EE669: VLSI Technology

Ion implantation

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"Design of **ion-implanted** MOSFETs with very small physical dimensions", Dennard et al., IEEE Journal of Solid-State Circuits, October 1974.

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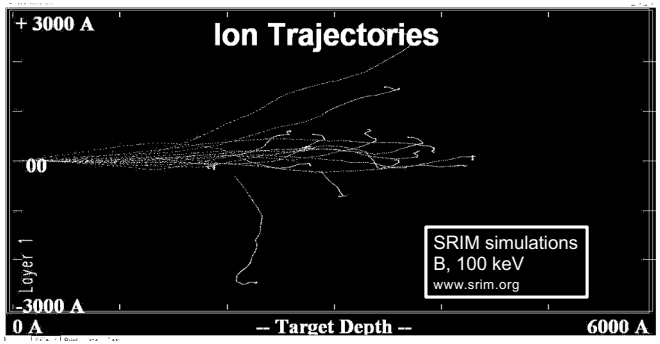
Visualization of ion implantation



SRIM : The Stopping and Range of Ions in Matter

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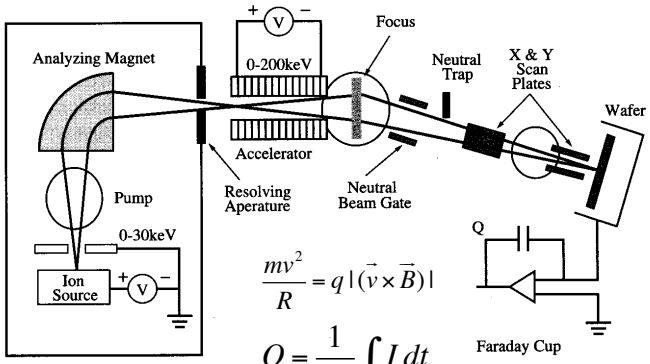
Ion Implanter



$$\frac{mv^2}{R} = q\,|(\vec{v}\times\vec{B})|$$

$$Q = \frac{1}{qA}\int I\,dt$$

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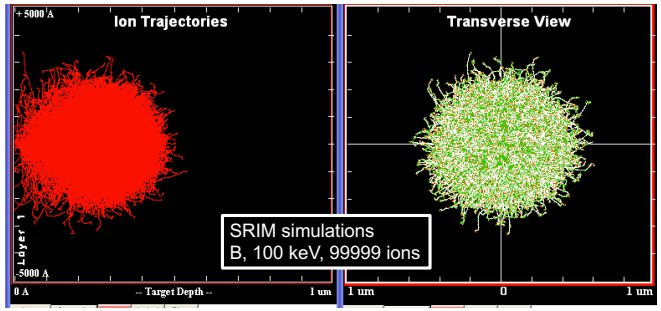
Ion implantation profiles



- **The traces of 99999 ions of Boron implanted into Si at 100 keV**

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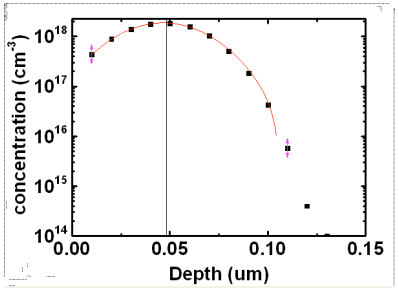
Ion implantation profiles (2)



SRIM simulations
B, 10 keV, 99999 ions

$$C(x) = C_P \exp\left(-\frac{(x-R_P)^2}{2\Delta R_P^2}\right)$$

$$Q = \int_{-\infty}^{\infty} C(x)dx = \sqrt{2\pi}\Delta R_P C_P$$

Range = 48 nm
Straggle = 20 nm

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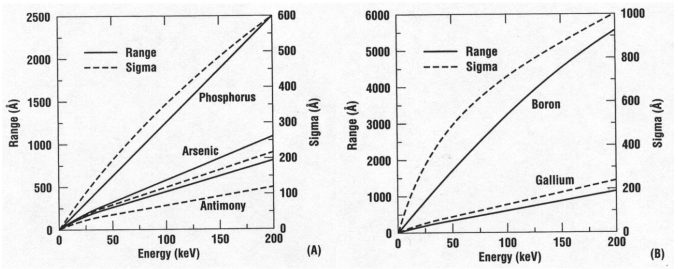
Ion implantation profiles (4)



Fabrication Engineering at the Micro and Nanoscale, Stephen Campbell, Oxford University Press

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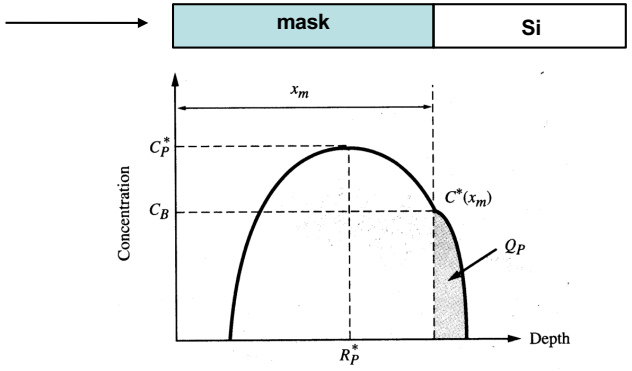
Masking of implants



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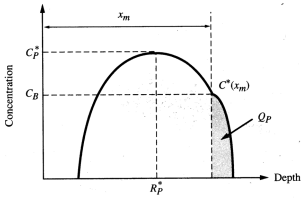
Masking of implants (2)

$$C^*(x_m) = C_P^* \exp\left(-\frac{(x_m - R_P^*)^2}{2\Delta R_P^2}\right) \le C_B$$

$$x_m \ge R_P^* + \Delta R_P^* \sqrt{2\ln\left(\frac{C_P^*}{C_B}\right)} = R_P^* + m\Delta R_P^*$$



$$Q_P = C_P^* \int_{x_m}^{\infty} \exp\left(-\frac{\left(x-R_P^*\right)^2}{2\Delta R_P^2}\right)dx = \frac{Q}{\sqrt{2\pi}\Delta R_P^*} \int_{x_m}^{\infty} \exp\left(-\frac{\left(x-R_P^*\right)^2}{2\Delta R_P^2}\right)dx$$

$$Q_P = \frac{Q}{2} erfc\left(\frac{x_m - R_P^*}{\sqrt{2}\Delta R_P^*}\right)$$

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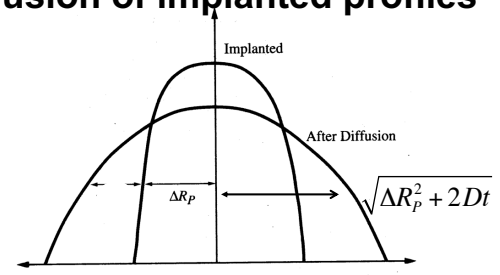
Masking of implants (3)

$$E = \int VJdt = V\int Jdt = qVQ$$

- The ions implanted are decelerated in the wafer resulting in dissipation of the kinetic energy of the ions
  - heating of the wafer
  - thermal mass of the wafer + chuck assembly
- The mask should withstand such temperature
- Photo resist used as mask undergoes chemical and physical changes ~ 120 C

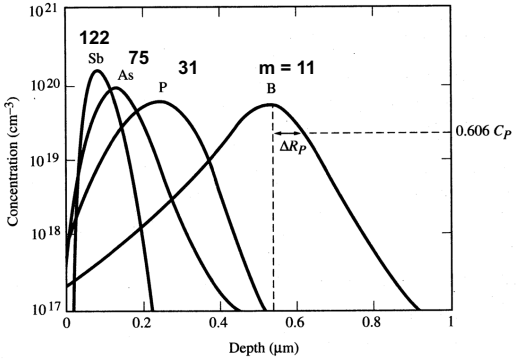
Diffusion of implanted profiles



$$C(x) = \frac{Q}{\sqrt{2\pi}\Delta R_p}\exp\left(-\frac{(x-R_p)^2}{2\Delta R_P^2}\right) \qquad C(x,t) = \frac{Q}{2\sqrt{\pi Dt}}\exp\left(-\frac{x^2}{4Dt}\right)$$

$$C(x) = \frac{Q}{\sqrt{2\pi(\Delta R_P^2 + 2Dt)}}\exp\left(-\frac{(x-R_p)^2}{2(\Delta R_P^2 + 2Dt)}\right)$$

Ion implantation profiles (3)



Implant energy = 200 keV

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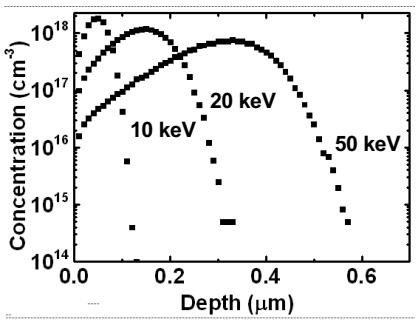
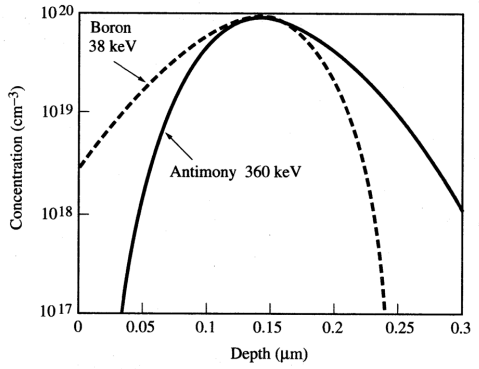
Deviation from the Gaussian profile



Boron implant simulated using SRIM

Scaled to a dose of 10^{13} cm^{-2}

Deviation from the Gaussian profile (2)



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4 moment distribution

1st moment ➔ Range: $R_P = \frac{1}{Q}\int_{-\infty}^{\infty} xC(x)dx$

2nd moment ➔ Straggle: $\Delta R_P = \sqrt{\frac{1}{Q}\int_{-\infty}^{\infty}\left(x - R_P\right)^2 C(x)dx}$

3rd moment ➔ Skew: $\gamma = \frac{\int_{-\infty}^{\infty}\left(x - R_P\right)^3 C(x)dx}{Q\Delta R_P^3}$

4th moment ➔ Kurtosis: $\beta = \frac{\int_{-\infty}^{\infty}\left(x - R_P\right)^4 C(x)dx}{Q\Delta R_P^4}$

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