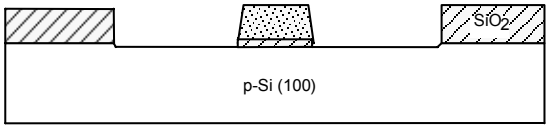
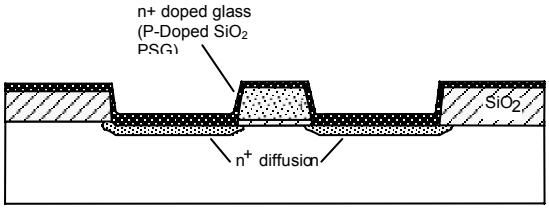
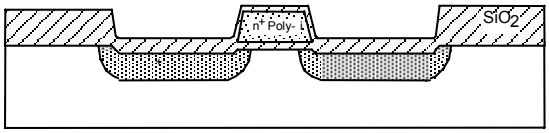
LAB #6 Phosphorus Pre-Deposition and Drive-in



Poly-Si Gate formed after Lab 5



Dope Source/Drain Regions and Poly-Si Gates with Phosphorus (Predep)



Diffuse (Drive-in) Junctions and Oxidized Exposed Si

- **Measure Oxide Thickness, Junction Depth, and sheet resistance on Si and Poly-Si after Pre-Deposition and Drive-in**
- **Calculate Doping Concentration and Junction Depth**
- **Carry out Tsuprem4 Simulations for Phosphorus Pre-Deposition and Drive-in**
- **Discuss Dopant Distributions (B and P) under Different Process Conditions and their Effects on Device Performance**
- **Compare Liquid Source to other Doping Techniques**

LAB #6 Phosphorus Pre-Deposition and Drive-in

Purpose:

A controlled phosphorus pre-deposition will be used to dope the source, drain, and gate regions. During the phosphorus pre-deposition step, an oxide that is heavily doped with phosphorus will be deposited and some of the phosphorus will diffuse into the Si substrate. After the pre-deposition, the phosphorus deposited will be diffused further into the source/drain regions to form a deeper junction. In addition, oxide will be grown on the exposed Poly-Si gate sidewalls to avoid shorting between the gate and the source/drain regions.

Process Steps:

1. Pre-furnace clean all wafers using the RCA cleaning procedures (Device wafer + monitor wafers). Use 100:1 HF in the HF steps to avoid excessive etching of the oxide under the gate.

2. Load all the wafers into the phosphorus pre-deposition tube. Deposit a Phosphorus-doped Silicate Glass (PSG) at 975 °C for 20 minutes with gas flows of 0.1 slpm O_2, 0.35 slpm N_2 through the $POCl_3$ bubbler, and 2.0 slpm N_2. PSG is an oxide doped heavily with phosphorus.

Temp.	Time	Ambient	Tube	Gas Flow	Gas Setting
975 °C	20 min	O_2	R2-15-D	0.1 slpm	36.0
		$POCl_3$	R2-15-D	0.35 slpm	107.2
		N_2	R2-15-C	2.0 slpm	42.5

3. Measure the PSG oxide thickness by ellipsometry after phosphorus pre-deposition on monitor wafer. Measure the junction depth after phosphorus pre-deposition by grove and stain on monitor wafer.

4. Etch the PSG from the wafers by BHF. It should take <1 min.

5. After the PSG etch, measure the sheet resistance on Si (monitor wafer) using four point probe. This is the sheet resistance on Si after phosphorus Pre-Deposition.

6. Measure the sheet resistance on the Poly-Si monitor wafer after phosphorus pre-deposition using four point probe.

7. Load wafers (Device wafer and remaining monitor wafers) into the diffusion tube. An oxide will be grown and the phosphorus will be diffused deeper into the Si substrate during this drive-in step.

Temp.	Time	Ambient	Tube	Gas Flow	Gas Setting
875 °C	5 min	Dry O_2	R2-15-C	3 slpm	66.5
	10 min	Wet O_2			
		O_2	R2-15-B	1.75 slpm	32.6
		H_2	R2-15-B	2.5 slpm	41.6
	5 min	Dry O_2	R2-15-C	3 slpm	66.5

Junction Depth should be ~1.5 μm after drive-in.

8. Measure the oxide thickness by ellipsometry after phosphorus drive-in on monitor wafer #6. Measure the junction depth after drive-in by grove and stain on monitor wafer.

9. Find the BHF etch time to remove the oxide grown during phosphorus drive-in by using monitor wafer (this etch time will be used in Lab#7).

10. Remove oxide from monitor wafers #8 and 9. Measure the sheet resistance on Si and on Poly-Si monitors after phosphorus drive-in using four point probe.

11. Inspect your device wafer under the microscope. Pay particular attention to the apparent color in the source/drain regions and over the Poly-Si.

INFORMATION TO BE INCLUDED IN THE LAB REPORT #2

1. Evaluate the measured oxide thickness, junction depth, and sheet resistance on Si and Poly-Si after Pre-Deposition and after Drive-In. Calculate the doping concentration in Si and Poly-Si from the sheet resistance, and explain their differences. Calculate junction depth after Pre- Deposition and after Drive-In. How do resistance in junctions and junction depth affect device performance?

2. Carry out Tsuprem4 simulation of phosphorus pre-deposition (Use Solid Solubility of P for all simulations):
   a. Use the same conditions as used in the lab and use the 'DEPOSITION' command (no gas flow needed) in Tsuprem4.
   b. Use the same conditions as used in the lab and use the 'DIFFUSION' command and specifying gas flow rates in Tsuprem4.
   c. Use the same conditions as used in the lab, the 'DIFFUSION' command, and use 'INERT' as the gas ambient in Tsuprem4.

   Print the output files and plots for the dopant distributions of B and P. Summarize the oxide thickness grown, Si consumed, B and P diffusion constants, B and P concentrations at the Si-SiO_2 interface, and junction depth for each case.
   Explain why the P distribution as well as the junction depth are different in the 3 cases. Compare simulated results to measured results and explain the limitations of Tsuprem4.

3. Carry out Tsuprem4 simulation of phosphorus Drive-In:
   Use the pre-deposition condition in Question 2 part b and drive-in condition used in the lab.
   Print the output file and plot the dopant distributions for B and P. Summarize the oxide thickness grown, Si consumed, B and P diffusion constants, B and P concentrations at the Si-SiO_2 interface, and junction depth after drive-in.
   Explain why drive-in is needed and how it affects the device performance.

4. What are the two advantages of using $POCl_3$ compared to using other sources for doping?