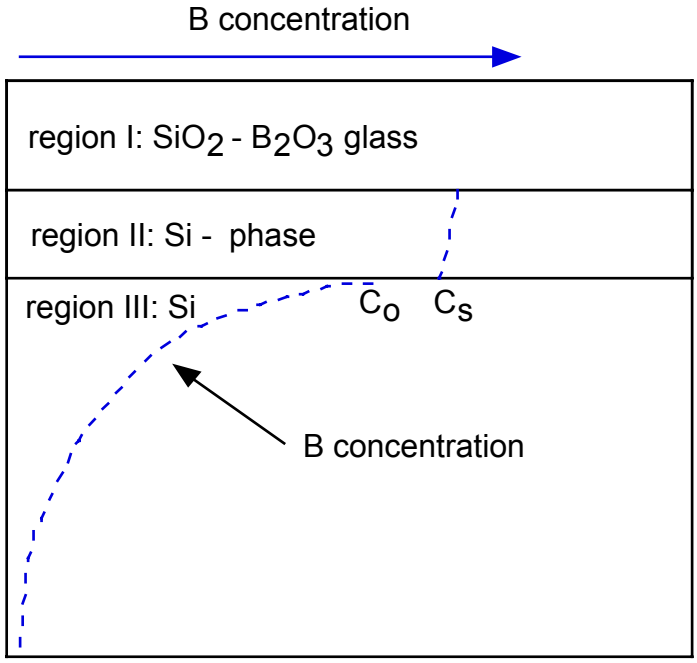
OP-D: Boron Predeposition

filename: BPREDP

Boron is the most commonly used p-type dopant for silicon, principally because it is the only column III element that can be masked by $Si0_2$. It is introduced into the silicon substrate using a two step, high temperature process. The first step, called the pre-deposition, is an open tube diffusion process that involves the gaseous tranfer of a compound containing the dopant to the Si wafer. The gas may be supplied in several different ways, but in almost all cases the final chemical reaction is

$$2B_20_3 + 3Si \rightarrow 3Si0_2 + 4B.$$

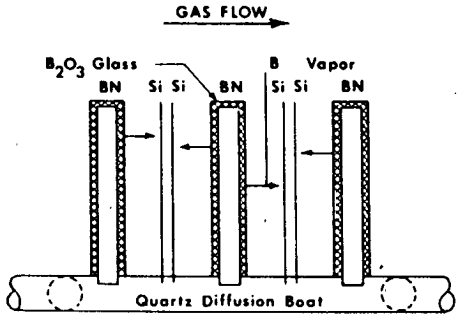
The resulting Si surface at the end of the pre-dep process is sketched in Figure 17. This first stage of doping is referred to as constant concentration diffusion.



Region I: layer of SiO_2 - B_2O_3 glass formed during pre-dep.
Region II: boron rich skin of SiB_x, can be up to 10 nm thick.
Region III: Si substrate with diffused boron. The concentration C_s is a function of temperature, while $C_o = k_s C_s$, where ks is the distribution coefficient between the boron rich region and the silicon.

Figure 17: Boron concentration after pre-dep.

Our boron pre-dep system produces B_2O_3 by an evaporation process from "solid source" wafers. In this method, Si wafers are stacked next to oxidized boron nitride wafers, as shown below. At the pre-dep temperature (in our case, 950°C) a concentration gradient induced diffusion is established between the source wafers and the silicon wafers. This concentration gradient is a function of the distance between the source and silicon, the temperature of the pre- dep, and the composition of the gas ambient (oxidizing or non-oxidizing, presence of H_20, etc.). Ideally, however, it is not a function of gas flow rate, which is low enough so that the gas between source and wafer is essentially stagnant. The concentration gradient results in the transfer of B_2O_3 to the silicon surface, and so produces a very thin, very highly doped region at the silicon wafer surface. The final level of doping and resulting sheet resistance is determined by time (see Figure 18) and the size of the concentration gradient. Note, however, that the pre-dep temperature is so low that very little boron diffusion into the silicon actually takes place.



The second stage of the diffusion process, called the drive-in, has as its objective the redistribution of the dopant deeper into the silicon, and is referred to as a constant source diffusion. For this process we first remove our silicon wafer from the pre-dep furnace and strip off the $Si0_2$-B_2O_3 glass using HF. The HF actually attacks the $Si0_2$, not the B_2O_3, so care must be used in the pre-dep step to prevent the deposition of excessive amounts of B_2O_3. This is done mainly by assuring no H_20 is present in the furnace, which would greatly increase the rate of transfer of B_2O_3 to the silicon. Also note the thin Si B_x phase on the wafer is hydrophilic, so the wafer will not de-wet after etching. The actual drive-in is performed at very high temperatures (1100°C in our lab). The drive-in is usually initiated in an oxidizing environment; the initial growth of $Si0_2$ prevents the out-diffusion of the boron during the rest of the process. For operation of the Drive-In Furnace, see 93.

REFERENCES

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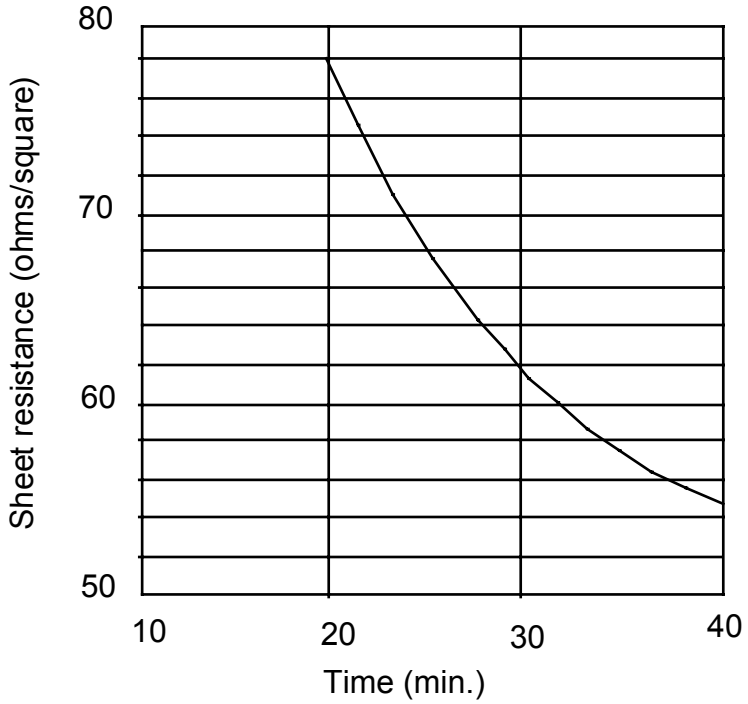

Figure 18: Sheet resistance vs. Boron pre-dep time.

BORON PRE-DEP PROCEDURE

1. Set gas flow rate: N_2 @ 70, steel ball.
2. Set furnace temperature controller: 926. Allow at least 30 min. for temperature to stabilize. This should normally be done by the lab TA before lab starts.
3. Remove furace cap and place it in the beaker on the table. Carefully remove the pull-rod and pull the wafer boat from the neck of the furnace. ALLOW ~ 1 min. TO COOL.

NOTE: NEVER USE ANY PULL-ROD OTHER THAN THE ONE SPECIFICALLY FOR THE FURNACE YOU ARE USING!

4. LOAD WAFERS: Place CLEAN Si wafers in slots immediately adjacent to the BN wafers (polished side next to BN). Note the location of your wafer in the boat in your lab notebook.

DO NOT TOUCH THE BN WAFERS OR QUARTZ BOAT WITH TWEEZERS!

5. Using the pull-rod, push the boat into the neck of the furnace. Allow to equilibrate for 1 min.
6. Slowly push boat into center zone of furnace: 1 min. push. The center zone is reached when the end of the pull-rod reaches the mark on the furnace tray. Replace pull-rod in its storage tube, and replace furnace end cap.

THE PULL ROD WILL BE VERY HOT: DO NOT TOUCH ANY PORTION WHICH WAS INSIDE THE FURNACE.

7. Allow to remain in flat zone for desired pre-dep time.
8. At the end of the pre-dep time, perform a SLOW PULL (1 min.) of the boat from the flat zone to the NECK of the furnace. Allow boat to cool in the neck of the furnace for 1 min.
9. Pull boat out of neck, and allow to cool for 1 min. Remove samples.
10. Store boat in neck of furnace, replace cap and pull-rod.

Stand-By:
-Boat should be in the neck of the furnace.
-N_2 flow-rate: 10, glass ball.
-Controller setting: 650.

Appendix: **Boron Nitride Activation**

The source of boron for our pre-dep system is actually a thin layer of B_2O_3 glass on the surface of the boron nitride (BN) wafers. This glass layer must be periodically grown on the BN, using the following activation procedure.

BN Activation Procedure

1) Wafers should be precleaned, finishing with a HF etch for 1 min., followed by at least 1 hour drying in the furnace neck.

2) Set furnace for 950^{o}C (926 on controller). Allow 30 min. to stabilize.

3) Turn O_2 on, set flow at 100 with steel ball. Allow 10 min. to equilibrate.

4) Oxidize boron nitride: push boat into the flat zone, hold there in O_2 for <u>30 min</u>.

5) Stabilize: turn O_2 off, turn N_2 on at 100 (steel ball) setting, hold for <u>30 min</u>.

6) Pull wafers to neck, turn N_2 down to 10 (glass ball), and set furnace temperature controller back to 650.