Classical Semiconductors (Transistors) Advantages & Disadvantages

Semiconductor:
- Conducts electric current
  - Better than insulators
  - Not as good as conductors

Si:
- 4 valence electrons
- Forms Tetrahedral crystal

Doping:
- n-type
- p-type

To make n-type semiconductor, you take pure silicon and inject a small amount of an element with 5 valence electrons, like Phosphorous:
- similar enough to silicon that it can fit into the lattice
- the semiconductor has more mobile charges and so it conducts current better

In p-type doping:
- p-type stands for "positive"
- element with only three valence electrons is added to the lattice
  - Ex. Boron
- Create a "hole":
  - a place where there should be an electron, but there isn't
  - increases the conductivity of the silicon because electrons can move into it
  - lack of an electron
    - acts as a positive charge

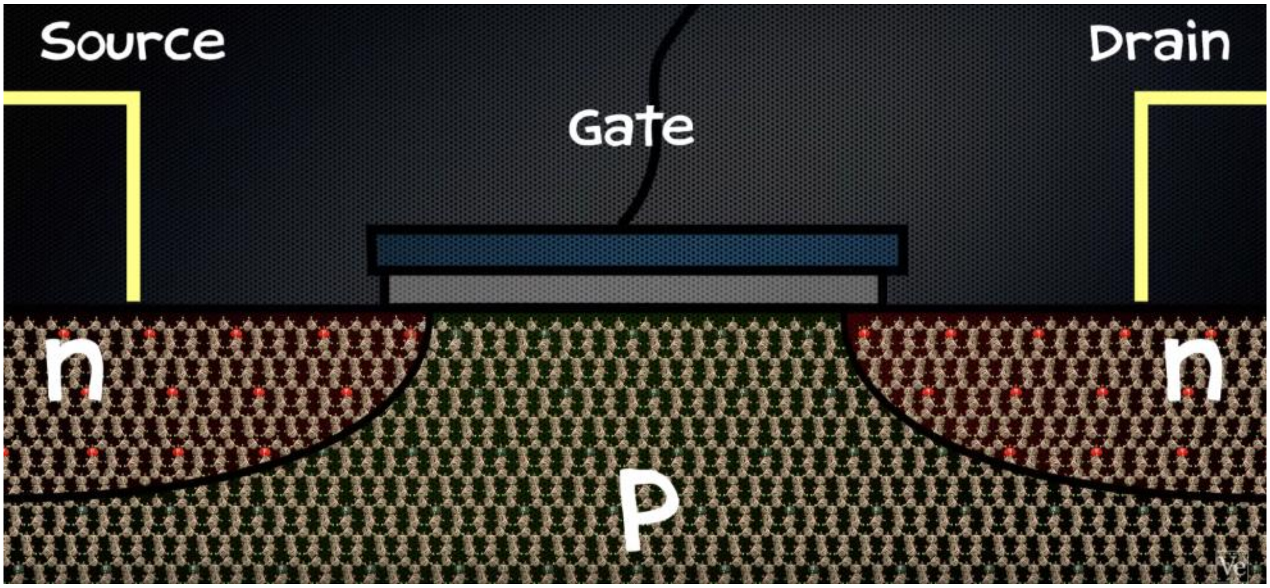
Now it's a common misconception that n-type semiconductors are negatively charged and p-type semiconductors are positively charged.

That's not true, they are both neutral because they have the same number of electrons and protons inside them.

"n" and "p":
- Only signs of charge that can move within them

in n-type, it's negative electrons which can move
in p-type it's a positive hole that moves.

Transistor:
- made with both n-type and p-type semiconductors
- A common configuration has n on the ends with p in the middle.
- Just like a switch a transistor has an electrical contact at each end and these are called the source and the drain.
- instead of a mechanical switch, there is a third electrical contact called the gate, which is insulated from the semiconductor by an oxide layer.



When a transistor is made:

- n and p-types don't keep to themselves -- electrons actually diffuse from the n-type
    - where there are more of them into the p-type to fill the holes.

Depletion layer:

- Depleted: Charges that can move
    - no more free electrons in the n-type
    - Because they've filled the holes in the p-type
- this makes the p-type negative thanks to the added electrons
    - because the p-type will now repel any electrons that try to come across from the n-type
- the depletion layer actually acts as a barrier
    - preventing the flow of electric current through the transistor
- the transistor is off, it's like an open switch, it's in the zero state.
- To turn it on, you have to apply a small positive voltage to the gate.
    - It actually shrinks the depletion layer so that electrons can move through and form a conducting channel.
    - So the transistor is now on, it's in the one state.
      exploiting the properties of a crystal we've been able to create a switch that doesn't have any moving parts, that can be turned on and off very quickly just with a voltage, and most importantly it can be made tiny.
    - Transistors today are only about 22nm wide;
        - means they are only about 50 atoms across.
- But to keep up with Moore's law, they're going to have to keep getting smaller.
    - Moore's Law states that every two years the number of transistors on a chip should double.
    - And there is a limit, as those terminals get closer and closer together, quantum effects become more significant and electrons can actually tunnel from one side to the other.
    - make a barrier high enough to stop them from flowing
        - real problem for the future of transistors, but we'll probably only face that another ten years down the track.

Math Formulas

Monday, October 9, 2023 3:12 PM

Newton's Law of Cooling

$$\frac{dT}{dt} = K[M(t) - T(t)]$$

$$\frac{dT}{dt} = K[M(t) - T(t)]$$

Trigonometric and Logarithmic Equations

$$\sin x = \sum_{n=0}^{\infty} (-1)^n \frac{x^{2n+1}}{(2n+1)!} = x - \frac{x^3}{3!} + \frac{x^5}{5!} - \frac{x^7}{7!} + \cdots$$

$$\cos x = \sum_{n=0}^{\infty} (-1)^n \frac{x^{2n}}{(2n)!} = 1 - \frac{x^2}{2!} + \frac{x^4}{4!} - \frac{x^6}{6!} + \cdots$$

$$\ln(1+x) = \sum_{n=1}^{\infty} (-1)^{n-1} \frac{x^n}{n} = x - \frac{x^2}{2} + \frac{x^3}{3} - \frac{x^4}{4} + \cdots$$

$$\sin x = \sum_{n=0}^{\infty} (-1)^n \frac{x^{2n+1}}{(2n+1)!} = x - \frac{x^3}{3!} + \frac{x^5}{5!} - \frac{x^7}{7!} + \cdots$$

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$$\mathbf{r}(t) = 8t^3\,\mathbf{i} + 4t^3\,\mathbf{j} + 6t^3\,\mathbf{k}$$

$$\begin{aligned}\mathbf{r}'(t) &= \left(3 \cdot 8t^2\right)\mathbf{i} + \left(3 \cdot 4t^2\right)\mathbf{j} + \left(3 \cdot 6t^2\right)\mathbf{k}\\ &= 24t^2\,\mathbf{i} + 12t^2\,\mathbf{j} + 18t^2\,\mathbf{k}\end{aligned}$$

$$\begin{aligned}\mathbf{r}''(t) &= (2 \cdot 24t)\,\mathbf{i} + (2 \cdot 12t)\,\mathbf{j} + (2 \cdot 18t)\,\mathbf{k}\\ &= 48t\,\mathbf{i} + 24t\,\mathbf{j} + 36t\,\mathbf{k}\end{aligned}$$

$$\mathbf{r}'''(t) = 48\,\mathbf{i} + 24\,\mathbf{j} + 36\,\mathbf{k}$$

Tangent Vector

$$\frac{ds}{dt} = \left|\mathbf{r}'(t)\right| = \sqrt{(24t^2)^2 + (12t^2)^2 + (18t^2)^2} = 6\sqrt{29}t^2$$

Tangent Unit Vector

$$\mathbf{T}(t) = \frac{\mathbf{r}'(t)}{|\mathbf{r}'(t)|} = \frac{48\,\mathbf{i} + 24\,\mathbf{j} + 36\,\mathbf{k}}{6\sqrt{29}t^2} = \frac{8}{\sqrt{29}}\mathbf{i} + \frac{4}{\sqrt{29}}\,\mathbf{j} + \frac{6}{\sqrt{29}}\,\mathbf{k}$$

Arc Length

If a = 1 and b = 2:

$$L = \int_a^b |\mathbf{r}'(t)|\,dt = \int_1^2 \left(\frac{8}{\sqrt{29}}\mathbf{i} + \frac{4}{\sqrt{29}}\,\mathbf{j} + \frac{6}{\sqrt{29}}\,\mathbf{k}\right)dt = \left|\frac{8}{\sqrt{29}}\mathbf{i} + \frac{4}{\sqrt{29}}\,\mathbf{j} + \frac{6}{\sqrt{29}}\,\mathbf{k}\right|_1^2 = \frac{8}{\sqrt{29}}\mathbf{i} + \frac{4}{\sqrt{29}}\,\mathbf{j} + \frac{6}{\sqrt{29}}\,\mathbf{k}$$

Normal Vectors

$$\mathbf{N}(t) = \frac{\mathbf{T}'(t)}{|\mathbf{T}'(t)|} = \frac{\frac{8}{\sqrt{29}}\mathbf{i} + \frac{4}{\sqrt{29}}\,\mathbf{j} + \frac{6}{\sqrt{29}}\,\mathbf{k}}{\sqrt{\left(\frac{8}{\sqrt{29}}\right)^2 + \left(\frac{4}{\sqrt{29}}\right)^2 + \left(\frac{6}{\sqrt{29}}\right)^2}} = \frac{8}{\sqrt{29}}\mathbf{i} + \frac{4}{\sqrt{29}}\,\mathbf{j} + \frac{6}{\sqrt{29}}\,\mathbf{k}$$

Binormal Vectors

$$\mathbf{B}(t) = \mathbf{T}(t) \times \mathbf{N}(t)$$

Curvature

$$\kappa = \frac{\left|\mathbf{r}'(t) \times \mathbf{r}''(t)\right|}{|\mathbf{r}'(t)|^3}$$

where $\mathbf{T}$: Tangent Unit Vector

Torsion

$$\tau = \frac{[\mathbf{r}'(t) \times \mathbf{r}''(t)] \cdot \mathbf{r}'''(t)}{\left|\mathbf{r}'(t) \times \mathbf{r}''(t)\right|^2}$$

Line Integrals

$$W = \int_a^b \mathbf{F}\big(\mathbf{r}(t)\big) \cdot \mathbf{r}'(t)\, dt = \int_a^b m\mathbf{r}''(t) \ \cdot \mathbf{r}'(t)\, dt$$

where $ds = \left|\mathbf{r}'(t)\right| dt$

Green's Theorem

$$\int_{\mathrm{C}} \mathrm{P\ dx + Q\ dy} = \iint_D \left(\frac{\partial Q}{\partial x} - \frac{\partial P}{\partial y}\right) dA$$

Curl

$$\text{curl}\ \mathbf{F} = \boldsymbol{\nabla} \times \mathbf{F} = \begin{vmatrix} \mathbf{i} & \mathbf{j} & \mathbf{k} \\ \frac{\partial}{\partial x} & \frac{\partial}{\partial y} & \frac{\partial}{\partial z} \\ P & Q & R \end{vmatrix} = \left(\frac{\partial R}{\partial y} - \frac{\partial Q}{\partial z}\right)\mathbf{i} + \left(\frac{\partial P}{\partial z} - \frac{\partial R}{\partial x}\right)\mathbf{j} + \left(\frac{\partial Q}{\partial x} - \frac{\partial P}{\partial y}\right)\mathbf{k}$$

https://spacemath.gsfc.nasa.gov/Calculus/10Page120.pdf

Problem 2 – The [definite] integral of the dose rate formula D(T) with respect to time is the accumulated total dose.

A) Perform this integration for one 10-hour orbit of the spacecraft assuming that the total dose over the time interval T: [0h, 10h] is equal to twice the dose rate over the time interval T: [0h, 5h]. Answer:

$$\text{Total Dose} = 120\int_0^5 \left(\frac{7+3T}{25}\right)^2 dT$$

$$= \frac{120}{625}\int_0^5 (49+42T+9T^2)dT$$

$$= \frac{120}{625}\left(49T+21T^2+3T^3\right)_0^5$$

$$= \frac{120}{625}\left(49x5+21x25+3x125\right)$$ = 220 milliGrays = **0.22 Grays/orbit.**

https://spacemath.gsfc.nasa.gov/Calculus/10Page113.pdf

Problem 2 –What is the total mass in tons of impacting objects each year, over the surface of Earth, in the mass range from 1 gram to 10^{20} grams? (Use π = 3.14 and assume a spherical Earth with a radius of 6,378 km).

Answer: The total mass is the area under the curve: Mass = N(m) dm

$$M = \int_{1}^{10^{20}} 0.025 m^{-0.9} dm$$

$$= 0.025 \frac{1}{0.1} [(10^{20})^{0.1} - (1)^{0.1}]$$

= 0.025(10)(100-1)

= **24.75 grams/km^2/year**

Area of Earth = $4\pi(6378)^2$ = 5.1×10^8 km^2

So the total meteoritic mass per year is

24.75 grams/km^2 x 5.1×10^8 km^2 = 1.26×10^{10} grams
or 1.26×10^7 kg

or **12,600 tons**.

https://spacemath.gsfc.nasa.gov/Calculus/10Page121.pdf

Θ in degrees	T: Time (hrs)	R in Re	G in Grays/hr
0	0.0	1.0	0.08
40	0.5	2.1	0.23
80	1.2	3.4	1.5
120	2.3	4.0	2.4
160	3.7	4.3	2.4
200	5.3	4.3	2.4
240	6.7	4.1	2.4
280	7.8	3.4	1.6
320	8.5	2.1	0.19