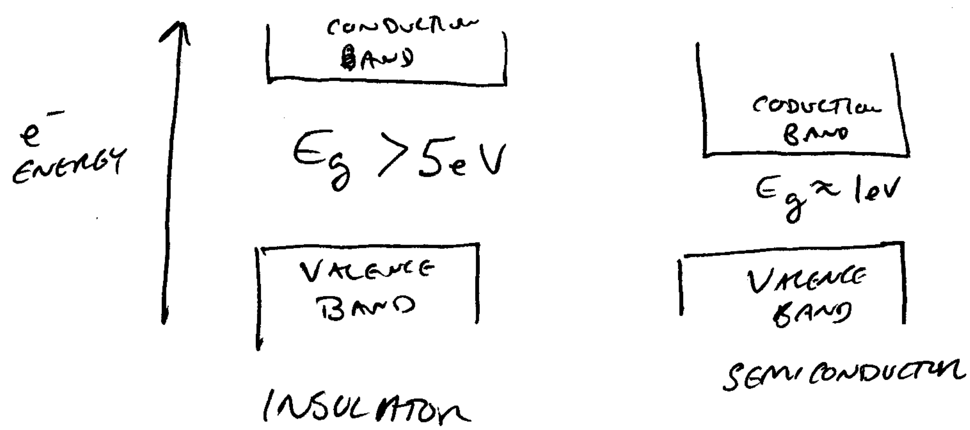
SEMI-CONDUCTOR DIODE DETECTORS

- SMALLER THAN GAS DETECTORS BECAUSE DENSITY ~1000x
- COMPARED TO ~~A~~ SCINTILLATION DETECTORS (WHICH HAVE RELATIVELY POOR ENERGY RESOLUTION) + MULTIPLE MANY INEFFICIENT STEPS.

  ~100 eV IS REQUIRED TO PRODUCE 1 INFO CARRIER

  ~6% → 10% FWHM

- NEED TO INCREASE # OF INFORMATION CARRIERS PER PULSE.
- Silicon PREDOMINATES IN THE DIODE DETECTORS FOR CHARGED PARTICLE SPECTROSCOPY.
- BAND STRUCTURE:



- CHARGE CARRIERS

AT NON-ZERO TEMPERATURES IT IS POSSIBLE FOR VALENCE ELECTRON TO BE ELEVATED ACROSS THE GAP TO THE CONDUCTION BAND.

- AGAIN CREATING AN e^--H PAIR
- WHICH MOVE UNDER THE INFLUENCE OF AN E-FIELD.

PROBABILITY $\bar{e}$-H PAIR IS THERMALLY GENERATED IS GIVEN BY

$$P(T) = C\,T^{3/2}\,e^{-E_g/2kT}$$

- E_g — BANDGAP ENERGY
- T — ABS TEMP
- C — PROPORTIONALITY CONSTANT CHARACTERISTIC OF THE MATERIAL

	Si	Ge
Z	14	32
ATOMIC WEIGHT	28.09	72.60
ρ	2.33 g/cm^3	5.32 g/cm^3
ATOMS/cm^3	4.96×10^{22}	4.41×10^{22}
FORBIDDEN ENERGY GAP @300K	1.115 eV	0.665 eV
" @0K	1.165 eV	0.746 eV

MIGRATION OF CHARGE

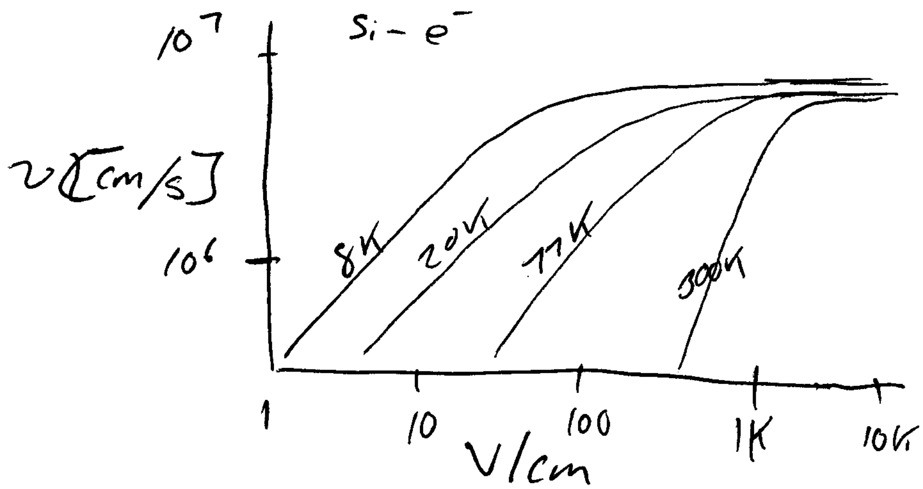
AT "LOW-TO-MODERATE" VALUES OF E-FIELD

DRIFT VELOCITY IS PROPORTIONAL TO APPLIED $\vec{E}$

$$v_H = \mu_h \mathcal{E}$$

$$v_{e^-} = \mu_{e^-} \mathcal{E}$$

AT HIGHER $\vec{E}$-FIELD, SATURATION VELOCITY IS REACHED



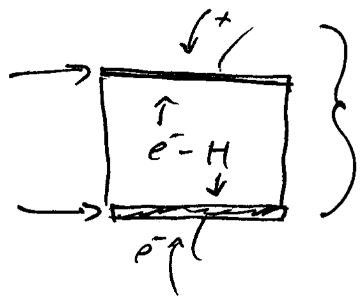
- COLLECTION TIME AT SATURATION VELOCITY ~ 10nS

SEMI-CONDUCTORS AS RADIATION DETECTORS

4

- COLLECTION PATH FOR CHARGE CARRIER

→ OHMIC CONTACTS



ELECTRICAL CHARGE EQUILBRIUM IS MAINTAINED.

- LEAKAGE CURRENT

RESISTIVITY OF THE HIGHEST PURITY SILICON AVAILIBLE IS 50,000 Ω-cm.

1-mm THICK SLABS INTO 1cm² WITH OMIC CONTACTS

R = 5000 Ω

500V → 0.1 AMP

CONTRASTING 10^{-6} AMP FROM A SUBSTATION RADIATION DOSE.

BULK LEAKAGE IS REDUCED BY BLOCKING CONTACTS

LEAKAGE IS TYPICALLY BROUGHT BELOW 10^{-7} AMPS

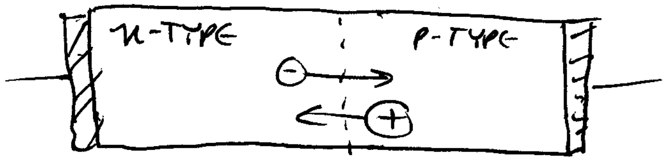
by p-N

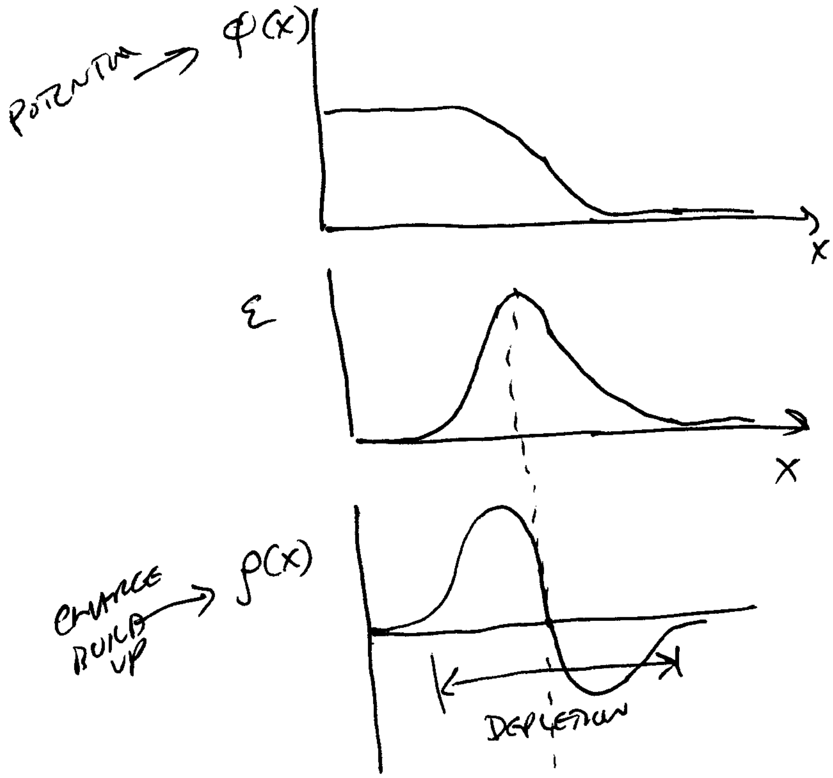
→ SURFACE LEAKAGE. BECOMES DOMINANT

~~SERIAL dielectric junctions~~

TO REDUCE BULK LEAKAGE, NON-INJECTING/BLOCKING ELECTRODES SUCH AS TWO SIDES OF p-N JUNCTION. i.e. IT IS DIFFICULT TO INJECT e⁻ FROM P SIDE; & HOLES ARE NOT EASILY INJECTED

SEMI-CONDUCTOR JUNTION





$$\nabla^2 \varphi = -\frac{\rho}{\epsilon}$$ ← dielectric const

IN 1-D

$$\frac{d^2\varphi}{dx^2} = -\frac{\rho(x)}{\epsilon}$$

$$\mathcal{E} = \vec{E} = -\text{GRAD}\ \varphi$$

$$\mathcal{E} = -\frac{d\varphi}{dx}$$

REVERSE BIAS:

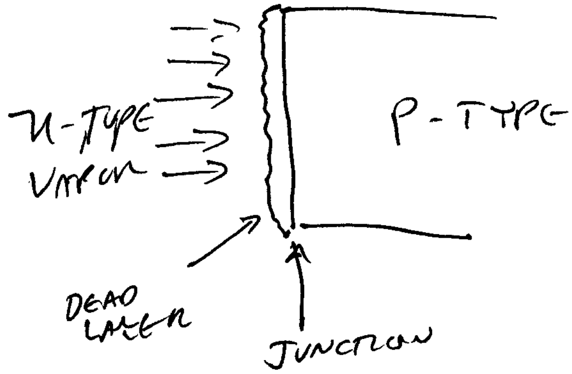
- ALMOST ALL OF THE APPLIED VOLTAGE WILL APPEAR ACROSS THE DEPLETION REGION
- MAX E-FIELD WILL OCCUR AT THE n-, p-TYPE TRANSITION

$$\mathcal{E} \cong \frac{2V}{d} = \left(\frac{2VNe}{\epsilon}\right)^{1/2} \approx 10^{+6}/10^{+7}\ V/m$$

↑ d: depletion thickness layer

FABRICATION OF P-N JUNCTION DETECTORS

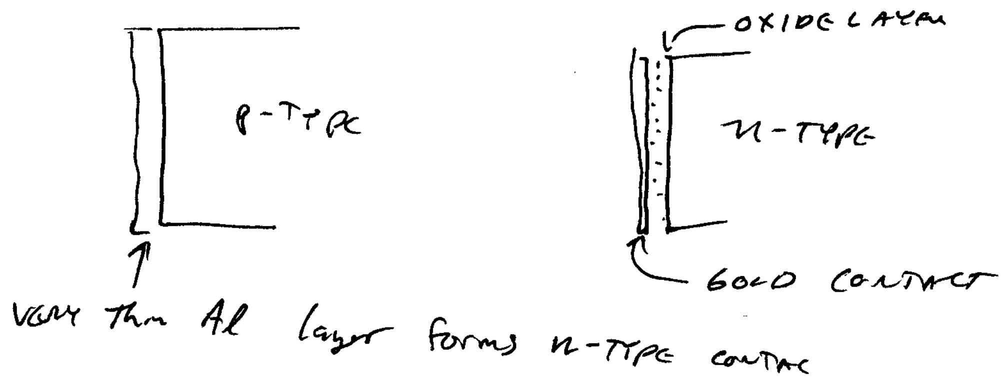
1. DIFFUSED JUNCTION



Thickness 0.1 → 2.0 μm

RADIATION MUST PASS THRU DEAD LAYER, LEADING TO LOST dE/dx INFORMATION

2. SURFACE BARRIER DETECTORS, WHERE JUNCTIONS LIES AT SURFACE



3. ION IMPLANTATION

DOPING IMPURITIES AT SURFACE BY ACCELERATING ION BEAM + IMPLANTING INTO THE SURFACE.

-Qr [M-6WRL-6WRK-6WOJ-6WOJ,p3=G-6WOJ
-R&O-R&N-6WOK-Qr [O-R&dP-R&N-6WRL-6WOK-R&N

WHICH FORM n^+ FROM PHOSPHORUS

p^+ FROM BORON

IMPLANTATION ENERGY ~ 10keV MONOENERGETIC

↳ WHAT IS DEPTH?

DETECTOR NOISE & ENERGY RESOLUTION

SOURCES.

REDUCTION TEMP. → 1. FLUCTUATION IN LEAKAGE CURRENT, SHOT NOISE

FABRICATION TECHNIQUES → 2. FLUCTUATION IN SURFACE LEAKAGE CURRENT

ASSOCIATED WITH THICKNESS OF ~~DEP~~ UNDEPLETED REGION (FABRICATION & BIAS V) → 3. JOHNSON NOISE: ASSOCIATED W/ SERIES RESISTANCE & BAD CONTACTS.

$$\Delta E_{noise}^2 = \Delta E_{bulk}^2 + \Delta E_{surf}^2 + \Delta E_{Johnson}$$