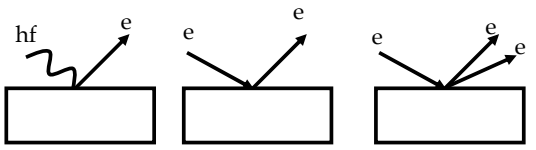
Photomultipliers

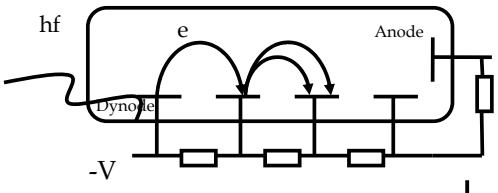


PE effect

Secondary electron emission

Electron multiplication

Photomultiplier tube

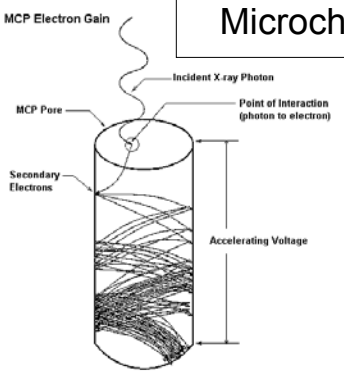


- Combines PE effect with electron multiplication to provide very high detection sensitivity
- Can detect single photons.

Microchannel plates

- The principle of the photomultiplier tube can be extended to an array of photomultipliers
- This way one can obtain spatial resolution
- Biggest application is in night vision goggles for military and civilian use

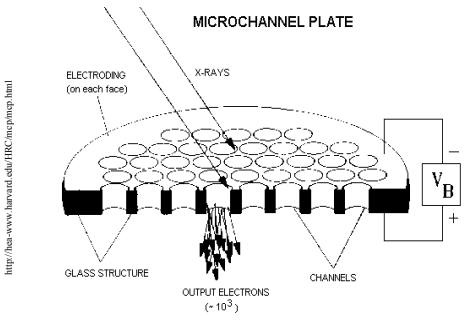
Microchannel plates



http://hea-www.harvard.edu/HRC/mcp/mcp.html

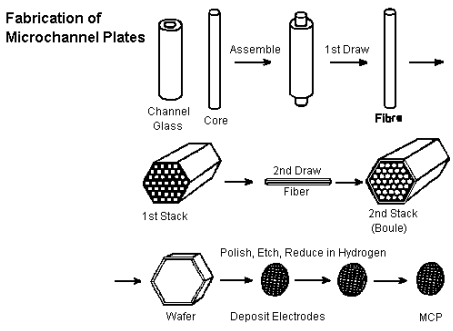
- MCPs consist of arrays of tiny tubes
- Each tube is coated with a photomultiplying film
- The tubes are about 10 microns wide

MCP array structure



http://hea-www.harvard.edu/HRC/mcp/mcp.html

MCP fabrication



http://hea-www.harvard.edu/HRC/mcp/mcp.html

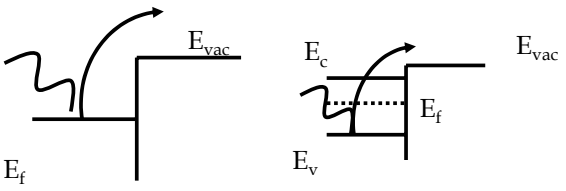
Disadvantages of Photomultiplers as sensors

- Need expensive and fiddly high vacuum equipment
- Expensive
- Fragile
- Bulky

Photoconductors

- As well as liberating electrons from the surface of materials, we can excite mobile electrons inside materials
- The most useful class of materials to do this are semiconductors
- The mobile electrons can be measured as a current proportional to the intensity of the incident radiation
- Need to understand semiconductors….

Photoelecric effect with Energy Bands

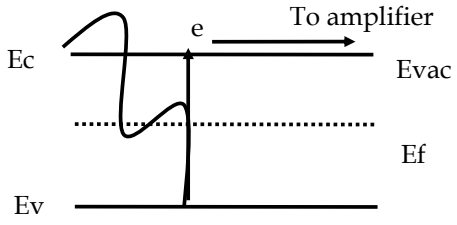


Metal

Semiconductor

Band gap: $E_g=E_c-E_v$

Photoconductivity



Semiconductor

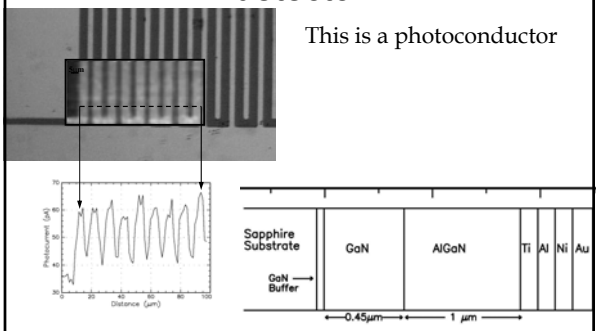
Photoconductors

- E_g (~1 eV) can be made smaller than metal work functions ϕ (~5 eV)
- Only photons with Energy $E=hf>E_g$ are detected
- This puts a lower limit on the frequency detected
- Broadly speaking, metals work with UV, semiconductors with optical

Band gap Engineering

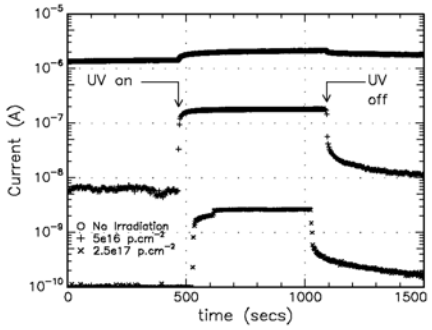
- Semiconductors can be made with a band gap tailored for a particular frequency, depending on the application.
- Wide band gap semiconductors good for UV light
- III-V semiconductors promising new materials

Example: A GaN based UV detector

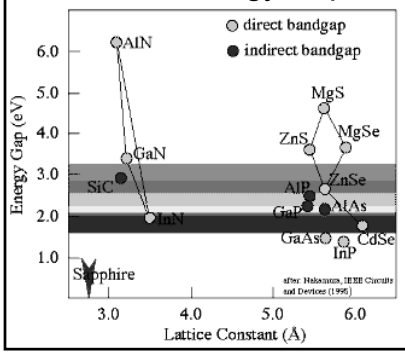


This is a photoconductor

Response Function of UV detector



Choose the material for the photon energy required.

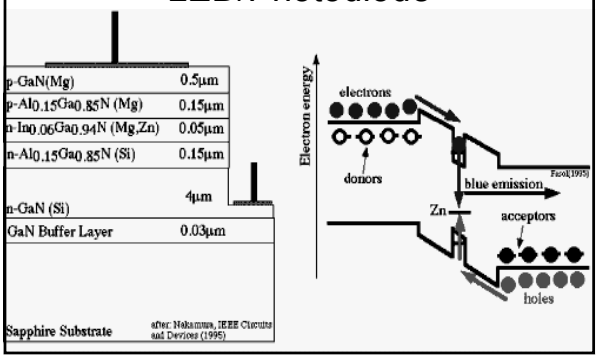


- Band-Gap adjustable by adding Al from 3.4 to 6.2 eV
- Band gap is direct (= efficient)
- Material is robust

Photodiodes

- Photoconductors are not always sensitive enough
- Use a sandwich of doped semiconductors to create a “depletion region” with an intrinsic electric field
- We will return to these once we know more about atomic structure

The structure of a LED/Photodiode



Characterization of Detectors

- NEP= noise equivalent power
  = noise current (A/√Hz)/Radiant sensitivity (A/W)
- D = detectivity = √area/NEP
- IR cut-off
- maximum current
- maximum reverse voltage
- Field of view
- Junction capacitance