

## Dispositivos Fotovoltaicos: Materiais e Tecnologia

### Série 4

2018/2019

---

1. A silicon ingot that should contain  $10^{16}$  boron atoms/cm<sup>3</sup> is to be grown by the Czochralski technique. What concentration of boron atoms should be in the melt to give the required concentration in the ingot? If the initial load of silicon in the crucible is 60 kg, how many grams of boron (atomic weight 10.8) should be added? The density of molten silicon is 2.53 g/cm<sup>3</sup>.
2. Consider a diffusion doping process of phosphorous done at 1000 C of a silicon wafer. It is known that a constant surface concentration of phosphorous exists during this process and has a value of  $4 \times 10^{22}$  at/cm<sup>3</sup>.
  - a) Determine the phosphorous concentration at a depth below the surface of 0.5 micron after a diffusion of 6 hours.
  - b) If the temperature is increased to 1200 C, maintaining the process time, what will be the phosphorous concentration at the same depth below the surface?
3. In a diffusion doping process gallium is used at a temperature of 1100 C during 3 hours. Determine the depth at which the concentration of gallium is  $10^{22}$  at/cm<sup>3</sup>, assuming a constant gallium surface concentration of  $10^{24}$  at/cm<sup>3</sup>. Assume  $D_{\text{gallium}}(1100\text{C}) = 7.05 \times 10^{-17}$  cm<sup>2</sup>/s

**TABLE 1 EQUILIBRIUM SEGREGATION COEFFICIENTS FOR DOPANTS IN SI**

Dopant	$k_0$	Type	Dopant	$k_0$	Type
B	$8 \times 10^{-1}$	<i>p</i>	As	$3.0 \times 10^{-1}$	<i>n</i>
Al	$2 \times 10^{-3}$	<i>p</i>	Sb	$2.3 \times 10^{-2}$	<i>n</i>
Ga	$8 \times 10^{-3}$	<i>p</i>	Te	$2.0 \times 10^{-4}$	<i>n</i>
In	$4 \times 10^{-4}$	<i>p</i>	Li	$1.0 \times 10^{-2}$	<i>n</i>
O	1.25	<i>n</i>	Cu	$4.0 \times 10^{-4}$	— <sup>a</sup>
C	$7 \times 10^{-2}$	<i>n</i>	Au	$2.5 \times 10^{-5}$	— <sup>a</sup>
P	0.35	<i>n</i>			

<sup>a</sup>Deep-lying impurity level.

