#18

Processing (continued)

A gradient in concentration causes a flow — diffusion

The flow: $F = -D \frac{\partial C}{\partial x}$ — concentration

diffusivity

$$\frac{\partial C}{\partial t} = -\frac{\partial F}{\partial x} \Rightarrow \boxed{\frac{\partial C}{\partial t} = D \frac{\partial^2 C}{\partial x^2}}$$

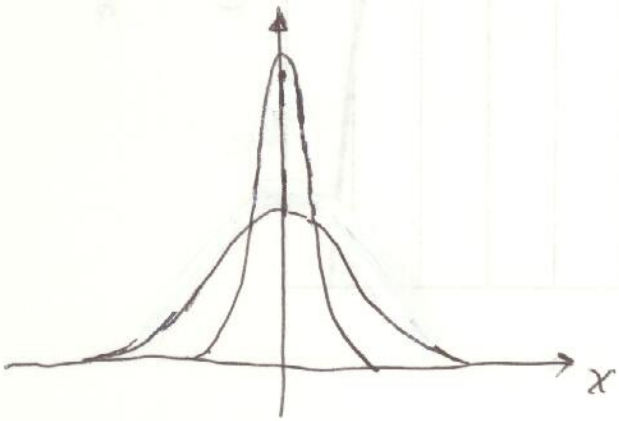
If D is a constant

Example: $C(x, 0) = Q\delta(x)$

total dose

Solution: $C(x, t) = \frac{Q}{2\sqrt{\pi D t}} e^{-\frac{x^2}{4Dt}}$

— Gaussian



Start w/ a Gassian.

always Gaussian.

Recall that the implanted profile is Gassian to the 1st order.

n and
alized

Fast vs. slow diffusers

Need slow diffusers for small dimensions, shallow junctions.

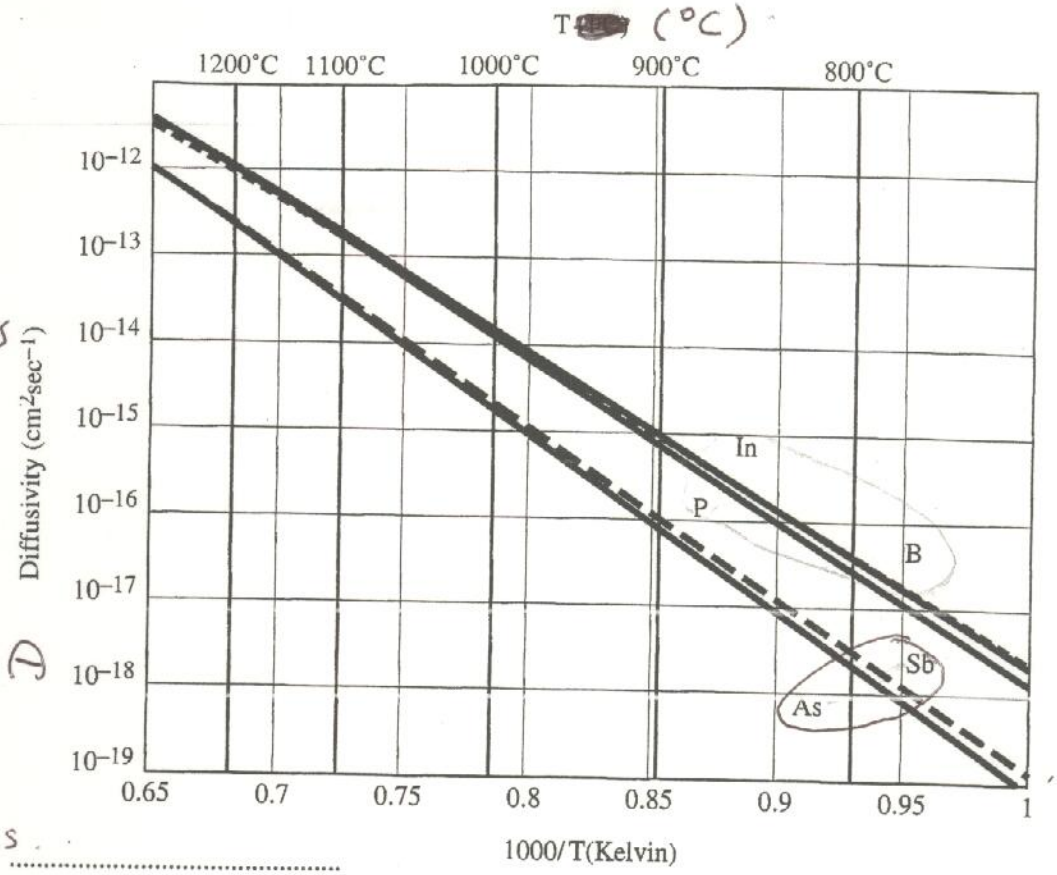


Figure 7–15 Arrhenius plot of the intrinsic diffusivity of the common dopants in silicon.

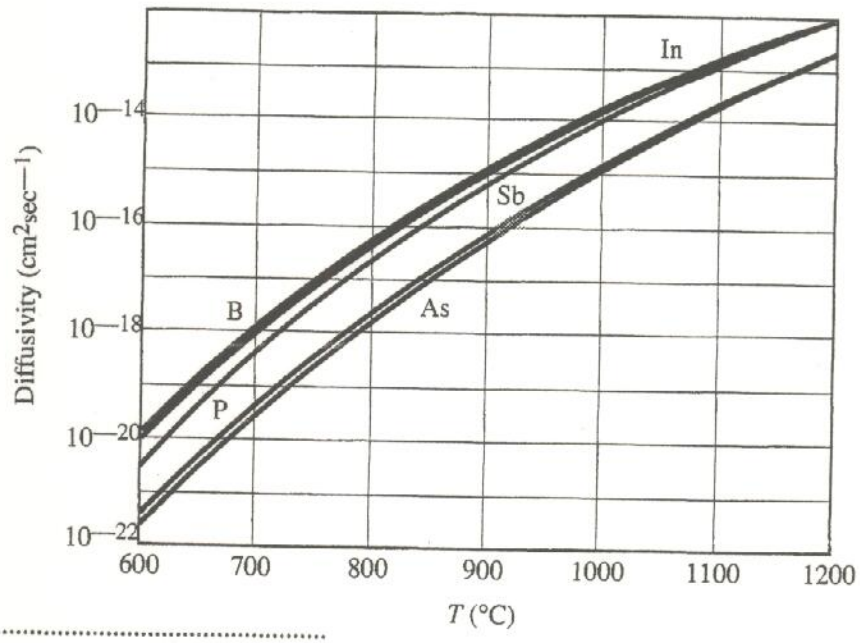


Figure 7–16 Temperature dependence of the intrinsic diffusion coefficient of common dopants in silicon.

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(7.29)

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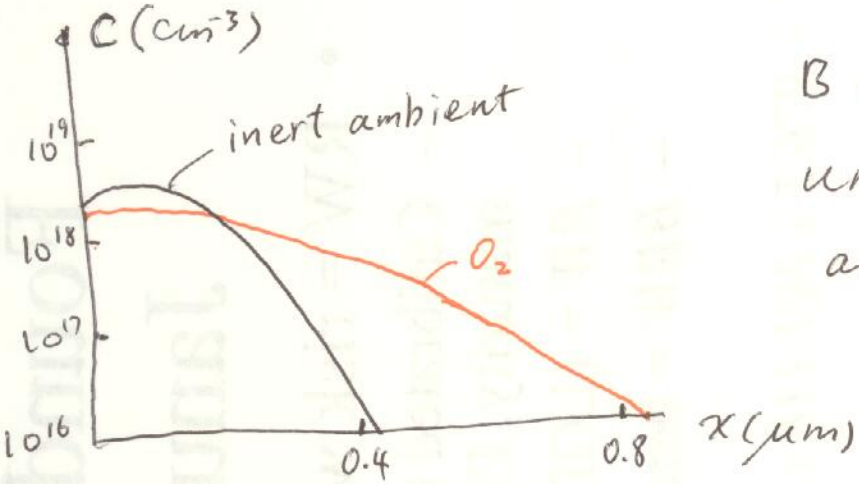
Anomalous diffusion behaviors

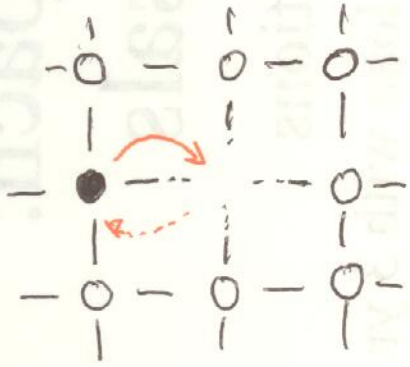


B diffusion under different ambients

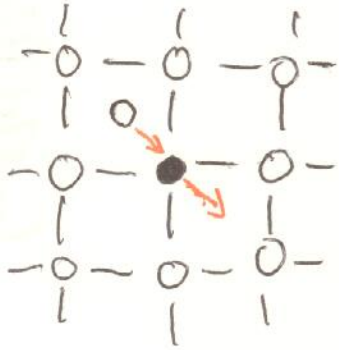
And this seems to be an effect "over distance"!

We must look into the microscopic mechanisms to understand this anomaly.

In the <u>solid state</u> dopants don't diffuse by themselves → assisted by point defects.



vacancy assisted



interstitial assisted.

[7.1 simula-
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a thermal oxide
shallow profiles
files are boron.
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n and undersatura-
mony for a vacancy
e elastic interaction
tch in size, so that a
all dopant atom may
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ng the surface of the
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(indicated schemat-
ing interface and is

(7.64)

A clever experiment

oxidation
↓
stress
↓
interstitial
injection
(generation)

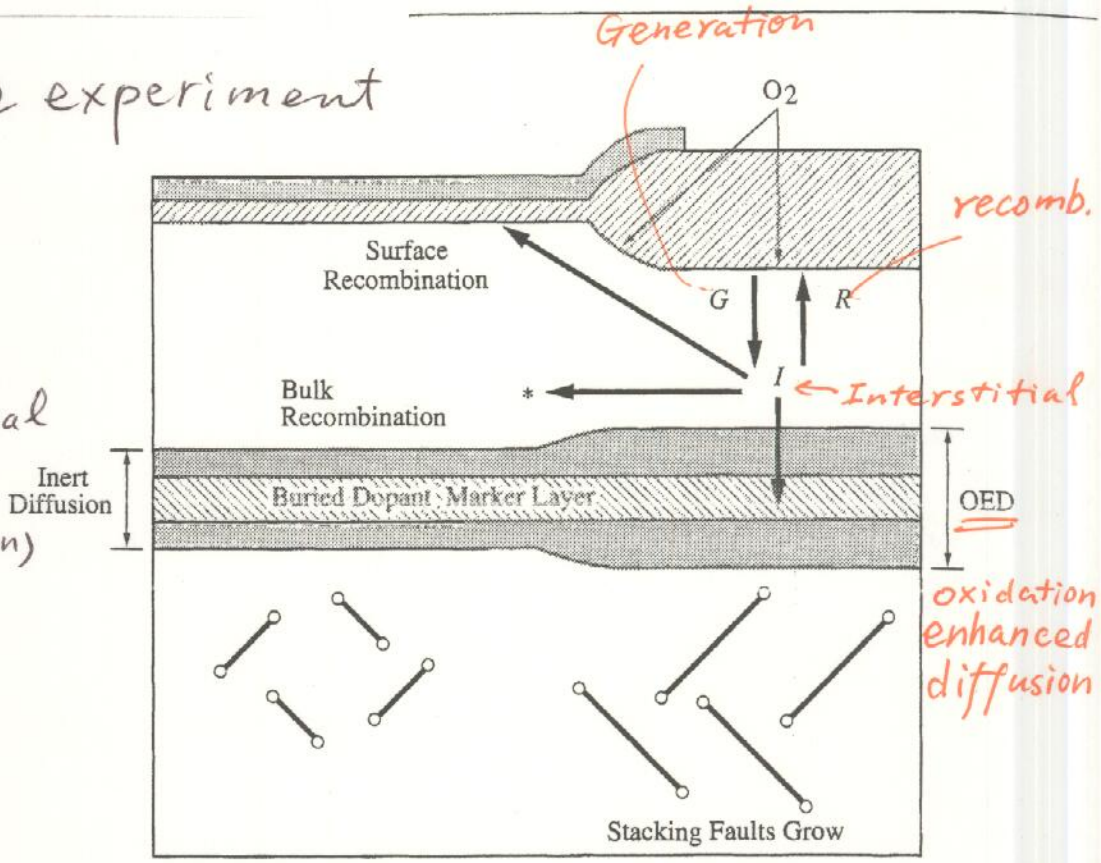

Figure 7–37 Generalized representation of point-defect generation (G), recombination (R), and diffusion processes in silicon. In this example, local oxidation (right side) generates interstitials which diffuse away from the Si/SiO_2 interface, locally enhancing the diffusion of dopants like B or P, while causing interstitial type stacking faults to grow.

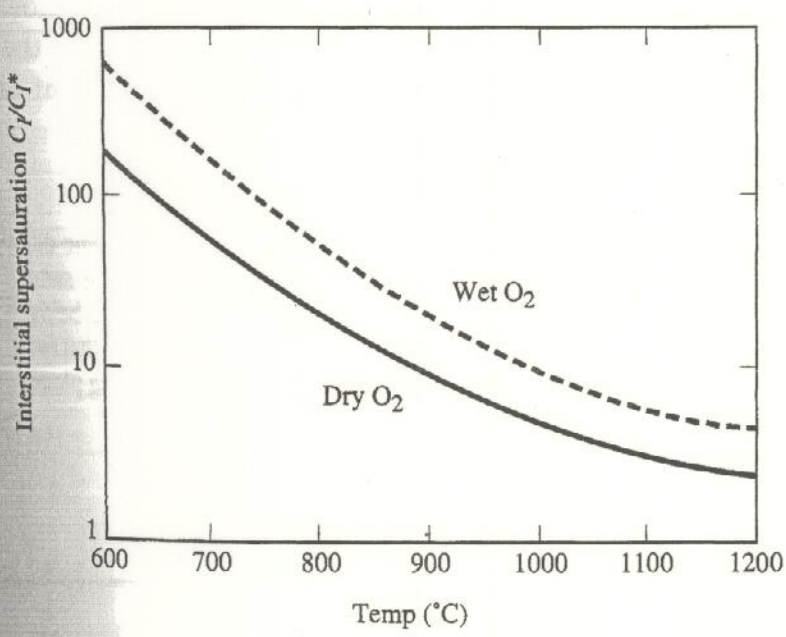

Figure 7–38 TSUPREM IV [7.14] si
of the interstitial supersaturation generat
dation in wet and dry O_2 at various tem
The oxidation time is chosen to be at the
between the linear and parabolic regime

This equation is a specific version of the more general forms given in (6.49). The interstitial supersaturation results from the balance between rate and the recombination rate of interstitials at the oxidizing interface excess above the equilibrium value (or supersaturation) depends prima

Some dopants are more interstitial-assisted,
Some more vacancy assisted.

B & P : 100% interstitial.

As. 40% interstitial, 60% vacancy

Sb almost 100% vacancy

For Sb : oxidation → interstitial injection

→ vacancy population decrease due to recombination

→ oxidation-retarded diffusion (ORD)

— — — — — — —

How many defects are there?

Under equilibrium,

$$C_{I0} = 1 \times 10^{27}\ cm^{-3} \cdot e^{-\frac{3.8eV}{kT}}$$

$$C_{V0} = 9 \times 10^{23}\ cm^{-3} \cdot e^{-\frac{2.6eV}{kT}}$$

zero charge

@ 1000°C, $C_{I0} = 10^{12}\ cm^{-3}$, $C_{V0} = 5 \times 10^{13}\ cm^{-3}$

Do you think these #'s are big or small?

Another anomaly:

For high implant doses (e.g. used for S/D, $> \sim 10^{14}\ cm^{-2}$), diffusion is anomalously faster than usual @ early stage of annealing.

$\boxed{\text{Transient - Enhanced Diffusion (TED)}}$

Implant $\Longrightarrow$ defects

$\downarrow$

Most interstitials & vacancies recombine.

$\downarrow$

In $\sim 10^{-2}$ s, only interstitials are those kicked out by the dopants.

$\downarrow$

@ high doses, the interstitials cluster up.

The clusters dissolve & release interstitials slowly $\Longrightarrow$ $C_I >$ Equlibrium value

$\Downarrow$

Enhanced diffusion.