Tool Identifier	Boron, Phosphorous diffusion furnaces
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SAMPLE PREQUIREMENT:

Sample should be either RCA cleaned or Piranha cleaned before being introduced in the furnace . This has to be strictly followed

STANDARD OPERATING PROCEDURE

Dopant Diffusion

Two chambers are dedicated to dopant introduction using Carborundum/St. Gobain Planar Diffusion Sources (PDS).

The PDS boron source wafers (boron nitride) are oxidized to form a B_2O_3 layer prior to a predeposition run. It is the boric oxide which has a significant vapour pressure at the diffusion temperatures. B_2O_3 reacts with silicon to form SiO_2 with an extremely high concentration of boron.

The wafers used for phosphorus predeposition are made with SiP_2O_7 in a fine SiO_2 lattice. The SiP_2O_7 decomposes at diffusion temperatures to form P_2O_5 which vaporizes and reacts with silicon.

EQUIPMENT SPECIFICATIONS

1. Naturally cooled open tube diffusion furnace.
2. Available gases: O_2, N_2.
3. Ability to process up to (about 6) 2" wafers simultaneously
4. Max Temp: 1200° C.
5. Process tube inside diameter: 3 inch.

➢ **Start Up**

1. Turning on necessary gases.

- First open the cylinders (O_2 or N_2) at the micro 1 service corridor, set the line pressure to 4 bar (sometimes varies depending upon the number of instruments using the same cylinder simultaneously).

- The gas flowing into the furnace can be controlled by mass flow controllers present near the tube.

2. Switch on the chillers & exhaust (2exhausts – one below the pass box, second near the litho exhaust fixed on wall) of the furnace.
3. Open water inlet corresponding to furnace for cooling.
4. Flip the furnace power switch (to power the heating coils).
5. Flip the furnace control power switch (to power the control unit of the furnace).
6. Now the temperature requirements of centre, right, left zones of the furnace can be set (ramp up rate, mode of ramping up can also be set).

➢ **Running**

1. Manually open the door of load in chamber, load your wafers (typical load in temperature is 700°c) and wait for the tubes to reach the desired temperature (see control panel display to check current temperature).
2. Check that only nitrogen is flowing in the furnace when loading.
3. Use the appropriate long pull rod to slowly push the boat until centre of tube (approximately 30 seconds to reach the centre of the furnace). Each furnace has its own long pull rod.
4. Carry on the process for your required time and ramp down the furnace to the unloading temperature (700 – 800°C and unload the wafers.

➢ **Shut Down**

1. Unload your wafers and the boats after your process (boats may be kept inside the tube itself).
2. Close the furnace door.
3. Switch off the furnace power (as it is naturally cooled).
4. Set the furnace for ramp down to room temperature.
5. Once the temperature becomes less than 300 in all the zones, Then the gases can be closed .
6. Then the water lines & exhaust can be switched off (Chiller is 24*7 on).

SAFETY INSTRUCTIONS & PRECAUTIONS

1. When working with the furnaces makes sure you are wearing the appropriate gloves.

2. Don't use metal tweezers to handle the solid diffusion sources.

3. During loading and unloading the wafers, wear goggles and facemasks. The loading and unloading temperatures are quite higher of the order of 700- 800 degree Celsius and there may be do pant vapours coming out of the furnace as you.

4. Never touch the hot furnace components and the wafers with gloves as it will contaminate the furnace.

INFORMATION SHEET

BORON AND PHOSPHOROUS DIFFUSION FURNACES

Boron diffusion furnace (Si-2 inch)	**Phosphorous diffusion furnace (Si-2inch)**
Type: solid source diffusion.	Type: solid source diffusion.

Planar Diffusion Source	Sheet resistance Range attainable.
BN 975(Saint Gobain)	5-500 ohm/square

Planar Diffusion source	Sheet resistance range attainable
PH 1025 (Saint Gobain)	5-25ohm/square.
PH 900 (Saint Gobain)	15-150 ohm/square

Diffusion steps

1. Predepositon
2. Drive in (if required)

Predeposition time and drive in time should be specified by the user depending upon the requirement. Solid sources available with us now can be activated and give uniform doping at temperatures greater than 825 degree Celsius. It may require two to three runs to get repeatable confirmed values.

Reference: www.saintgobain.com.

System owner/AU

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Authorised user for Phosphorus diffusion furnace:

Bandana singha – Department of Energy Science

Amrutha – Department of Energy science

Materials allowed

Silicon (for other materials you can contact Professor BM Arora).

Training

For training please contact system owner.

LOG BOOK:

Please make an entry in the log book.

UNDERSTANDING THE PROCESS OF DIFFUSION

Introducing controlled amount of chemical impurities in silicon crystal lattice is diffusion. Interstitial, substitutional, inter change and combined diffusion are the various forms by which the diffusion of the dopant atoms can happen. Two step diffusion method is followed, Predeposition phase - diffusion from constant source and drive in phase – diffusion from the instantaneous source.

Step 1: Predeposition (dose control): a shallow region of impurity is introduced near the surface of the wafer.

Step 2: Drive-in (Profile control): The impurities are driven deeper into the wafer.

The solid diffusion sources as supplied by saint gobain available with us are

Boron –PDS –BN F39450 used

775 to 1000 degree centigrade -→ sheet resistance range 20-500 ohm-cm.

Phosphorous-Ntype-PDS –PH 1025 used

975 to 1025 degree celsius---→ sheet resistance range 3 to 25 ohm-cm.

Controlling parameters:

A)Diffusion time (t -secs),

B)Diffusion temperature(T degree celsius) —controls→ diffusivity(D -cm^2/sec)

↓ controls

Solid solubility limit (N01-atoms/cm^3)

N_{01}-surface concentration, D-diffusion coefficient($\frac{cm^2}{s}$) can be obtained from preobtained experimental plots varying as the function of Diffusion temperature.

Predeposition phase (Diffusion from inexhaustible dopant source):

The solution to the diffusion equation $\frac{dc}{dt} = D^2 \frac{\partial^2 c}{\partial x^2}$ assuming the zero applied electric field subjecting it to the boundary conditions C(x,0)=0, C(0,t)=N_{01}, C(∞,t)=0. Matches the complementary error function complex function and hence erfc term comes in the formula.

$$N(x,t) = N01 * erfc \frac{x}{2\sqrt{Dp * tp}}$$

$$Q = 2 * N01 * \sqrt{\frac{Dp * tp}{3.14}}$$

N01 - Solid solubility limit or surface concentration (atoms/cm^3).

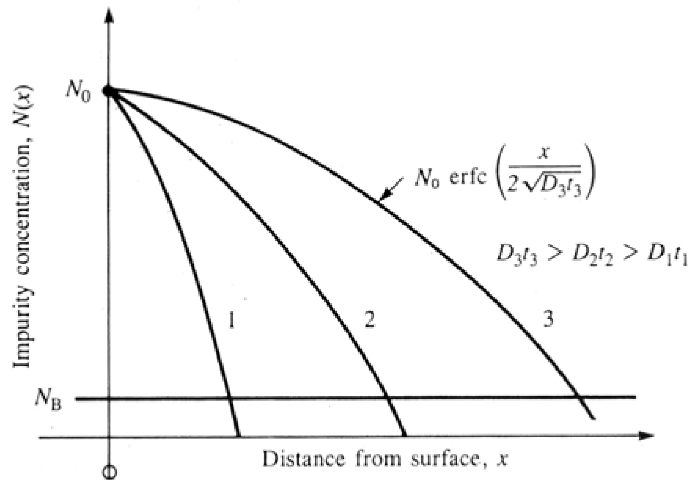
Dp - Diffusion coefficient corresponding to predeposition temperature (cm^2/sec)

Tp - Predeposition time (seconds).

Q - Quantity of matter diffused after predeposition (atoms/cm^2).

Erfc - Mathematical error function values.

X - Depth of wafer in microns.



A constant-source diffusion results in a complementary error function impurity distribution. The surface concentration N_0 remains constant and the diffusion moves deeper into the silicon wafer as the Dt product increases. Dt can change as a result of increasing diffusion time, increasing diffusion temperature, or a combination of both.

In the predeposition cycle the circular solid discs rich in phosphorous at high temperatures at about 975 Celsius emits phosphorous pent oxide vapors which are carried by the inert nitrogen carrier gas and they react with the silicon surface to form phosphosilicate glass which gets deposited over the wafer and this acts as the inexhaustible dopant source as long the solid dopant sources are available and thus in this phase we mainly control the number of dopant atoms diffused in the substrate rather than the depth to which the dopant atoms have diffused. In the open tube diffusion system the partial pressure of the dopant atoms in the carrier gas is very high so that it reaches the solid solubility limit. Once it reaches this limit it does not follow the Henry's law according to which if there is no resistance to the transport of the impurity from the gas to the solid surface the surface concentration C_s in the solid will be in equilibrium with the partial pressure of the impurity in the gas and hence after reaching the solid solubility limit by varying the partial pressure we will not be able to increase the surface concentration above that limit.

Drive in Phase:

$$N(x, t) = \frac{Q}{\sqrt{3.14 \times Dd \times td}} \times e - \left(\frac{x}{2\sqrt{Dd \times td}}\right)^2$$

Where

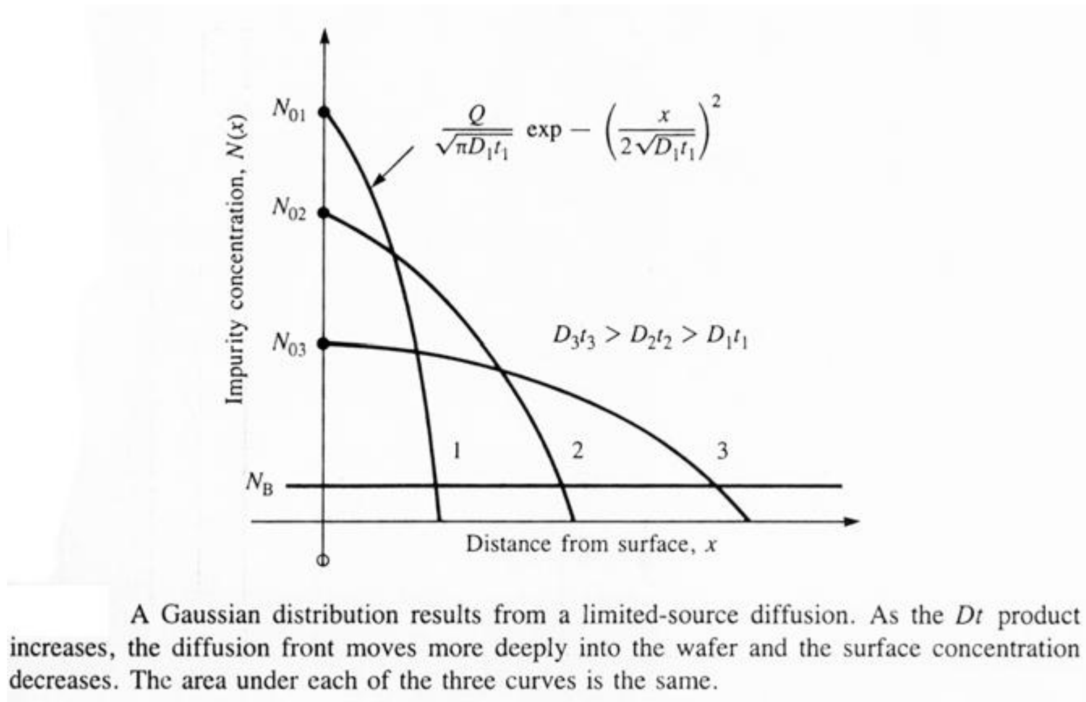
Dd - Diffusion coefficient corresponding to the drive in temperature (atoms/cm2).

Td - Drive in diffusion time (seconds).

Q - Quantity of matter diffused in the predeposition phase.

X - Depth of wafer in microns.

N(x,t) - Dopant concentration (atoms/cm3).



A Gaussian distribution results from a limited-source diffusion. As the *Dt* product increases, the diffusion front moves more deeply into the wafer and the surface concentration decreases. The area under each of the three curves is the same.

This involves the redistribution of the dopant deeper into the silicon and is constant source (dopant atoms diffused during the predep phase) diffusion the diffusion length in the drive in phase for the impurities is several time greater than in the predeposition phase and here the depth and the profile control is possible by varying the temperature and the drive in time the surface concentration will not be constant as in this case.