R E P O R T

반도체공정

담 당 교 수 :	이 성 식 교 수 님
과 목 :	반 도 체 공 정
학 번 :	2 0 1 8 8 3 6 1 8
성 명 :	전 양 지
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Semiconductor Process (EB68684)

Report 2 Assignment

Oct. 18, 2019

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■ **How & When to submit your report :**

1. **Electronic submission: Submit your report in PDF via E-mail to** leedevicelab@gmail.com
2. **Deadline:** Oct. 24, 2019

■ **Answer the questions (problems) of the Chapter 3 with explanations and/or calculations:**

Chapter 3: Thermal Oxidation of Silicon **(2nd elementary process)**

Problem 3-1: Explain the definition of the thermal oxidation of Silicon in terms of thermo-dynamically chemical reaction and related chemical formula about two different types (i.e. dry and wet).

Problem 3-2: In order to derive the equation of the oxidized thickness as a function of time and temperature, we employ the Fick's first law of diffusion. Here, why the diffusion is the key physical mechanism for the thermal oxidation.

Problem 3-3: In the derived equation of oxidized thickness, there are two parameters /constants. Explain what they are, and how to extract them from the experiments.

Problem 3-4: Explain why the oxidation effectiveness is different from the crystal orientation of Silicon, and why the linear rate constant is changed rather than the parabolic rate constant.

Problem 3-5: Explain the difference between the oxidation and oxide film deposition.

Problem 3-6: A <111> silicon wafer has a 2000-Å oxide on its surface. Now, solved the problems below graphically as well as mathematically:

(a) How long did it take to grow this oxide at 1000° C in wet oxygen?

(b)The wafer is put back in the furnace in dry oxygen at 1200° C.

How long will it take to grow an additional 3000 Å of oxide?

Problem 3-7: Explain the difference between the Dry and Wet oxidation in terms of Pros and Cons.

Problem 3-8: Compare the classical Local field oxide (LOCOS) and recessed one.

Problem 3-9: Explain the advantage and disadvantage of the Deep trench isolation.

Problem 3-10: Explain the CMP process briefly.

■ Answer the questions (problems) of the Chapter 3 with explanations and/or calculations:

Chapter 3: Thermal Oxidation of Silicon (2nd elementary process)

Problem 3-1: Explain the definition of the thermal oxidation of Silicon in terms of thermo-dynamically chemical reaction and related chemical formula about two different types (i.e. dry and wet).
Thermal oxidation of silicon is easily achieved by heating the wafer to a high temperature, typically 900 to 1200°C, in an atmosphere containing either pure oxygen or water vapor. Oxygen arriving at the silicon surface can then combine with silicon to form silicon dioxide. The chemical reaction Dry Oxidation : Si + O_2 -> SiO_2 Wet Oxidation : Si + $2H_2O$ -> SiO_2 + $2H_2$

Problem 3-2: In order to derive the equation of the oxidized thickness as a function of time and temperature, we employ the Fick's first law of diffusion. Here, why the diffusion is the key physical mechanism for the thermal oxidation.
In order for oxidation to occur, oxygen must reach the silicon interface. The growth rate decreases as time goes on. A simple model for oxidation can be developed by assuming that oxygen diffuses through the existing oxide layer. Fick's first law of diffusion states that the particle flow per unit area, J (called particle flux), is directly proportional to the concentration gradient of the particle: $J = -D\partial N(x,t)/\partial x$, where D is the diffusion coefficient. So, the diffusion is the key physical mechanism for the thermal oxidation.

Problem 3-3: In the derived equation of oxidized thickness, there are two parameters /constants. Explain what they are, and how to extract them from the experiments.

The oxidation thickness equation is as follows.

$$X_o(t) = 0.5A\left[\left\{1+\frac{4B}{A^2}(t+\tau)\right\}^{1/2}-1\right]$$

There are two parameters, A and B. where $A=2D/k_s$, $B=2DN_0/M$.

B is called the parabolic rate constant. the ratio B/A is called the linear rate constant.

$$B = B_0 \cdot \exp\left(-\frac{E_A}{kT}\right),\ \frac{B}{A} = \left(\frac{B}{A}\right)_0 \cdot \exp\left(-\frac{E_A}{kT}\right)$$

Values for the coefficient $B_0[(B/A)_0]$ and activation energy E_A for wet and dry oxygen are given in Table3.1.

TABLE 3.1 Values for Coefficient D_0 and Activation Energy (E_A) for Wet and Dry Oxygen*

	Wet O_2 (X_i = 0 nm)		Dry O_2 (X_i = 25 nm)	
	D_0	E_A	D_0	E_A
<100> Silicon				
Linear (B/A)	9.70×10^7 μm/hr	2.05 eV	3.71×10^6 μm/hr	2.00 eV
Parabolic (B)	386 μm^2/hr	0.78 eV	772 μm^2/hr	1.23 eV
<111> Silicon				
Linear (B/A)	1.63×10^8 μm/hr	2.05 eV	6.23×10^6 μm/hr	2.00 eV
Parabolic (B)	386 μm^2/hr	0.78 eV	772 μm^2/hr	1.23 eV

Problem 3-4: Explain why the oxidation effectiveness is different from the crystal orientation of Silicon, and why the linear rate constant is changed rather than the parabolic rate constant.

The crystal orientation changes the number of silicon bonds available at the silicon surface, which influences the oxide growth rate and quality of the silicon-silicon dioxide interface.

Heavy doping of silicon also changes its oxidation characteristics. Phosphorus doping increases the linear rate constant without altering the parabolic rate constant.

Problem 3-5: Explain the difference between the oxidation and oxide film deposition.

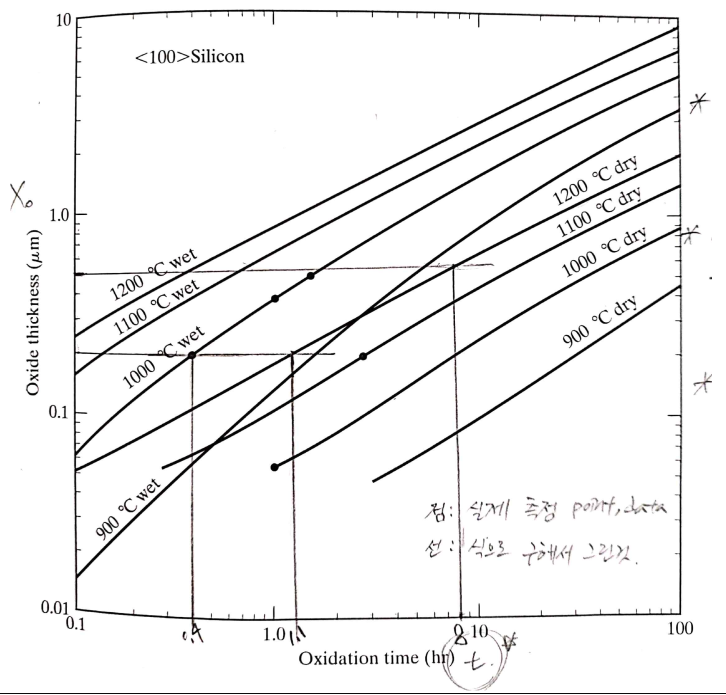
Oxidation relies only on diffusion. That is, it depends on time and temperature(high temp. 900-1200°C).

But, deposition is influenced by time, temperature(low temp. less than 400°C) and additional factors such as pressure.

Problem 3-6: A <111> silicon wafer has a 2000-Å oxide on its surface. Now, solved the problems below graphically as well as mathematically:

(a) How long did it take to grow this oxide at 1000°C in wet oxygen?

(b)The wafer is put back in the furnace in dry oxygen at 1200°C.
How long will it take to grow an additional 3000 Å of oxide?



(a) According to Fig, it would take 0.4 hr to grow a 0.2um oxide in wet oxygen at 1000°C.

(b) We can solve part (b) graphically using Fig. The total oxide at the end of the oxidation would be 0.5um. If there were no oxide on the surface, it would take 8 hr to grow 0.5um. However, there is already a 0.2um oxide on the surface, and the wafer thinks that it has already been in the furnace for 1.1 hr. The time required to grow the additional 0.3um of oxide is the difference in these two times: $\triangle t = (8 - 1.1)hr = 6.9\,hr$

Problem 3-7: Explain the difference between the Dry and Wet oxidation in terms of Pros and Cons.

Dry oxidation	Wet oxidation
pros - more dense - better quality	pros - The oxide layer is thick because H2O has a higher diffusivity and solubility than O2. - fast growth
cons - slow growth - The oxide layer is thin.	cons - less dense - low quality

Problem 3-8: Compare the classical Local field oxide (LOCOS) and recessed one.

Selective oxidation processes result in improved device packing density and more planar final structures.

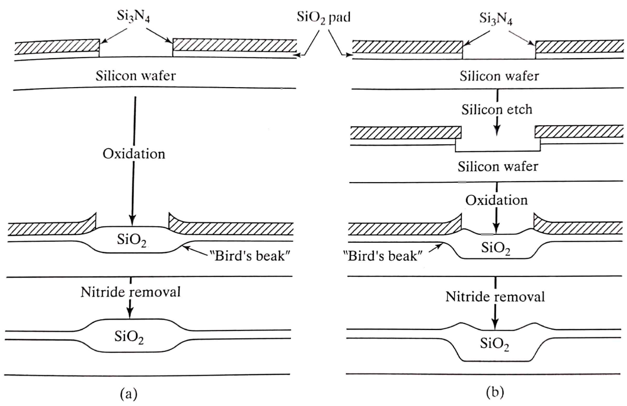


FIGURE 3.12
Cross section depicting process sequence for local oxidation of silicon (LOCOS): (a) semirecessed and (b) fully recessed structures.

classical LOCOS	recessed LOCOS
A thin layer (10 to 20nm) of silicon dioxide is first grown on the wafer to protect the silicon surface. Next, a layer of silicon nitride is deposited over the surface and patterned using photolithography. Oxide grows wherever the wafer is not protected by silicon nitride.	A fully recessed oxide can be formed by etching the silicon prior to oxidation. This process can yield a very planar surface after the removal of the nitride mask.

<table>
<tr><td colspan="2">Problem 3-9: Explain the advantage and disadvantage of the Deep trench isolation.</td></tr>
<tr><td colspan="2">Method of filling SiO2 after etching the area to be isolated.</td></tr>
<tr><td>advantage
- Excellent isolation ability
- Solving problems from LOCOS
- Troubleshooting Bird's beak</td><td>disadvantage
- The process is complicated.
- High cost</td></tr>
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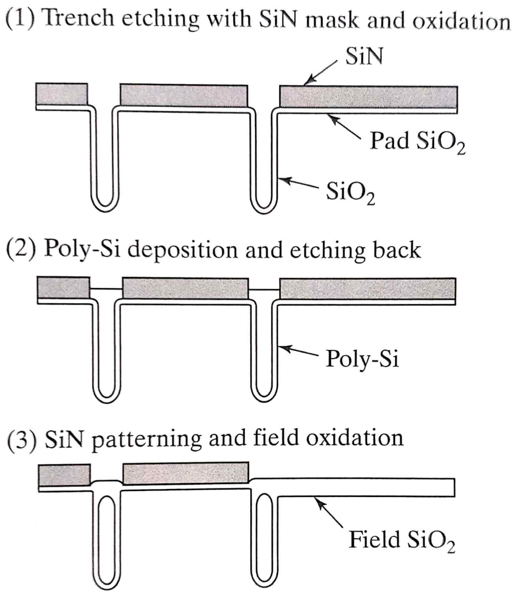
<table>
<tr><td colspan="2">Problem 3-10: Explain the CMP process briefly.</td></tr>
<tr><td>

Fabrication procedure of trench isolation and field oxide.
(a) Deep-trench process</td><td>CMP was introduced into fabrication processing during the early 1990s and is now widely used in both bipolar and MOS processes to achieve the highly planar topologies required in deep submicron lithography. The wafer is mounted on a carrier and is brought into contact with a polishing pad mounted on a rotating platten. A combination of the vertical force between the wafer and the abrasive pad as well as the chemical action of the slurry is used to polish the surface to a highly planar state. In the case of formation of the shallow trenches, the nitride layer serves as a polishing stop. Polishing terminates when the nitride layer is fully exposed.</td></tr>
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