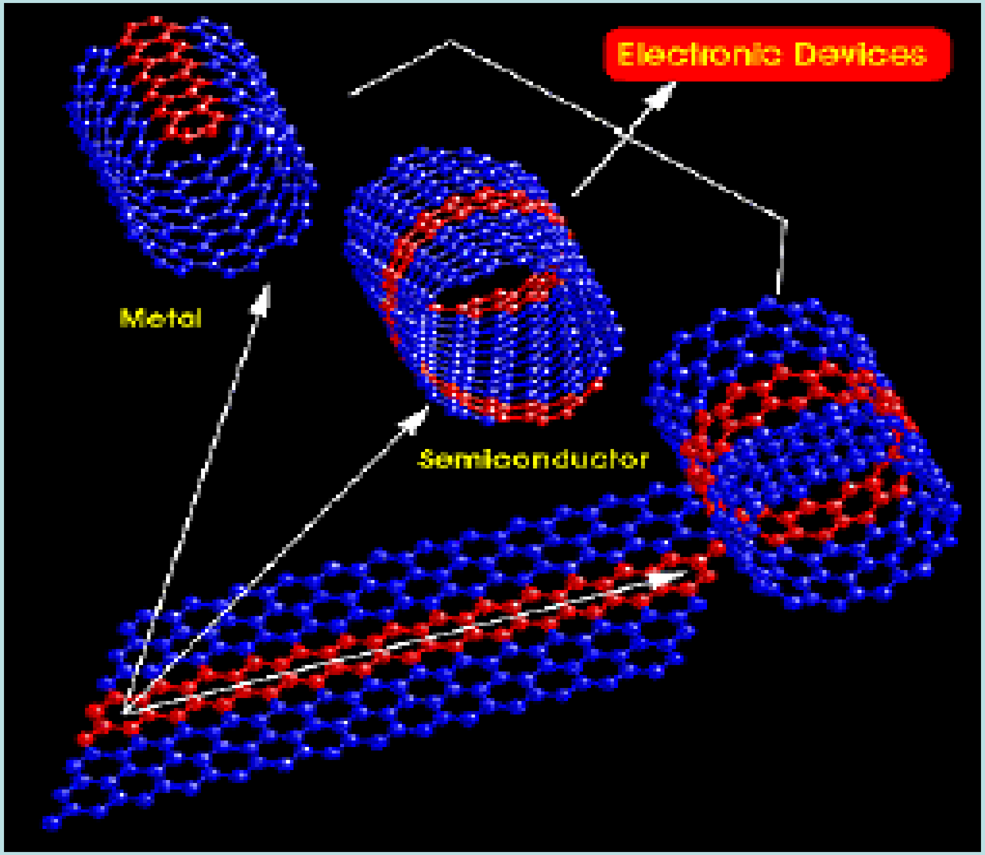
- Where â1 and â2 are unit vectors in the two-dimensional hexagonal lattice, and *n* and *m* are integers. The nanotubes are described by these numbers as (n, m). Another important parameter is the chiral angle, which is the angle between *C*h and â1.
- If (n – m) is divisible by 3 then the tube is metallic and if (n – m) is not divisible by 3 then the tube is a semiconductor. On the basis of Cirality nanotubes can be divided in to three classes:
- Zigzag if either n = 0 or m = 0
- Armchair if n = m
- Chiral if n ≠ m
- Armchair type is always metallic and the other two types can be either metallic or semiconductor depending on their Chiral condition.

CNT



Different types nanotubes: a. **Zigzag,** b. **Armchair,** c. **Chiral**

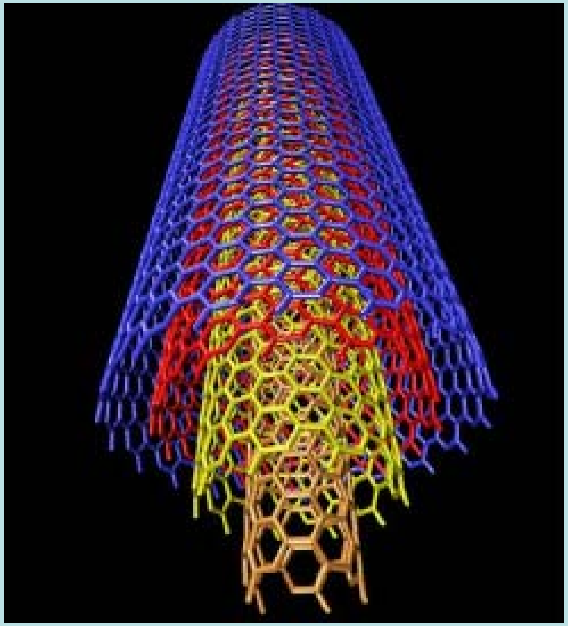
CNT

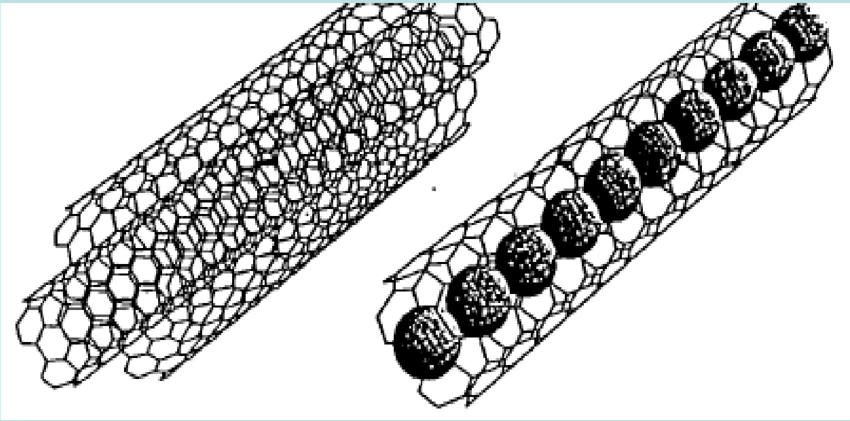


CNT

- Nanotubes have a very broad range of electronic, thermal, and structural properties that change depending on the different kinds of nanotube (defined by its diameter, length, and chirality, or twist). They can transfer heat very efficiently and more useful in the circuit as they can be cooled faster. They can be made to perform as a metal or a semiconductor depending on the way they are rolled.
- Nanotubes can have single cylindrical wall (SWNTs) or multiple walls (MWNTs) i.e. cylinders inside the other cylinders.

CNT





Carbon Nanotubes Production Processes

- Production processes for carbon nanotubes, vary from blasting carbon with an electrical arc or a laser to growing them from a vapor. These processes vary considerably with respect to the type of nanotube produced, quality, purity and scalability. Carbon nanotubes are usually created with the aid of a metal catalyst and this ends up as a contaminant with respect to many potential applications, especially in electronics. IBM has very recently, however, grown nanotubes on silicon structures without a metal catalyst.
- Fabrication techniques
- LASER EVAPORATION METHOD
- CARBON ARC METHOD
- CHEMICAL VAPOR DEPOSITION METHOD

Applications of Nanosystems

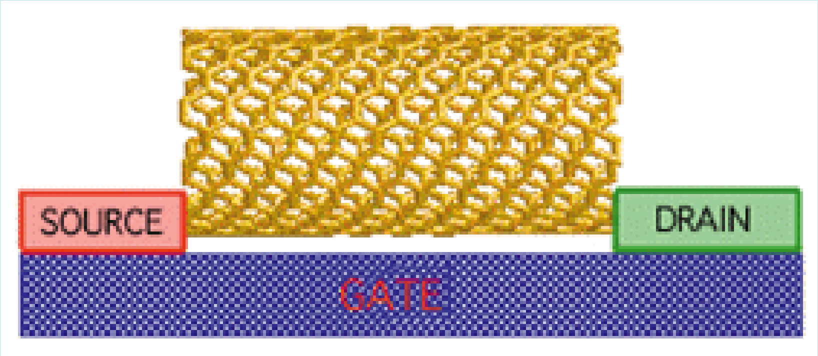
Applications in electronics, photonics, energy, and biomedical areas

- Devices:
- The nano-devices are based upon various nanotechnologies.
- Carbon nanotubes transistors
- Solid state quantum effect devices
- Molecular electronic devices
- Integration of those nanostructures together with MEMS technology is very promising for future photonic devices.
- Sensors (optical, biomedical, gas,…)
- Drug delivery
- Drug Discovery

Carbon nanotube field effect transistors (CNFET)

- A carbon nanotube device is similar to a MOSFET where a gate is used to control the flow of current through the device by varying the field through a channel. The new idea here is the mechanism of transport of electrons from the source to drain. Instead of having a channel whose field can be controlled by a gate electrode, these devices have a tiny tubular structure of carbon nanotube. Carbon nanotube with diameter 2nm have extremely low resistance and thus can carry large current without heating, so it could be use as interconnectors. It also has very high thermal conductivity means that they can also serve as heat sink i.e. allows heat to be rapidly transferred away from the chip.

CNFET



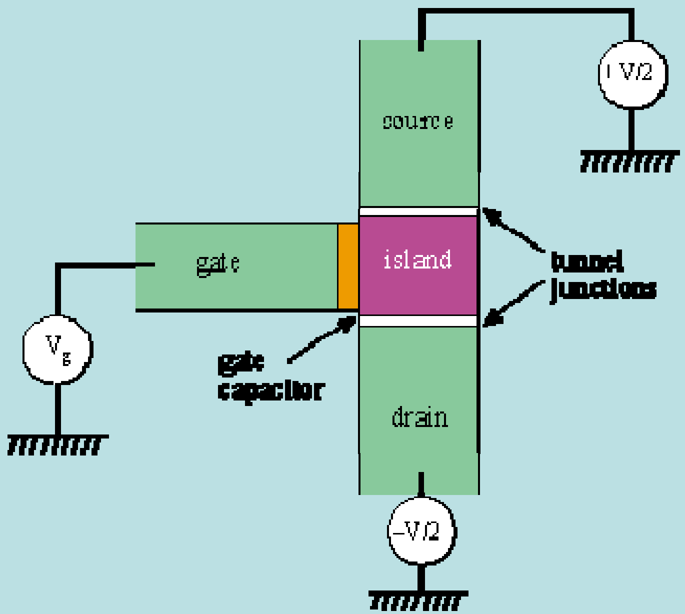
A Carbon nanotube field effect transistors (CNFET)

Single Electron Transistor

- The single electron transistor or SET is a new type of switching device that uses controlled electron tunneling to amplify current. An SET is made from two tunnel junctions that share a common electrode. A tunnel junction consists of two pieces of metal separated by a very thin (~1 nm) insulator as shown in the figure below. The only way for electrons in one of the metal electrodes to travel to the other electrode is to tunnel through the insulator. Since tunneling is a discrete process, the electric charge that flows through the tunnel junction flows in multiples of the charge of a single electron.

Applications

SET



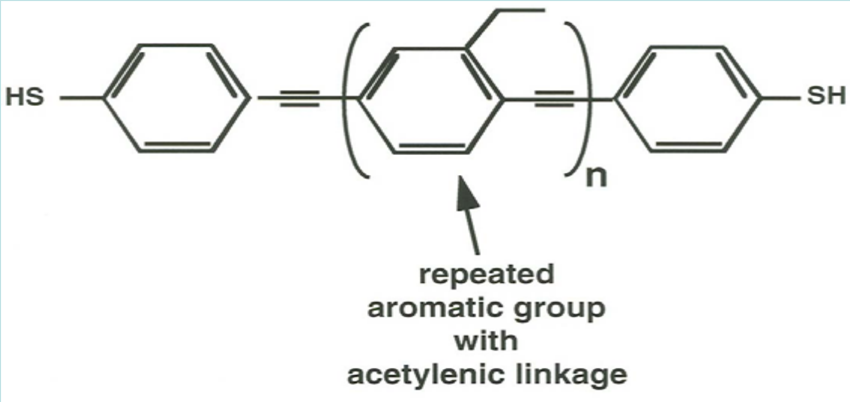
A tunnel junction and its schematic diagram

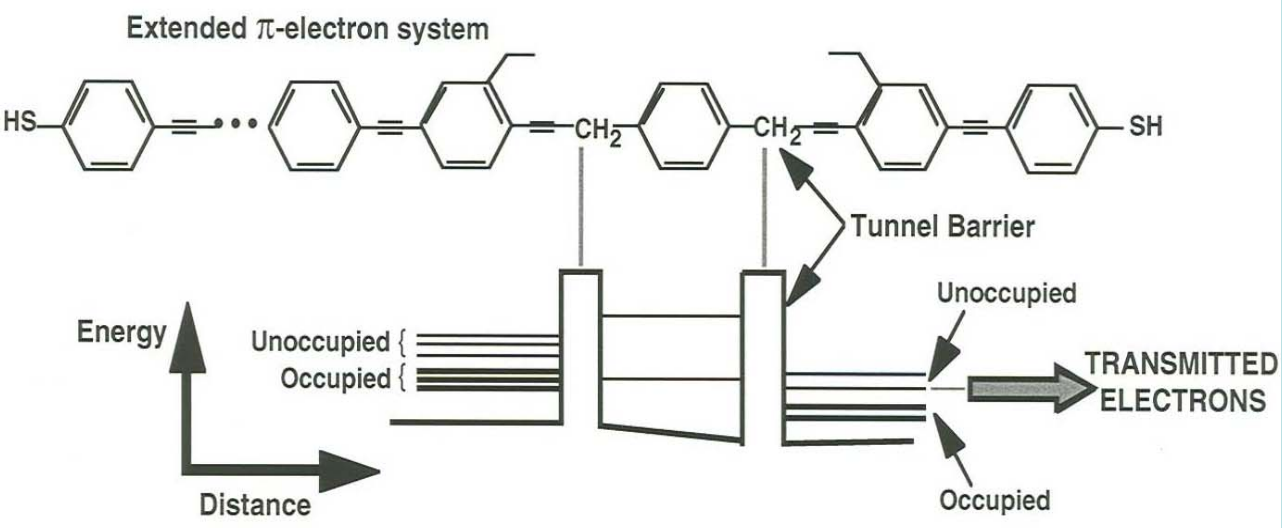
SET

- A SET can be made by placing two tunnel junctions in series as shown in the figure below. It has double barrier potential. The double junction is a circuit consisting of two tunneling junction in series which forms an island between them called "Coulomb Island" that electrons can only enter by tunneling through one of the insulators. This device has three terminals like an ordinary field effect transistor: the outside terminal of each tunnel junction, and a "gate" terminal that is capacitively coupled to the node between the two tunnel junctions. The capacitor may seem like a third tunnel junction, but it is much thicker than the others so that no electrons can tunnel through it. The capacitor simply serves as a way of setting the electric charge on the Coulomb Island.

Applications

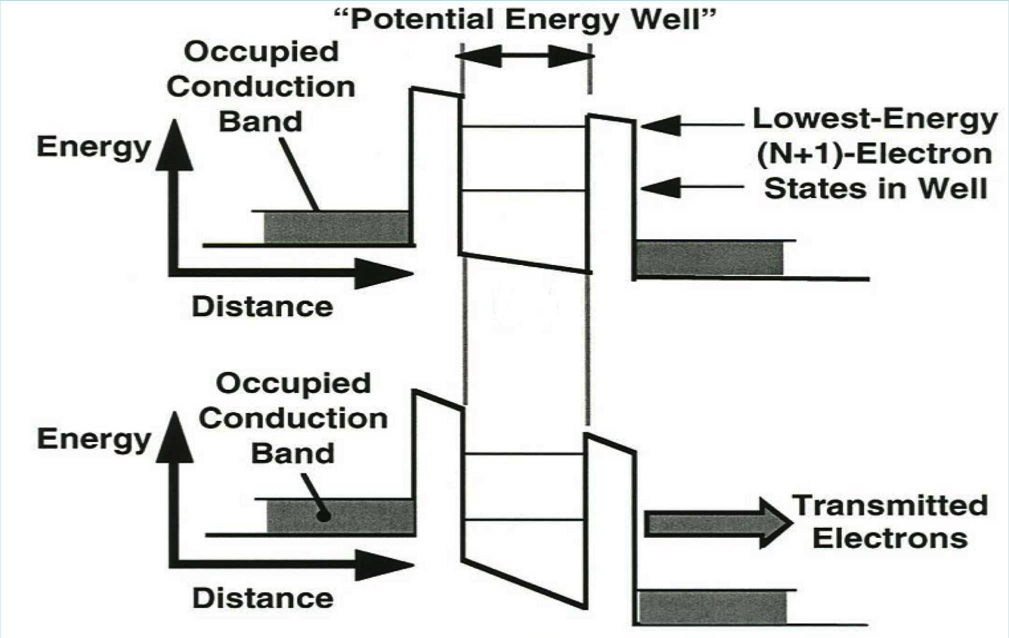
Molecular Transistors

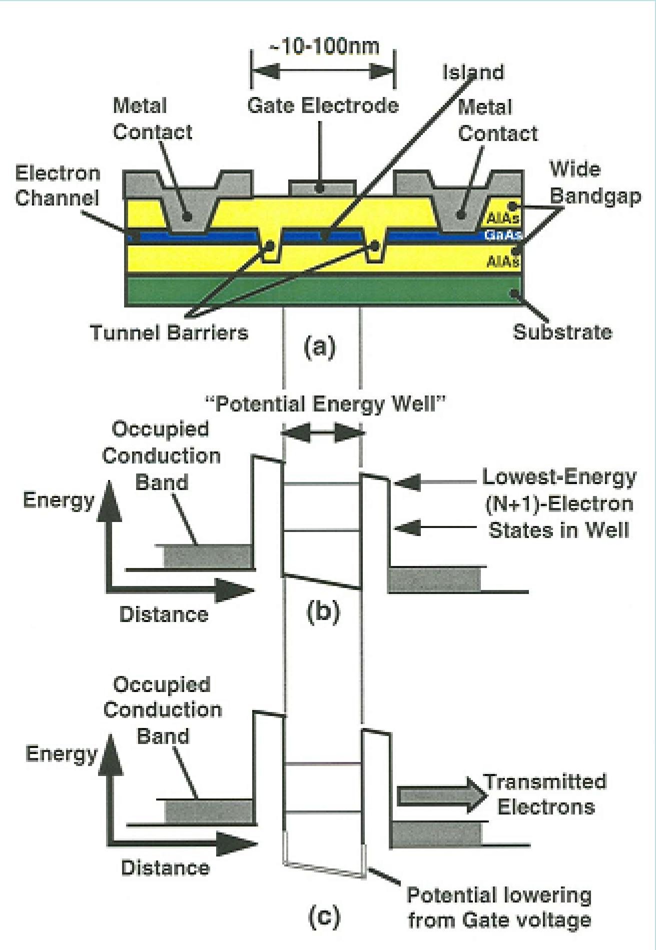


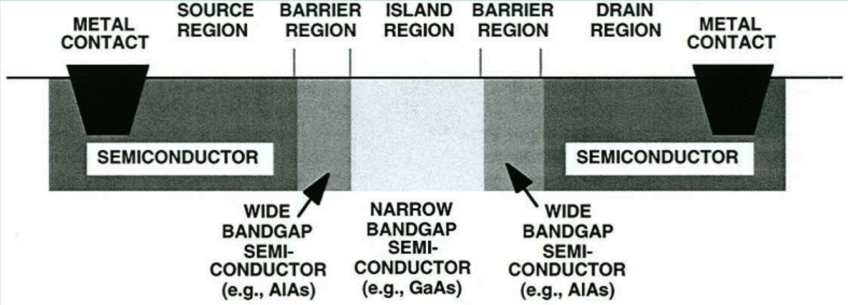


Applications

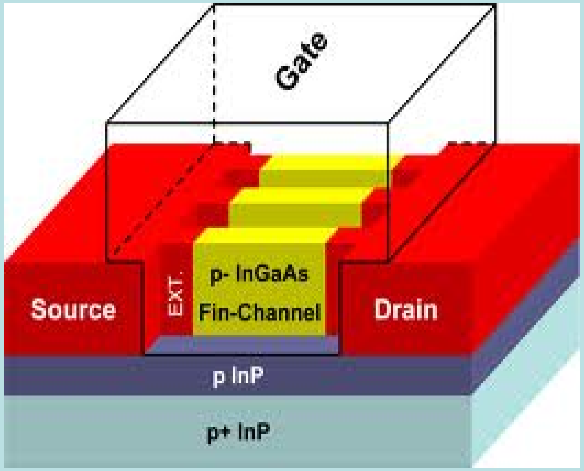
Resonant Tunneling Diodes

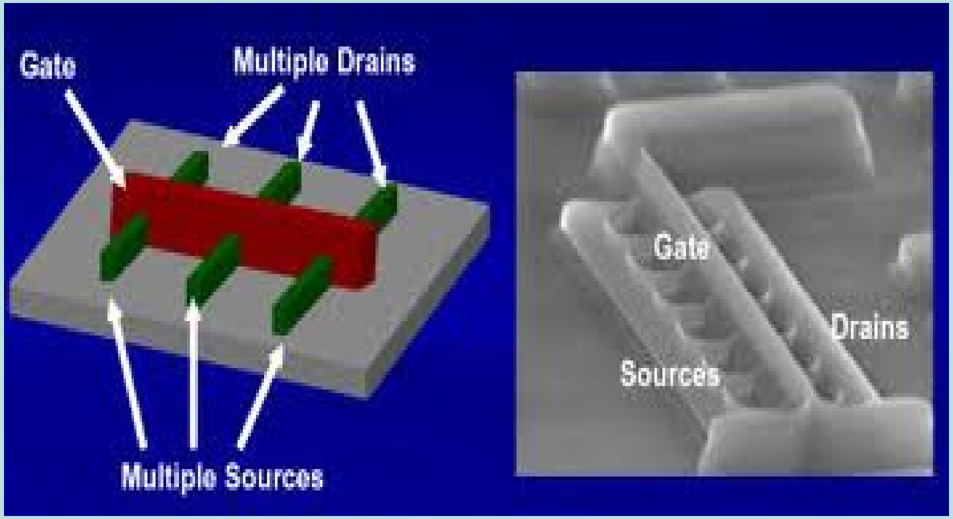






FINFETs in CMOS technologies





Applications

LEDs, Tunable lasers

- Researches have demonstrated that semiconducting quantum dots can provide the necessary efficient emission of laser light for the development of optical and optoelectronic devices such as tunable lasers, optical amplifiers, and LEDs. Quantum dots perform well in a wide temperature range and can be tuned to emit at different wavelengths. It is possible to make LEDs from quantum dots that are accurately tuned to blue or green wavelengths.

Applications

Telecommunications

- The availability of tunable semiconductor quantum-dot lasers opens possible applications in the telecommunications industry, especially because dots are also promising materials for making ultra-fast all-optical switches and logic gates. “The properties of semiconductor quantum dots offer great potential for optical amplifiers at telecommunication wavelengths,”

Quantum Computing

- Unlike conventional computation, quantum-dot-based quantum computers would rely on the manipulation of electron spin to carry information and perform computations.

Applications

Biotechnology and DNA Analysis

- Recent biosensors use fluorescence-based dyes, but these dyes emit light across a broad spectral width-which limits their effectiveness to a small number of colors and degrade over time under the microscope. Quantum dots can be fine-tuned to emit at different wavelengths simply by altering the size of the dot. Thus, dots can be used to label and measure several biological molecules simultaneously. And because quantum dots are crystals instead of organic molecules, they remain almost completely stable or unchanged under the microscope. Semiconductor quantum dots attached to a bio-molecule for use in cell and tissue analysis.
- The other application of using the quantum dots as inorganic fluorescent probes to shed light on cellular processes, such as the forming or breaking of chemical bonds. The scientists recently announced that it had successfully labeled breast cancer cells with quantum dots, which can also be used to color-code other kinds of cancer cells and they hope to extend the emission range of quantum dots into the near-infrared.

Applications

- DNA Analysis It is very promising to "bar-code" DNA and proteins, using metal nano-particles like quantum dots (QD) or polystyrene particles loaded with QDs or species with distinguishable electrochemical properties. The basic concept relies on finding a way to develop a large number of smart nanostructures with different electrochemical properties that have molecular-recognition abilities and built-in codes for rapid target identification.
- Medical
- Aerospace

Nanotechnology and Renewable Energy

- Batteries
- Solar cells
- Fuel Cells
- Hydrogen Storage
- Wind Energy
- Hydro
- Nano-energy generator

Batteries; Methanol Fuel Cell / Hydrogen Fuel Cell

- Energy Density of a Battery is the amount of energy that can hold.
- Power Density of a Battery measures the speed of energy dissipation from the battery.
- Chemical reactions (induce energy density and power density) within a battery or fuel cells need CATALYSTS. Nanoparticles play important role as their surface-to-volume ratio is much larger than macro/micro particles.

Solar cells

- Conventional solar cells: Low efficiency, 10-15%; high manufacturing cost.
- Embedded nanoparticles or nanorods or nanotubes in polymers solar cells make the manufacturing cost very low, although the efficiency is even lower than the conventional solar cells.

Hydro

- Changing copper or aluminum cables to carbon nanotubes: CNT: one of the strongest materials available. High electric current capability 10^9 amp/cm2 (1000 x larger than what copper can carry).
- Erosion resistant for turbine blades; using nano particle paints.
- Nano particles can improve the mechanical properties of many composite materials make them suitable to build turbine blades, and will mills
- Nanosensors to monitor power and gas leaks, like SF_6 used in power switches.

Issues & Implications in Nanotechnology

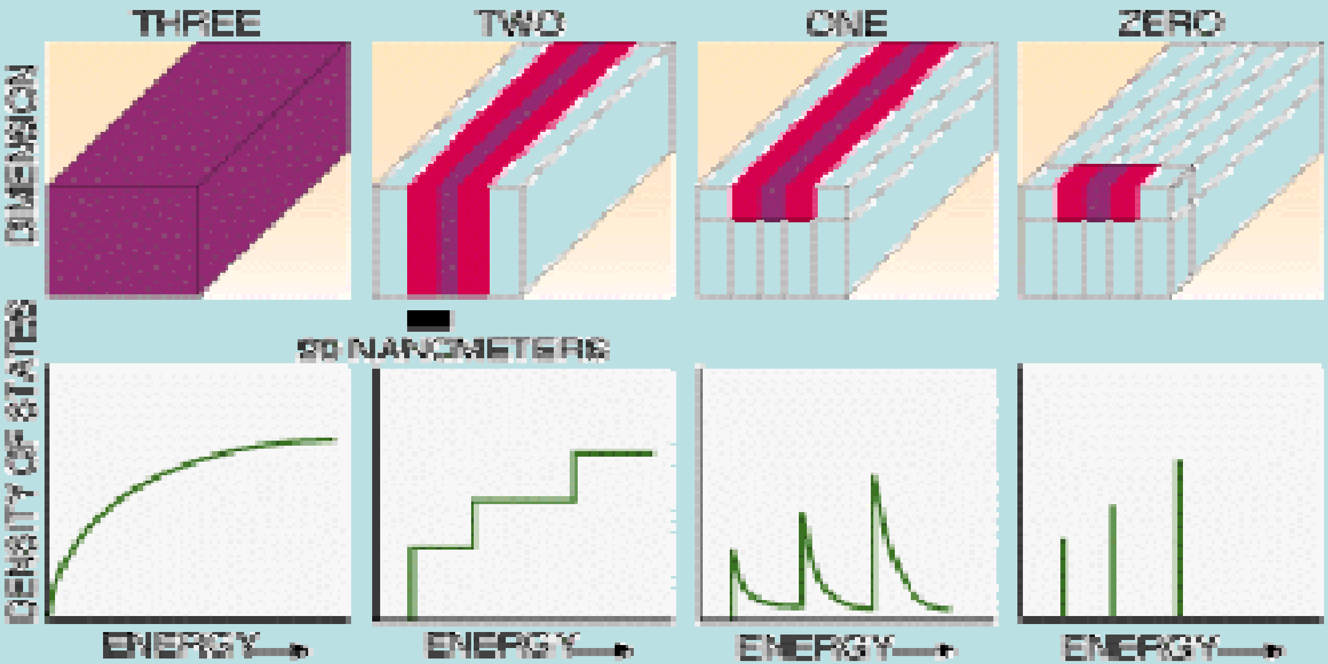
- The classical physics fails to answer many phenomena..
- There are many issues even when applying the Quantum laws

Issues & Iomplications

- Transport properties are function of confinement length (e.g. in quantum wells) because of the change in the Density of States
- Relative strength of each scattering different from bulk
- Electrons tend to stay away from the interface as wave function vanishes near the interface

Nanostructures

Density of States



Issues & Implications

- Effective resistance

  (ballistic & effects of splitting energy level)

$$\frac{1}{\rho} = \frac{nq^2\tau}{m} = \sigma$$

$$\frac{dP}{dt} = \frac{mv}{\tau}$$

- Conductance is quantized and has a maximum value for a channel with one level

$$G = \frac{2q^2}{h}$$

- Familiar voltage divider and current divider rule may not be valid on submicron scales

Issues & Implications

- Validity of effective mass approximation
- Doping and effects in nanostructures
- Surface Effects
- Recombination
- Hot Carrier Effects
- Coulomb Blockade

Issues & Implications
(Looking at nanotechnology from different Angle)

- Societal
- Ethical
- Environmental
- Health and safety
- Security
- Legal and public implications

Research Programs in ECE

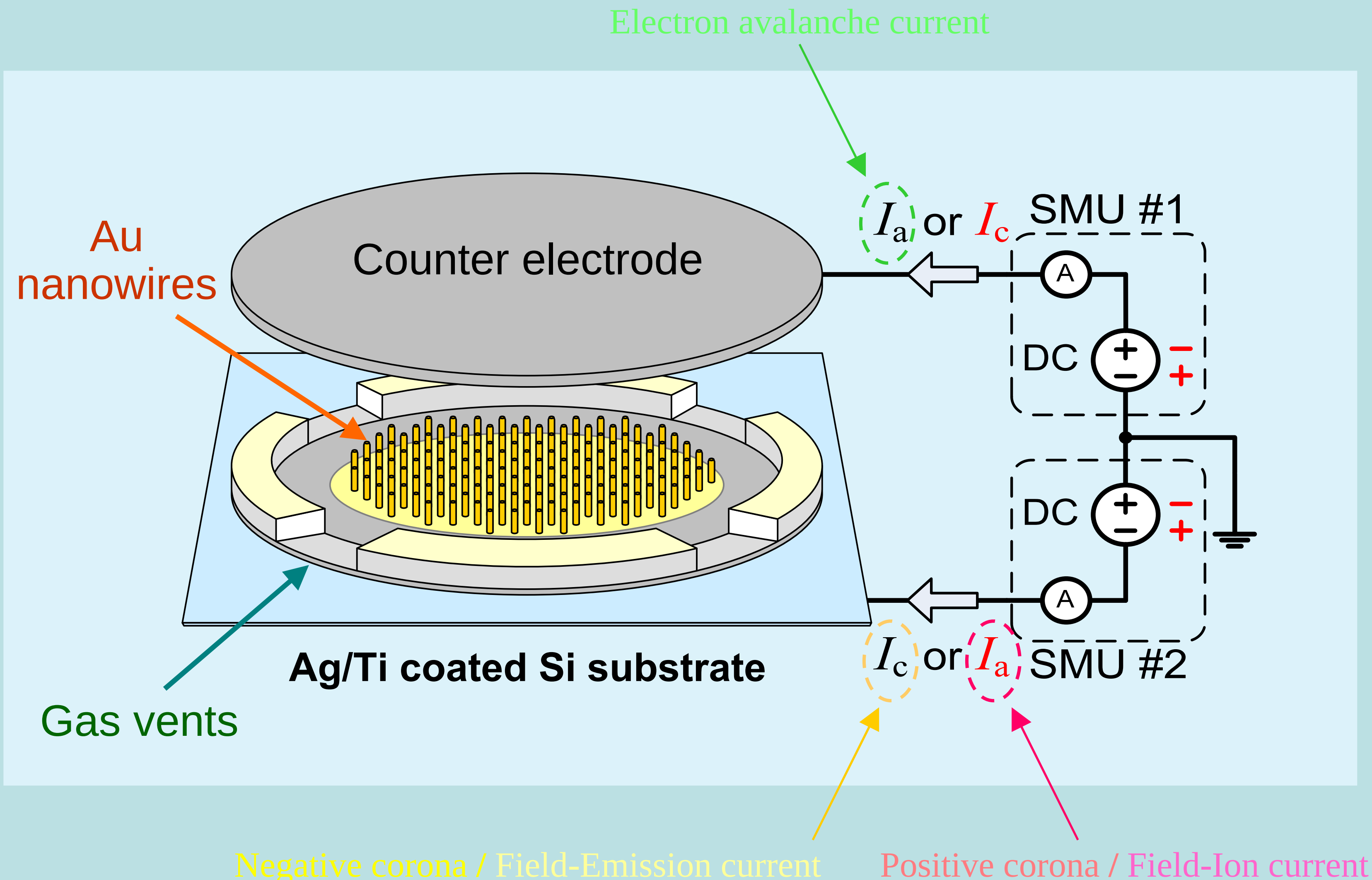
At present there are 10 graduate students working in this area :

- 5 PhD
- 6 M.A.Sc

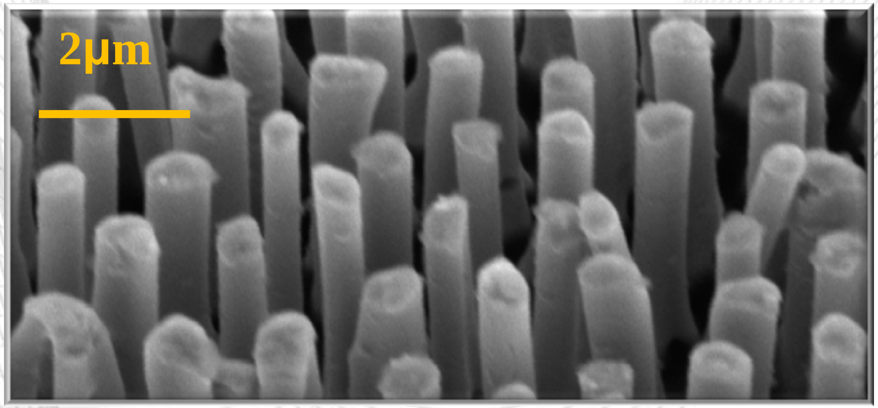
On going researches: 4 major projects

- Nanodevices based on nanowires; gas sensors, Solar cells
- Nanodevices based on nanoparticles; biomedical sensors
- Optical Sensors; Materials Health Monitoring
- Investigation on principle issues related to the nanodevices

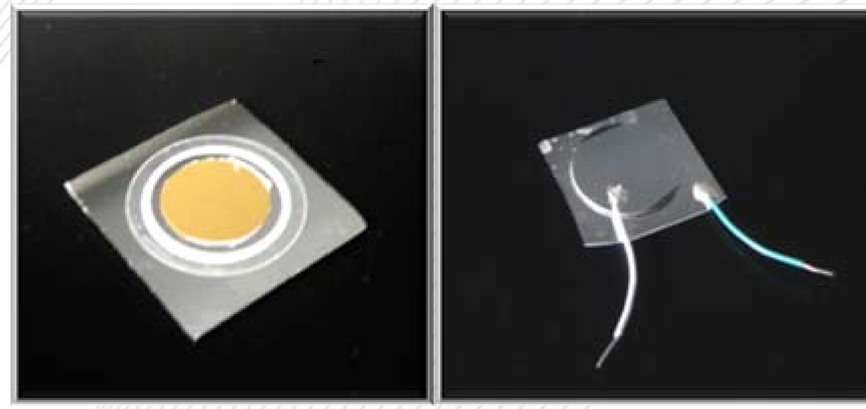
GIS; Device Schematic



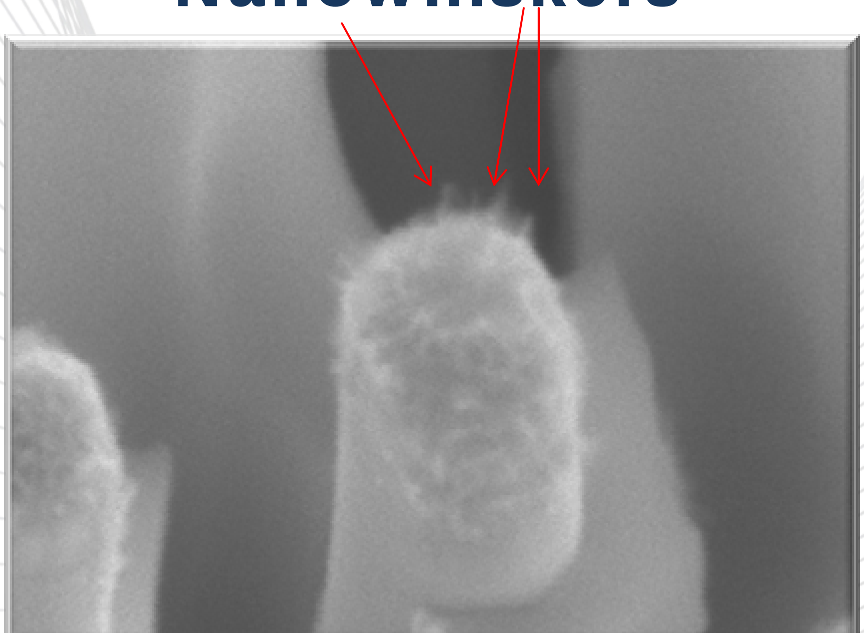
Silver-Nanowires



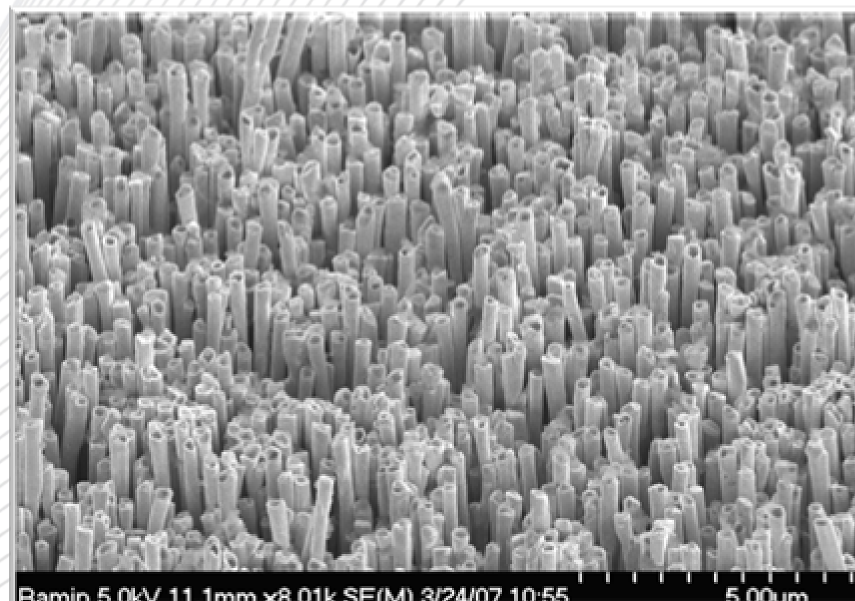
Photographs



Nanowhiskers



Gold-Nanowires



Metallic Nanowire : SEM Results

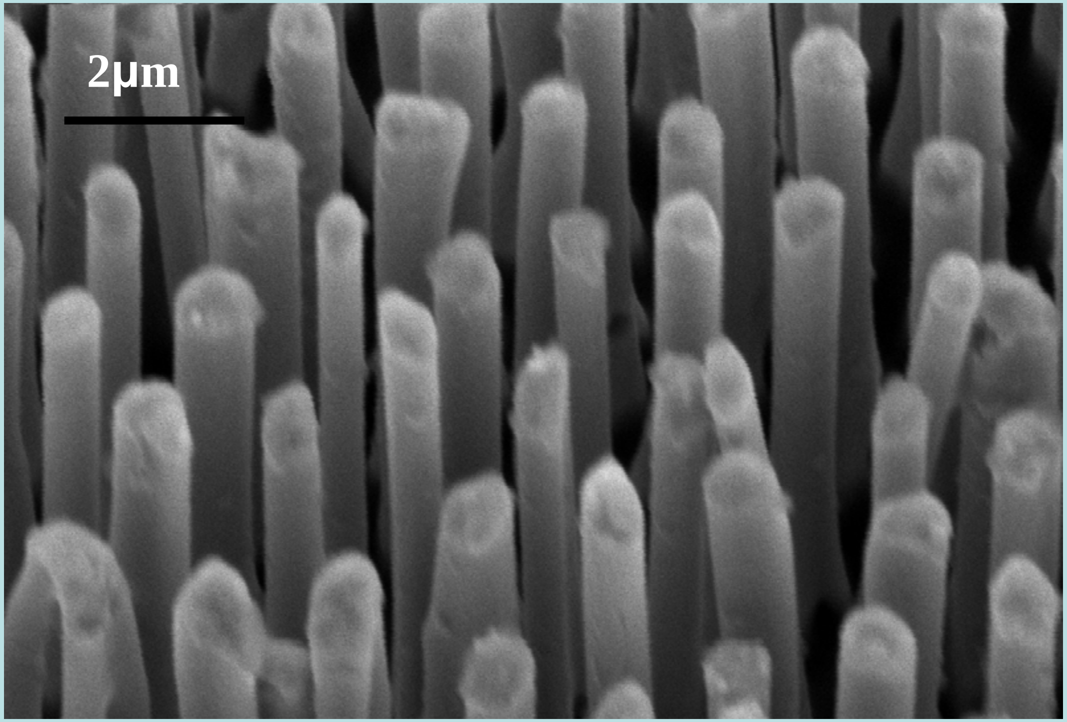


Figure 18. Silver-gold alloy nanowires, fabricated by electrochemical deposition for 80 minutes in a modified AAO (with polystyrene microspheres) , I=2mA (L= 4μm).

Results and Discussion

The mentioned textured silicon was electrochemically etched using the same anodization conditions as sampl#7 (I=85mA, t=30min (all conditions are kept constant)).

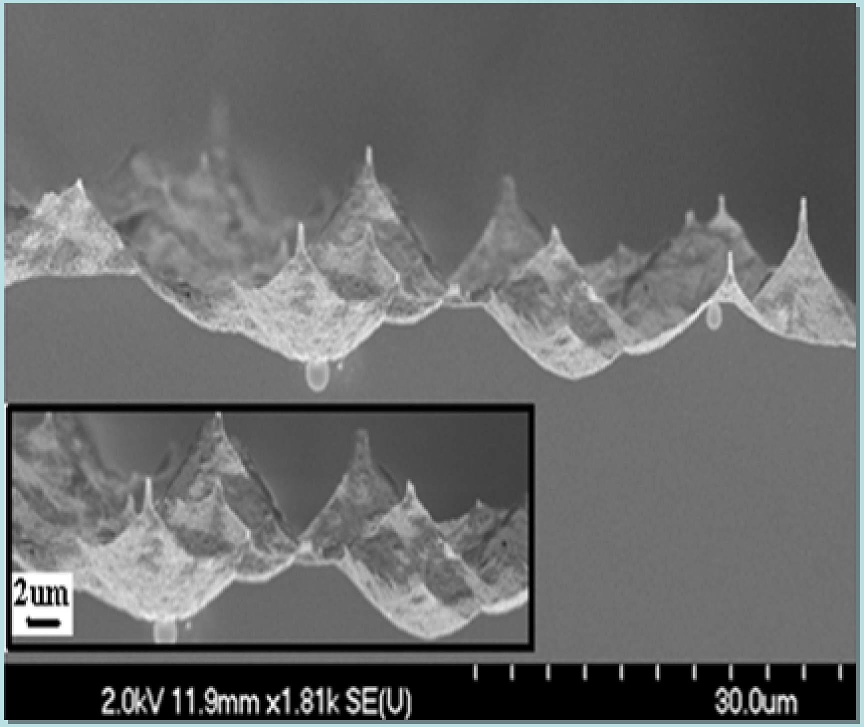


Figure 22-a: Cross section of pyramidal PS fabricated on Si surface of high-concentration hillocks-sample#10.

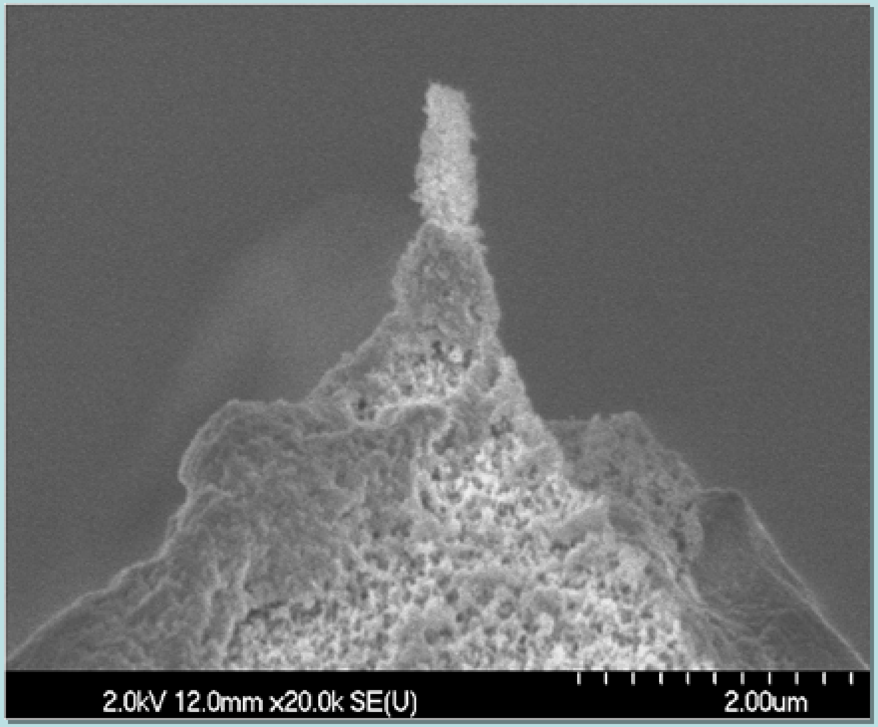
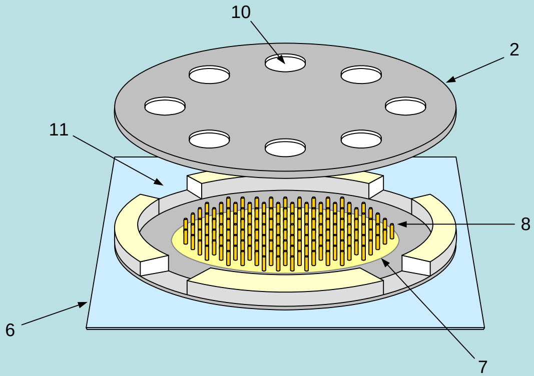


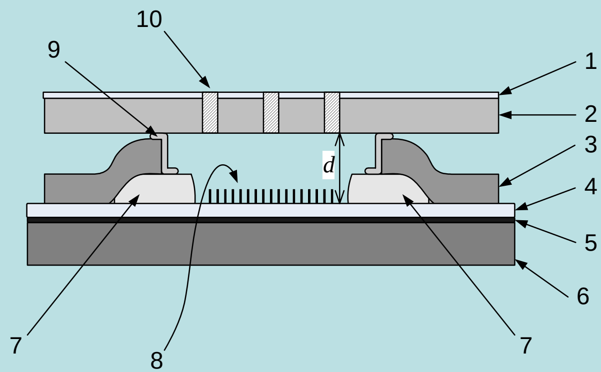
Figure 22-b: Cross section of one pyramid from sample#10. This image is representing a silicon nano-rod.

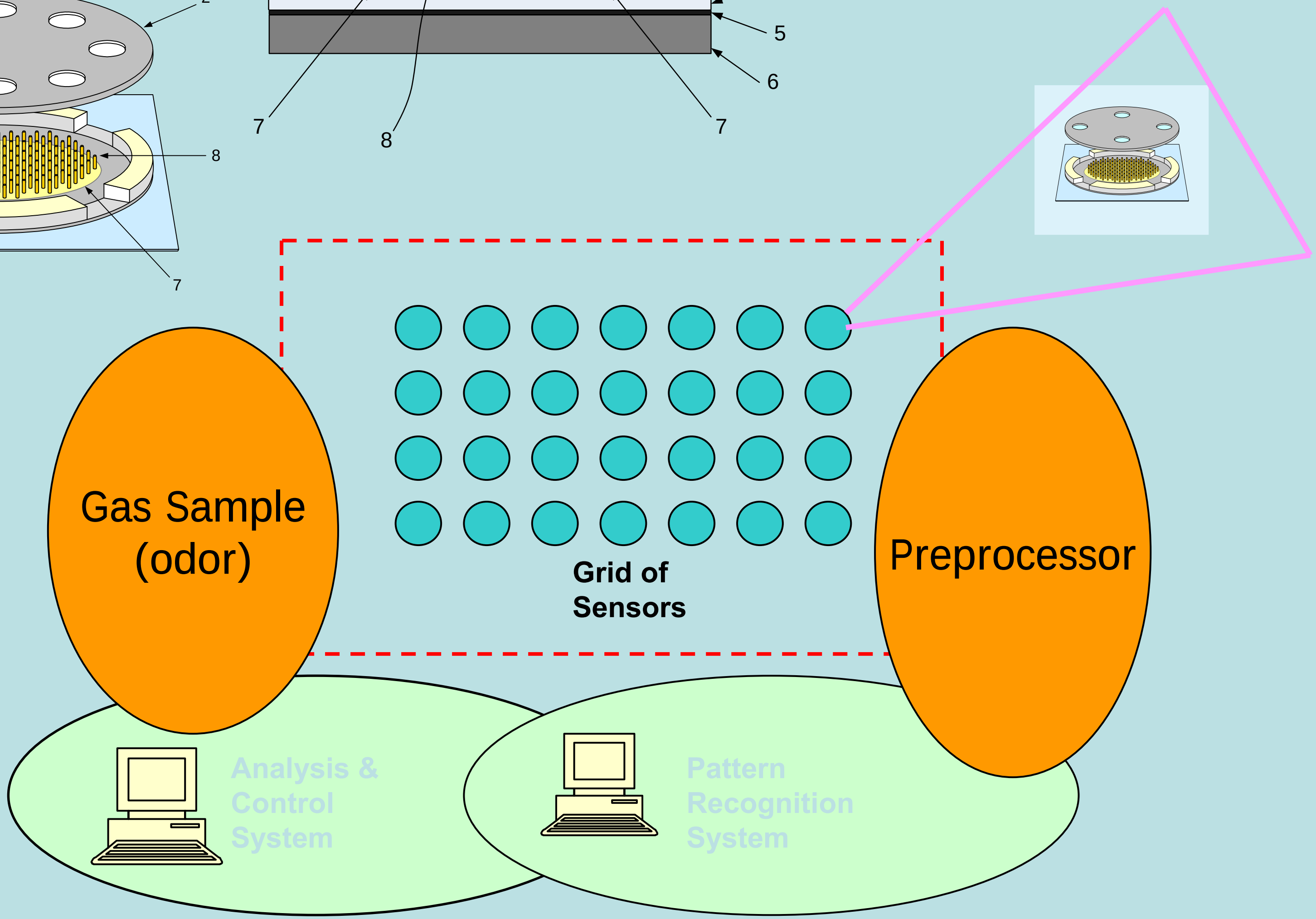
Silicon nano-rods were fabricated on the tip of the pyramidal porous silicon structure with diameter of 200nm and length of 800nm.

This structure is of potential for photovoltaic applications. The nano-rods with sharp tips can be also used as AFM probes.

ENose

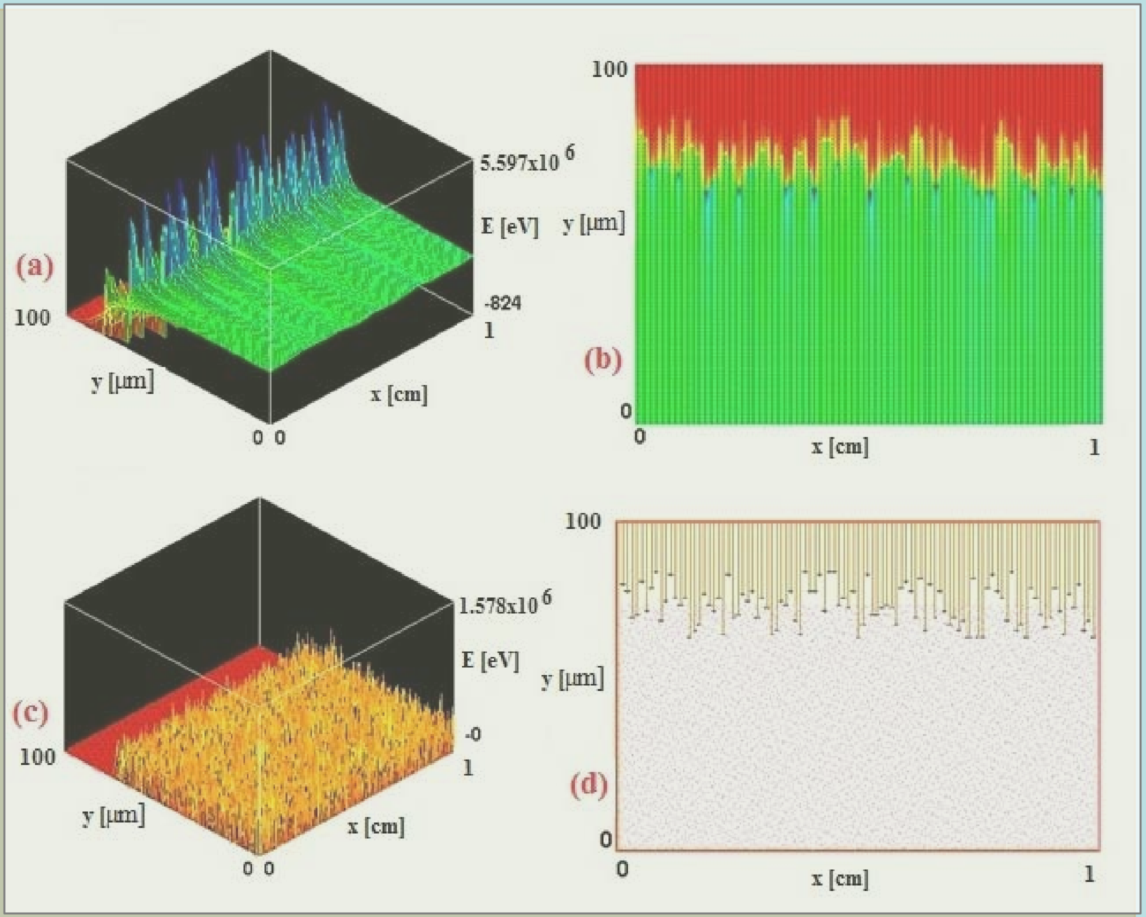






R. B. Sadeghian & M. Kahrizi, pending patent, 2007

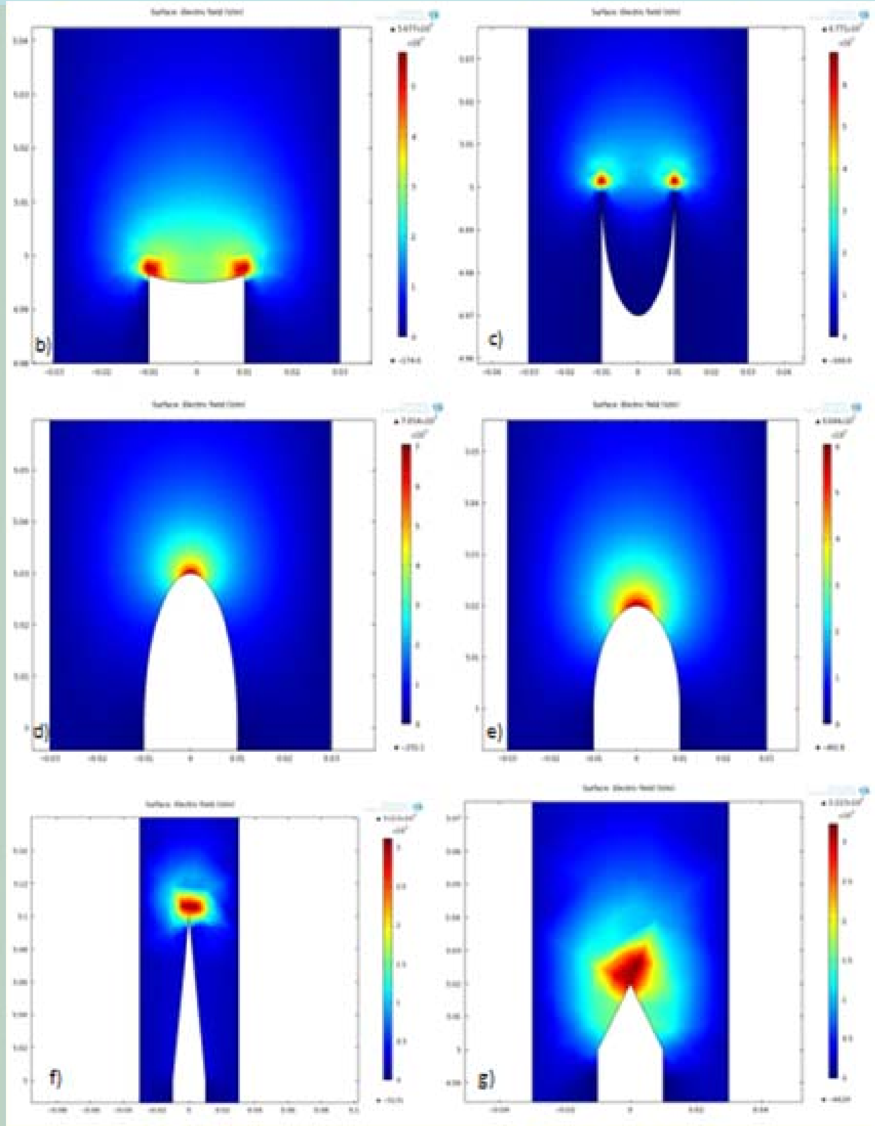
Simulated electric field intensity inside the sensor

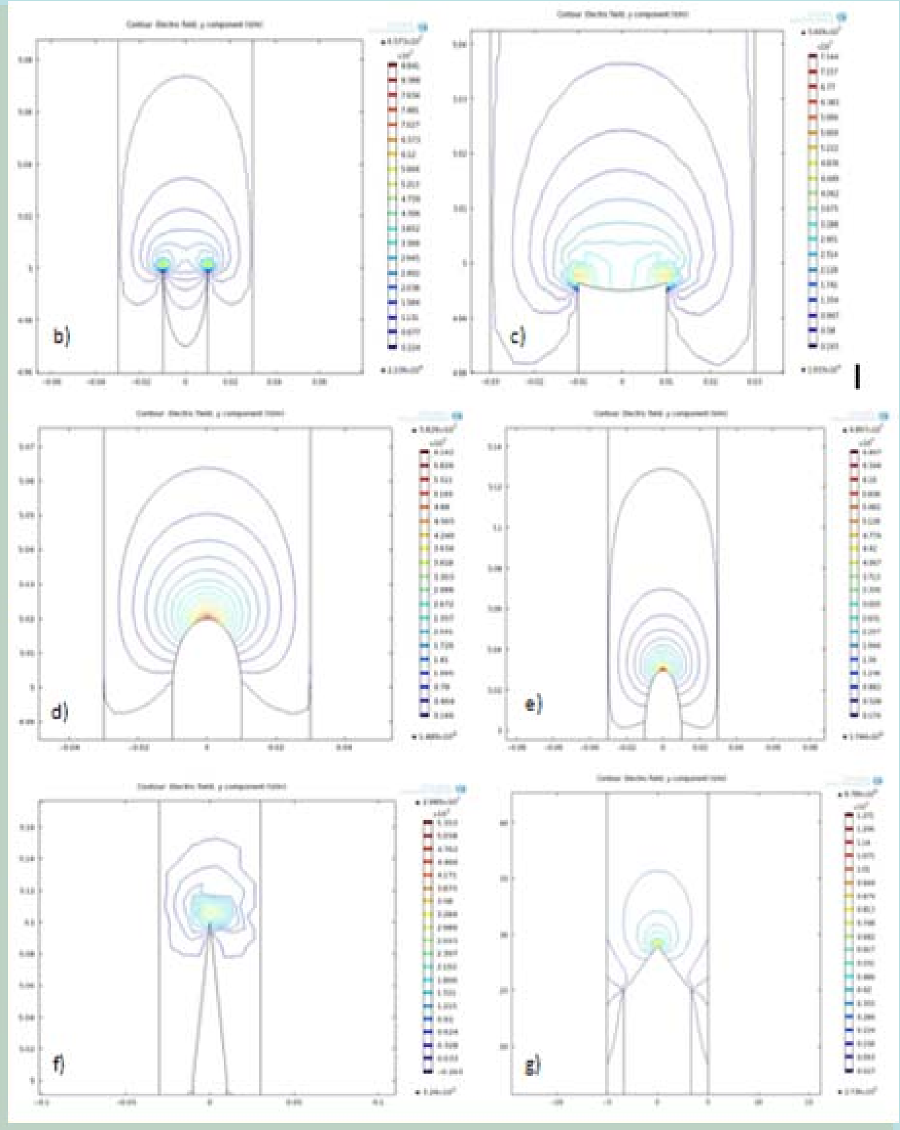


- the electric field due to the aspect ratio of the nanowires is enhanced largely compare to the applied field at the bottom of the cell on cathode electrode side.
- the mathematical axes x and y corresponds to the 1cm chamber width and to the gap distance of 100 µm respectively.
- The electric field intensity reaches a maximum of 5.6x10^{06} eV at the tip of the nanowires. Figure c) and Figure d) show that there is no charge distribution between the nanowires, as a result the electric field (represented by the red zone on the graphs) is zero in these regions.

Simulations of the Modeled Electric Field Generated Around Nanowires

The Shape Effect of Nanowires tips

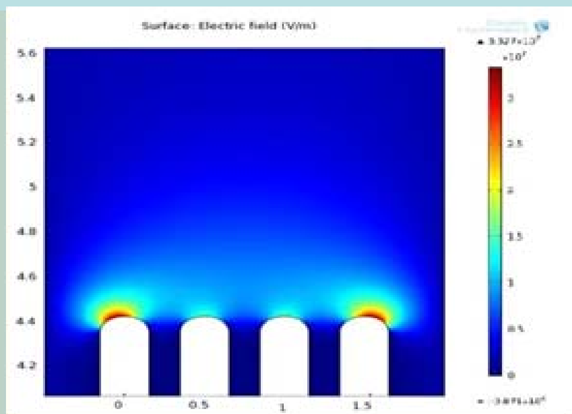


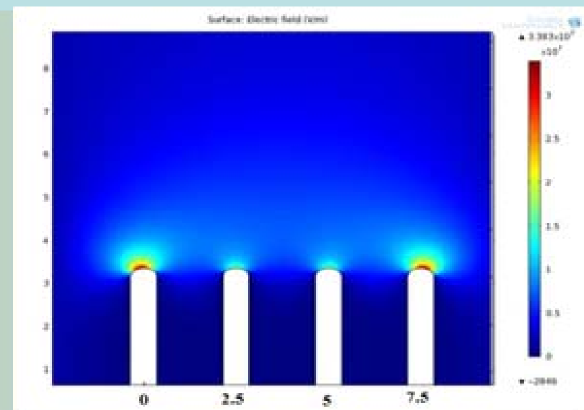


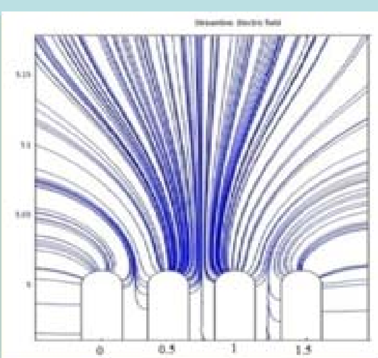
Effect of the Nanowires Separation on Electric Field Distribution

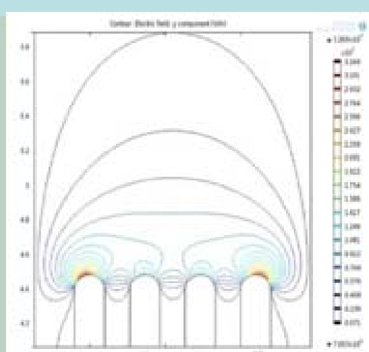
Parameters used in these simulations:

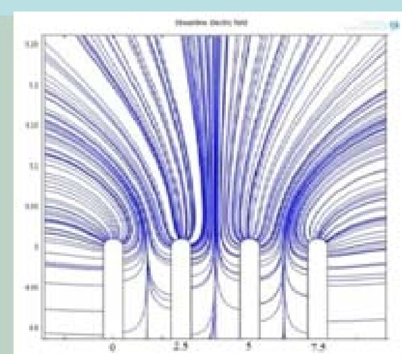
- Nanowires lengths of 5 microns
- Applied voltage of -150 V
- Nanowires interspace of, s, 0.5 – 50 microns

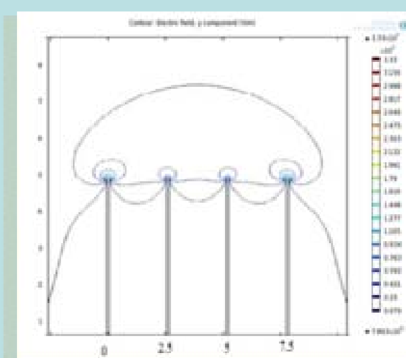






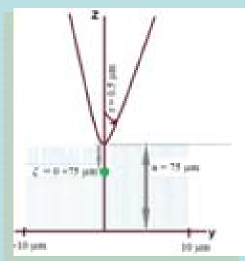


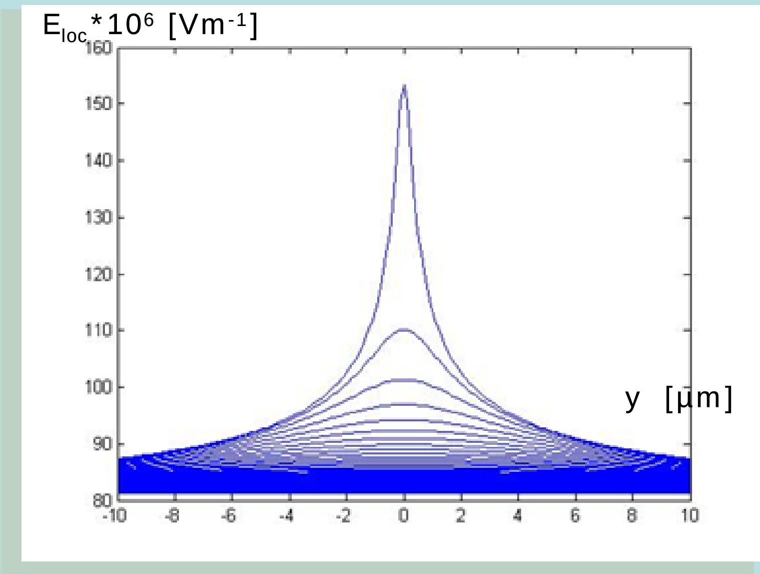




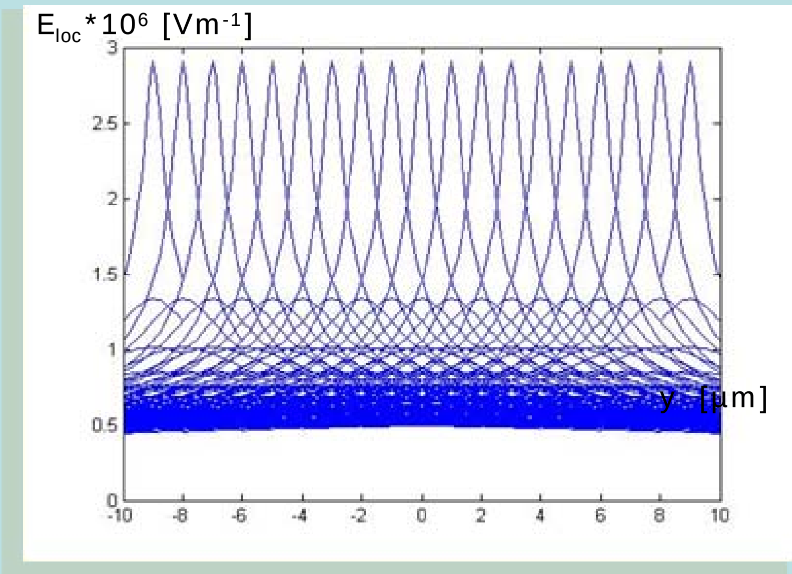
Electric Field along the Nanowires

- We have used MATLAB to plot the electric field surrounding the nanowires.
- The local electric field is computed on every ξ point on a surface defined by the coordinates (-10, 75) for the left corner down and (10, 0) for right corner up, where ξ (0, 0) corresponds to the point at the nanowire tip.
- The maximum electric field is reached at the nanowire tip, due to the field enhancement.
- When an array of nanowires is taken into considerations due to the electrostatic interaction between individual nanowires the total electric field is reduced (screening effect).





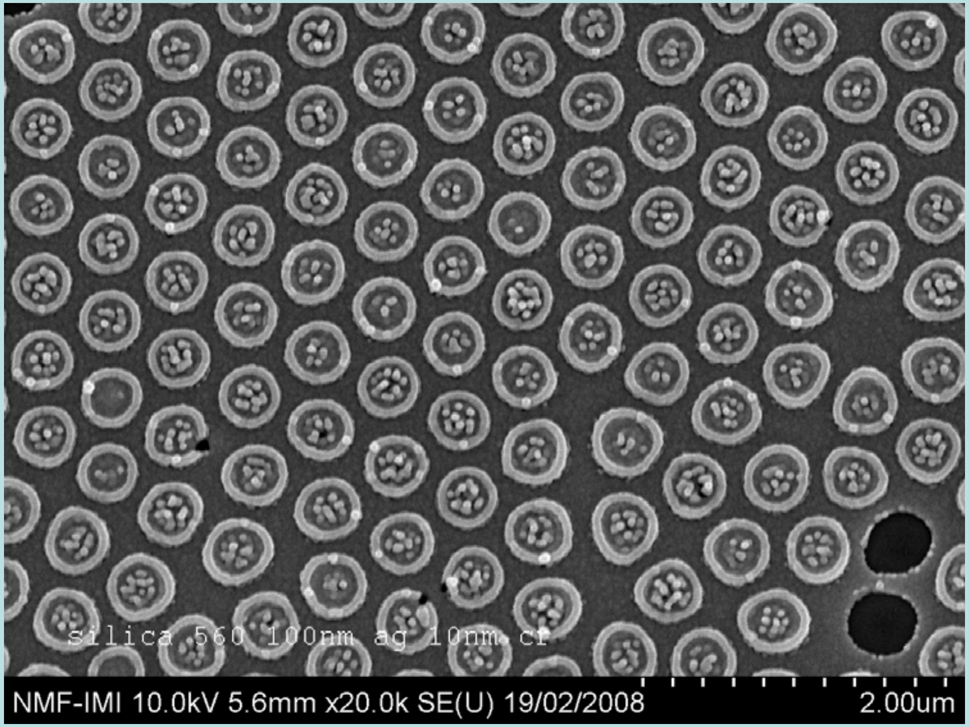
The local electric field calculated in z-y plane in a needle to plan electrode system; nanowire length *l*=25µm, tip radius r = 0.5µm and gap distance d=100 µm.



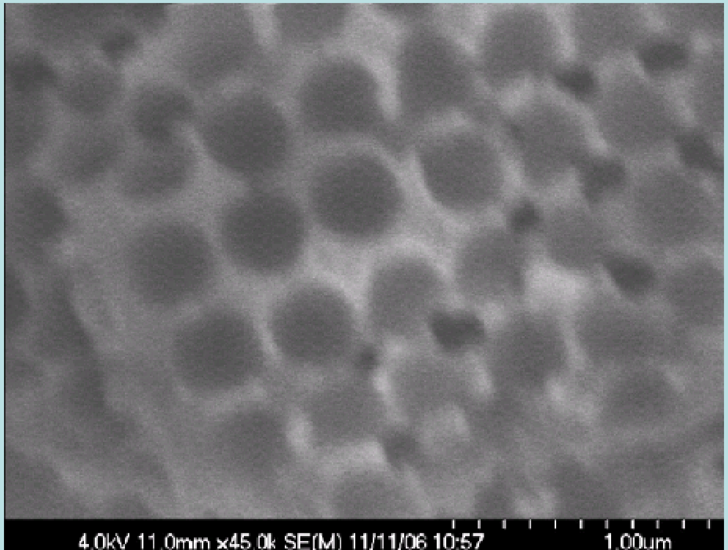
Electric field intensity versus distance from the nanowires tip calculated in z-y plane, tip radius r = 1 µm.

Biomedical Sensors

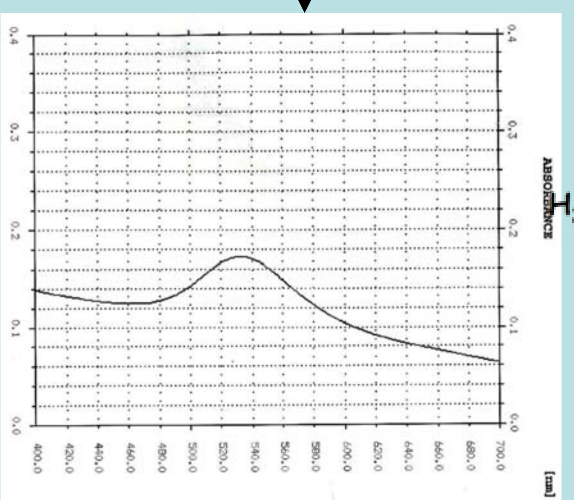
- Devices based on EOT (Extraordinary Optical Transmission) phenomena

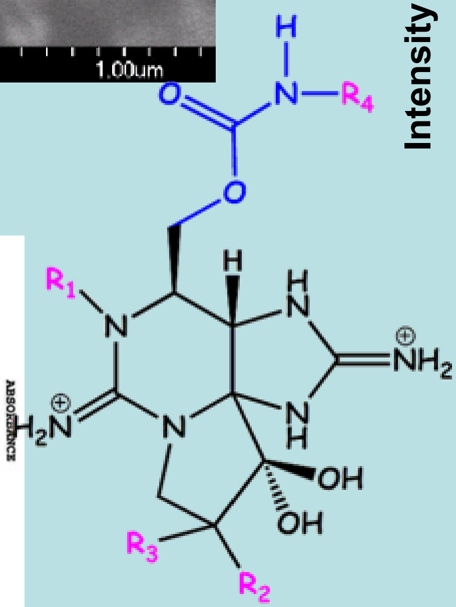


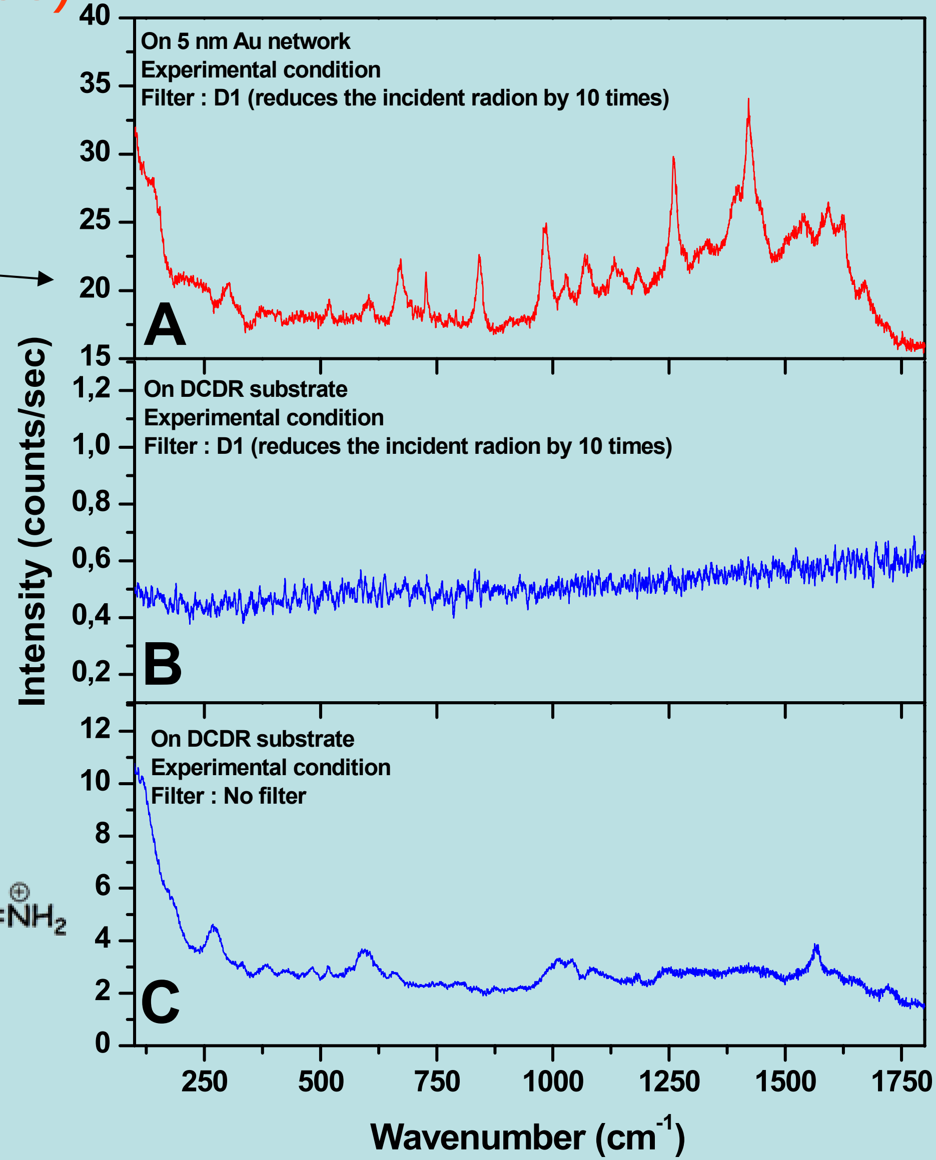
Biomedical Sensors (SPR devices)



Spectrophotometry



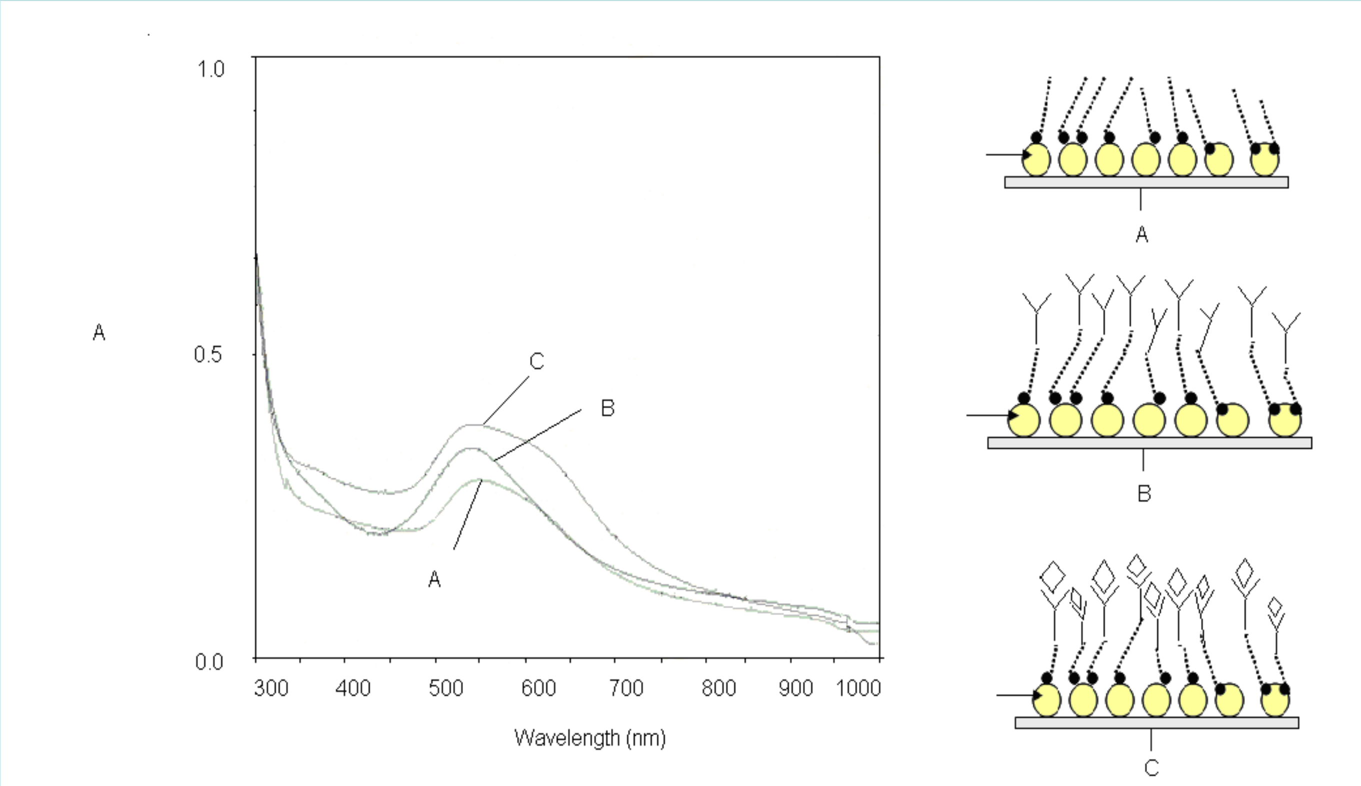




A. R. Hajiabol & M.Kahrizi, CSTC 2007

Comparing the Raman intensity to the toxin on DCDR substrate (commercially available)

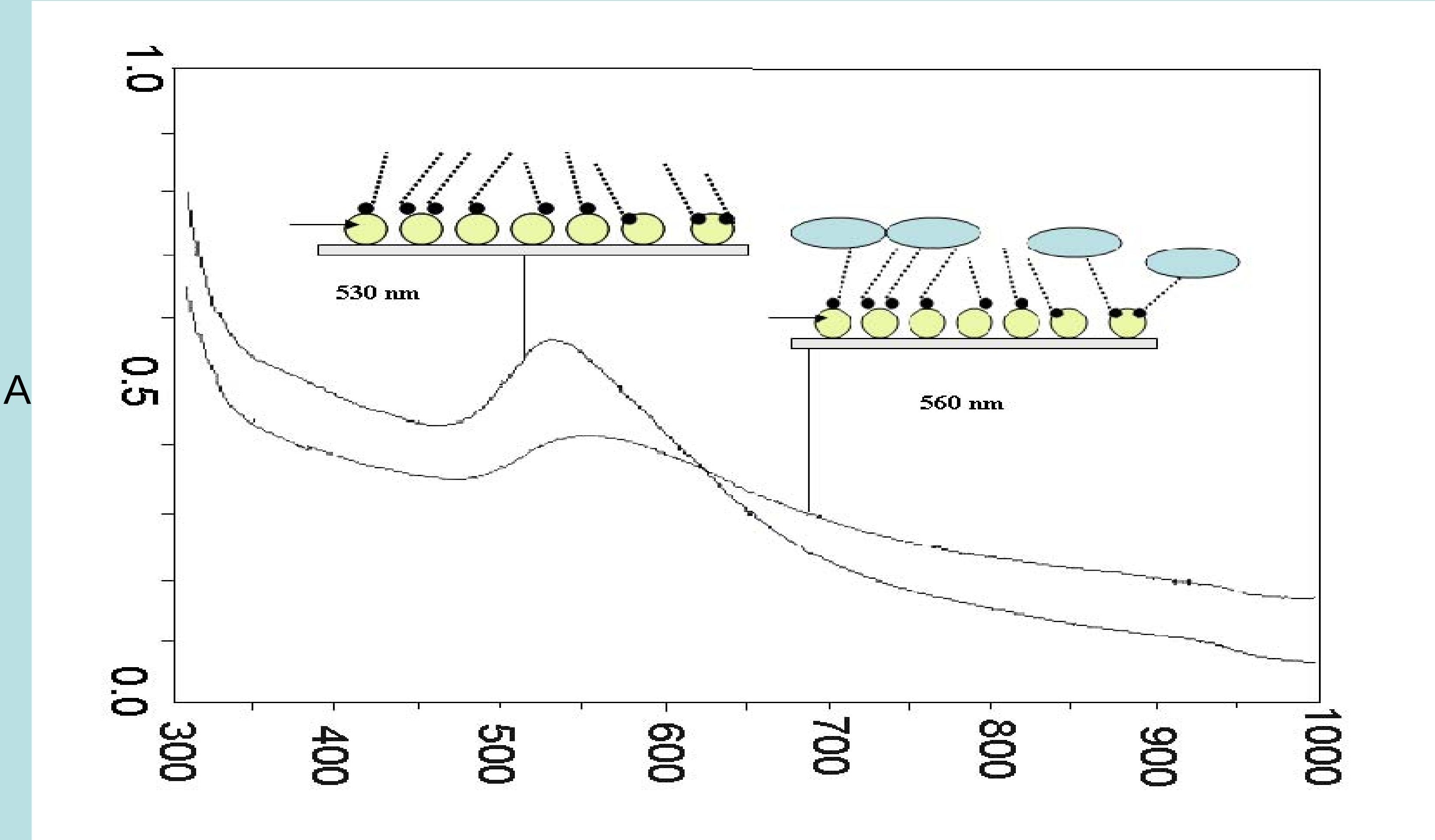
Biomolecular Interactions cont’d



Spectra corresponding to the protein-antibody interaction: A) spectrum of the functionalized substrate using Au that was prepared in the lab B) spectrum of the antibody adsorbed on the substrate C) spectrum of the previously absorbed antibody followed by the adsorption of the protein on the substrate

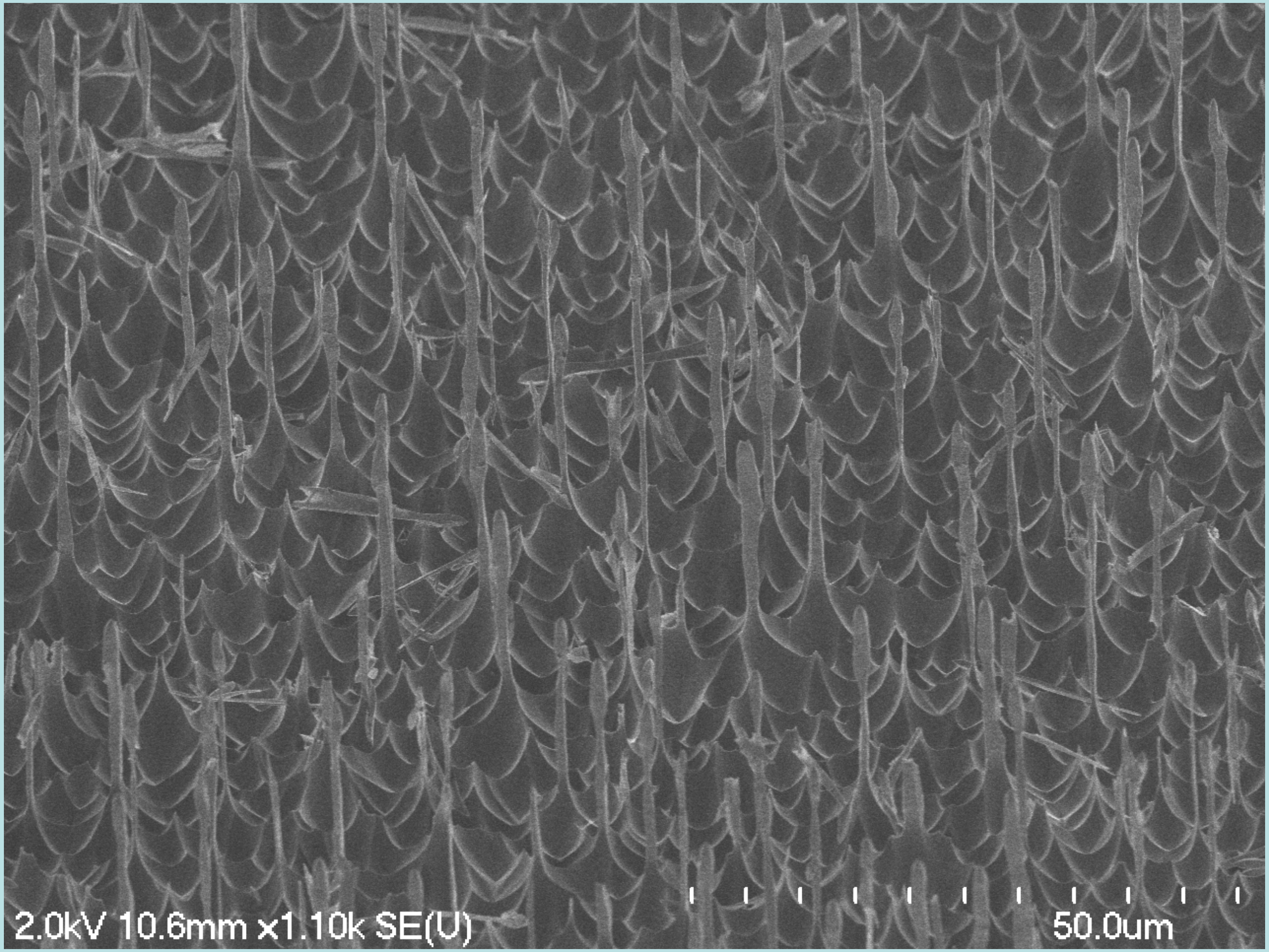
- Observed shift of ~10 nm when antibody adsorbed
- After protein adsorption no additional shift but observed shoulder around 600 nm.

UV-VIS SPECTRUM OF ADDLs ON GOLD



Wavelength (nm)

Silicon nanowires for application of Solar Cell



Self-Standing Si-NWs

Subjects to be covered:

- Quantum Mechanics & Nanostructures (a brief introduction to the principles of QM, followed by discussion on issues related to nanostructures)
- Nanostructures (in this section we discuss fabrications and characterizations of nanoparticles, nanowires, thin films, quantum dots, and carbon nanotubes.)
- Physical phenomena in nano-scale structures (we discuss self-assembly, plasmonic effects, …)
- Applications of nanotechnology (physical, mechanical, chemical, biological, medical,… applications will be presented)
- Current and future of nanotechnology
- Nanotechnology and societal implications (issues like health, safety, security, environmental,…will be discussed)
- Course projects (the projects presented by students in the class are complimentary to the materials covered in the class