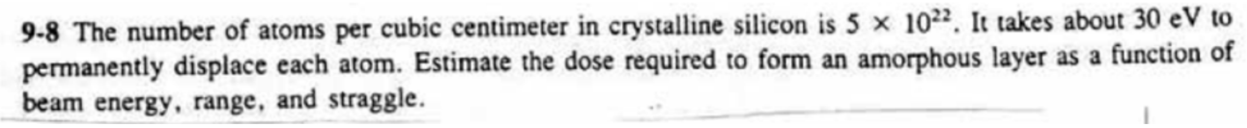
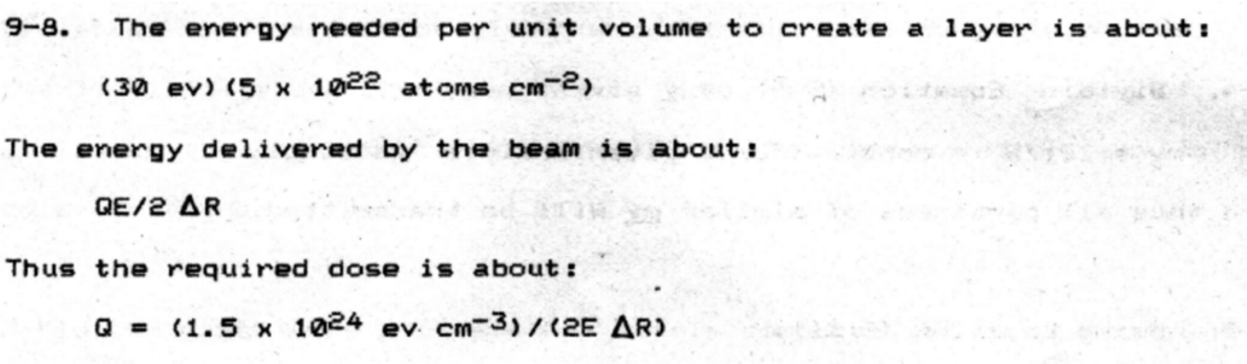
ENSC 495/851 Problem Workshop 4 Apr. 13, 2016



9-8 The number of atoms per cubic centimeter in crystalline silicon is 5×10^{22}. It takes about 30 eV to permanently displace each atom. Estimate the dose required to form an amorphous layer as a function of beam energy, range, and straggle.



9-8. The energy needed per unit volume to create a layer is about:

$(30\ \text{ev})(5 \times 10^{22}\ \text{atoms cm}^{-2})$

The energy delivered by the beam is about:

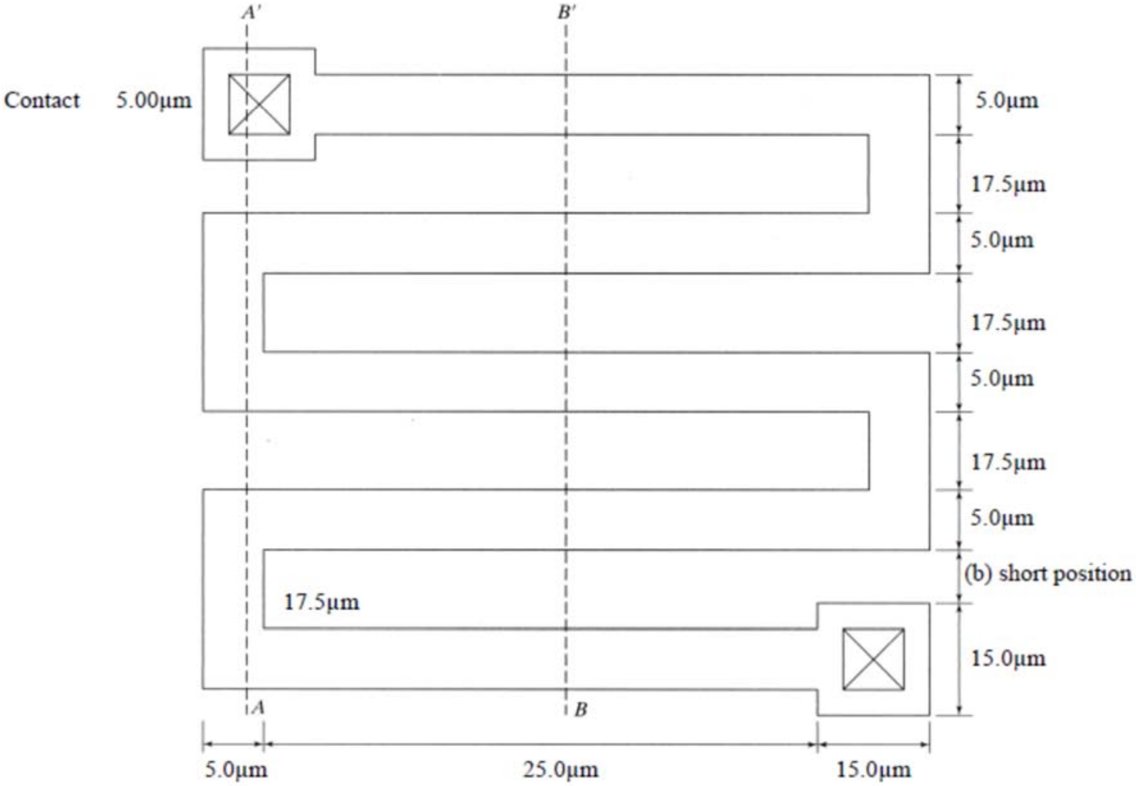
$QE/2\,\Delta R$

Thus the required dose is about:

$Q = (1.5 \times 10^{24}\ \text{ev cm}^{-3})/(2E\,\Delta R)$

2(a) The figure below shows a snake type structure used to check resistance over steps. If the resistivity of the Aluminum is 8.0micro-ohm cm and the thickness is 0.250 µm calculate the expected sheet resistance. Then use that to calculate the total resistance of the line without any losses due to step. Give both squares and total resistance. Note the contact is the inner square with a cross in it at the beginning/end pads. (5 marks)

(b) If one of the loops is shorted out how much would the resistance change (assume the short is effectively zero resistance). (1 mark)



Solution:

(a) First calculate the sheet resistance of the Aluminum when resistivity ρ = 8.0micro-ohm cm and the thickness t= 0.250 µm

$$R_s = \frac{\rho}{t} = \frac{8.0 * 10^{-6}}{0.250 * 10^{-4}} = 0.320\ ohm/square$$

(1 mark)
Now calculate the number of square in the snake
In the horizontal lines with end pads

$$S_{he} = \frac{25.0}{5.0} = 5.0\ squares$$

For those without end pads add two line widths $S_h = 5.0 + 2 = 7.0\ squares$

In the vertical connector

$$S_v = \frac{17.5}{5.0} = 3.5\ squares$$

For each corner $S_c = 0.56$ squares
For the end pads in this design $S_p = 0.65$ squares

Thus the total number of squares is

$$S_{snake} = 2 * S_{he} + 3 * S_h + 4 * S_v + 8 * S_c + 2 * S_p = 2 * 5.0 + 3 * 7.0 + 4 * 3.5 + 8 * 0.56 + 2 * 0.65$$
$$= 50.78\ squares$$

Thus the total resistance is $R_{snake} = S_{snake} R_s = 50.78*0.320 = 16.25$ ohms
(4 marks)
(b) If the short removes the last loop then the resistance becomes.

$$S_{snake} = S_{he} + 2 * S_h + 3 * S_v + 5 * S_c + 1 + 2 * S_p = 5.0 + 3 * 7.0 + 3 * 3.5 + 5 * 0.56 + 1 + 2 * 0.65$$
$$= 34.60\ squares$$

(last corner becomes a square followed by the short)
Thus the total resistance is $R_{snake} = S_{snake} R_s = 34.60*0.320 = 11.07$ ohms
Clearly easy to detect (1 mark)

1. A <100> silicon wafer is oxidized twice during an IC process. Find the total thickness of the silicon dioxide in the field (which received both oxidations) after the following furnace steps are carried out in this sequence.
(i) At 1100°C for 40 min in dry oxidation
(ii) Followed by 1000°C for 120 min in wet oxidation
For each of these do the calculations twice. (a) using the charts in the notes, but extrapolate if needed for times (4 marks).
(b) Use the A and B parameters and a full calculation to compare the theory to the actual furnace values. (5 marks

Solution
(a) Using the charts from lesson 2 then for
(i) Start at 1100°C for 40 min (= 0.667 hr) in dry oxidation
which gives 0.100μm of oxide on the dry oxide chart (1 mark)

(ii) Followed by 1000°C for 120 min (= 2.000 hr) in wet oxidation
First must convert the 0.100μm of dry oxide into the τ for the wet oxide. From wet oxide chart this g
$\tau = 0.130$ hr of wet oxide.
Thus the new growth is

$$t+\tau = 2.000 + 0.130 = 2.130 \text{ hr}$$

of wet oxide. From the wet oxide charts this gives 0.580 μm of final oxide (3 marks)

(b) Using the full Grove growth formula

$$x_o^2 + Ax_o - B\,(t+\tau) = 0$$

(i) Start at 1100°C for 40 min = 0.667 hr in dry oxidation
$A = 0.090$ μm, $B = 0.027$ μm^2/hr, $B/A = 0.300$ μm/hr, $\tau = 0.067$ hr

$$t+\tau = 0.667 + 0.067 = 0.734 \text{ hr}$$

$$x_0 = \frac{-A+\sqrt{A^2+4B(t+\tau)}}{2} = \frac{-0.090+\sqrt{0.090^2+4x0.027(0.734)}}{2} = 0.103\ \mu$$

(2 marks)

(ii) Followed by 1000°C for 120 min (= 2.000 hr) in wet oxidation
$A = 0.226$ μm, $B = 0.287$ μm^2/hr, $B/A = 1.270$ μm/hr, $\tau = 0.000$ hr
Again must convert the 0.103μm of dry oxide into the $\tau_{wet\text{-}dry}$ for the wet oxide.

$$\tau_{wet-dry} = \frac{x_0^2 + Ax_0}{B} = \frac{0.103^2 + 0.226\text{x}0.103}{0.287} = 0.118\ hr$$

Now get the total equivalent time of wet oxidation (note $\tau_{wet\text{-}dry}$ includes any initial τ for that growth)

$$t + \tau_{wet\text{-}dry} = 2.000 + 0.118 = 2.118 \text{ hr}$$

$$x_0 = \frac{-A+\sqrt{A^2+4B(t+\tau)}}{2} = \frac{-0.226+\sqrt{0.226^2+4x0.287(2.118)}}{2} = 0.675\ \mu$$

Thus the combined total thickness of both oxidations is 0.675 μm. (3 marks)