Week 10 PSET

Thermal Expansion of Two Glasses

(A): (a) A
(b): B
(c): C

Carburization of Iron

Recall Fick's Second Law:

$$\frac{C(x,t) - C_s}{C_0 - C_s} = \text{erf}\left(\frac{x}{2\sqrt{Dt}}\right)$$

then, plug in

$C_s = 0.012$

$C_0 = 0$

$C(x,t) = C(0.001\ m, t) = 0.009$

$x = 0.0001\ m$

$D = 1 \cdot 10^{-10}$

$$\frac{0.009 - 0.012}{0 - 0.012} = \text{erf}\left(\frac{0.0001}{2\sqrt{10^{-1} \cdot t}}\right)$$

defer to an erf value table and find

$$\text{erf}^{-1}\left(\frac{0.009 - 0.012}{0 - 0.012}\right) \approx 0.225, \text{ thus}$$

$$0.225 = \frac{0.0001}{2\sqrt{10^{-1} t}}$$

$$\Downarrow$$

$$t = 496\ \text{sec} \square$$

Hydrogen Diffusion in Steel

Recall Flick's Second Law:

$$\frac{C(x,t) - C_s}{C_0 - C_s} = \text{erf}\left(\frac{x}{2\sqrt{Dt}}\right)$$

Then,

$C(x,t) = 1/2$

$C_s = 0$

$C_0 = 1$

$x = 0.05$

~~$D = 3.09 \times 10^{-4}$~~ D is unknown

$t = 50 \cdot 60$

$$\frac{1/2}{1} = \text{erf}\left(\frac{0.05}{2\sqrt{D \cdot 50 \cdot 60}}\right)$$

$$\Downarrow$$

$$0.475 = \frac{0.05}{2\sqrt{D \cdot 50 \cdot 60}}$$

$$(0.475)^2 = \frac{(0.05)^2}{4 \cdot D \cdot 50 \cdot 120}$$

$$D = 4.82 \cdot 10^{-7}$$

Nitrogen Diffusion in Cobalt

See that the diffusion constant

$$D = D_0 \exp\left(\frac{-E_A}{8.314 \cdot T}\right)$$

$$= 2.69 \cdot 10^{-10} \frac{cm^2}{s}$$

Then, Fick's Second law:

$$\frac{1662 - 111}{3091 - 111} = 0.52 = \text{erf}\left(\frac{X}{2\sqrt{Dt}}\right)$$

$$\Downarrow$$

$$t = 3440 \text{ seconds}$$

Aluminum Diffusion In Silicon

Once again, recall Fick's Second Law. Plug in $C_s = 1$, $C_0 = 0$, $C(x,t) = C(x, 590400) = 35\%$, and $D = 10^{-14}$;

$$\frac{0.35 - 1}{0 - 1} = \text{erf}\left(\frac{x}{2\sqrt{10^{-14} \cdot 590400}}\right)$$

$$\Downarrow$$

$$0.66 = \frac{x}{2\sqrt{10^{-14} \cdot 590400}}$$

$$x = 1.01 \cdot 10^{-4} \text{ cm}$$

Chromium Diffusion In Steel

Calculate the diffusivity:

$$D = D_0 \exp\left(\frac{-E_A}{8.314\,T}\right)$$

$$= 0.54 \exp\left(\frac{-286000}{8.314\,(980+273)}\right)$$

$$= 6.446 \cdot 10^{-13}$$

Then plug into Fick's Second Law:

$$\frac{0.018-1}{0-1} = \operatorname{erf}\left(\frac{0.002}{2\sqrt{6.446 \cdot 10^{-13} \cdot t}}\right)$$

$$\Downarrow$$

$$\frac{0.002}{2\sqrt{6.446 \cdot 10^{-13}\, t}} = 1.675$$

$$\frac{(0.002)^2}{4 \cdot 6.446 \cdot 10^{-13}} = (1.675)^2\, t$$

$$t = 6.4 \text{ days}$$

Boron Diffusion In Silicon

Once again, apply Fick's Second Law, where we let

$C(x,t) = 10^{15}$

$C_0 = 0$

$C_s = 10^{20}$

$D = 3 \cdot 10^{-11}$

$x = 0.0006$

Then,

$$\frac{C(x,t) - C_s}{C_0 - C_s} \simeq 0.999990 = \operatorname{erf}\left(\frac{0.0006}{2\sqrt{3 \cdot 10^{-11} t}}\right)$$

$$\Downarrow$$

$$3.12 = \frac{0.0006}{2\sqrt{3 \cdot 10^{-11} t}}$$

$$(3.12)^2 \simeq \frac{(0.0006)^2}{4 \cdot 3 \cdot 10^{-11} t}$$

$$t = 308$$

Surface Strengthening

(Also Option 4

Cooling Rates

(A): Glass B

KCl Salt Bath

(a): Options

(b): option 5