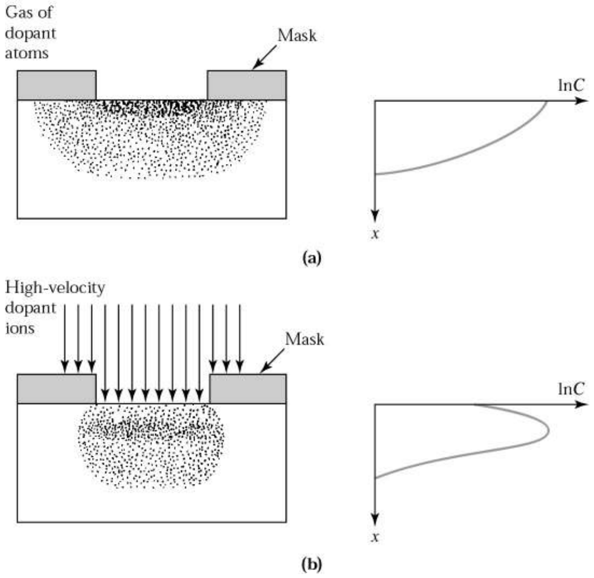
DIFFUSION

Diffusion

- Impurity doping is the introduction of controlled amounts of impurity dopants in into semiconductors. Practical use of impurity doping mainly has been to change the electrical properties of the semiconductors.

- Two main method for introducing the impurity:
  - Diffusion → deep junction
  - Ion implantation → shallow junction

Comparison of (a) diffusion and (b) ion-implantation techniques for the selective introduction of dopants into the semiconductor substrate.

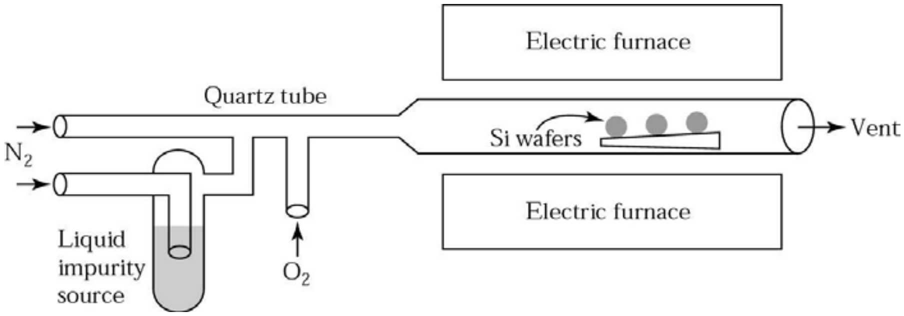


Diffusion

- Covering topics in diffusion:
  - – The movement of impurity atoms in crystal lattice (high temperature and high concentration dopant gradient profile)
  - – Impurity profile for constant diffusivity and constant dependent diffusivity .
  - – The simulation with SUPREM

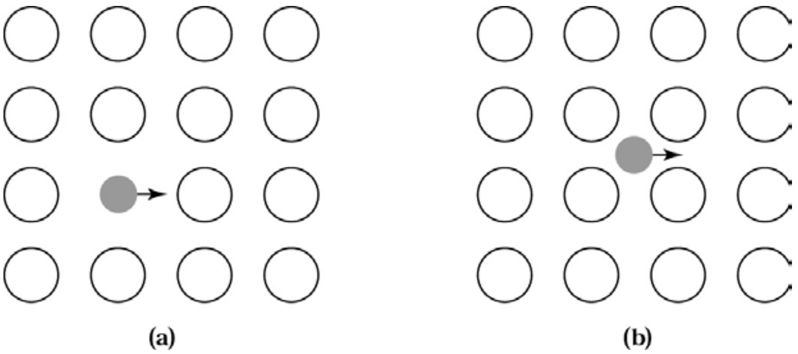
Basic Diffusion Process

- Diffusion of impurity is typically done by placing semiconductor wafers in a carefully controlled high temperature quartz-tube furnace and passing a gas mixture that contain the desired dopant through it.
- The temperature usually ranges between 800 °C and 1200 °C for silicon and 600°C and 1OOO °C for gallium arsenide. The number of dopant atoms that diffuse into the semiconductor is related to the partial pressure of the dopant impurity in the gas mixture.

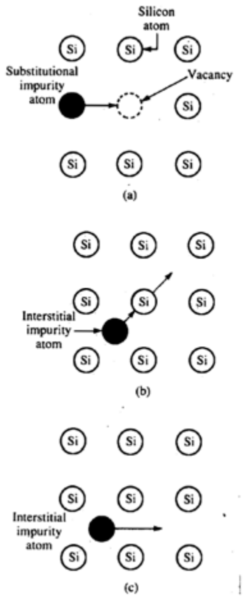


Schematic diagram of a typical open-tube diffusion system.

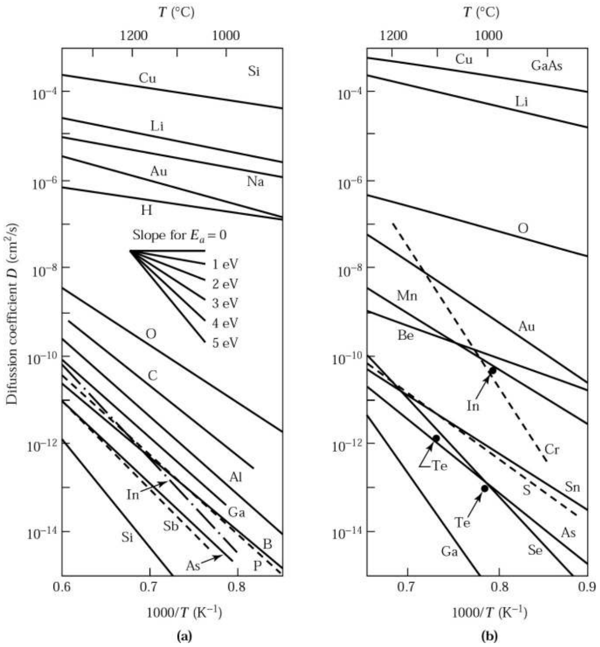
Diffusion mechanisms

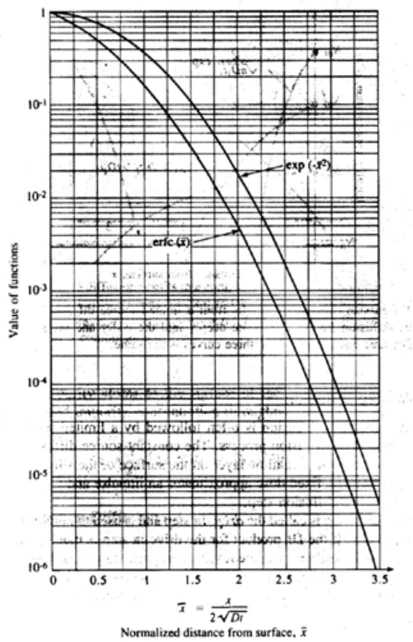


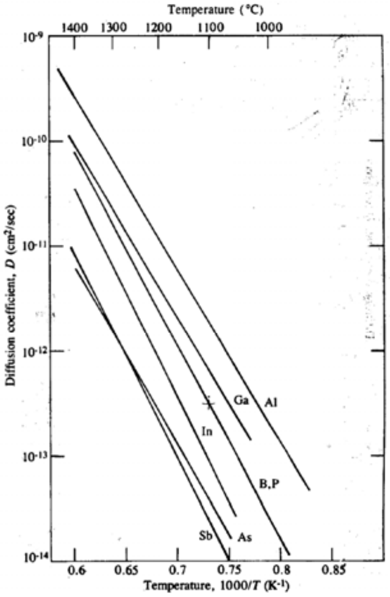
Atomic diffusion mechanisms for a two-dimensional lattice. (a) Vacancy mechanism. (b) Interstitial mechanism.



Diffusion coefficient (also called diffusivity) as a function of the reciprocal of temperature for (a) silicon and (b) gallium arsenide.

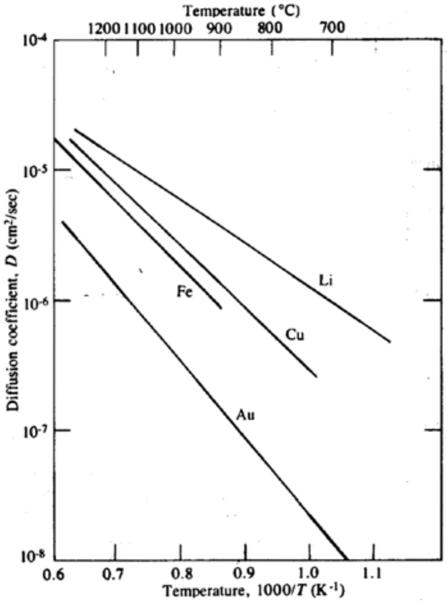






(a)

Fig. 4.5 Diffusion constants in silicon for (a) substitutional diffusers (above) and (b) interstitial diffusers (next page). Copyright John Wiley & Sons, Inc; reprinted with permission from ref. [25].



(b)

Fig. 4.5 (continued)

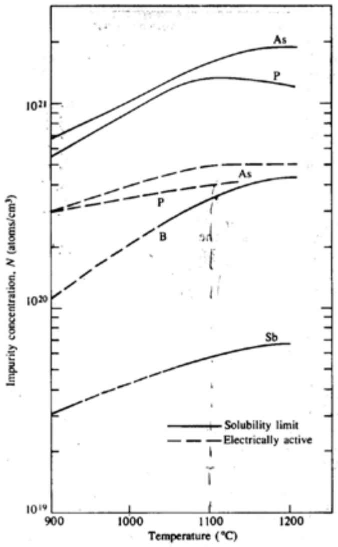


Fig. 4.6 The solid-solubility and electrically active impurity-concentration limits in silicon for antimony, arsenic, boron, and phosphorus. Reprinted with permission from ref. [26]. This paper was originally presented at the 1977 Spring Meeting of The Electrochemical Society, Inc., held in Philadelphia, Pennsylvania.

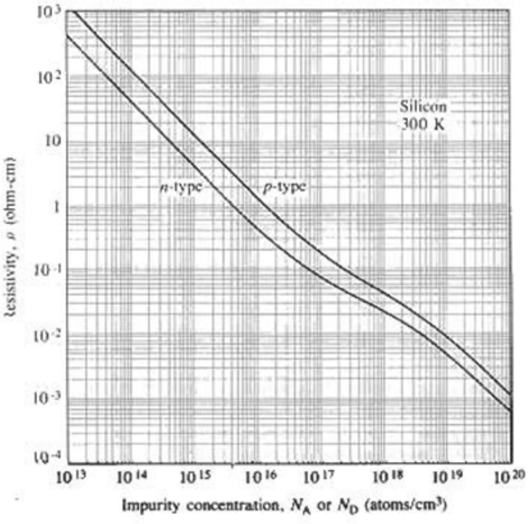
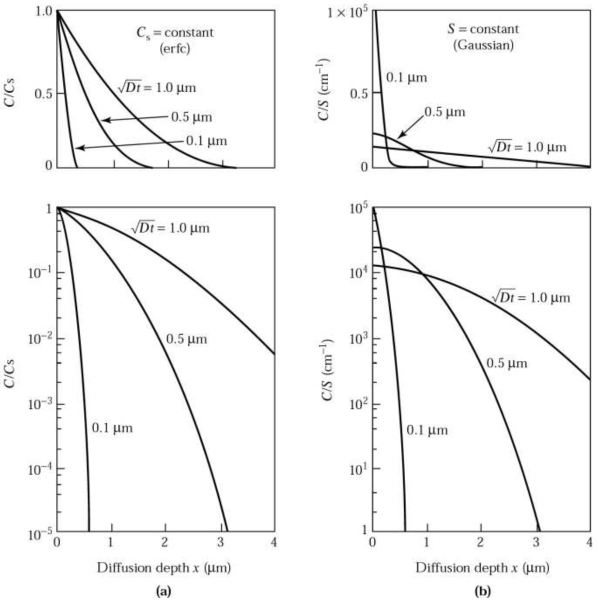
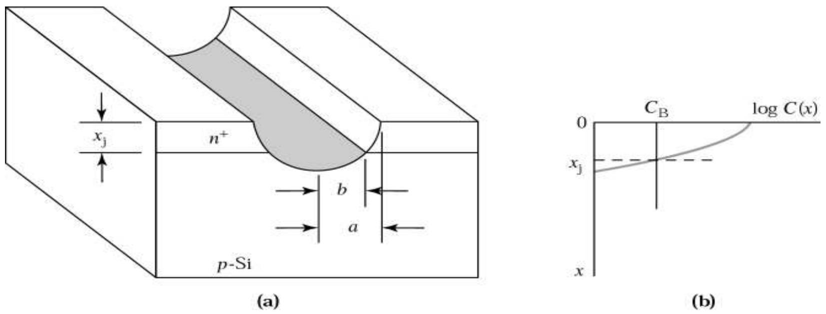


Fig. 4.8 Room-temperature resistivity in *n*- and *p*-type silicon as a function of impurity concentration. (Note that these curves are valid for either donor or acceptor impurities but not for compensated material containing both types of impurities.) Copyright 1987 Addison-Wesley Publishing Company. Reprinted with permission from ref. [3].

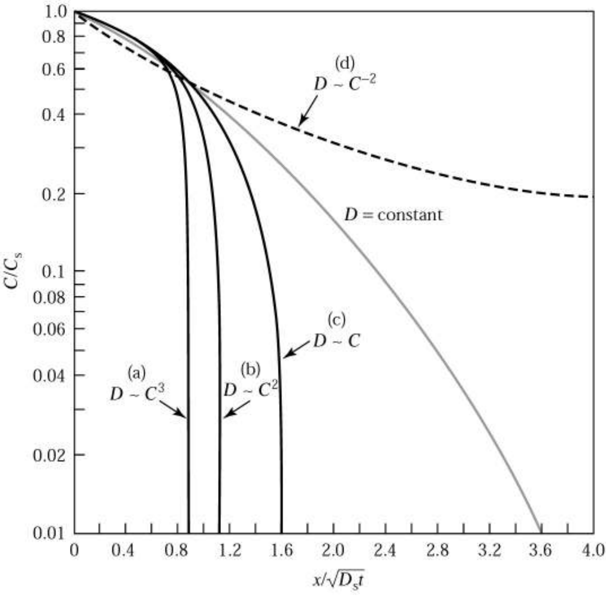
Diffusion profiles.
(a) Normalized complementary error function versus distance for successive diffusion times. (b) Normalized Gaussian function versus distance.



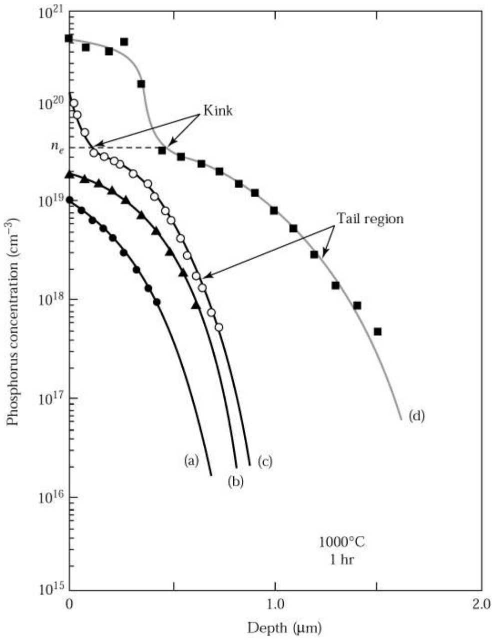


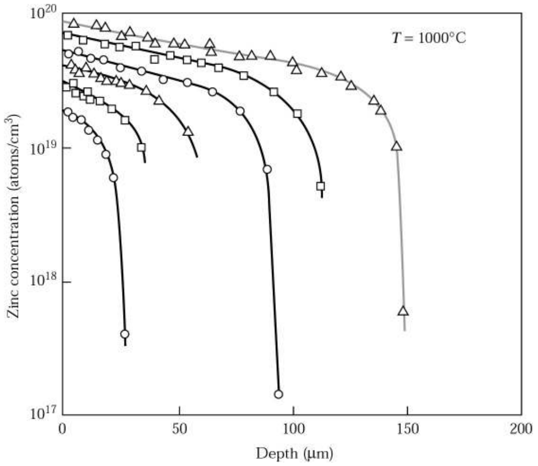
Junction-depth measurement. (a) Grooving and staining. (b) Position in which dopant and substrate concentrations are equal.

Normalized diffusion profiles for extrinsic diffusion where the diffusion coefficient becomes concentration dependent.

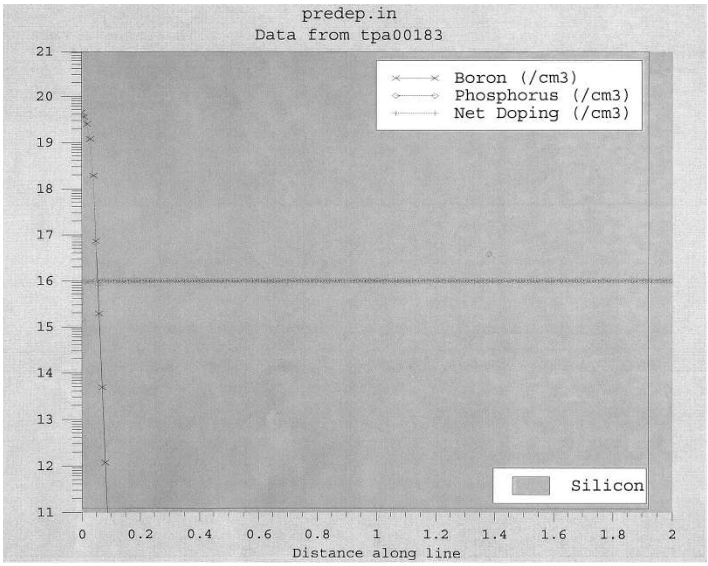


Phosphorus diffusion profiles for various surface concentrations after diffusion into silicon for 1 hour at 1000°C.





Diffusion profiles of zinc in GaAs after annealing at 1000°C for 2.7 hours. The different surface concentrations are obtained by maintaining the Zn source at temperatures in the range 600°C to 800°C.



Plot of boron concentration as a function of depth into the silicon substrate, using SUPREM.