# Thin Films

# Goals

- Make electrical or optical devices that are
  - small
  - cheap (process and materials)
- Make materials (textiles, engine blocks) more
  - durable (protective coatings)
  - stable (resist oxidation)

# One Solution …

- Make devices that consist of thin layers of various materials.
- Deposit thin layers of coatings to get the desired properties.
- The thickness of the layers can range from 10 nanometers to several micrometers.

# Examples of Devices

- Transistors, diodes, integrated circuits
- Photovoltaic cells
- Electrochromic devices
- Sensors
- LEDs

# Thin Film Transistors

- Many layers
  - Doping
  - Lithography
  - Etching
- Metal contacts
  - ITO for transparent contacts

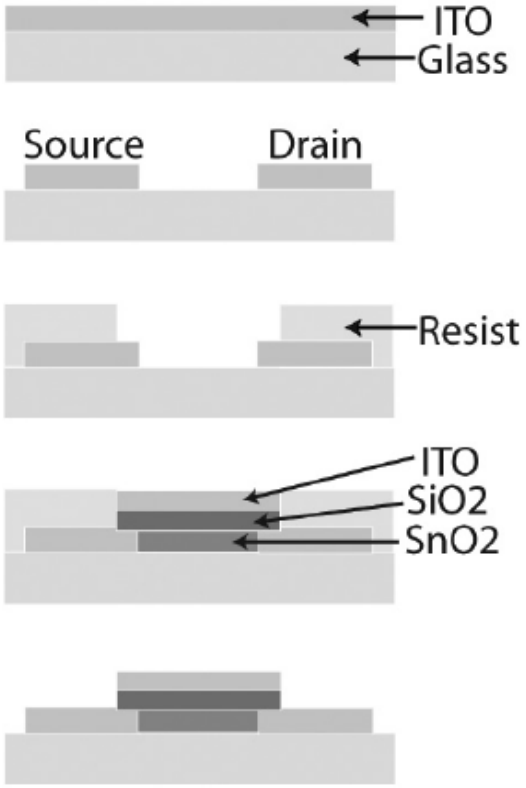
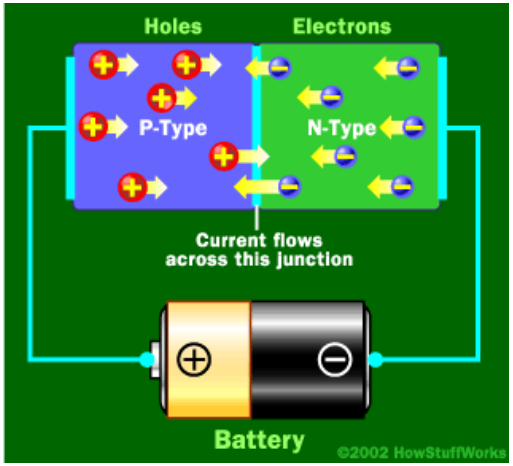


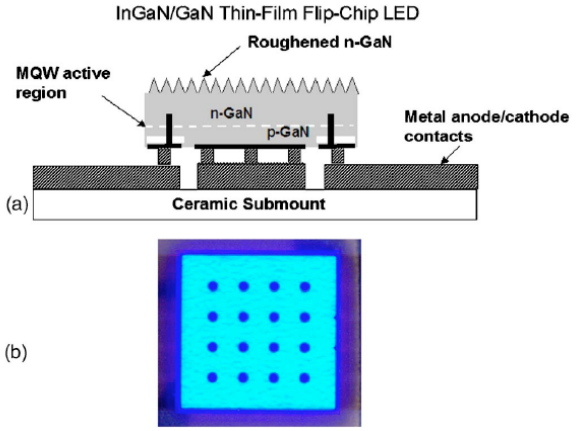

**Figure 1.** Schematic for the fabrication of transparent transistor using LbL self-assembled nanocrystal multilayers.

Nanotechnology **18** (2007) 195204 (5pp)

# Light Emitting Diodes

- The battery supplies the current (a flow of electrons).
- When electrons move they leave behind positively charged vacancies (holes).
- Electrons and holes attract each other and recombine.
- Their energy is released as light.

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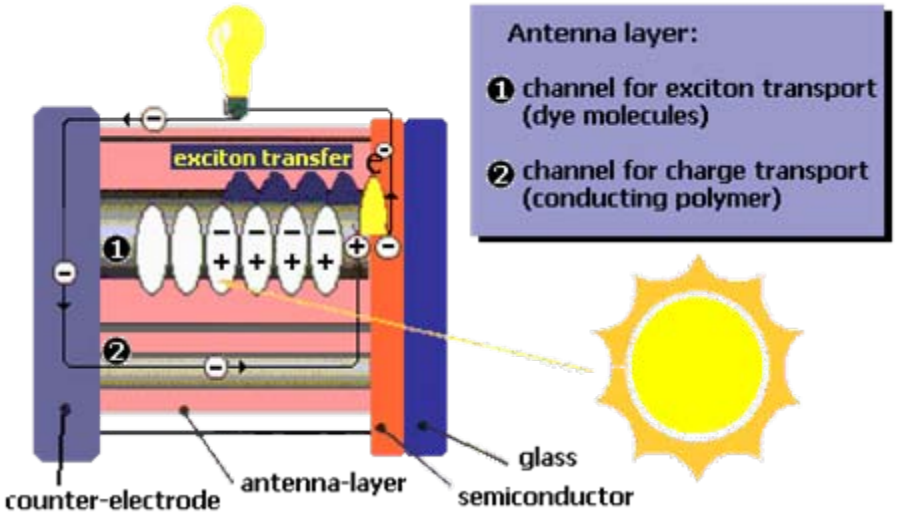
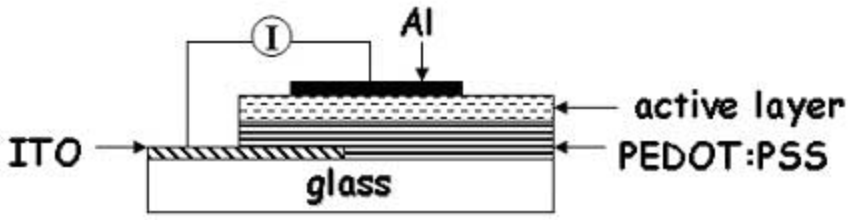
# Photovoltaic Cells

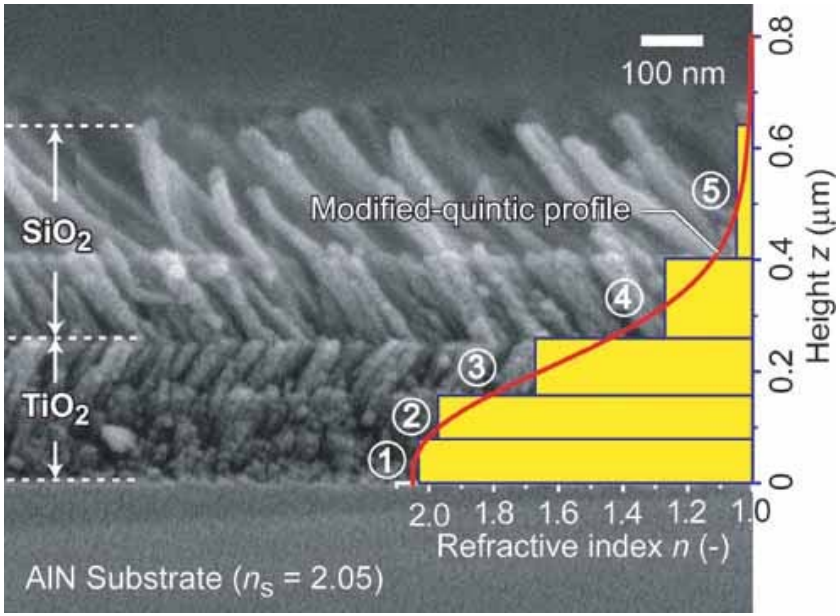
- Layered thin film device
- Electricity from light

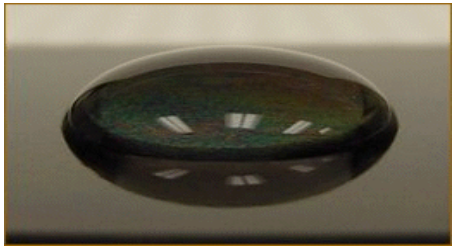


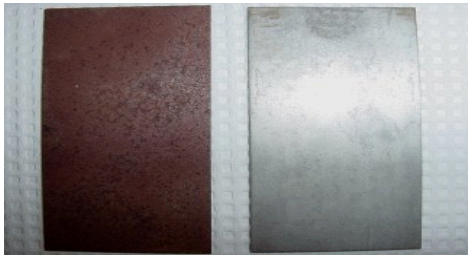



# Coatings

- Anti-reflection coatings on glasses
- Anti-oxidation layers on metals
- Ceramics to prevent overheating
- Hydrophobic coatings





# Thin Film Deposition

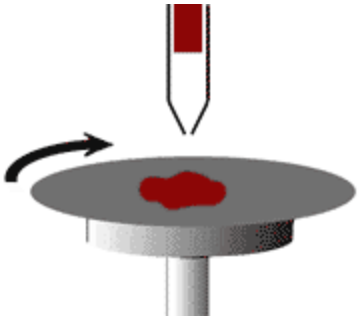
- Need a clean substrate – the base material to deposit the film on.
- Need a source for the film material.
- Somehow bring the source material in contact with the substrate and have it stick.
- If necessary pattern and etch the film.

# Deposition Methods

- Solution processing
  - Spin coating
- Vapor deposition
  - Chemical
  - Physical
  - Vacuum Evaporation
- Molecular Beam Epitaxy

# Solution Processing

- Used for conjugated polymers and soluble materials.
- Dissolve thin film material in a solvent (mostly carcinogenic stuff)
- Place a drop on the substrate.
- Use a spin coater or a doctor blade to spread the film.



# Chemical Vapor Deposition

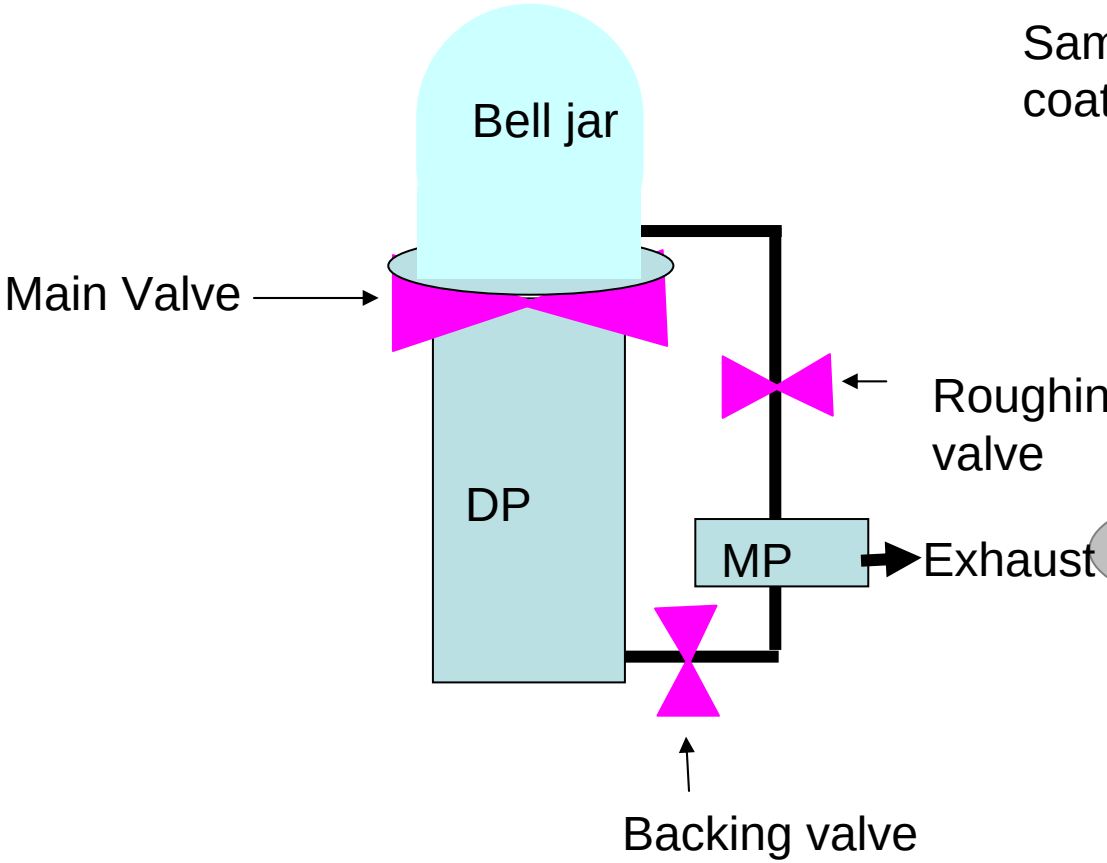
- Use a chemical reaction between several vapor source materials (precursors) on the substrate to synthesize and deposit the thin film.
- Mostly used in the semiconductor industry.

$$SiH_4 \rightarrow Si + 2H_2$$

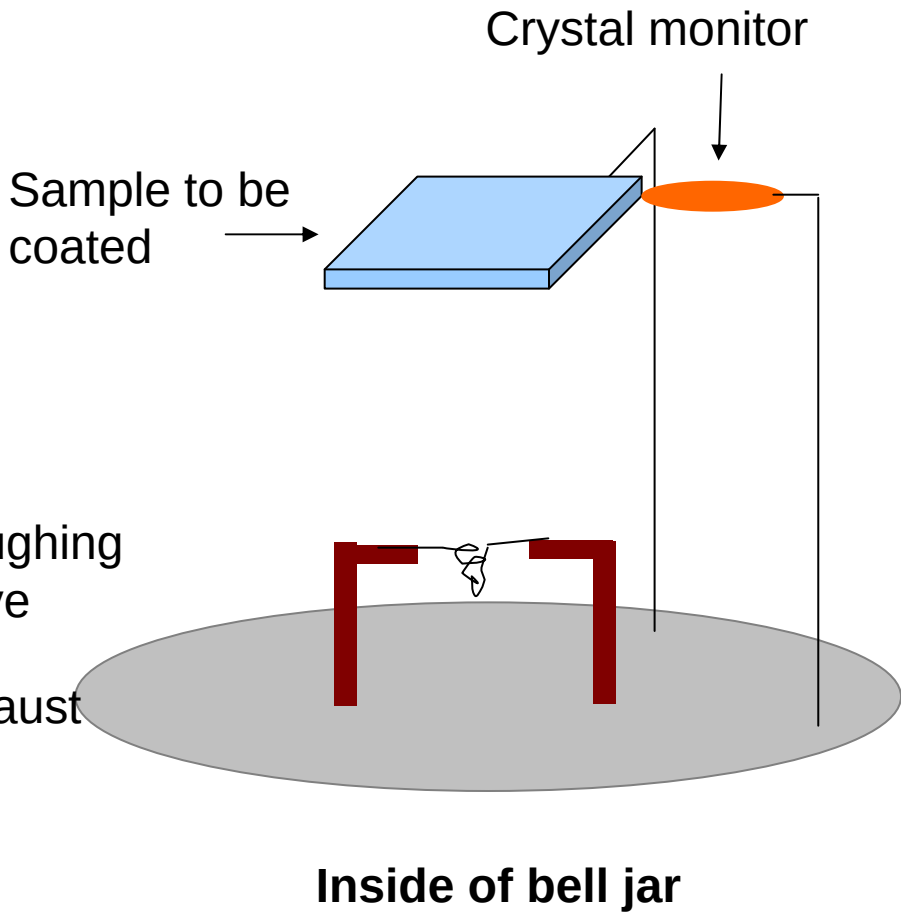
# Physical Vapor Deposition

- Use physical means (heating, ablation, plasma) to generate a vapor of the thin film material.
- The atoms/molecules of the material then travel to or are guided to the substrate and get deposited.
- Generates high heat at the source and substrate and generally requires a vacuum.
- Used mostly for metallic films.

# Vacuum Evaporation




**Complete vacuum evaporator**




**Inside of bell jar**

# Molecular Beam Epitaxy

- Creates very high purity, single crystal films atomic layer by atomic layer.
- Each atomic source is heated separately and allowed to condense on the substrate.
- It is a slow process that requires very high vacuum.
- Used to make quantum structures such as quantum wells.

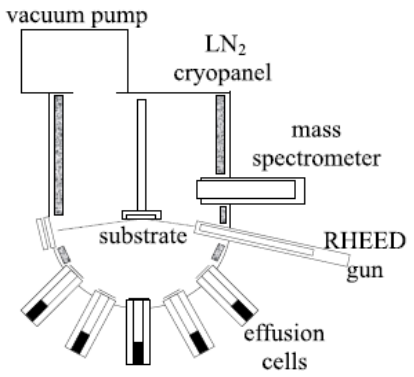
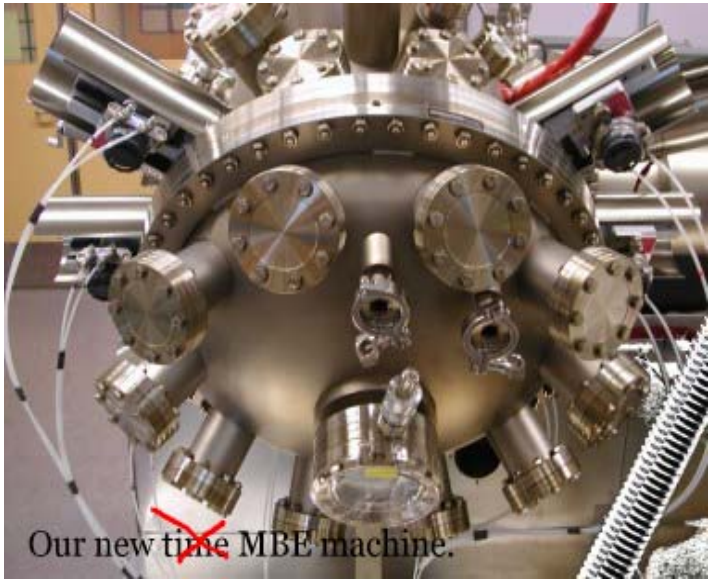
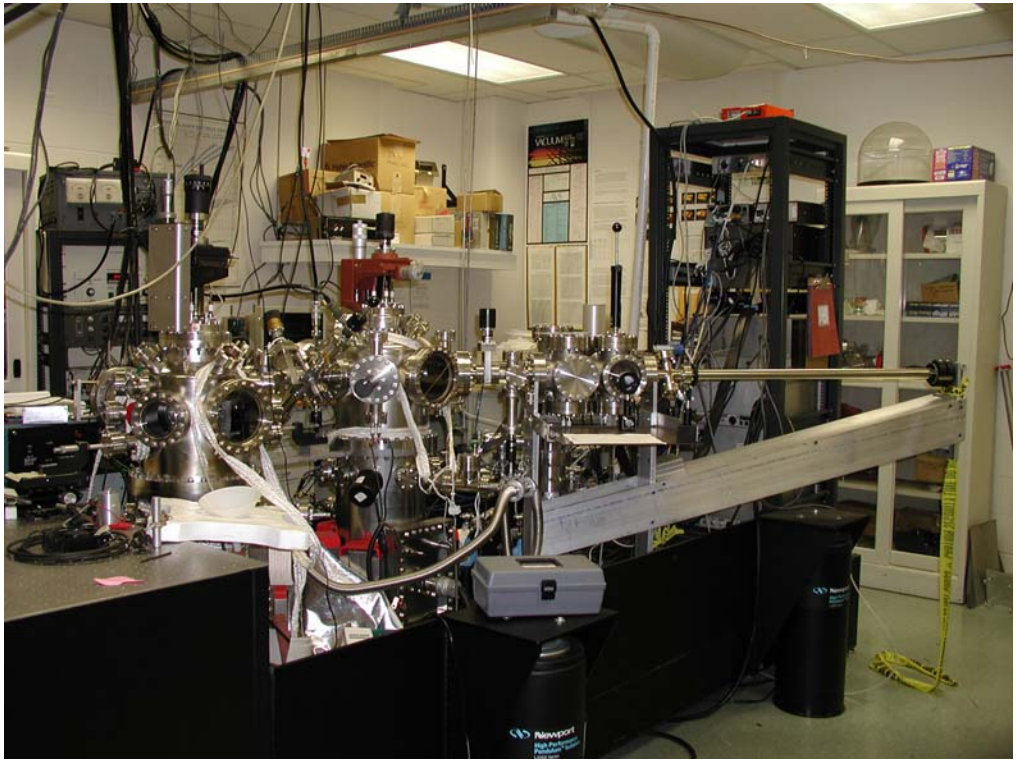



**Fig. 1:** A typical MBE system.



# Vacuum Systems

- Vacuum pump
  - Mechanical
  - Diffusion
  - Turbo
- Vacuum chamber
  - Glass or pyrex
  - Steel
- Instrumentation
  - Vacuum gauges
  - Thermocouples
  - Feedthroughs



# Testing Thin Films

- Physical measurements
  - Thickness – Profilometer
  - Microscopy – AFM, TEM, SEM, Optical
- Optical measurements
  - Luminescence, absorption
- Composition measurements
  - Defects - XRD, LEED, FTIR, Raman
- Electrical measurements
  - Conductivity – 4 point measurements
- Thermal measurements
  - Thermal conductivity
- Mechanical measurements
  - Stress/strain