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Exercises "Electronic Materials"

#11

Exercise 11: Si oxidation

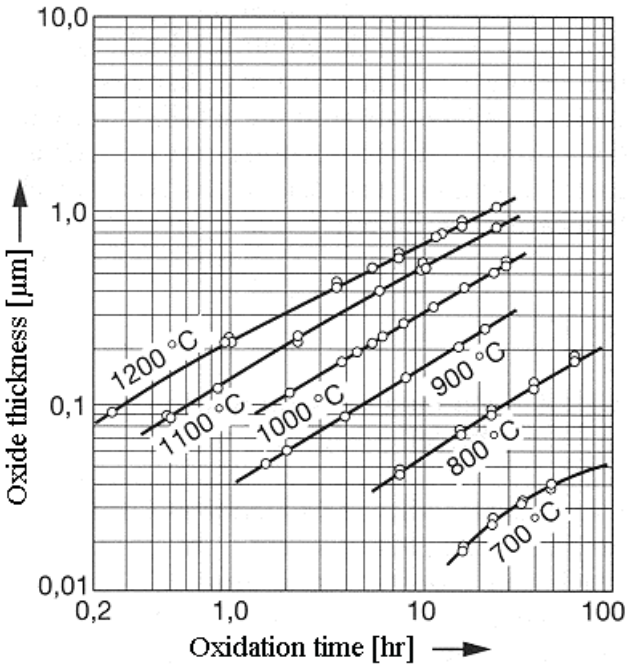

Fig. 1: Oxide growth kinetics for dry thermal oxidation.

a) What is the difference between dry and wet thermal oxidation?
b) Name at least 3 different applications for oxides in silicon technology besides gate and field oxide.
c) Produce **two** recipes for making a 10 nm gate oxide (**Fig. 1**), i.e. heating at temperature *T* for time *t*.
d) Which recipe is probably better? Discuss your choice.
e) If the gate oxide is made on a wafer that already contains patches with a 300 nm thick field oxide, how much does the field oxide grow in thickness if you apply your recipes from a) (i.e. heating your new sample for the same time *t* at the same temperature *T*)?

To enhance transistor performance, the transistors are shrinked during every technology generation, together with the applied voltages. One trick to enhance the dielectric constant of the gate oxide is to use SiO_2 with some nitridation.

f) Explain, why you have to scale down the gate oxide thickness when you scale down the gate voltage. Why can't you lower the gate voltages in the same manner like the oxide thickness?
g) Shortly discuss what you expect to happen to the dielectric constant, the stress within the layer and the interface quality when you mix in nitride during the oxide growth. Why don't you use pure Si_3N_4 as a gate dielectric?
h) Which processes could you suggest to grow an oxynitride?

Assume that the refractive index of an oxynitride varies nearly linearly with the nitrogen content (n_{SiO2} = 1.4, n_{Si3N4} = 2.0). The leakage current through the gate oxide is given by $J_{Gate} = 2.4 \cdot 10^{12} \frac{\text{mA}}{\text{cm}^2} \exp\left\{-\frac{12}{\text{nm}} d_{ox}\right\}$. The equivalent oxide thickness EOT is the thickness of a pure SiO_2 layer, which gives the same capacity for the gate stack.

i) What is the formula for calculating the capacitance of the gate stack? How is the amount of charges in the channel connected with the capacitance for a given gate voltage?

j) What is the thickness of an oxynitride (60 % nitrogen) which shall replace a 2.4 nm pure oxide?

k) How does the gate leakage current change if it was 0.8 mA/cm^2 for the pure oxide?

l) If the EOT scales down by 0.2 nm every year and the maximum acceptable leakage current (for low power applications) is set to 3 mA/cm^2 , how many years can you continue to use a pure oxide resp. the 60% oxynitride?

m) What is a major problem for completely different gate dielectric materials (e.g. HfO_2)?