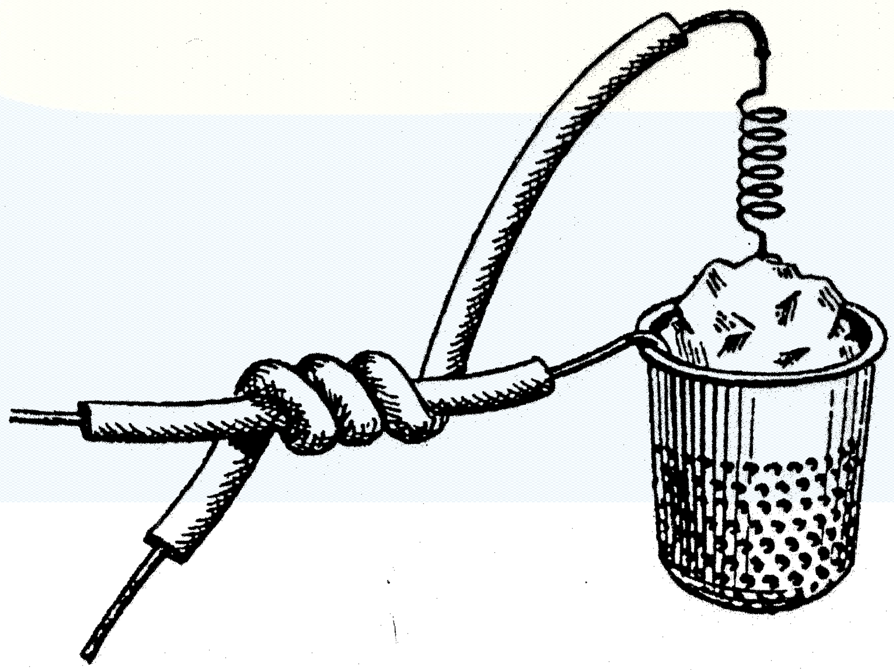
Detectors for Ionised (-ing) Particles



Outline

- Introduction
- Radioactivity
- Particle interaction with matter
- Ionised particle detectors
- Assignments- Simulation Task

Introduction

Detection of particles (or gamma photon, se also the presentations about photodetectors) from a radioactive decay means, the particles must interact with (ionising) the detector. The three necessary processes are:

1) Carrier generation by incident particle
2) Carrier transport (with or without carrier multiplication)
3) Interaction of current with external circuit to provide the output signal

Radioactivity

- Spontaneous disintegration of atomic nuclei.
  - Alfa decay (He nucleus)
  - Beta decay (electron, positron)
  - Gamma decay (photon)

Particle interaction with matter

Stopping Mechanism

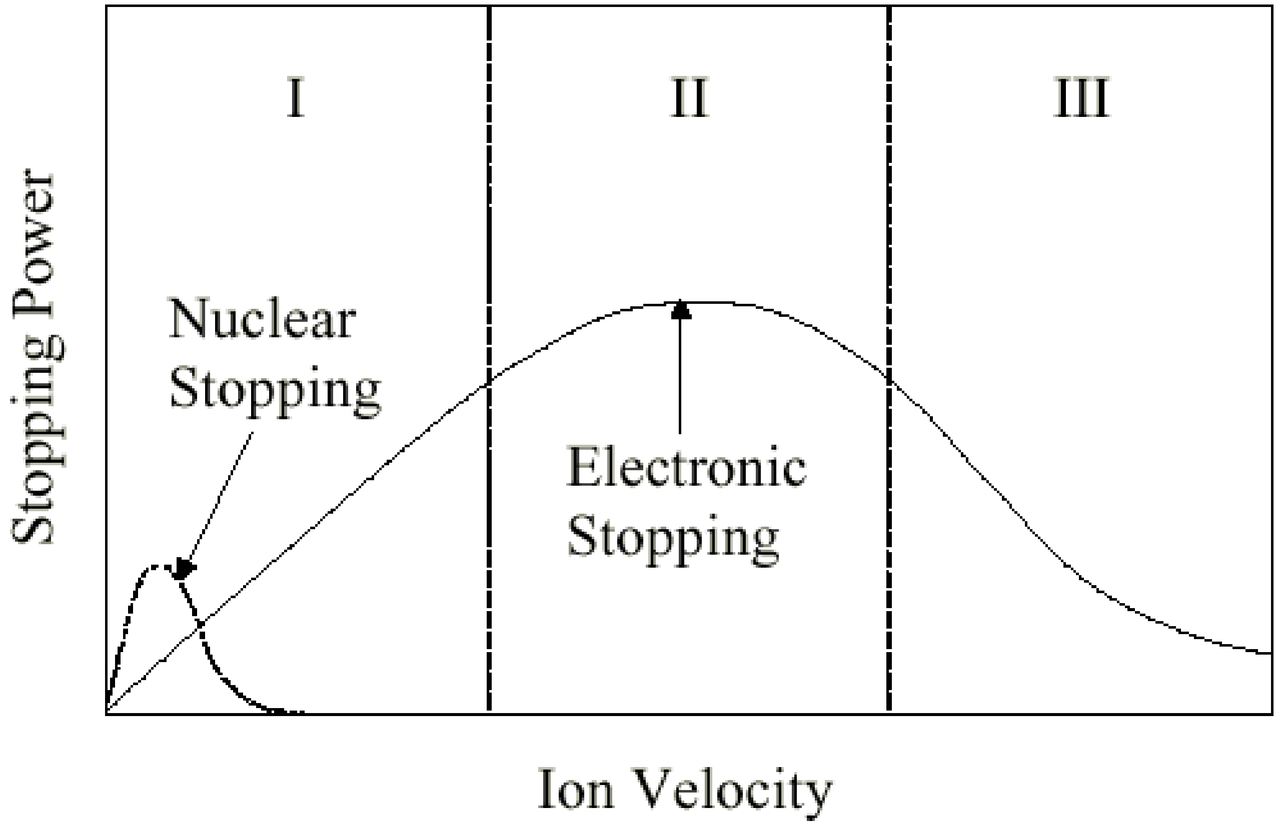
- The total stopping power

$$S_{total} = S_n + S_e$$

- S_n: nuclear stopping, S_e: electronic stopping
- Low E, high A ion implantation: mainly nuclear stopping
- High E, low A ion implantation, electronic stopping mechanism is more important

Particle interaction with matter

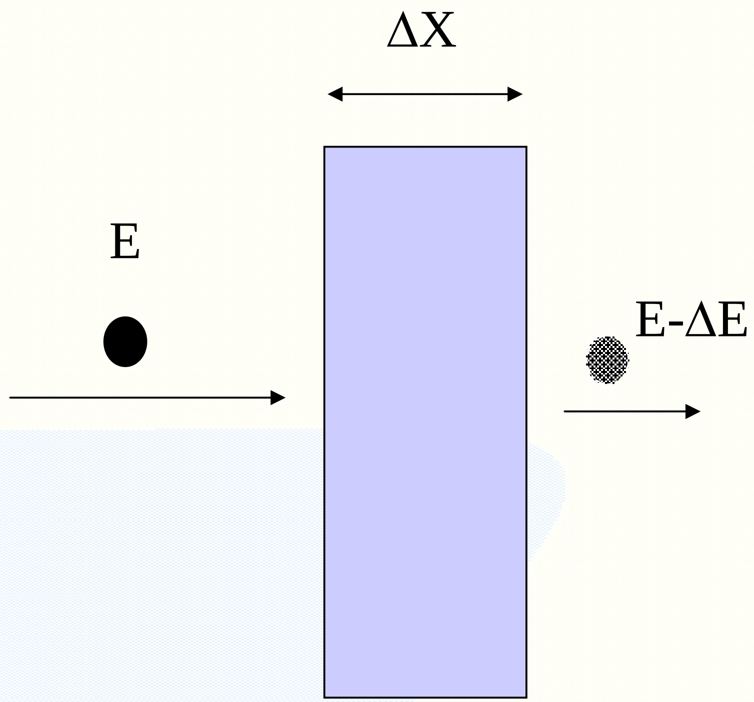
Stopping Power and Ion Velocity



Particle interaction with matter

$$\frac{dE}{dx} = \left.\frac{dE}{dx}\right|_e + \left.\frac{dE}{dx}\right|_n$$

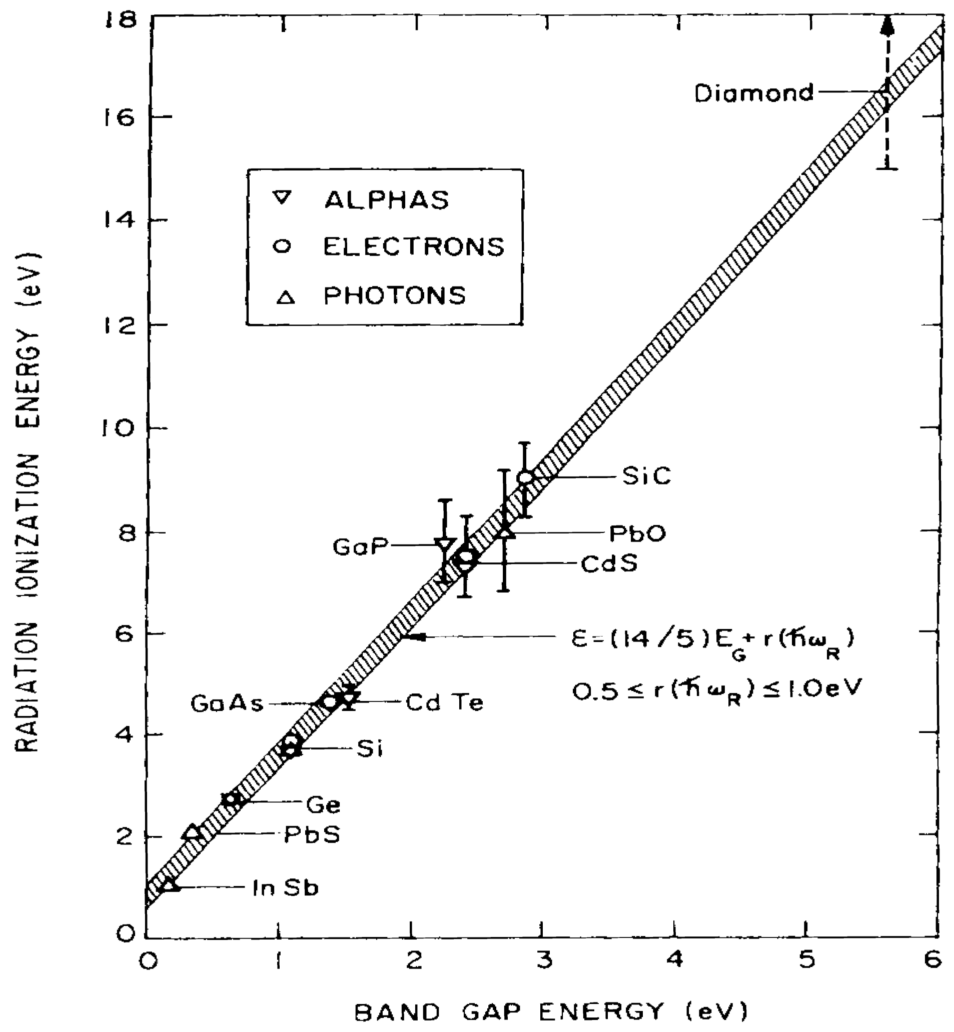
$$\Delta E = \int_0^{\Delta x} \left(\frac{dE}{dx}\right) dx$$



Simulation of stopping power can be done with SRIM software “SRIM.org”

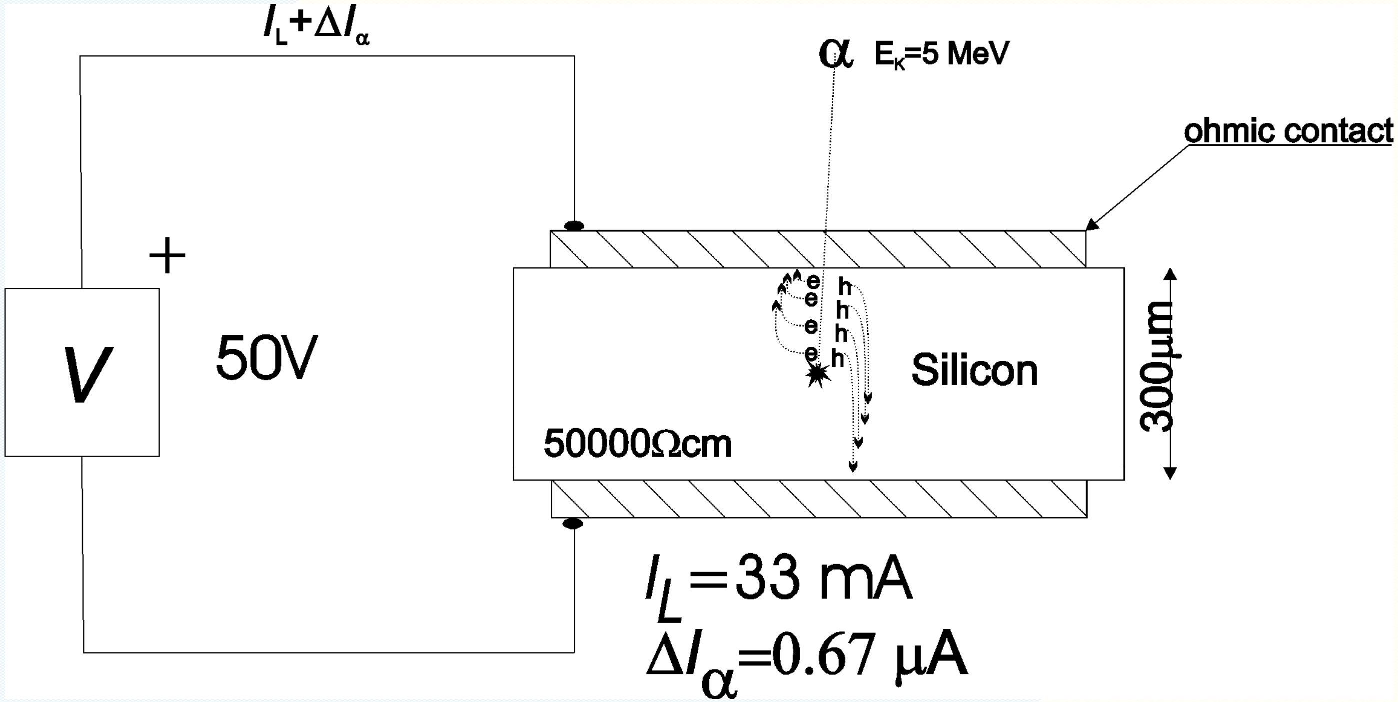
Particle interaction with matter

- Ionisation of semiconductor
  - Particle and high energy photons (x-ray,gamma) result in an generation of one e/h-pair /~3Eg
  - For silicon is needed 3.6eV to generate one e/h-pair

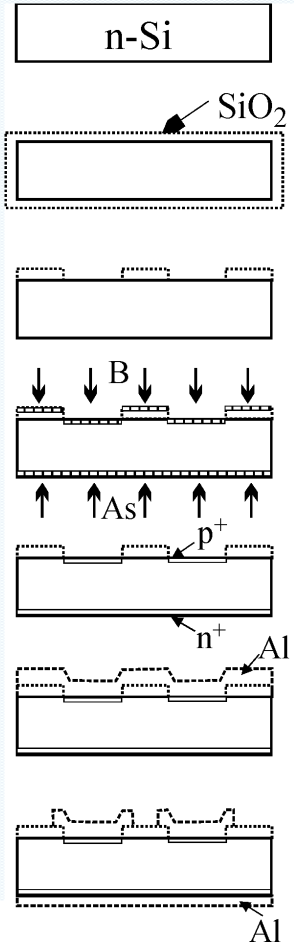


  - Picture; C. A. Klein, J. Appl. Phys., **39**, No.4, 2029, (1968)

Ionised particle detectors



Ionised particle detectors



n-Si Wafer

Oxide passivation

Opening of windows

Doping by ion implantation
B 15 keV 5×10^{14} cm^{-2}
As 30 keV 5×10^{15} cm^{-2}

Annealing at $600^{o}C$, 30 min

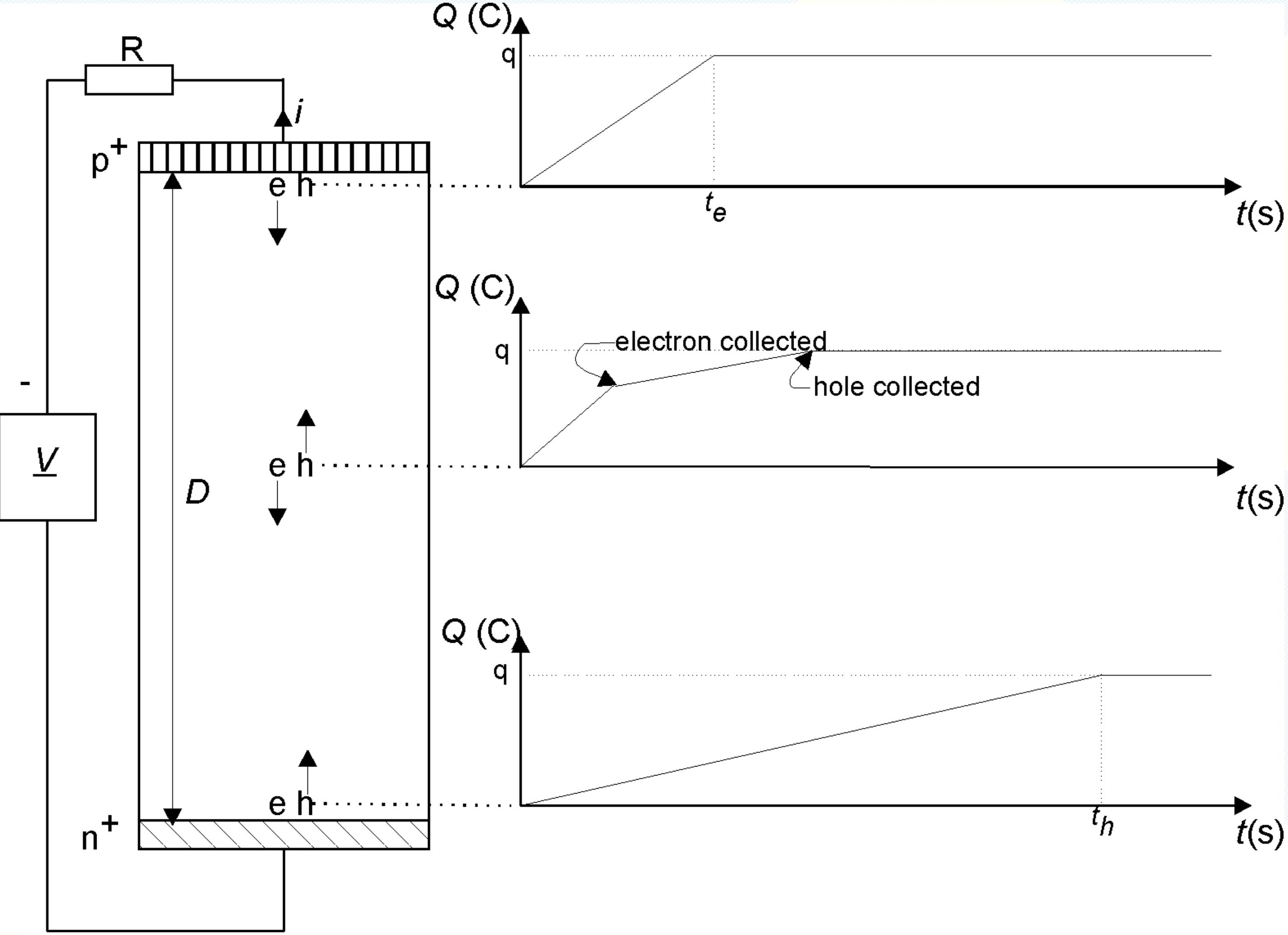
Al metallisation

Al pattering at the front
Al-rear contact

- Passivated, silicon planar diode detector
- Almost operated with reverse bias voltage, (except photodiodes normally operated with zero bias voltage)

- J. Kemmer, Nucl. Instr. and Meth. **226**, 45, (1984)

Ionised particle detectors

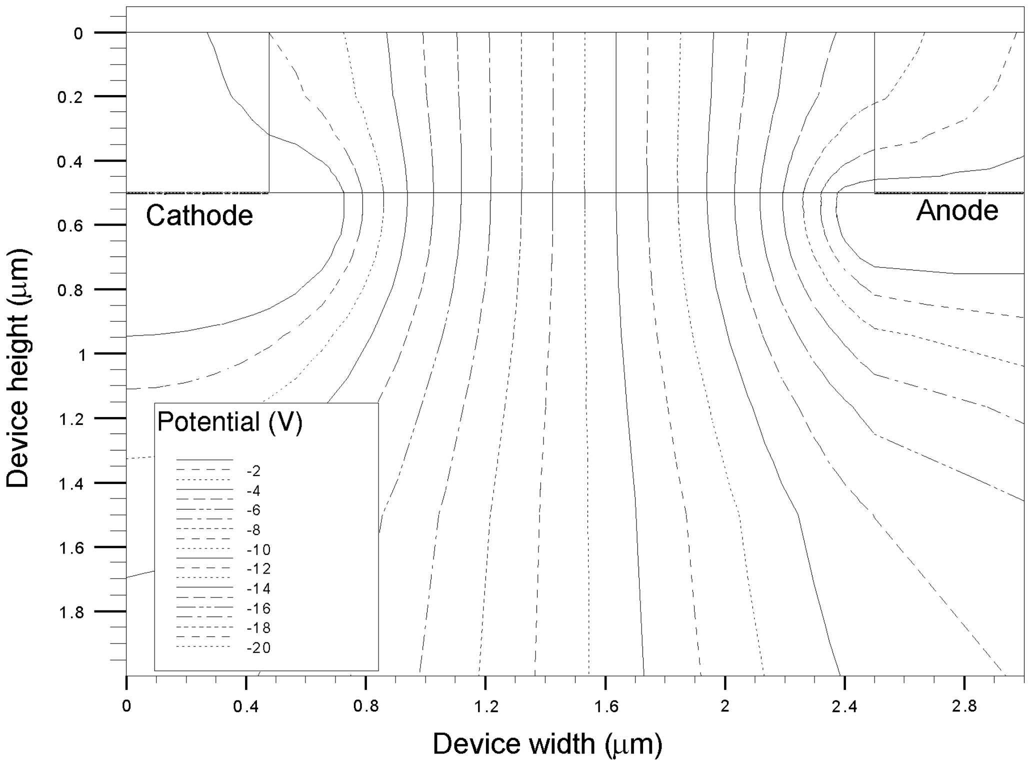


- Drift of generated carrier in the detector

$$v = \mu \cdot \overline{\mathrm{E}} \quad \text{for } v < vs$$

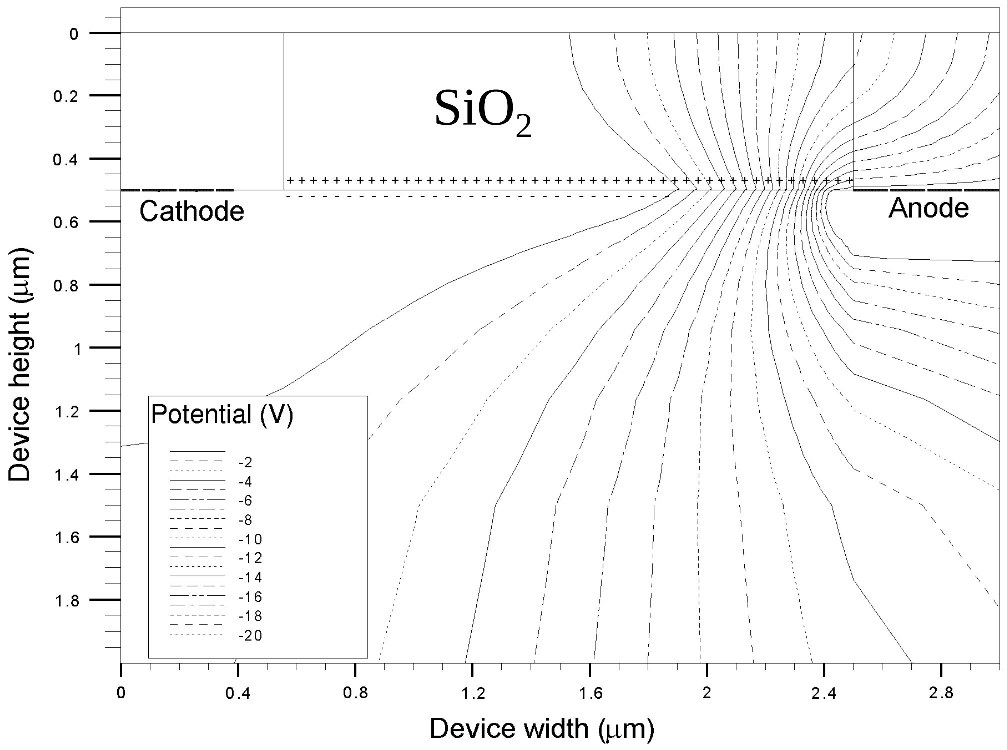
- Fast current pulse-high electric field in the detector
- High mobility for holes and electrons
- The mobility for holes are in most cases lower than electrons.

Ionised particle detectors



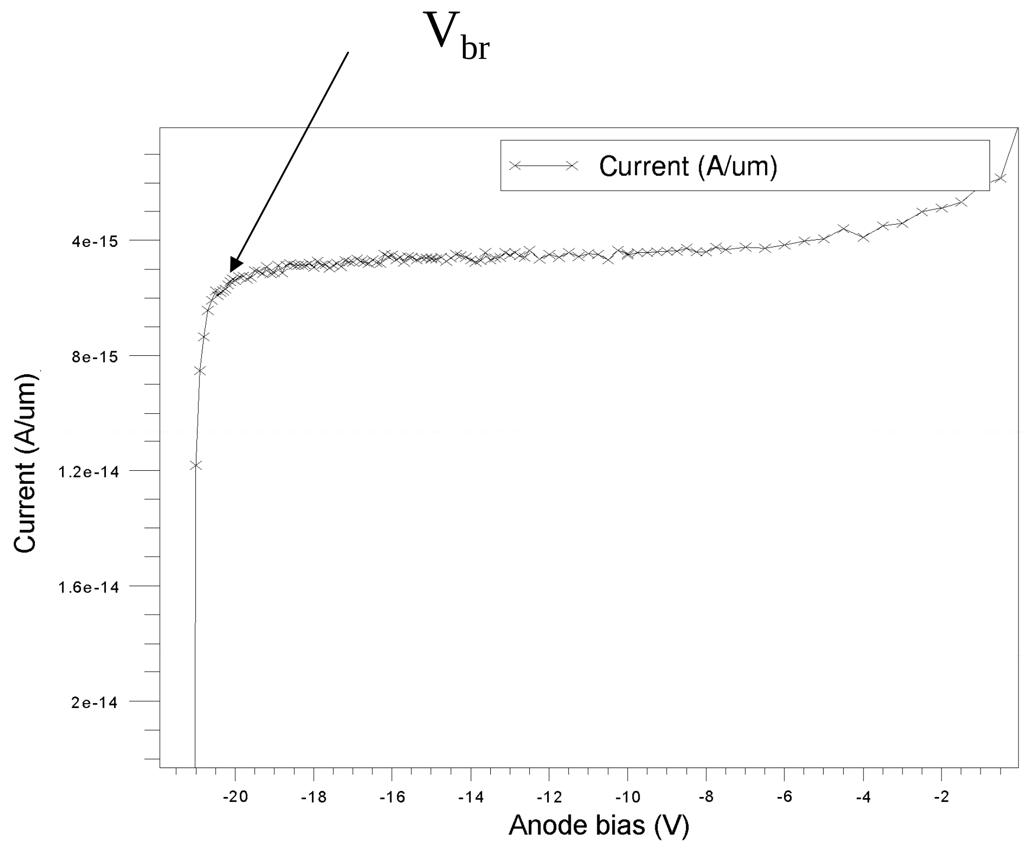
- High reverse bias in the detector generate high electric field
- Reverse bias 20 V

Ionised particle detectors



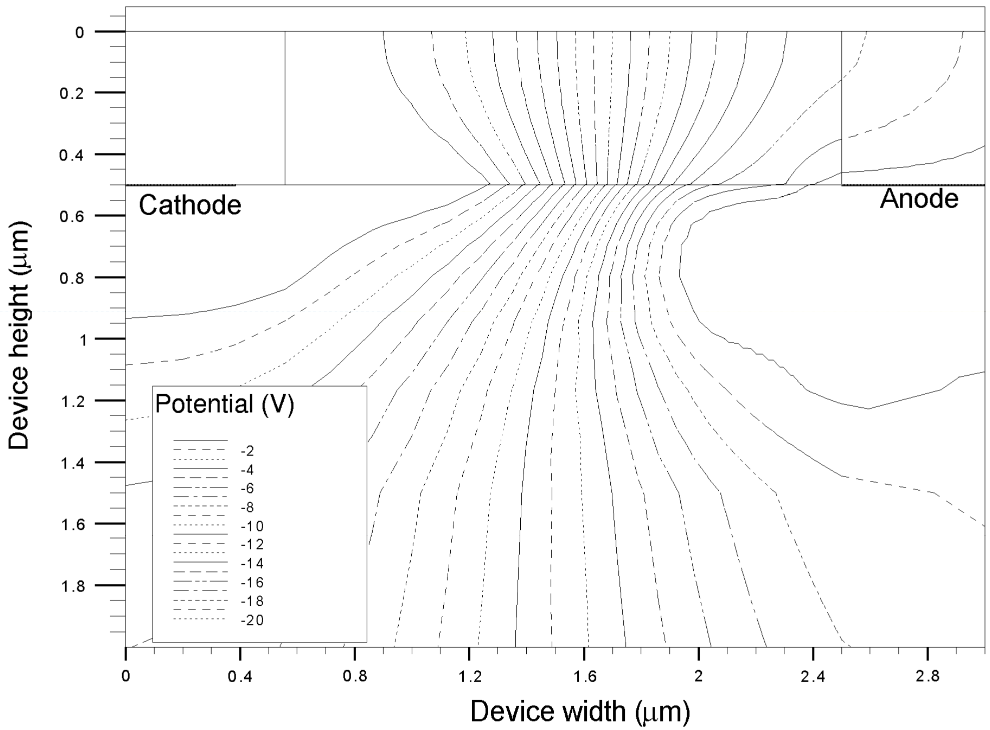
- $Q_f=2\cdot10^{12}$ q/cm^2
- Vr=20V
- Result in high electric field at anode

Ionised particle detectors



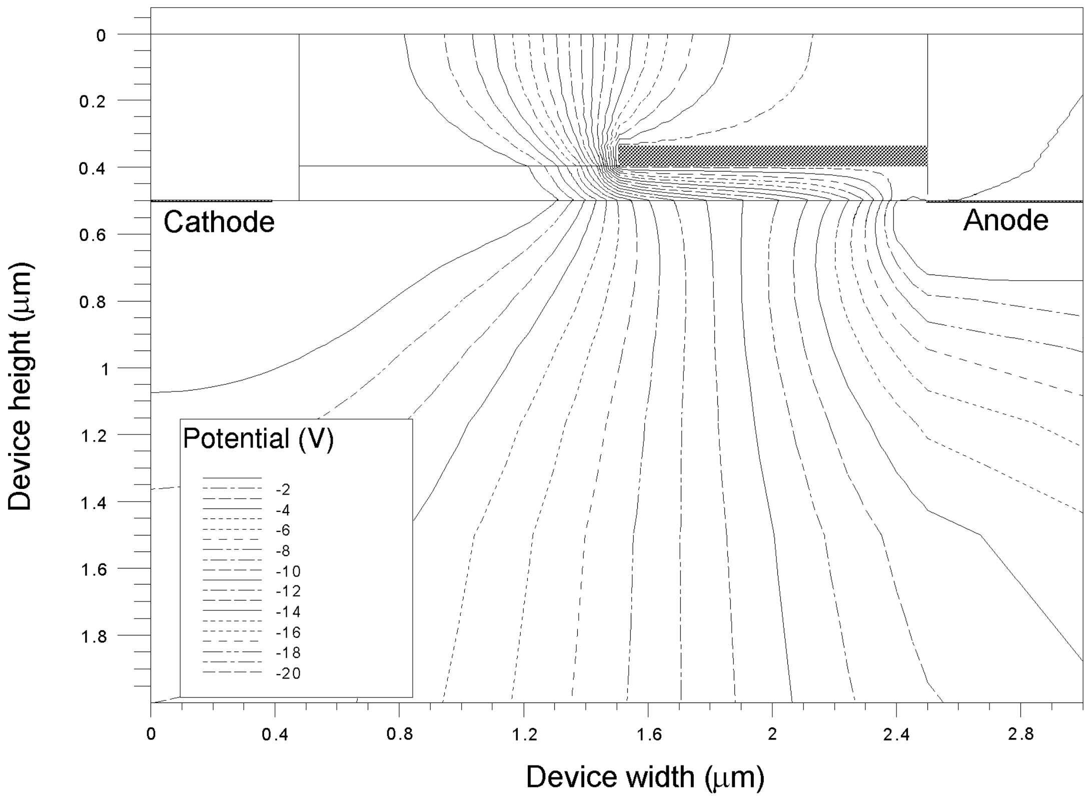
And surface avalanche breakdown

Ionised particle detectors



- Edge termination
  - Edge implantation (edge of anode) or diffusion drive in

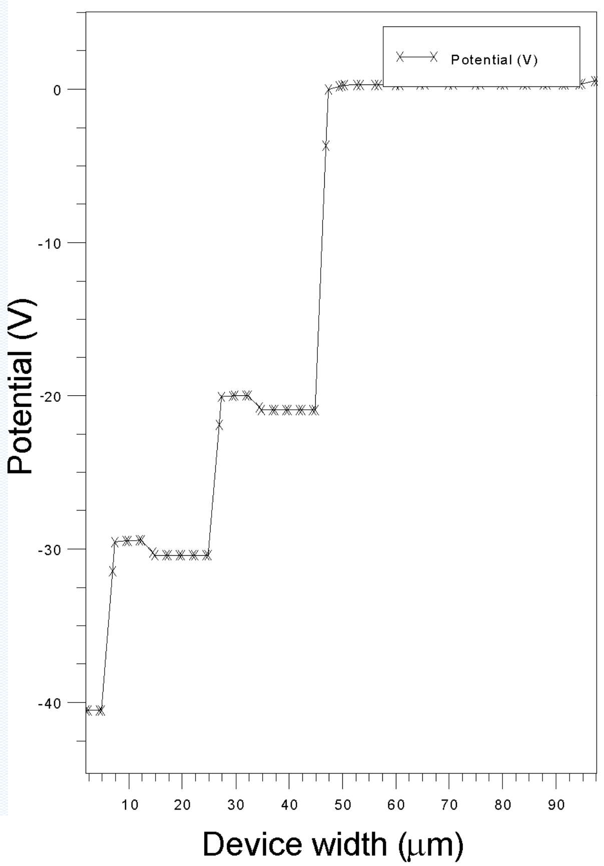
Ionised particle detectors



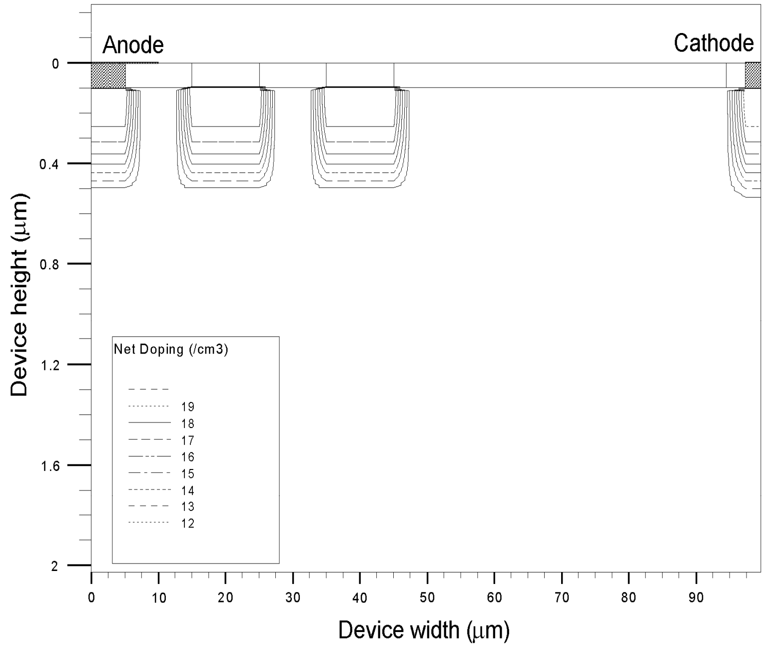
Edge termination

–Field plate

Ionised particle detectors



- Edge termination
  - –Floating guard rings, reverse bias 40 V , Qf=$2 \cdot 10^{12}$ q/cm^2



Assignments- Simulation Task

- Simulate stopping power for 5 MeV $\alpha-$ particle in silicon using SRIM
- Use the simulated data to generate an realistic e/h-pair generation in Medici
- As an Input file to medici use an file from tsupreme4 with the data;
  - 50x500um,
  - field oxide thickness=5000Å,
  - resitivity of bulk=20000 Ωcm, n-type Phos.,
  - detector window doping=950C, boron, 30 min N_2 followed by 30 min O_2
  - detector window opening width=30um

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Assignments- Simulation Task

- In medici use $Qf=1\cdot10^{11}$ q/cm^2
- Simulate the current response with Vr=0V, Vr=100V and with generation of e/h pair (alfa particle) at front and at back of the detector, i.e. four different cases!
- Integrate the current pulse and compare the resulting charge collection for the four cases