

## Solution problem 300-9 FYS4310

Short rerun of what the problem is

Si, B doped Poly-Si gate electrodes

Gate oxide is 10 nm

Cs concentration of B in oxide close to polySi gate (i.e. SiO<sub>2</sub>/Metal interface)  $1e21$

QTmax maximum permissible diffusion into Si,  $= 3e11$

=====

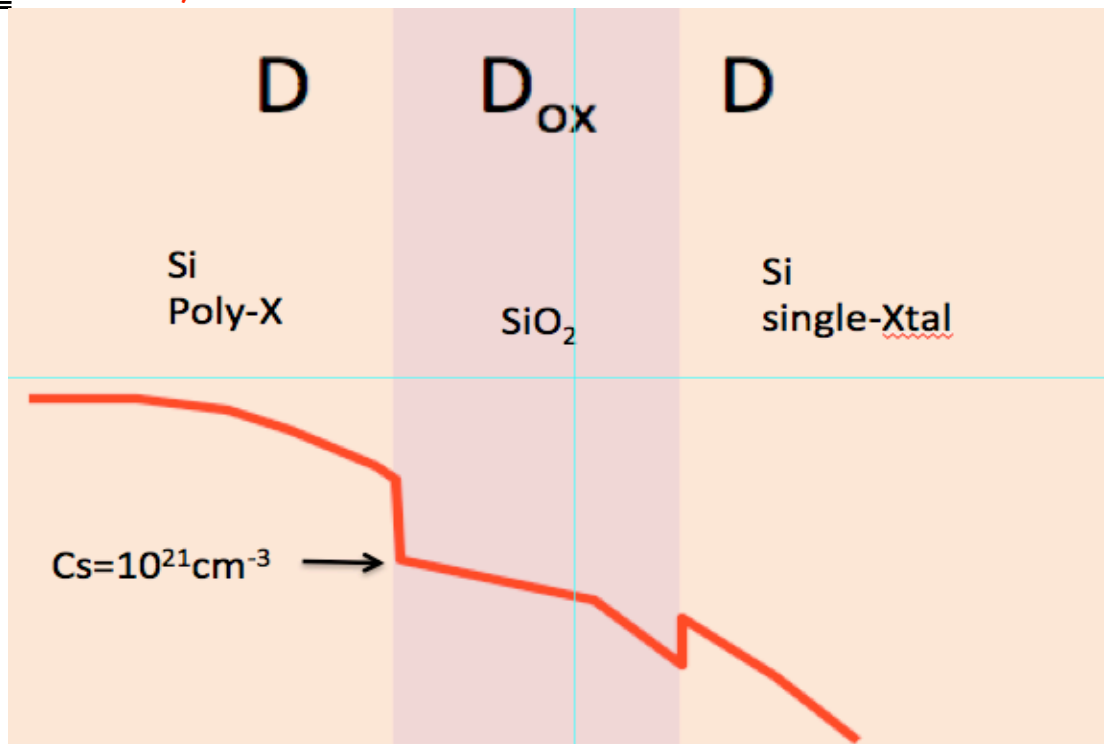
Use table 3,4, we see that  $D_{ox}=3e-4$   $E_{ox}=3.53$   $C_s < 3e20$

$T=1000$  C,  $t=4*60*60$  sec

calculate QT, dose of impurities entering semicond.

Is it lower than QT max?

> restart;



We would have to solve the diffusion equation simultaneously in three regions, Poly\_S, Oxide, SingleXtalSi

with the constrain that the flux ( $= -D \cdot dC/dx$ ) at the interfaces are the same independent of which material the B is in, and that the ratio of the concentrations at the interfaces are given by the segregation coefficients.

We could have done this numerically, but not analytically.

When we have not readily available the diffusivity for the poyXtal material, we rather look for an estimate not involving the diffusivity in polyX Si.

We can assume that the diffusivity in polyX is larger than that in single Xtal Si.

We can show that the diffusivity in single Xtal Si is larger than that in SiO<sub>2</sub>; Then it will be the diffusivity in SiO<sub>2</sub> that is the limiting factor.

We can try to make an estimate of how much B can diffuse into single Xtal Si, based on that.

We also see a calculation of a similar situation in Example 3.3 in the book.

Pay attention to the info in the book that diffusivity is 10X higher in thin oxide at high concentration compared to bulk SiO<sub>2</sub> at small implanted concentrations.

Table 3.4 is from the 1960s when measured diffusivities were summarized, the actual values varied a lot.

**The text of chapter 3.6 says that for B in thin gate SiO<sub>2</sub> values of  $D_{\text{ox}}=0.18$  and  $E_{\text{aox}}=3.82$  has been reported**

We have the following parameters from chapter 3.2 and table 3.2 and the text of chapter 3.6

Units are eV, cm, sec, K,

```
> pars:={k=8.617065e-5,Doox=3e-4,Eaox=3.53, QTmax=3e11};
      pars := {Doox = 0.0003, Eaox = 3.53, QTmax = 3. 1011, k = 0.00008617065}
```

The diffusivity in the oxide is

```
> eq1A:=Dox=Doox*exp(-Eaox/k/T);
```

$$eq1A := Dox = D_{\text{oox}} e^{-\frac{E_{\text{aox}}}{kT}}$$

We can calculate how much would diffuse into the oxide if there was no Si underneath - as an indication

We could calculate like predeposition with a surface concentration at  $C_s=3e20$

```
> eq7A:=evalf(subs(pars union {T=1000+273},eq1A),3);
```

$$eq7A := Dox = 2.81 \cdot 10^{-18}$$

```
> eq8:=QT=2/sqrt(Pi)*Cs*sqrt(Dox*t);
```

$$eq8 := QT = \frac{2 C_s \sqrt{Dox t}}{\sqrt{\pi}}$$

```
> evalf(subs(pars union {Cs=1e20,t=4*60*60} union {eq7A},eq8));
```

$$QT = 2.269809792 \cdot 10^{13}$$

This value would larger than what can be accepted for MOS transistors.

Now we calculate an estimate the way it is done as an example in the book. It would be a maximum estimate?

Yes, the largest thinkable steady flux is  $dC/dx$ , and the max  $dC$  is  $C_s=1e21$ , with  $dx=10\text{nm}$

```
> eq9:=J=-Dox*dC/dx;
```

$$eq9 := J = -\frac{Dox dC}{dx}$$

```
> eq9A:=subs({eq7A} union {dC=-1e21,dx=10*1e-7},eq9);
```

$$eq9A := J = 2.810000000 \cdot 10^9$$

```
> eq10:=QT=J*dt;
```

$$eq10 := QT = J dt$$

```
> subs({eq9A} union {dt=4*60*60 },eq10);
```

$$QT = 4.046400000 \cdot 10^{13}$$

We see this estimate is not very different, and higher than acceptable, because it would create a too large shift in threshold voltage