Detector Basics (5/16)

Semiconductor Detectors

Shotaro Yanagawa

Contents

Reference:

Experimental Techniques in Nuclear and Particle Physics

Stefaan Tavernier

Abstract

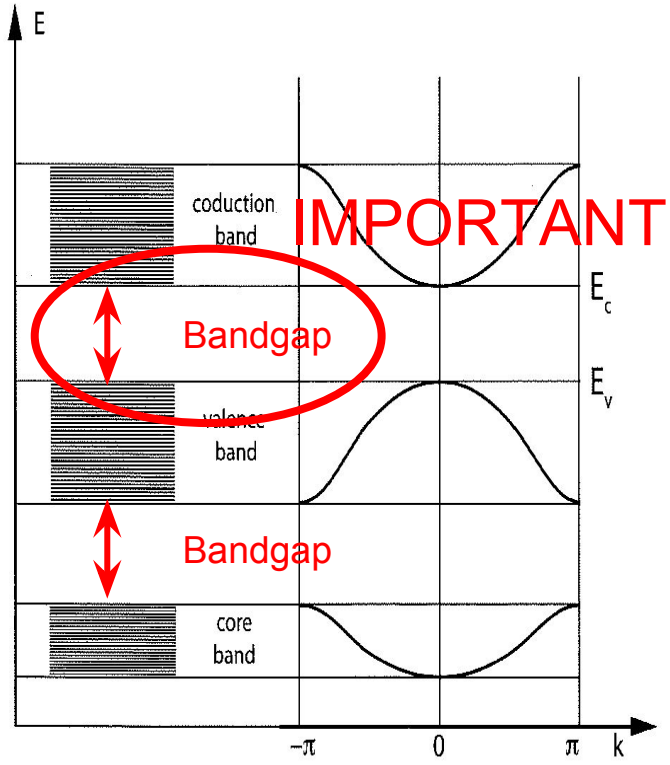
- Mainly used for position sensing devices and photodetectors.
- Silicon and Germanium are the most commonly used. (CdTe , CdZnTe etc are also being studied)
- Signals are very small and fast.
- Extremely good low-noise electronics is essential.

Principle (Band)

- The energy levels of individual atoms form so-called “Bands”.

→ The energy levels closely spaced, and it looks like band.

- Different energy level inside a band are distinguished by wave number.

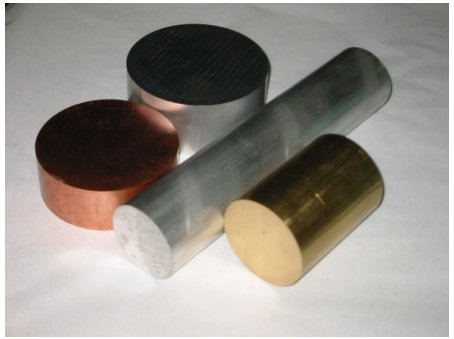


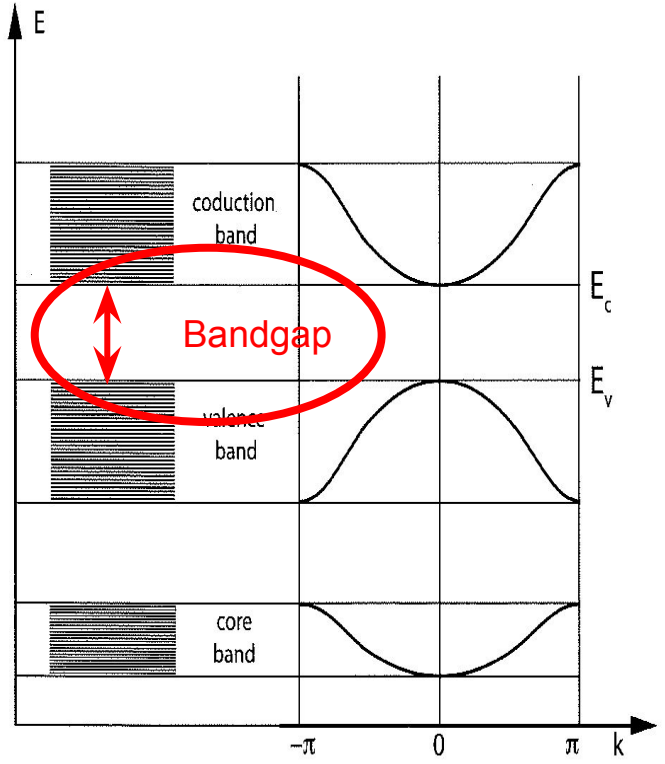
Principle (Band)

Much larger than 1 eV -> Insulator

In the order of 1 eV -> Semiconductor

Extremely small bandgap -> Conductor

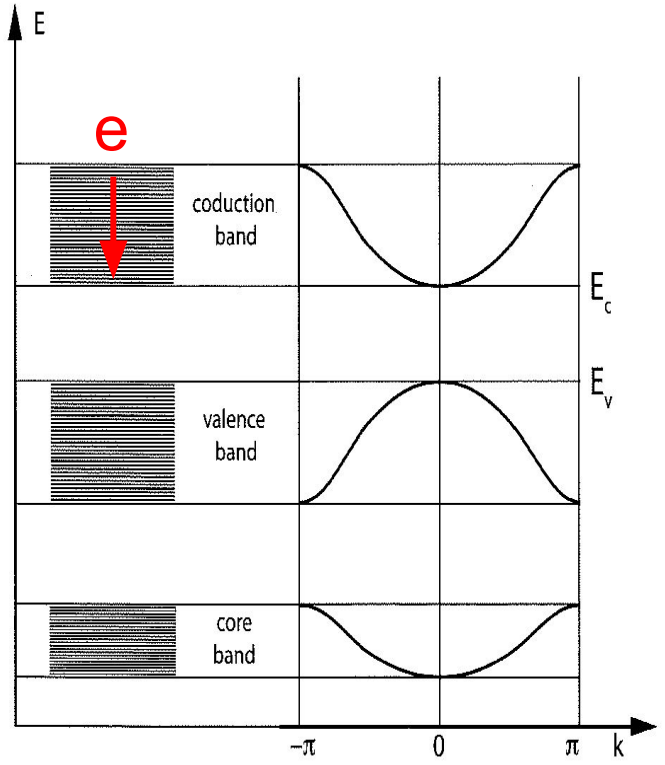




Principle (e-h pair)

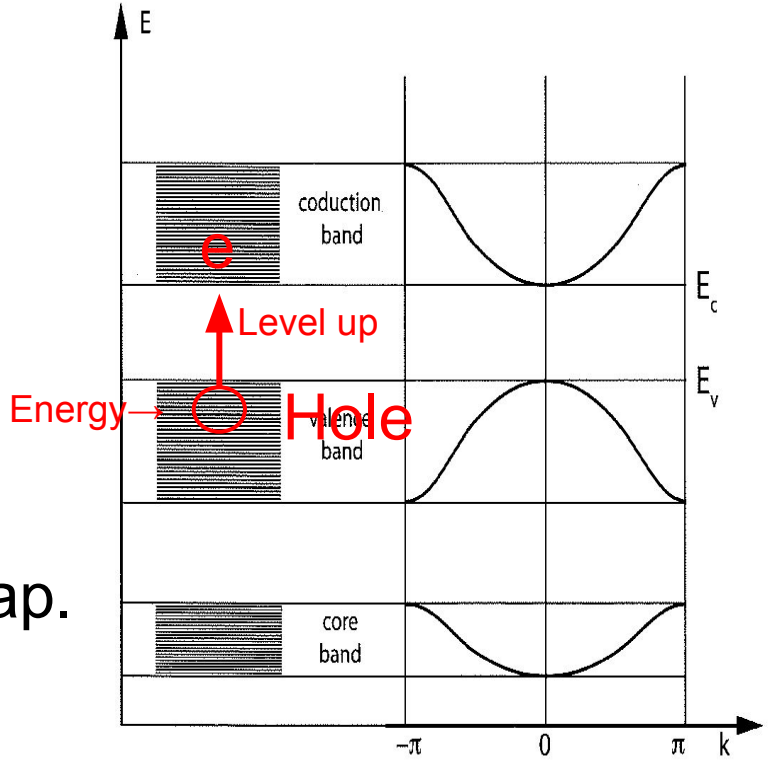
- If there are so many electrons in conductionband, they will sink to the bottom of the band.

→This movement will give rise to a current.



Principle (e-h pair)

- Absorbed energy forms electron-hole pairs.
- Hole is a vacancy of electron in valence band.
- The required energy to form e-h pair is proportional to the bandgap.
- A hole near the top of the band behave as positive particle.



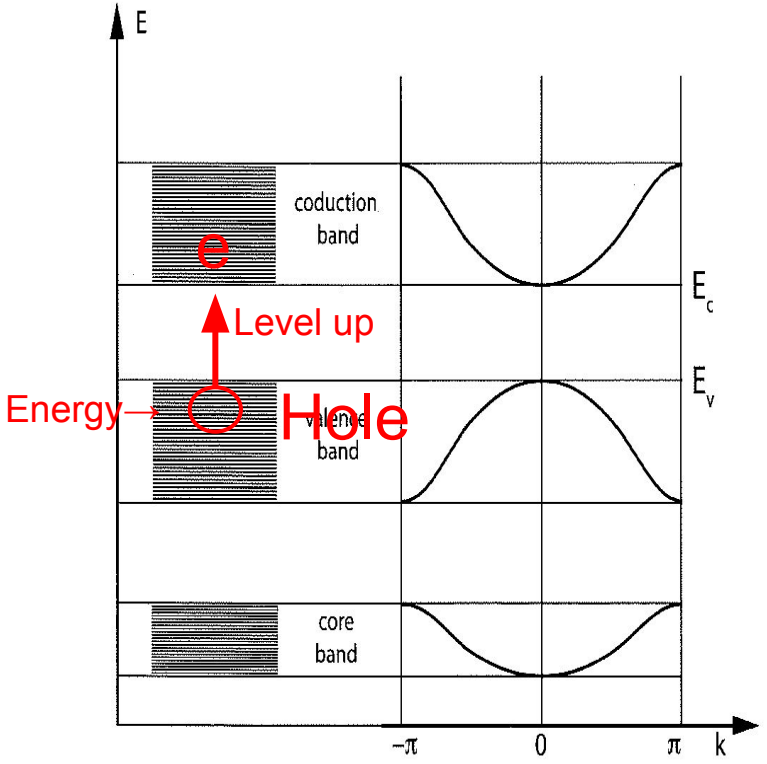
Principle (e-h pair)

- A hole near the top of the band behave as positive particle.

- The number of e-h pair N is

$$N = E/E_i$$

Larger N is good for energy resolution.



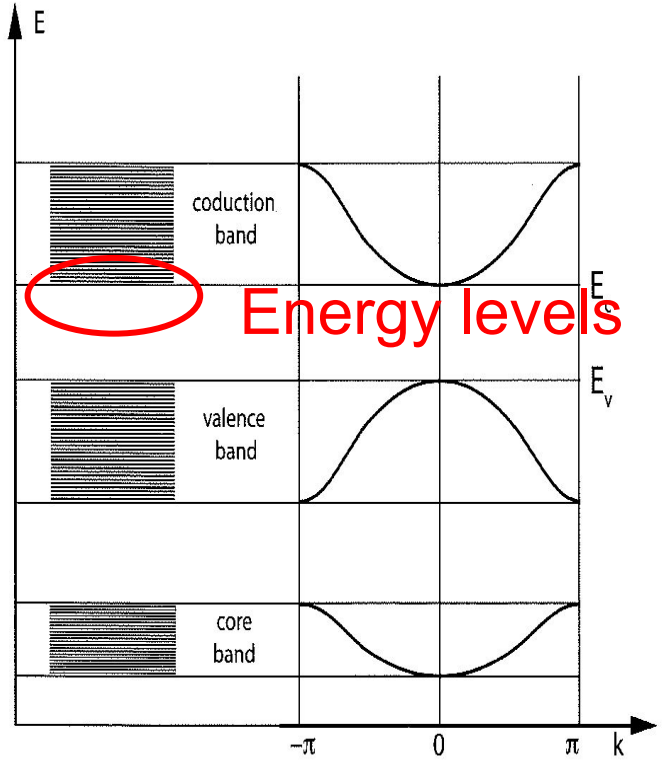
Principle (Material)

Phosphorus : P

- Phosphorus have 1 more electron in 3p orbital than silicon.

- Phosphorus creates a localised energy level below conduction band.

→ Decrease bandgap
Called “N-type” materials.

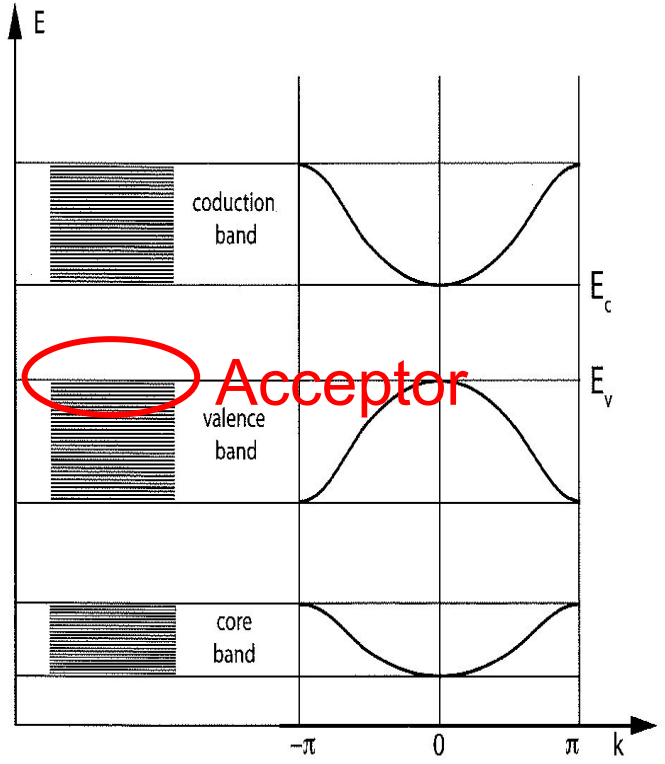


Principle (Material)

Gallium, Boron, Indium

- These materials create empty acceptor levels above valence band.

→ Acceptors will give rise to holes.
Called “P-type” materials



Principle (Detection)

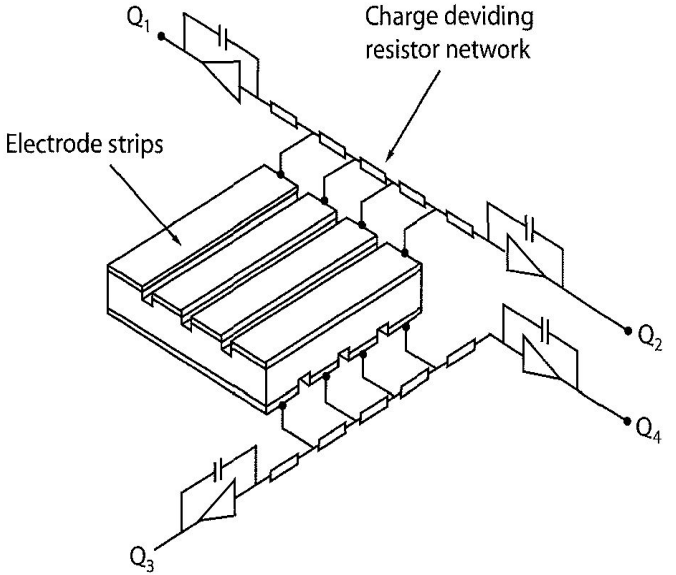
- Additional electron or holes will be collected by collection electrodes.
- Collected electrons or holes will be the signal.
- Collection electrode form can be cm-scale pad or strips,or μm-scale pixels.

Detectors(silicon)

- Silicon Semiconductor Detector(SSD) is mainly used for charged particles.

- SSD is an almost ideal detector for measuring energy of alpha particles.

CCD, DEPFET , Vertex detectors...etc

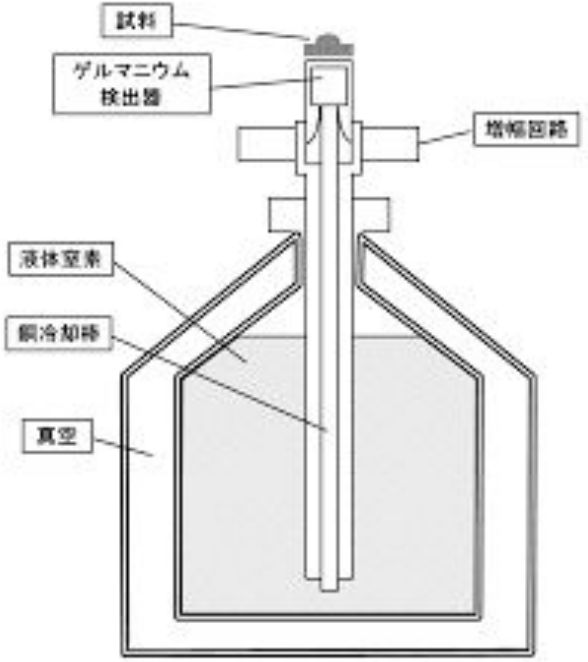


Detectors(Germanium)

- Germanium Semiconduction Detector is mainly used for gamma ray. (Very good resolution)

- Operated under liquid nitrogen temperature.

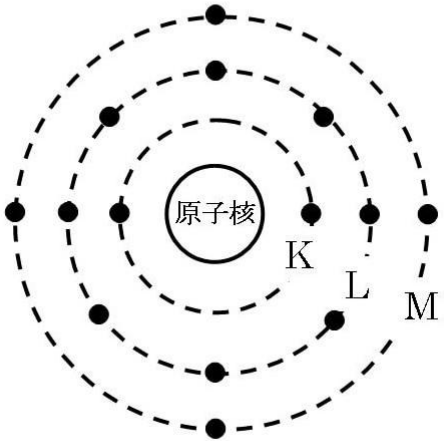
→Thermal e-h pairs give rise to unacceptable large noise in room temperature.



http://www.thec.pref.tochigi.lg.jp/instrument/ge-sd.htm

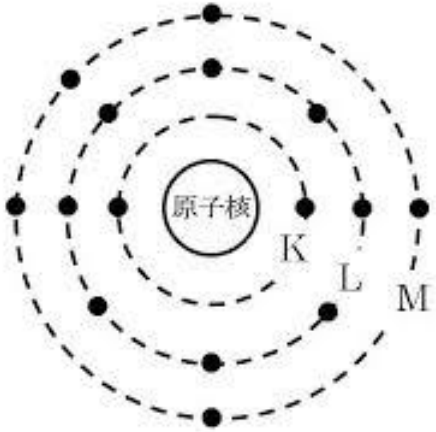
Appendix(Si & P & B)

Siの電子配置



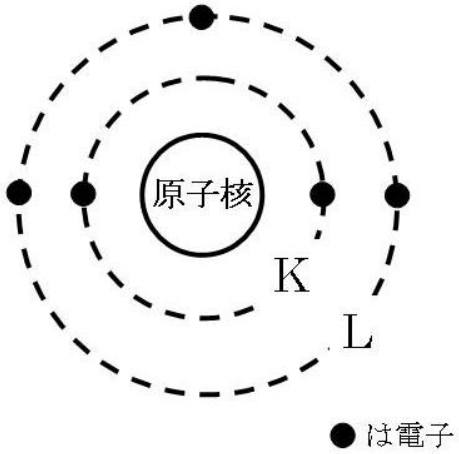
Valence electron : 4
Electron in 3p : 2

Pの電子配置



Valence electron : 5
Electron in 3p : 3

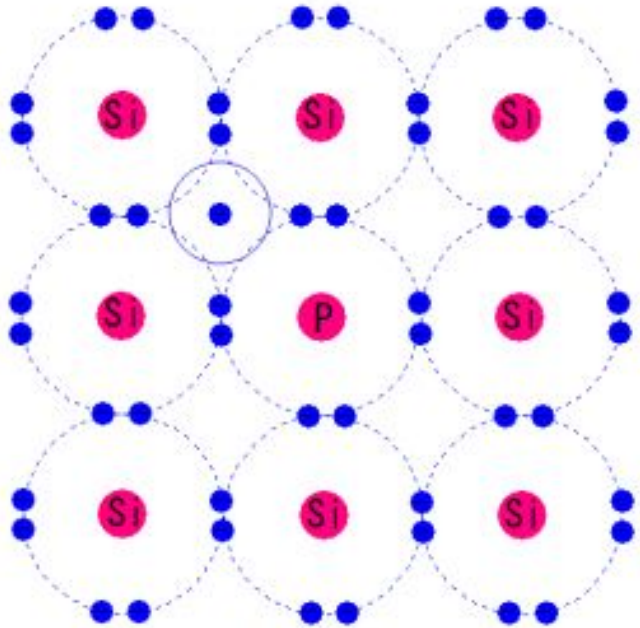
Bの電子配置



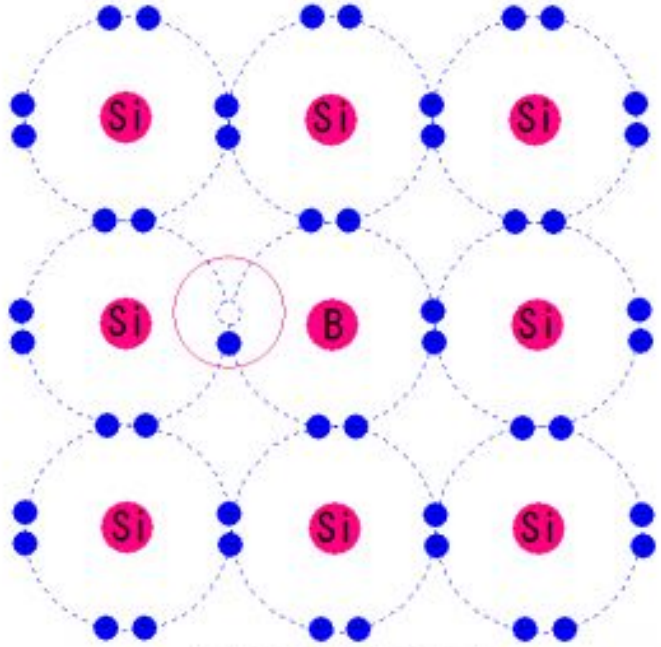
Valence electron : 3
Electron in 2p : 1

http://kagakuimage.com/densihaiti.html

Appendix(Doped Crystal)



（N型半導体）



（P型半導体）

https://alllearnhobby.com/archives/575.html

Appendix (Links)

https://www.tel.co.jp/museum/exhibition/principle/semiconductor.html 東京エレクトロン　半導体の仕組み