Implantação Iônica

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POSMAT - UNESP

Aplicações

- Semicondutores
  - Dopagem
  - Inserção de camada isolante
- Mecânicas
  - Endurecimento de superfícies (nitretação, carbetação)
  - Aumento de área superficial efetiva
- Biomateriais
  - Criação de rugosidade superficial
  - Produção de filmes de óxido ou nitretos por implantação do O

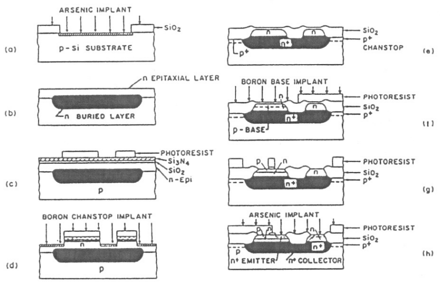


Figure 1.12 *Sequence of n-p-n bipolar transistor fabrication steps:(a) buried-layer implant, (b) epitaxial layer, (c) photoresist mask, (d) channel stop implant, (e) oxide isolation, (f) base implant, (g) removal of thin oxide, (h) emitter implant (from ref. 1.18).*

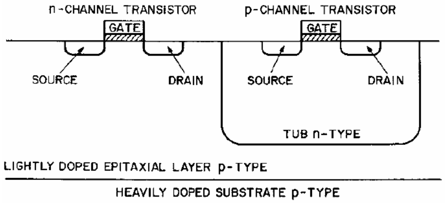
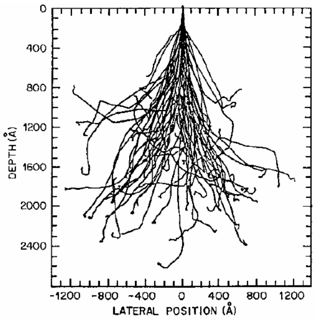
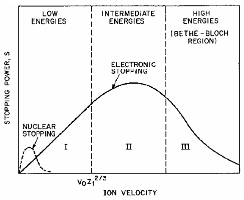


Figure 9:19: Cross section of an epi-substrate CMOS device.

$$S = \left(\frac{dE}{dx}\right)_{nuclear} + \left(\frac{dE}{dx}\right)_{eletrônica}$$

B→ Si (50 keV, 128 trajet. Monte Carlo)





v_o- veloc de Bohr $\frac{q^2}{4\pi\varepsilon_o\hbar^2}$

Z_1 - numero atômico do íon

$$T = \frac{4M_1M_2}{(M_1+M_2)^2}E \ \sin^2\left\{\frac{\theta}{2}\right\}$$

$$S_n = \left(\frac{dE}{dx}\right)_{nuclear} = N\int_0^{T_{\max}} T\,d\sigma$$

$$n(x) = n_o \exp\left\{-\frac{(x-R_p)^2}{2\sigma_p^2}\right\}$$

$$n_o = \frac{\phi}{\sqrt{2\pi}\sigma_p} \cong \frac{0.4\phi}{\sigma_p}$$

R – comprimento da trajetória (p – projeção x)

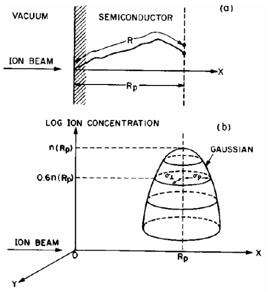


Figure 9.3: Schematic views of the ion range. (**a**) The total path length R is longer than the projected R_p. (**b**) The stopped atom distribution is two-dimensional Gaussian.

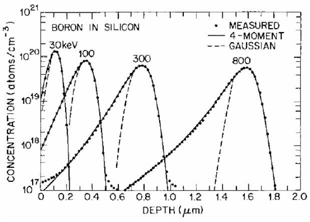


Figure 9.4: Boron implanted atom distributions, comparing measured data points with four-moment (Pearson IV) and Gaussian fitted distributions. The boron was implanted into amorphous silicon without annealing.

Table 9.1: Boron ranges in various materials.

100 keV boron implantation				
Material	Symbol	Density (g/cm^3)	R_p(Å)	σ_p(Å)
Silicon	Si	2.33	2968	735
Silicon dioxide	SiO_2	2.23	3068	666
Silicon nitride	Si_3N_4	3.45	1883	408
Photoresist AZ111	$C_8H_{12}O$	1.37	10569	1202
Titanium	Ti	4.52	2546	951
Titanium silicide	$TiSi_2$	4.04	2154	563
Tungsten	W	19.3	824	618
Tungsten silicide	WSi_2	9.86	1440	555

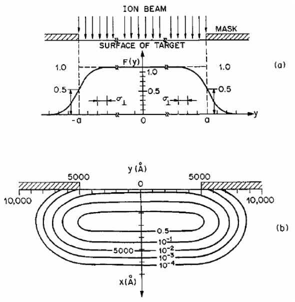


Figure 9.5: Two-dimensional implantation profiles. (**a**) Fraction of total dose as a function of lateral position for an opaque mask. (**b**) Equi-concentration contours for a 70 keV boron implant through a 1 µm slit.

Amorfisação / Annealing

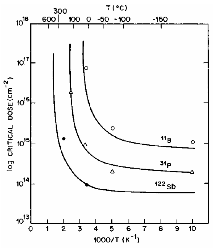


Figure 9.6: A plot of the critical dose necessary to make a continuous amorphous layer as a function of temperature.

Amorfisação / Annealing

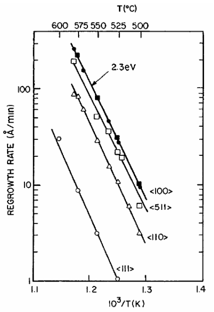
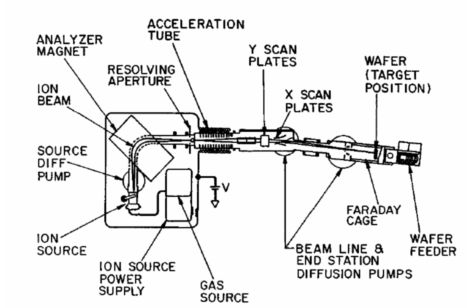


Figure 9.13: The solid-phase epitaxial growth rate of amorphous silicon as a function of temperature for various crystal orientations.

Esquema de implantador comercial



$$\phi = \frac{1}{QA}\int I dt$$

- ϕ - dose (átomos/área)
- I – corrente
- A – área
- Q – carga do íon
- t – tempo de implantação

Implantação de O em Si

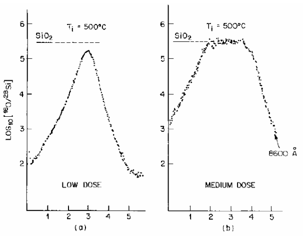


Figure 9.20: Unannealed profiles for 200 keV oxygen implanted into silicon. (**a**) For a low oxygen dose, the profile has the usual Gaussian shape. (**b**) For a high enough oxygen dose and after high temperature annealing, oxygen diffuses toward the implant peak to form a stoichiometric buried silicon dioxide layer.

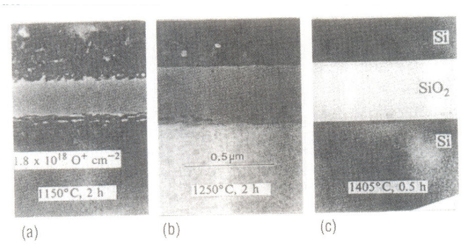
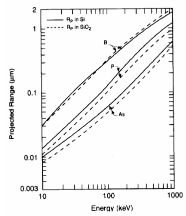
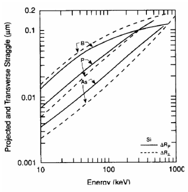


Figure 8.13 *TEM cross section of* $1.8 \times 10^{18}/cm^2 - 200keV0^+$ *implanted samples annealed at* 1150^0C*-2h(a),* 1250^0C *- 2h(b) and* 1405^0C*, 0.5h(c) (from ref. 8.34).*

Exemplo / Exercício



Projected range (R_p) for B, P, and As in Si and SiO$_2$ at various implantation energies



Ion projected straggle or standard deviation (ΔR_P or σ_p) for As, P, and B in silicon

Dados:

- Wafer de Si, diam = 200mm
- Energia dos íons (B^+) = 100 keV
- Dose $5x10^{15}$ /cm^2
- Tempo de implantação: 90 s
- Distrib. gaussiana

Pede-se:

- Alcance projetado (R_p)
- Desvio padrão projetado (σ_p)
- Corrente do feixe

Respostas:

- Da figura (100 keV, B)
- => R_p = 0.3 µm , σ_p= 0.07 µm

$$n_o = \frac{\phi}{\sqrt{2\pi}\sigma_p} = 2.85\times10^{20} cm^{-3}$$

Total de íons implantados = área x dose = $1.57x10^{18}$ íons

Corrente = carga total implant. / tempo de implant. = $1.57x10^{18}/90$ = 2.8 mA

Conclusão/Implantação

- Processo largamente utilizado
  - Dopagem semicondutores
  - Modificação de superfícies
  - Biomateriais
- Equipamento relativamente complicado
  - Operação simples
  - Profundidades de penetração / energia

Referências

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