```
> restart;
```

FYS9n4310 solution 200-19

In an attempt to form a heavily doped p-type boule of Si, a Czochralski growth process is run in which the initial melt concentration of boron (B) was 0.5 atomic %. Assume that the solidification temperature was 1400 °C, and that the boule cooled rapidly after solidification.

a) What is the solubility of B at this temperature?

b) What fraction of the boule must be pulled (i.e. solidified) before the concentration of the boron in the solid will begin to exceed the solid solubility of boron in silicon?

c) What is the concentration (in percent) of boron in the liquid at this point, assuming that the liquid has a uniform concentration.

d) What qualitative modification to the solution would we have if the concentration in the liquid were not constant?

solution

a)

Look in the book, Fig 2.6 ,

The solubility of B in Si is around 1.4 e21 cm-3,

b)

We have from eq 2.13 in the book

```
> eq2_13:=Cs=k*C0*(1-X)^(k-1);
```

$$eq2\_13 := Cs = k\,C0\,(1 - X)^{k-1} \quad \textbf{(1)}$$

We solve equation 2_13 with respect to X

```
> eq1A:=X=solve(eq2_13,X);
```

$$eq1A := X = -e^{\frac{\ln\left(\frac{Cs}{C0\,k}\right)}{k-1}} + 1 \quad \textbf{(2)}$$

we set in parameters we call the set 'nums_b'

```
> nums_b:={Cs=1.4e21/5e22,C0=0.5/100,k=0.8};
```

$$nums\_b := \{C0 = 0.005000000000,\ Cs = 0.02800000000,\ k = 0.8\} \quad \textbf{(3)}$$

```
> answer_b:=evalf(subs(nums_b,eq1A));
```

$$answer\_b := X = 0.9999405010 \quad \textbf{(4)}$$

Well most of the boule can be pulled. There is only a fraction 6e-5 remaining.

c)

The concentration of B in the liquid is then given by the segregation coefficient

```
> CL=subs(nums_b,solve(k=Cs/CL,CL));
```

$$CL = 0.03500000000 \quad \textbf{(5)}$$

```
> answer_c:=3.5*pecent;
```

$$answer\_c := 3.5\ pecent \quad \textbf{(6)}$$

The most likely situation with nonuniform B concentration is due to finite diffusivity of B in the melt. It would lead to a snow plowing pilup of B and more B would enter into the Xtal Si. Thus we would reach the solid solubility limit at smaller fraction grown.

How much pileup will depend upon the growth velocity versus the diffusion speed of B.